An Alternative VisionEval Concepts Primer

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Preface

This is an adaptation of the VisionEval **Concepts Primer** put together by Tara Weidner. It reorganizes the content a bit and attempts to create a version with decent lexicon that doesn't get in the way of reading the text. In this adaptation VisionEval a number of keywords stand out:

- Certain keywords have specific meaning when describing constructs in VisionEval, and are colored green in the text. For example, you will see age groups often in the text. You can click on any of these links to open a lexicon in a separate window. You can scroll to the specific term you're interested in. This concept primer and the lexicon are meant to be used together (i.e., opened in separate windows).
- Links to other documents and websites appear as clickable blue text, like this one that will take you to the VisionEval front page.
- Specific variable or filenames are shown in `offset text`. For example, you might see a reference to the `FudgeFactor` in the `ModuleName` module. These keywords are generately **not** clickable for variable names, but often are for module names.

Chapter 1

Introduction

VisionEval differs from traditional travel demand models both in how it works and what kind of planning concerns it helps to address. This **Concepts Primer** provides a quick introduction approach to the unique features and applications of VisionEval. It reviews the main model components and key concepts at a high level, to assist new users in understanding concepts they will apply as they set up scenarios, develop inputs and evaluate outputs. Links to more detailed documentation will allow the reader to delve further into each topic, as they choose.

1.1 What can I do with VisionEval?

Structurally, VisionEval may be described as a "disaggregate demand/aggregate supply" model. That is, it combines rich demographic and socioeconomic detail from a synthetic population with aggregate treatments of travel (multi-modal VMT and congestion without explicit trips, or transport networks). The implication of the "aggregate supply" model is that VisionEval cannot be used to evaluate performance of specific projects or corridors.

What VisionEval can do, and even makes especially simple, is to evaluate large numbers of scenarios and explore how combinations of alternative future conditions might affect performance measures. Travel demand models, whether built using traditional trip-based or more contemporary activity-based techniques, sacrifice network detail for flexibility. It is difficult in such models to capture novel behaviors such as an increased propensity to use inexpensive ride-hailing services, or to express shifts in vehicle ownership and occupancy that may be influenced by multiple factors some of which have not yet been observed. Yet these potential shifts are often very important for assessing the potential of pricing, investment strategies or other policy priorities. VisionEval also makes it relatively simple to explore risks and opportunities that may eventually be realized as new transportation options mature.

VisionEval won't help us determine if a particular highway segment should be built or upgraded, or what kind of transit service improvements should be extended into new areas. But it can help us look at the market for new technologies, and explore future scenarios that are based both on changed circumstances (altered demographics, increased congestion, or alternate road pricing strategies) as well as on changed behaviors (including behaviors that *might* happen, but that we have not yet observed because the key enabling technologies are too early in their deployment). VisionEval results can be explored in detail by market segment, asking questions about how benefits might be distributed regionally, and what overall system performance might look like.

Ultimately, VisionEval is a system for asking a very broad range of "what if" questions about how the transportation system might perform, and how its benefits and costs might be distributed over the community. It can efficiently process hundreds of scenarios looking at many different types of interventions, alternative policies, and hypothetical future conditions and travel behaviors. The results can inform strategic questions, helping decision makers answer questions such as "What are our options for achieving this performance result?" or "What are our risks if new transportation technologies develop in these different ways?"

Using VisionEval to answer such questions does not make other types of modeling obsolete (such as travel demand models or corridor microsimulations). Instead, it helps to determine what is worth the effort to code into these more detailed models, and also to explore and document novel assumptions about the future that may require extra effort to implement, and that would be prohibitively expensive to explore through traditional planning models.

1.2 Strengths and limitations

VisionEval operates at broad geographic levels and without explicit network representations to enable very fast analyses across scores of different assumptions and inputs. It is especially well suited for quickly evaluating several different combinations of policies or assessing the range of impacts when uncertainty exists in several key inputs. Because much of the travel behavior is asserted based on observed travel patterns the latter can be changed to reflect expected changes due to new technologies, services, and expected changes in behavior over time. Thus, VisionEval is better suited than traditional travel modeling approaches for certain pursuits:

- Screening a wide range of policy actions, especially in the face of uncertainties where ranges of expected responses or effects must be considered
- Resilience testing under uncertainties (e.g., population growth, household size, fuel prices)
- Directly "comparing and contrasting" broad ranges or combinations of policies (e.g., ITS, transit service, active transport, demand management)

- Analysis of broad policy or technology changes (e.g., carbon taxes, low-carbon fuels)
- Evaluating fuel consumption, particulate emissions, and greenhouse gas emissions impacts of proposed policies

However, VisionEval is not well suited for detailed geographic analyses, to include the effects of congestion on individual trips or tours. Thus, examining the effects of localized land use or network assumptions cannot be carried out using VisionEval. Improvements in network capacity, efficiency, or safety can only be indirectly incorporated in VisionEval.

1.3 VisionEval geographies

Traditional travel forecasting models divide a study area into thousands of traffic analysis zones in order to facilitate highly granular spatial analyses. This allows trip (tour segment) origins and destinations to enter and exit a detailed representation of the multimodal transportation network in order to study network flows, congestion, and efficiency outcomes. VisionEval operates at a much broader spatial scale, using several levels of geography:

- A `region` defines the entire area covered by the VisionEval analyses
- `Azone`s are large areas such as cities, counties, or Public Use Microdata Areas (PUMAs)
- `Bzone`s are subdivisions of Azones that represent neighborhoods, Census tracts or block groups, or other relatively homogenous areas
- Metropolitan areas (`Marea`s) are defined as groups of Azones that define them

The *location type* of each household is also coded as urban, town, or rural areas. A *place type* is also defined in terms of urban density and its mix of jobs and housing. Both are usually defined for each Bzone used in the model.

> Watch a video presentation with more information about VisionEval geographies

1.4 Performance metrics

The following table summarizes many of the possible performance metrics that can be summarized at the region level. The ability to easily export the data enables the analyst to construct new or different performance measures easily.

- Mobility
  - Daily VMT per capita
  - Annual walk trips per capita
  - Daily Bike trips per capita
- Economy
  - Annual all vehicle delay per capita (hours)

  - Daily household parking costs
  - Annual household vehicle operating cost (fuel, taxes, parking)
  - Annual household ownership costs (depreciation, vehicle maintenance, tires, finance charge, insurance, registration)
- Land Use
  - Number or percent of residents living in mixed use areas
  - Number of dwelling by housing type (e.g., single family [SF], multi-family [MF])
- Environmental
  - Annual greenhouse gas emissions per capita
  - Household vehicle greenhouse gas/mile
  - Commercial vehicle greenhouse gas/mile
  - Transit vehicle greenhouse gas/mile
- Energy
  - Annual per capita fuel consumption for all vehicles (gallons)
  - Average fuel efficiency (net miles per gallon) for all vehicles
  - Annual external social costs per households (total/percent paid)

Chapter 2

Typical applications

VisionEval can be used to inform planning in several different realms, as described in the following sections.

2.1 Strategic modeling

VisionEval is a strategic modeling system. It differs from traditional travel demand and microsimulation models principally in that it is applied earlier in the planning process, and it is used for different purposes. Rather than examining the detailed performance of specific facilities (assessing individual projects), VisionEval estimates regional and small area performance metrics that reflect overarching policy goals such as emission reduction, regional VMT, or mode share.

Traditional travel models used for planning purposes are applied to estimate outcomes under a small number of alternate input scenarios that vary either land use (socioeconomic data) or characteristics of the transportation network (alignment, land configuration, tolls, etc.). In these models, the response to the changed inputs is estimated based on parameters typically derived from household surveys and other related data sources: that is, the behavior in the model is presumed to be what we see today. Even though such models are often behaviorally complex (e.g., activity-based models), the effort required to assess many alternative scenarios is often prohibitive, and because such models are built using complex estimation procedures rooted in detailed data about existing behavior, it can be technically difficult or impossible to reliably encode possible future shifts in behavior, or to explore alternative possible future behaviors.

VisionEval is typically set up to run many scenarios that explore a broad set of alternative policies and investment priorities that may result from a variety of possible categories of policy and project interventions, or from a range of possible future conditions (strong or weak economic growth, demographics that shift at different rates), or from uncertain deployment of new technologies such as app-based ridesharing (Transportation Network Companies or TNCs).

A full application of VisionEval may examine hundreds or even thousands of permutations of inputs representing many possible future outcomes. The outputs allow planners and decision-makers to explore the outcomes of each scenario compared to the others. so they can visualize and discuss the relative impact and cross-influences, as well as the unintended consequences, of factors represented across the scenarios. VisionEval allows planners to assess alternative assumptions about uncertain phenomena such as AV deployment, it is a very effective tool for identifying risks and opportunities, as well as for formulating effective strategic responses to new challenges for which little current data exists or for which many outcomes are possible yet none are certain. The most interesting of the resulting strategic plans can be refined with more detailed models. Based on the strategic modeling findings, uncertainties can be confidently simplified into a smaller number of scenarios to explore in detail.

Notwithstanding its typical application as a strategic model, VisionEval does allow detailed investigation of certain phenomena such as fleet composition and vehicle ownership in relation to Greenhouse Gas Analysis. It also is unique in its ability to explore budget constraints on travel. Its simulation of individual households enables it to assess policies that would be difficult or impossible to model successfully with traditional models.

2.2 Local policy actions

VisionEval is well suited for evaluating a wide range of local policies at varying levels of geography:

- Demographics (Azone)
  - Population by age (households & non-institutional group quarters)
  - Average household size and percent of single-person households
  - Licensure drivers rate (optional)
  - Average per capita Income
- LandUse (Bzone)
  - Employment by type (Total, Retail, Service)
  - Dwelling units by type (SF, MF)
  - Income quartiles (for allocating households to dwelling units)
  - Share of households in Urban Mixed Use areas (optional)
  - Built Form Ds (Design & Transit)
  - Acres, centroid latitude and longitude
- Actions
  - Road lane-miles (freeways, arterials) (Marea)
  - Transit Service (service miles by transit mode) (Marea)
  - Car Service costs, substitutability & access time (Azone)
  - Short Trips SOV Diversion (bike, personal electrics, etc.) (Azone)

  - ITS-Operations (Ramp metering, Incident response, (Marea)
  - ITS-Speed smoothing (Freeway ATM, Art Signal optimization) (Marea)
  - VMT covered by Drivers in Eco-Drive programs (Marea)
  - EV Charging infrastructure (residential) (Azone)
- Pricing
  - Fuel and electricity costs (Azone)
  - Road Cost Recovery – Registration Fee, gas taxes, VMT fee (Azone)
  - Carbon Pricing (social cost recovery) (Region)
  - Congestion Fees (Marea)
  - PAYD insurance participation (Azone)
- Vehicle, Fuels, & Emissions
  - Electricity Carbon Intensity (Azone)
  - Fuel Carbon Intensity (composites by vehicle group) (Region)
  - LDV-HH percent Light Trucks (stock) (Azone)
  - LDV-HH vehicle age average (Azone)
  - LDV CarService, vehicle mix (stock) (Region)
  - Transit vehicles & fuels mix (Marea)
  - LDV CommService vehicle mix, %Light Trucks (stock) (Region)
  - Heavy truck vehicle mix (stock) (Region)

2.3 Scenario analyses

A key value of VisionEval is how it facilitates running many scenarios or possible futures. In practices, the user typically starts by setting up the model with a reference scenario, best estimate of future conditions. The model can be validated at this point. This Reference scenario then serves as a pivot point for manual or automated scenario testing. Typically that includes a mix of the following, reflecting "what if?" type questions:

- Sensitivity tests (manual): Ad hoc tests that change a single category of inputs for each run
- Combination scenarios (automated): Several combinations of categories combined

Note that the number of combinations scenarios grows quickly, in a multiplicative manner. For instance, all combinations of 3 levels each of land use transit, bike, parking, and TDM policies and 3 fuel price scenarios would result in 243 scenarios (3x3x3x3x3). For this reason, *categories* are often used that combine multiple inputs. Automated processes aid in the set-up and running of these scenarios, which the analyst can use a variety of data mining and visualization tools to explore the results.

Chapter 3

Building blocks

3.1 Household synthesis and land use

One of the strengths of VisionEval is the rich detail on individual households. This allows for household specific policies, travel behavior can respond to specific household costs and attributes, and outputs can be mined for differences by population groups. The approach of building on a synthesized population borrows from the state of the practice in activity-based travel demand models.

> Watch a short video on household synthesis

VisionEval takes user input statewide population by age group, assembles them into households with demographic attributes (lifecycle, per capita income) and allocates them to BZone-level dwelling units. Separately, BZones are attributed with employment and land use attributes (location type, built form 'D' values, urban mixed use, and employment by type). Household members are identified as workers and/or drivers and the number of household vehicles are estimated. Each home and work location is tied to a specific Bzone with its associated attributes.

Policies are added to each household as a function of their home and work Bzones:

- Parking restrictions (work and non-work)
- Travel demand management (TDM) programs (home and work-based)
- CarService program availability

The following sections describe each module that contributes to this concept.

3.1.1 Synthesize households

Household synthesis is carried out in several steps:

1. *Create customized PUMS dataset*: This is done prior to setting up a model in VisionEval. A household dataset is prepared from Census PUMS data for the modeled region. The default data included with VisionEval is for Oregon. PUMS data for other regions may be used instead, rebuilding the package to reflect Census households for the region of interest.
2. *Create Households*: The identified types of PUMS households are expanded to meet user control totals and other demographic inputs. Census PUMS data are used define probabilities that a person by age group would be found in each of hundreds of household types. A matrix balancing process is used to allocate persons by age to each of the PUMS household types in a way that matches input control totals and optional constraints. The sampled households are expanded to meet user control totals and other demographic inputs.
3. *Predict Workers*: The number of workers by age group within each simulated household is predicted using Census PUMS probabilities.
4. *Assign LifeCyle*: Categorizes households are categorized by six lifecycle categories given the household age mix and employment status.
5. *Predict Income*: The annual income for each simulated household is predicted as a function of the household's worker count by age group, the average per capita income where the household resides (AZone), and interactions between neighborhood income and age (all and seniors). The models are estimated with Census PUMS data.

3.1.2 Household drivers and autos

The number of drivers and autos in each household are calculated in two steps:

1. *Assign Drivers*: Drivers by age group are assigned to each household as a function of the numbers of persons and workers by age group, the household income, land use characteristics, and transit availability. Metropolitan areas are also sensitive to transit service level and urban mixed use indicators at the home location. Optional restriction on drivers by age group can be used in calibration or to address trends such as lower millennial licensure rates.
2. *Assign Vehicle Ownership*: The number of vehicles owned or leased by each household are determined as a function of household characteristics, land use characteristics, and transportation system characteristics. Households in metropolitan areas are also sensitive to transit service level and urban mixed use indicators at the home location. The model first predicts zero-auto households and then the number of vehicles owned (up to 6), if any.

3.1.3 Land use attributes

Two steps are required to add land use attributes to the synthetic population:

1. *Calculate 4D Measures*: Several land use 5D built form measures are

calculated for each Bzone. The `density`, `diversity`, and `destination` accessibilities are based on Bzone population, employment, dwelling units, and `developable land area` inputs. The `design` variable is a user input.
2. *Calculate Urban Mixed Use Measure*: An urban mixed measure for the household is calculated based on population density of the home Bzone and dwelling unit type. The model is based on 2001 NHTS data. The model iterates to match an optional input target on the share of households to locate in urban mixed-use areas.

3.1.4 Land use-household linkages

Several land use attributes are added to each household:

1. *Assign Location Types*: Households are assigned to land use location types – urban, town, or rural – by random allocation based on the household's dwelling unit type and input proportions on the mix of dwelling types in its enclosing Bzone.
2. *Predict Housing*: Dwelling unit types are assigned to regular and group quarter households based on the input Bzone supply of dwelling units by type. Residential households also consider the relative costliness of housing within the Azone (logged ratio of the household's income relative to mean income in their Azone), household size, oldest age person, and the interaction of size and income ratio.
3. *Locate Employment*: The number of input jobs by Bzone and employment type (retail, service, total) are scaled so that total jobs equals total household workers within the Marea. A worker table is developed and each worker is assigned to a work Bzone. The assignment essentially uses a gravity-type model with tabulations of workers and jobs by Bzone (marginal controls) and distance between residence and employment Bzones (IPF seed, inverse of straight-line distances between home and all work Bzone centroids).

3.1.5 Policy levers

Several assumptions about parking, demand management, and mobility services can also be coded:

1. *Assign Parking Restrictions*: Households are assigned specific parking restrictions and fees for their residence, workplace(s), and other places they are likely to visit based on parking inputs by BZone (within Bzones coded as within metropolitan areas [Marea] only).

    - *Residential Parking Restrictions & Fees*: The number of free parking spaces available at the household's residence is set based on input value that identify the average residential parking spaces by dwelling type in each Bzone. For household vehicles that cannot be parked in a free space a residential parking cost (part of auto ownership costs) is identified as a function of input parking rates for the home Bzone (if any).

- *Employer Parking and Fees*: Which workers pay for parking is set by inputs that define the proportion of workers facing parking fees in each Bzone. Whether their payment is part of a cash out/buy back program is similarly set by input proportions by Bzone and associated fees set by input parking rates for the work Bzone.
- *Non-work Parking Fees:* The cost of parking for other activities such as shopping is estimated as the likelihood that a household would visit each Bzone and the parking fee in that Bzone. The likelihood is calculated with a gravity-type model, given the relative amount of activity in the Bzone (numbers of households by Bzone and the scaled retail and service job attractions by Bzone as marginals) and the proximity to each destination (inverse distance matrix from home Bzone seed matrix). The average daily parking cost is a weighted average of the fee faced in each destination bzone and the likelihood of visiting that Bzone.

2. *Assign Demand Management*: Households are assigned to individualized marketing programs based on input participation levels within their home Bzone. Each worker in the household can also be assigned to an employee commute options program based on input participation levels for workers within their assigned work Bzone. A simple percentage reduction in household VMT is applied based on the household's participation in one or more of these program (maximum of multiple program participation, to avoid double-counting). Worker reductions are only applied to that worker's work travel portion of overall household VMT, and summed if multiple workers in the household participate in such programs.

   > Caution: The model assumes high-caliber TDM programs are in place that produce significant VMT savings. Inputs should reflect this.

3. *Assign CarSvc Availability*: A car service level is assigned to each household based on the input car service coverage for where the household resides (Bzone). High Car Service availability can have an impact on A auto ownership costs (which affects number of autos owned by the household) and auto operating cost (see the discussion in the next chapter on household costs and budgets).

3.2 Household multimodal travel

Watch a video overview of the Household Multimodal Travel module

Travel of various modes by households (vehicle, transit, bike, and walk modes) is estimated as a simple function of the rich demographic and land use attributes of the household. In metropolitan areas travel is also influenced by inputs on transport supply on a per capita basis, such as available roadway capacity and bus-equivalent transit service levels. Traditional travel models incorporate behavioral dynamics in choice models to build tours and trips for each synthetic person. VisionEval, by contrast, uses simple regression equations that directly estimate average per capita trips and miles by mode, linked by average trip lengths.

After adjusting VMT for household budget limitations it is further adjusted for household participation in TDM programs (home & work-based) and short-trip SOV diversion before calculating household trips for all modes. The household's bike miles are also adjusted to reflect SOV diversion input.

The following sections describe each module, which are implemented in sequence:

1. The household's daily VMT is calculated with household budget adjustments
2. The vehicle operating costs are calculated
3. The vehicle operating costs are adjusted to fit within the `BudgetHouseholdDvmt`
4. Daily VMT reductions due to TDM measures and short-trip SOV diversions are calculated
5. Vehicle and non-vehicular (AltMode) trips are calculated for each household

3.2.1 Transport supply

Transport supply variables are defined in two steps. Note that these calculations are only carried out within metropolitan areas (Mareas) only:

1. *Assign Transit Service*: Transit service levels are input for each metropolitan areas and neighborhood (Bzone). Annual revenue-miles (i.e. transit miles in revenue service) by eight transit modes are read from inputs for each metropolitan area. A Bzone-level Transit D attribute defines access to transit (not yet work access) for each household based on inputs on relative transit accessibility. Using factors derived from the National Transit Database (NTD), input annual transit revenue miles for each of the eight transit modes are converted to bus-equivalent miles by three transit vehicle types (van, bus, and rail). Per capita relative transit supply and bus-equivalent service-miles are calculated.
2. *Assign Road Miles*: Stores input on the numbers of freeway lane-miles and arterial lane-miles by metropolitan area and year. Computes the relative roadway supply, arterial and freeway lane-miles per capita.

3.2.2 Household travel calculations

Household travel by vehicles are calculated in three steps:

1. *Calculate Household Daily VMT (Dvmt)*: Household average daily vehicle miles traveled (VMT) is estimated as a function of household characteristics(income, workers, children, drivers), vehicle ownership, and attributes

of the neighborhood (population density) and metropolitan area (urban mixed-use, transit service level, road lane-miles) where the household resides. It also calculates household VMT percentiles which are used by other modules to calculate whether a household is likely to own an electric vehicle (EV) and to calculate the proportions of plug-in hybrid electric vehicles (PHEV) VMT powered by electricity. First, households with no VMT on the travel day are identified. Then VMT is estimated for those that travel. Average and VMT quantiles are estimated to reflect day-to-day variance that helps identify whether an EV vehicle is feasible for this households typical travel. These values are derived from the 2001 NHTS data.

2. *CalculateVehicleTrips*: This module calculates average daily vehicle trips for households consistent with the household VMT. Average length of household vehicle trips is estimated as a function of household characteristics (drivers/non-driers, income), vehicle ownership (auto sufficiency), and attributes of the neighborhood (population density) and metropolitan area (urban mixed-use, freeway lane-miles) where the household resides, and interactions among these variables. The average trip length is divided into the average household VMT to get an estimate of average number of daily vehicle trips.
3. *Calculate AltMode Trips*: This module calculates household transit trips, walk trips, and bike trips. The models are sensitive to household VMT so they are run after all household VMT adjustments (e.g., to account for cost on household VMT) are made. Twelve models estimate trips for the three modes in metropolitan and non-metropolitan areas, in two steps each. The first step determines whether a household has any AltMode trips and the second part determines the number of trips. All of the models include terms for household characteristics (size, income, age mix) and the household's overall VMT. Neighborhood factors (population density) factors into all but the bike trip models. For households in metropolitan areas transit service level has an impact as well, with transit ridership also sensitive to when residents live in urban mixed-use neighborhoods.

3.2.3 SOV diversion

Household single-occupant vehicle (SOV) travel is reduced to achieve bike and micro-transportation input policy goals, i.e., for diverting a portion of SOV travel within a 20-mile tour distance (round trip distance). This allows evaluating the potential for light-weight vehicles (e.g. bicycles, electric bikes, electric scooters) and infrastructure to support their use, in reducing SOV travel. First, he amount of the household's VMT that occurs in SOV tours having round trip distances of 20 miles or less is estimated. Then the average trip length within those tours is estimated. Both models are sensitive to household characteristics(drivers, income, kids), vehicle ownership (auto sufficiency), and attributes of the neighborhood (population density, dwelling type) and metropolitan area (urban mixed-use, freeway lane-miles) where the household resides, and the household's overall VMT. Both models have multiple stages, including stochastic simulations to capture day-to-day variations.

The diversion of these short trips is assumed to only apply in urban and town location types. The VMT reductions are allocated to households as a function of the household's SOV VMT and (the inverse of) SOV trip length. In other words, it is assumed that households having more qualifying SOV travel and households having shorter SOV trips will be more likely to divert SOV travel to bicycle-like modes. The estimates of the household's share of diverted VMT, average trip length of diverted VMT are applied elsewhere to reduce DMVT and increase bike trips. Zero vehicle households are not allowed to divert SOV travel. Census PUMS data is used to estimate the models.

3.2.4 DVMT reductions

Each household's VMT is adjusted for their TDM program(s) participation, if any, as well as input from metropolitan area short-trips SOV diversion goals. The SOV diversion also increases bike trips (diverted SOV VMT divided by SOV average trip length).

3.3 Vehicles, fuels and emissions

The powertrains, fuels, and associated emissions datasets for all modeled vehicle groups are among the most complex inputs used in VisionEval. Default datasets are included in the VisionEval installer to simplify this for the user. The user can use these defaults or develop their own data that matches the VisionEval input requirements. It is anticipated that different datasets will be developed by users that can be shared with the VisionEval community. For example, one package may represent a base scenario of federal vehicle, fuel, and emission standards, while another package represents the California zero-emissions vehicle (ZEV) rules and low carbon fuel for the home location's CarService.

The model looks in household vehicle sales tables indexed by vehicle type and age to determine the probability of each powertrain in that sales year, along with its associated fuel efficiency and other attributes. Each household vehicle is assigned attributes consistent with these probabilities. In some cases electric vehicles (EVs) are replaced by plug-in hybrid electric vehicles (PHEVs) if household VMT and residential charging limitations exist.

The powertrain mix of non-household vehicle groups – car service, commercial service, transit, and heavy trucks – is applied to VMT (rather than individual vehicles) in the scenario year (rather than sales year). There is some input adjustment for average vehicle age and commercial vehicle type share.

Fuels for each vehicle groups can rely on the package defaults, or use one of two input options. The user can either provide a *composite carbon intensity* representing all gallons of fuel used for that vehicle group, or provide fuel mix shares (base fuel mix, biofuel blend proportions), combined with package default *lifecycle (well-to-wheels) carbon intensity* for the individual fuels. The resulting carbon intensity per gallon are applied to gallons generated from VMT and vehicle fuel efficiency assumptions. Adjustments to fuel efficiency due to reduced speeds due to congestion as well as ITS operational programs (e.g., speed smoothing) and EcoDrive programs.

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The table below summarizes the vehicle and fuel options available within VisionEval.

Vehicle Group	Vehicle Types	Powertrain Options	Veh Input Adjustments	Fuel Options
Household Vehicles	automobile, light truck	ICE, HEV, EV, PHEV	(default veh mix), age, %LtTrk	gas/ethanol, diesel/biodiesel, CNG/RNG
Car Service VMT	automobile, light truck	ICE, HEV, EV	veh mix, age (HH %LtTrk)	gas/ethanol, diesel/biodiesel, CNG/RNG
Commercial Service VMT	automobile, light truck	ICE, HEV, EV	veh mix, age, %LtTrk	gas/ethanol, diesel/biodiesel, CNG/RNG
Heavy Truck VMT	heavy truck	ICE, HEV, EV	veh mix	gas/ethanol, diesel/biodiesel, CNG/LNG
Public Transit VMT	van, bus, rail	ICE, HEV, EV	veh mix	gas/ethanol, diesel/biodiesel, CNG/RNG

Note that individual vehicles are modeled for households, based on sales year default datasets and age of the owned vehicle. Other groups' vehicle and fuel attributes apply to VMT in the scenario modeled year. As a result, PHEVs do not exist other than household vehicles, instead PHEVs are represented as miles driven in HEVs and miles in EVs.

Watch a video overview of vehicles, fuels, and emissions

3.3.1 Household vehicle table

The household vehicle table is generated in two steps:

1. *Create Vehicle Table:* A vehicle table is created with a record for every vehicle owned by the household, and additional vehicle records are added to reach the household's number of driving age persons. Each vehicle record is populated with household ID and geography fields (Azone, Marea) and *time-to-access vehicle* attributes. Each vehicle record is either "own" or

(worker without a vehicle) assigned access to a *Car Service level*, depending upon coverage in the household's home Azone.
2. *Assign Vehicle Type:*. Identifies how many household vehicles are light trucks and how many are automobiles as a function of number of vehicles, person-to-vehicle and vehicle-to-driver ratios, number of children, dwelling type, income, density, and urban mixed use data (in metropolitan areas only).

3.3.2 Powertrains and fuels defaults

These values are defined in two steps:

1. *Load Default Values:*. This script, run before the rest of VisionEval is started, reads and processes the default powertrains and fuels files in the package and creates datasets used by other modules to compute fuel and electricity consumption, and well as associated fuel and electricity *carbon intensity* emissions from vehicle travel.
2. An *Initialize* step is run by VisionEval as part of its initialization on each run. Optional user-supplied vehicle and fuel input files, if any, are processed (including input data checks). When available, modules that compute carbon intensities of vehicle travel will use the user-supplied data instead of the package default datasets.

3.3.3 Assign household powertrains and fuels

The powertrain and fuel type is assigned to each vehicle in each household in three steps:

1. *Assign Vehicle Age:* Assigns vehicle ages to each household vehicle and `Car Service` vehicle used by the household as a function of the vehicle type (household vehicles only), household income, and assumed mean vehicle age by vehicle type and Azone. The age model starts with an observed vehicle age distribution and relationship between vehicle age and income. These data are currently based on summaries of the 2001 NHTS. Adjustments are made based on user average vehicle age inputs (household by vehicle type, car service overall).
2. *Assign Household Vehicle Powertrain:* This module assigns a powertrain type to each household vehicle. The age of each vehicle is used with default tables by vehicle type that identify the powertrain mix of vehicles sold in each sales year. Other default tables identify vehicle characteristics tied to powertrain that include battery range, fuel efficiency, and emissions rate. Assignments of EVs may be changed to PHEVs if the battery range is not compatible with estimated day-to-day trip lengths, or the home dwelling lacks vehicle charging availability.
3. *Calculate Carbon Intensity:* This module calculates the average carbon intensity of fuels (grams CO2e per megajoule) by vehicle group and, if applicable, vehicle type. Average fuel carbon intensities for transit vehicle

modes are calculated by metropolitan area (Marea), other vehicles are calculated for the entire model region. The module also reads the input average carbon intensity of electricity at the Azone level.

3.3.4 Assign non-household powertrains and fuels

The assignment of powertrain and fuel characteristics is carried out in two steps:

1. *Calculate Transit Energy And Emissions:* This module calculates the energy consumption and carbon emissions from transit vehicles in urbanized areas. Assumptions (package default or user input) on powertrain mix and fuels for three transit vehicle types by metropolitan area are applied to associated Marea transit service miles for these types. Assumptions (package default or user input) on average carbon intensity of fuel and electricity by transit vehicle types are then applied to Marea fuel and electricity usage across types to calculate carbon emissions.
2. *Calculate Commercial Energy And Emissions:* The energy consumption and carbon emissions of heavy trucks and commercial service VMT (no vehicles) are calculated by on-road (not sales) year. VMT shares of Commercial Service powertrains by vehicle type and Heavy truck powertrains are calculated (per package default or user input). Any fuel efficiency (MPG and MPKWH) adjustments are then applied, due to policies (eco-driving, ITS speed-smoothing and/or congestion (including effects of any ITS-operational and congestion fee policies). Ecodriving applies only to internal combustion engine (ICE) vehicles and ITS operational policies and congestion apply only in metropolitan areas. Both vary by powertrain and for commercial vehicles, vehicle type. Combining fuel efficiency and VMT (from the Household Multimodal Travel Model) results in estimates of energy usage (fuel and electricity). Fuel carbon intensity for these modes is calculated by metropolitan area (Marea) and/or region and applied to fuel and electricity usage to estimate CO2e emissions.

Chapter 4

Adjustments

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4.1 Congestion adjustments

Congestion, only calculated on urbanized roads (a subset of metropolitan area roads, requires estimating and combining together the VMT of all Vehicle Groups. For non-household vehicles, base year VMT is calculated directly from inputs and model parameters, while future year is a function of the input growth basis. Initial allocations of DMVT across road class is based on input values.

Light duty vehicle (LDV) VMT is allowed to re-allocate between freeways and arterials to balance demand (VMT) and roadway supply (lane-miles) through a generalized cost framework (including roadway speed and congestion fees, if any). Roadway supply (i.e., capacity) is adjusted by delay-reducing ITS-operations policies based on fuel-speed curves by powertrain, the resulting congested speeds impact vehicle fuel-efficiency. Further adjustments are applied to reflect any ITS-speed smoothing and eco-drive programs that may not affect delay but reduce acceleration and deceleration with associated impacts on fuel efficiency.

No fuel efficiency adjustments for congestion or policies are made to non-urban roadway VMT. The delays faced by each household and associated fuel economy impacts are applied to each individual household's VMT and vehicles. Resulting overall average speeds, delays, and DMVT proportions, by road class at each congestion level on urbanized and other roads are also tabulated along with the resulting average per mile congestion fees paid, if any, and overall vehicle hours of delay (VHD) by vehicle group.

Watch a video summary of VisionEval's congestion adjustment

4.1.1 Initialize roadway conditions

The roadway conditions in the model are calculated in three steps:

1. *Load Default Road VMT Values:* These calculations are completed before the model run starts. The base year roadway VMT is processed, including LDV and Heavy Truck VMT by state and urbanized area as well as VMT proportions by urbanized area, vehicle group, and road class. The user can either provide direct inputs for these values or specify a state and/or urbanized area and the model will use default data from the `20xx USDOT Highway Statistics`, where available.
2. *Initialize:*. This step is run when the model run is initialized. User inputs used by several modules are read and checked (many with several valid options, proportions sum to 1, consistency, congestion fees increase with congestion level). Some of these values are optional, using default data where not specified. This includes various assumptions on base year VMT within both urbanized area(s) and the full model region, by vehicle group, allocation among road class, growth basis, and assumptions for freight vehicle groups. It also checks inputs on ITS-operational policies and eco-driving programs, including any user-specified "other ops" programs and congestion fees (by road class and congestion level).
3. *Calculate Road VMT:* Adds together metropolitan area VMT of all vehicle groups (Households, CarService, Commercial Service, Heavy Truck, Transit) and allocates it across road classes (freeway, arterial, other), limiting it to urbanized area roadways for use in congestion calculations. To do so, several factors are established in the base year. One uses the input growth basis (population, income, household VMT) to estimate future year freight vehicle group (Commercial service and heavy truck) VMT (using input base year VMT values by region and Marea, if provided, model-estimates otherwise). A second base year factor identifies the urban and non-urban allocation of VMT from metropolitan area households and related commercial service vehicles. For Heavy Trucks VMT an input specifies the proportion of VMT on urbanized roads while transit VMT (of all Transit service modes) is assumed to only occur on urbanized roads. Base year allocations of urban VMT by vehicle group among road classes are based on input shares, subject to adjustment during subsequent congestion calculations. Finally, to assess delay faced by each household and associated fuel efficiency impacts, each individual household's VMT is split between miles on urbanized and other road miles.

4.1.2 Congestion model and adjustments

Three adjustments are made based on congestion levels:

1. *Calculate Road Performance:* Congestion level by road class and the associated amounts of VMT are iteratively estimated. LDV VMT is allowed to re-allocate between freeways and arterials to balance demand

and roadway supply (lane-miles) through a generalized cost framework (including roadway speed and congestion fees, if any and an estimated base year urbanized area lambda parameter based on the area's population and freeway-arterial lane-mile ratio). DMVT allocation at different aggregate demand-supply ratios relies on data from the 2009 Urban Mobility Study (UMS) for 90 urbanized areas, where the model chooses the 5-10 cities with most similar congestion ratios.

The supply calculation considers the delay-reduction effects of deploying urban area ITS-operations programs (freeway ramp metering, freeway incident management, arterial signal coordination, arterial access control or user-defined "other ops" programs. The standard ITS-operations program impacts are based on research (Bigazzi and Clifton, Task 2 Report, 2011). Non-urban speeds are also calculated, using a simple ratio of rural-to-urban travel volumes.

The resulting average speeds, delay and DMVT proportions, by road class at each congestion level on urbanized and other metropolitan area roads are calculated, as is the resulting average per mile congestion fees paid, if any, and overall VHD by vehicle group.

2. *Calculate Mpg Mpkwh Adjustments:* Adjustments to fuel efficiency (MPG and MPKwhr) for all Vehicle Groups resulting from traffic congestion, congestion fees, ITS-speed smoothing (i.e. active traffic management which reduces speed variation), and eco-driving are calculated. The fuel-speed curves vary by road class, congestion powertrains (LdIce, LdHev, LdEv, HdIce) and, where applicable, vehicle type relative to reference speeds by road class. The adjustments are based on drive-cycle level simulation research (Bigazzi and Clifton, Task 1 Report, 2011). Note that no adjustments are made for ITS policies (standard and speed smoothing policies) or eco-drive programs on 'other' road classes (non-freeway or arterials) and non-urbanized roads, which are assumed to be uncongested.

3. *Adjust Household Vehicle MPg Mpkwh:* Implements the fuel efficiency (MPG and MPKwh) adjustments of household vehicles (including Car Service VMT), reflecting the effects of congestion, congestion fees, ITS-speed smoothing, and eco-driving that were calculated elsewhere. These adjustments vary by vehicle powertrain, vehicle type, and the proportion of the household's travel that is driven on urban and non-urban roads within the metropolitan area. Joint effects are calculated as the product of congestion speed effects and the maximum of implemented speed-smoothing policies (eco-driving & ITS-speed smoothing).

4.2 Household costs and budgets

Two adjustments are made in response to household budgets. Auto ownership costs are calculated and an adjustment is made to the number of household owned autos if the costs are less than switching to a 'High' level Car Service, where available (subject to input limits on Car Service substitutability). Vehicle ownership costs include financing, depreciation, insurance (unless in PAYD program), annual registration fees, and residential parking fees.

Additionally, in order to respond to pricing policies and energy costs, VisionEval imposes a budget limitation. Household VMT is constrained such that annual vehicle operating costs must stay below a maximum share of annual household income, or budget limit. A household-specific average annual vehicle operating costs is first calculated, including out-of-pocket per mile costs for each household owned and Car Service vehicles used by the household, as well as time-equivalent cost (input access times, estimates of VMT at congested speeds, and value-of-time input). Vehicle operating costs determine the proportional split of VMT across household vehicles. Out-of-pocket costs include the energy, Maintenance, Repair, & Tires, road use taxes (including EV surcharge and optional calculation of fee to fully recover road costs), work/non-work parking, PAYD insurance, input share of carbon and other social costs, as well as CarService fees by the household.

The following sections describe each module that contributes to this concept.

Watch a video overview of costs and budgets

4.2.1 4.2.1 Auto Ownership Cost & Adjustment

Two steps are required to calculate and adjust auto ownership costs:

1. *Calculate Vehicle Own Cost:* Average vehicle ownership costs are calculated for each vehicle based on the vehicle type, age, and annual VMT (financing, depreciation, and insurance), annual registration fees (flat and ad valorum), combined with any residential parking fees (if household exceeds free parking limits). To do so, PAYD insurance participation is assigned based on household characteristics (drivers by age, annual mileage, income, location type, vehicle type and age) and input PAYD insurance program participation. The ownership cost is converted into an average vehicle-specific ownership cost per mile by dividing by estimated household VMT per vehicle.

   Note that PAYD insurance does not affect the cost of vehicle ownership when determining whether a household will substitute car services for one or more of their vehicles. It does affect the out-of-pocket operating cost used in budget limitations on household VMT.

   2. *Adjust Vehicle Ownership:* Household vehicle ownership is adjusted based on a comparison of the cost of owning versus 'high' car service per mile rates (from the Household Multimodal Travel module), where available. The module identifies all household vehicles in a 'High' car service area, where the car service mileage rate exceeds the household's estimated vehicle ownership cost per annual household VMT. The

household's vehicle table entry changes from 'Own' to 'HighCarSvc' for these vehicles, limited by input assumptions regarding the average likelihood that an owner would substitute car services for a household vehicle (separate values are specified by Vehicle Type). Other auto ownership values are also updated (e.g., insurance, total vehicles).

4.2.2 4.2.2 Auto Operating Cost & Adjustment

Three primary adjustments adjustments to auto operating cost are carried out in VisionEval:

1. *Calculate Vehicle Operating Cost:* A composite per mile cost is calculated as an out-of-pocket cost for various household and Car Service vehicle VMT (see below), combined with cost equivalent of travel time (access time and travel time at congested speeds times value-of-time (VOT)). Total costs result from applying this vehicle-specific cost rate to each vehicle's VMT, where VMT is split among household vehicles (including car services used by household members) as a (reciprocal) function of this vehicle-specific composite cost rate:

    - **Vehicle maintenance, repair, and tire cost (MRT)** costs are calculated as a function of the vehicle type, powertrain and vehicle age based on data from the American Automobile Association (AAA) and the Bureau of Labor Statistics (BLS).
    - **Fuel and energy costs** are calculated as energy rates time average fuel efficiency (miles per gallon or Kwhr electricity).
    - **Gas taxes** are federal, state and local per gallon taxes to cover road costs. For Electric vehicles, an equivalent per mile cost is calculated and can be applied to some or all electric vehicles ($/gallon or EV vehicle surcharge tax).
    - **Other Road Cost Recovery taxes** (i.e. VMT tax) is a user input. If the (optional) `BalanceRoadCostsAndRevenues` module is run, an extra VMT tax is calculated that recovers household share of road costs, consistent across all model households.
    - **Congestion fees** are calculated average congestion price ($/mile) for travel on urbanized roads in the Marea multiplied by the proportion of household travel occurring on those roads.
    - **Carbon fee** and **other social cost fees** are carbon cost per mile is calculated as the input price of carbon times the average household emissions rate (grams/mile), a VMT-weighting of all vehicles in the household. Of the other social costs, some are per gallon (non-EV vehicle miles) others per mile (regardless of powertrain). The full per mile costs are discounted to only reflect the input proportion of social cost paid by user.
    - Daily **parking costs** from work parking costs (workers who pay for parking) and other parking cost (cost of parking for shopping, etc.) are summed and divided by the household DMVT. Note that

residential parking costs are included in the vehicle ownership not per mile cost calculations.

- **Pay-as-you-drive (PAYD) insurance** is defined for participating households as the sum of the annual insurance cost for all the household vehicles is divided by the annual household VMT.
- **Car-service costs** are the cost of using a car service (dollars/mile) is a user input by car service level (Low, High).

2. *Balance Road Costs And Revenues:* Optionally, an extra mileage tax ($/mile) for household vehicles needed to make up any difference in the cost of constructing, maintaining, and operating roadways and the revenues from total road cost fees including fuel, VMT, and congestion charges. Optionally, an additional mileage fee ($/mile) on household travel is calculated that would fully pay for roadway costs attributable to household vehicle travel. The cost of existing and new freeway and arterial lane-miles by Marea is calculated from the difference in input lane-miles relative to the base year and input unit road costs (constructing, maintaining, and operating). Reductions in lane-miles are ignored. The proportion of road costs attributable to households is set as the ratio of household VMT divided by the sum of household (including CarService), commercial service, and car-equivalent heavy truck VMT (multiply by PCE). Average road taxes collected per household vehicle mile are calculated as a weighted average of the average road tax per mile of each household (calculated by the `CalculateVehicleOperatingCost` module) using the household VMT (calculated by the `BudgetHouseholdDvmt` module) as the weight. Currently no annual fees contribute to road cost recovery.

3. *Budget Household Dvmt:* Household VMT is adjusted to keep within the household's vehicle operating cost budget, based on the historic maximum proportion of income the household is willing to pay for vehicle operations. This proportions varies with income. The household's DMVT is then reduced as needed to keep annual vehicle operating cost within that share of the household's annual income. Annual vehicle operating costs include the household's VMT times their own per mile vehicle costs, adding credits for selected annual payments (annual work parking fee if in a work parking cash-out-buy-back program, annual vehicle insurance if in a PAYD insurance program, and annual auto ownership costs if car service program reduced auto ownership). The module relies on aggregate survey data from the U.S. Bureau of Labor Statistics (BLS) Consumer Expenditure Survey (CES) for years 2003-2015.

Chapter 5

Processing

VisionEval is designed to be easy to install, run, and summarize, even when comparing scores of different scenarios. It produces consistent and detailed performance metrics. The user can modify the metrics produced by the model or define their own from data exported from the model. There are also several ways to think about validation of the model within the VisionEval mindset. These topics are explored in this chapter.

5.1 Running VisionEval

VisionEval is implemented entirely in the R statistical language and operates on recent versions of Microsoft Windows. All development work in done there, although macOS and Linux versions are usually distributed. A fully self-contained installer for the more recent production release of VisionEval can be found on the download page. It permits installation of the full VisionEval platform, to include example data, even behind firewalls that prevent access to R Project and GitHub repositories.

Once installed the user assembles data into a standard directory structure. Once the model run script is customized by the user it is typically run from a command prompt. Running it in this manner allows several different scenarios to be run at the same time with minimal user interaction. The results can then be mined or visualized using a variety of VisionEval and third-party products. Some users use [R Shiny] or similar interactive environments for summarizing and visualizing the output from VisionEval. Such an environment is especially useful when comparing key metrics from a large number of scenarios.

5.2 Typical outputs

VisionEval generates a large set of performance metrics at varying summary levels. Several pre-defined metrics are compiled for mobility, economic, land use, environmental, and energy categories in each model run. They can be tabulated for individual scenarios or compared to other scenarios, as well as visualized using a variety of tools.

The intermediate data generated during the various VisionEval module steps can be compiled as performance metrics, both in absolute and per-capita terms and at various geographies. Traditional transportation network metrics such as VMT, vehicle and person hours of travel, and total delay are easily compiled by overall or focused areas within the model. Likewise, emission estimates and fuel consumption are tabulated. These can be viewed in standard reports or in `VEScenarioManager` files, especially when comparing such values between scenarios.

One example of a set of region-wide performance metrics used by Oregon DOT includes:

- Mobility
  - Daily per capita VMT
  - Annual walk trips per capita
  - Daily Bike trips per capita
- Economy
  - Annual all vehicle delay per capita (hours)
  - Daily household parking costs
  - Annual HH vehicle operating cost (fuel, taxes, parking)
  - Annual HH ownership costs (depreciation, vehicle maintenance, tires, finance charge, insurance, registration)
- Land Use
  - Residents liming in mixed use areas
  - Housing type (SF: MF)
- Environmental
  - Annual GHG emissions per capita
  - HH vehicle GHG/mile
  - Commercial vehicle GHG/mile
  - Transit Vehicle GHG/mile
- Energy
  - Annual all vehicle fuel consumption per capita (gallons)
  - Average all vehicle fuel efficiency (net miles per gallon)
  - Annual external social costs per households (total/% paid)

5.3 Exporting data

Most of the data generated during a VisionEval model run can be exported (using exporter.R) if desired for further analyses. The user can then mine and visualize the data using a variety of open source and proprietary tools. This provides the user with considerable flexibility for creating more detailed statistics than those provided by the program. These VisionEval outputs might further serve as inputs to other models (e.g., emissions models, economic impact models) and visualization tools, and compilation of additional performance metrics.

5.4 Validation

Setting up the model includes the steps required to apply the model for a given study. It is somewhat related to validation, both for informing what types of studies that VisionEval are appropriately sensitive to and interpreting the results. See the Getting Started page on the wiki for an overview of getting started initially.

Validation is the assessment of a model's suitability for its intended purpose, often informed by comparisons against information not used in its original development. In traditional transportation planning models the comparison of observed versus modeled link flows is often a key component of validation. VisionEval is a data-driven model in that most of its inputs values are exogenously defined rather than emergent behavior from complex mathematical equations. Its aggregate representation of travel demand dictates that it be validated at the same level, with an emphasis on a wider number of comparisons than many traditional models.

The metric used in validation can range from relatively few, such as per-capita mobility estimates (e.g., VMT and VHT by mode), to a large number of more detailed targets. Examples of the latter include comparisons to external sources (e.g., HPMS data, DMV data), sensitivity tests of key variables, and comparison to comparable communities. An example of detailed validation criteria used by the Oregon DOT provides examples of these targets.

There are several options for making adjustments in order to calibrate and validate the models. These adjustments vary in difficulty, and the most appropriate approach varies by module. From easiest to most difficult the options for making adjustments are:

- *Self-calibration:* Several of the modules are self-calibrating in that they automatically adjust calculations to match input values without intervention by the user.[Selected value should be validated to confirm the calculations are done correctly]
- *Adjustment of model inputs:* Some modules allow the user to optionally enter data that can be used to adjust the models to improve their match to observed conditions.
- *Model estimation data*: Several modules use data specific to the region where the model is deployed, such as household synthesis. Functions within each module generate cross-tabulations required from these data. Census PUMS data from Oregon were used to develop the original models, and

should be replaced with Census PUMS data for the modeled area.

- *Model estimation scripts:* An advanced user or developer can make adjustments to the model code itself in order to facilitate better matching observed local behavior or patterns. This, of course, is the most difficult option and opens up potential for significant errors, but it is possible for users that know what they are doing.

The main validation targets have historically included household income, vehicle ownership, vehicle miles of travel, and fuel consumption. The number of workers and drivers within each geography have recently become more widely used. These statistical comparisons can be made for the modeled area as a whole or for large geographies nested within them (e.g., Azones, Mareas). Sensitivity tests should be performed to evaluate the reasonableness (eg. correct direction and magnitude) of the VisionEval output estimates. Comparable community applications of VisionEval may also provide a reasonableness check that the model is functioning appropriately.

> Note that HPMS definition of VMT differs from that used in VisionEval. VisionEval reports on all household travel regardless of where it occurs, and adds Commercial vehicle and Heavy Duty Truck and Bus travel on MPO roads. HPMS reports vehicular travel of all modes on roads within the MPO boundary.
>
> Additional detail on validation can be found in a separate validation document