Appendix A: An Overview of the Modeling Process

Travel Demand Modeling

Travel behavior for this report was modeled by Metro, the Portland area regional government. The Metro travel demand model has the following components:

The **auto ownership model** predicts levels of car ownership (0, 1, 2, 3+) at the household level. Household size, number of workers, household income, jobs within a 30 minute transit trip, the quality of the pedestrian environment, and density of retail employment are inputs into the auto ownership model. The model outputs are important inputs into the trip generation, pre-mode choice, and mode choice models for home-based trip purposes.

The **trip generation model** predicts trip origins and destinations by each of six purposes: home based work, home based school, home based college, home based other (trips to stores, offices, recreational facilities etc.), work related non-home based, and non-work/non-home based. This model depends upon the demographic characteristics of households and characteristics of destinations, such as total employment, total households, or students and employees at colleges.

The **destination choice, or trip distribution, model** determines the attraction ends of the trip productions. This model therefore implies a trip length distribution as it estimates the number of trips from each origin zone to the other zones in the metropolitan area.

The **pre-mode choice model** estimates the percentage of trips using the walk or bicycle only modes for each origin-destination pair. Data is currently insufficient to distinguish between the two modes. Inputs into the pre-mode choice model include trip distance, car ownership levels, number of workers, employment densities at destinations, and the quality of the pedestrian environment.

The **mode choice model** determines how many vehicular trips use auto or transit. For home based work trips, the split between single occupant auto and carpool and between auto and walking access to transit is also estimated. Inputs into this model include number of vehicles; employment densities of destination; residential densities; times for walking to, waiting for, and transferring on transit; number of workers per household; out of pocket costs; and the quality of the pedestrian environment.

The **trip assignment model** assigns auto trips to highways and transit trips to transit routes. Vehicle trips per hour are assigned to multiple paths between origins and destinations in an interactive process, termed "network equilibrium," which results in the use of a number of paths having approximately equal travel times. Transit trips are allocated to paths based on weighted path travel times.[1]

1. For additional information on Metro's travel model, *see* 1000 Friends of Oregon, *Making the Land Use, Transportation, Air Quality Connection,* Vol. 1, *Modeling Practices* (Portland, Oregon, 1991) *and* ibid., Vol. 4, *Model Modifications* (1996).

Air Quality Modeling

Carbon monoxide (CO), nitrogen oxides (NOx), and hydrocarbon (HC) emissions were modeled using MOBILE5a, a computer program developed by EPA that calculates emission factors in grams per mile of travel from gasoline- and diesel-fueled highway motor vehicles. The burden analysis was based on emissions from vehicles traveling on roadways within the study areas as predicted by Metro's travel demand model.

MOBILE5a emission estimates consider temperatures, speed, vehicle mixes, inspection and maintenance programs, percent hot and cold starts, and mileage accrual rates. Because MOBILE5a accounts for gradual replacement of older vehicles over time with newer, less polluting vehicles, predicted CO and HC emission rates for future conditions are lower than existing conditions, and generally decrease with increased speeds. Predicted NOx emission rates for future conditions are also lower than existing conditions, but are different than CO and HC because NOx emission rates increase with speeds above 15 miles per hour.[2]

Greenhouse Gas and Energy Consumption Modeling

Another analysis was conducted to estimate the amounts of mobile-source based emissions of "greenhouse gases"—carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). An energy consumption analysis was also conducted.

Metro's travel demand model provided the traffic data required for this analysis. The vehicle miles of travel (VMT) data was aggregated on a 24 hour basis for the study area. The fleet percentages for each vehicle type were provided from Table 1 in Metro's "Modified Link-based Emission Documentation" from the Oregon Department of Transportation Western Bypass Study.

Emission rates for CH_4 and N_2O were determined using procedures from EPA's *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*. Emission control technologies appropriate for each vehicle model year were determined for each vehicle type, based on a 2010 vehicle fleet. The type of control technology for each vehicle type and model year were determined from referencing Tables D13-1 to D13-11 in the EPA manual and MOBILE5a registration data. Composite emission rates were calculated and multiplied by the total VMT for each alternative resulting in total emission burdens for CH_4 and N_2O.

The emission rate for CO_2 was determined by estimating the energy intensity for each vehicle type based on the distribution of the vehicle model years in the fleet, which resulted in the total carbon content of the fuel consumed. The energy intensity based on BTU per vehicle-mile was determined from the *Transportation Energy Data Book: Edition 14* for each vehicle type in the 2010 fleet. CO_2 emissions were then determined, based on the percent of carbon that is oxidized from energy consumption of the vehicle fuel use.

The energy consumption (BTUs) for each alternative was determined using the CO_2 emis-

2. For additional information on air quality modeling *see* Oregon Department of Transportation, *Western Bypass Study Sunset Highway-Pacific Highway Air Quality Technical Report* (Portland, Oregon, 1994).

sion burden calculations which were based on energy intensity (BTU per vehicle-mile) for each vehicle type and multiplied by the total VMT under each of the alternatives.

Total emission burdens for CH_4, N_2O and CO_2 were calculated by multiplying the 24 hour VMT for each alternative by the corresponding emission rate that was calculated based on the EPA's *State Workbook* methodology.

How Key Concepts In The LUTRAQ Alternative Were Included in the Modeling Process

Transit Oriented Developments (TODs) are described in detail in LUTRAQ Volume 3: *The LUTRAQ Alternative*. TODs differ from more standard models of suburban development by their concentration and mixture of uses, and the quality of the pedestrian environment. Through model enhancements developed by the LUTRAQ project, these factors are now inputs into Metro's auto ownership, pre-mode choice, and mode choice models. The urban design of TODs affects the quality of the pedestrian environment, a factor that was added to the travel models as described below. In addition, the TODs attract smaller households because more of the housing is multi-family than in the rest of the study area.[3] Household size and number of workers were estimated for TOD housing types and included in the auto ownership, pre-mode choice, and mode choice models.

Regarding the pedestrian environment, a variable measuring pedestrian environmental quality, called the "Pedestrian Environment Factor" (PEF), was created and included in the travel demand modules. The measure represents a composite measure of the "pedestrian friendliness" of each of the analysis zones in the model system. Recognizing that a number of factors at the neighborhood and street level affect individual's willingness and ability to choose to walk, four different parameters were selected to measure PEF:

- Ease of street crossings
- Sidewalk continuity
- Street connectivity (grid versus cul-de-sac)
- Topography

Because of data and time constraints, a qualitative approach was used. Four Metro staff members evaluated each zone on each factor assigning a value from 1 to 3. Values for each of the parameters were summed, leading to a ranking for each zone from 4 to 12, with 4 representing the lowest possible score and 12 the highest.

For estimating the ease of street crossing in each of the zones, staff identified key intersections and evaluated their width, extent of signalization, and traffic volumes. Regarding sidewalk continuity, staff judged the extensiveness of sidewalks on principal arterials serviced or likely to be served by transit. For the characteristics of the street systems, staff

3. N.B.: The LUTRAQ alternative assumes household demographic characteristics in 2010 that are consistent with the continuation of current economic, social, and political trends. If these trends were to vary dramatically during the study period, significant shifts in housing choices and travel behavior would be expected. For example, if household income growth were to stagnate, or if current financial incentives for home ownership were trimmed, one would expect to see a stronger multi-family housing market, and a wider range of household types choosing multi-family housing products, than was assumed for the LUTRAQ alternative. Likewise, a substantial increase in transportation and energy costs would likely result in less vehicle travel—by residents of all housing types—than was estimated for the LUTRAQ alternative.

estimated the extent of grid street patterns throughout each of the zones. They also examined the fineness of the grid. For topographic considerations, staff evaluated zones in terms of the extensiveness of sloping terrain and the steepness of these slopes. The results by each staff member were compared, and some zonal scores were modified. This simplified Delphi process resulted in consensus rankings for the entire network of zones.

Once established, PEF scores were incorporated into the LUTRAQ alternatives. TODs were given high PEF scores, while future non-TOD development received low scores, recognizing that this development was likely to resemble current pedestrian "hostile" development patterns. In addition, PEF scores within one-quarter mile of transit stations and bus lines were adjusted to reflect the street crossing and sidewalk improvements that were included as part of the alternatives. In the LUTRAQ/Congestion Pricing alternative, these scores were further increased to the maximum value within one quarter mile of bus service with headways of ten minutes or less.[4]

Pricing

Pricing was modeled by adding to the out-of-pocket cost variable in the mode choice model. Parking pricing added $3.00 for each work trip by a single occupant vehicle whose destination was in the study area. Congestion pricing added $0.15 cents a mile to work trips by cars that begin or end in the study area. The Metro model is a peak period, not a full-day model, so these charges represent peak period pricing.

The method of operationalizing congestion pricing was the best available at the time, but was by all accounts a rather crude measure. A per mile charge for all work trips but not for trips for other purposes can readily be included in the model, but could not be easily implemented in the real world. The model uses this information to reallocate trips to modes. The model currently cannot shift any of the trips to other times of day, a result one would expect in the real world under a peak hour pricing scheme. As part of a federally funded congestion pricing demonstration study, Metro plans to re-estimate their travel demand models in 1996-97 using data from stated preference surveys to simulate the effects of prices on travel behavior. This will improve the ability of the models to analyze congestion pricing options.

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4. It should be noted that one of the limitations of the PEF approach is that it restricts the range of pedestrian friendliness that can be included in possible scenarios to a level already in existence in the area being studied. In other words, because observed data is available only from existing development patterns, it is difficult to use the PEF approach to hypothesize alternatives where pedestrian friendliness is greater than the existing environment. For the LUTRAQ analysis, downtown Portland was assumed to be the most pedestrian friendly environment in the region. Although there are arguably many other places in the world more pedestrian friendly than downtown Portland, the LUTRAQ alternative includes PEF scores that, at best, only approach or match downtown's pedestrian environment.