

Appendix H: Model Methodologies

Travel Demand Model

The Mid Region Council of Governments employs a travel model to assess the anticipated future travel demand in the region. The four-step model is the most widely used transportation model for MPO agencies throughout the country to help determine future demand and regional travel patterns. The four steps of the model are:

1. Trip generation
2. Trip Distribution
3. Mode Choice, and
4. Trip assignment

More detail on each step, including data needs and outputs is provided below. The travel demand model is currently developed in the Cube software (Citilabs) platform with several components written in Python.

The travel model is run for a *scenario year*, to represent a particular year, set of projects, or can be project-specific. There are 3 main inputs needed, including a socio-economic file generated by the land use model, a road network, and two transit networks for the peak and off-peak time.

The socio-economic file has information by Data Analysis Sub Zone (DASZ) such as employment by type, number of households, and population while the road network has road characteristics such as posted speed, number of lanes, and functional class.

In order to better represent the travel behavior of the area, the model must be calibrated for a base-year using a travel survey to understand current travel patterns and characteristics. Observed travel patterns, such as trip-purpose split to distinguish different trip types is used to validate the accuracy of the model. For this, MRCOG conducted a 2014 Household travel survey to update for this MTP. The survey findings were used to adjust the different trip purpose factors needed to represent the trip distribution by trip purpose and time of day.

The four travel demand steps are:

Step 1: Trip Generation – *How many trips are generated?*

The first step of the model is the trip generation (production) step to estimate the number of trips that each DASZ generates and attracts. A set of equations is used to determine the number of trips produced by and attracted to each zone based on socio-economic characteristics. For example; the more employment a DASZ has, the more work trips it attracts. The more retail employees in a DASZ, the more shopping trips are assumed to be attracted there.

Step 2: Trip Distribution – *Where do trips go?*

The second step is where each zone productions and attractions are transformed into origins and destinations. Trip ends are linked to create complete trips. This can occur within the same

zone, or between adjacent zones with varying distance. For example; trips between residential areas and employment center or locations.

Step 3: Mode Choice – *What travel mode is used for each trip?*

The third step predicts the mode-type that individuals or groups choose in making their trip. The primary objective is to predict the share of trips attracted to public transportation and other modes such as walk or bike. Critical factors considered for mode choice include: travel time, travel cost, and access to mass transit options.

Step 4: Trip Assignment – *What is the route of each trip?*

The final step is to determine the routes on the network travelers choose to reach their destinations. During the assignment step, the model uses a utility function to assign all trips that are calculated in the network to determine the best route for all travelers in terms of time. In this step, the model does many iterations comparing travel times among all trips and routes until it determines that all the travelers have achieved their best possible travel time. For example, a congested corridor might change the route of a user to take a different route with a longer distance but same travel time. After the assignment, the model's final results appear on the network and include travel statistics such as volumes, volume to capacity, vehicle miles travelled, and delay which are then used in the evaluation of new or future transportation projects or improvements.

For this MTP, the travel demand model has been modified to run interactively with the land use model to better capture the interaction between land use development and transportation and the combined influence on regional growth patterns. To exemplify this importance, consider how land-use development relies on roadway infrastructure in order to facilitate access and mobility needs. Also, land use density patterns have a direct effect on trip generation and thus may necessitate additional roadway capacity and/or public transit service. In the planning context, land use development without adequate supportive infrastructure can result in more congestion, which results in longer travel times.

Figure H-1: Access to Jobs without Travel Demand Model Integration

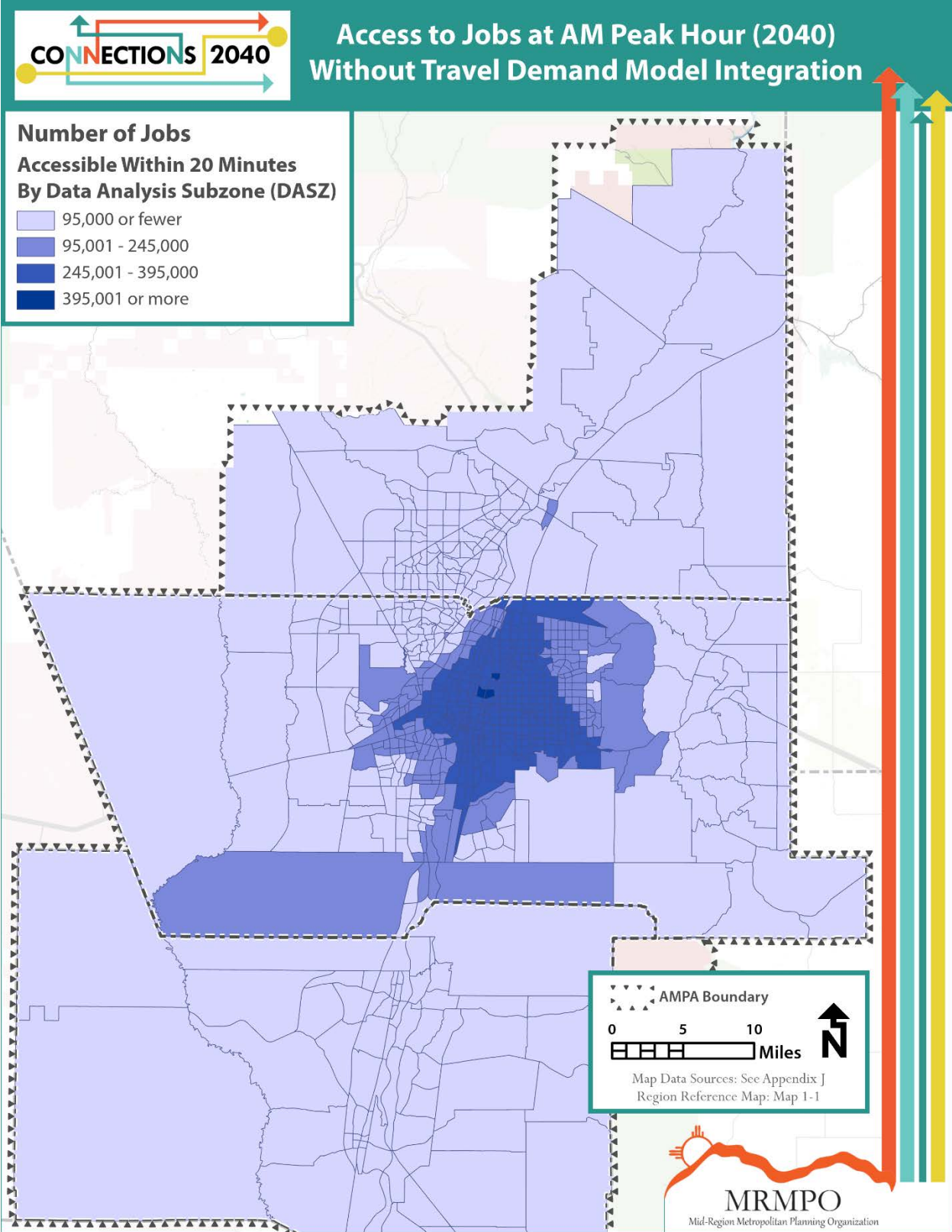
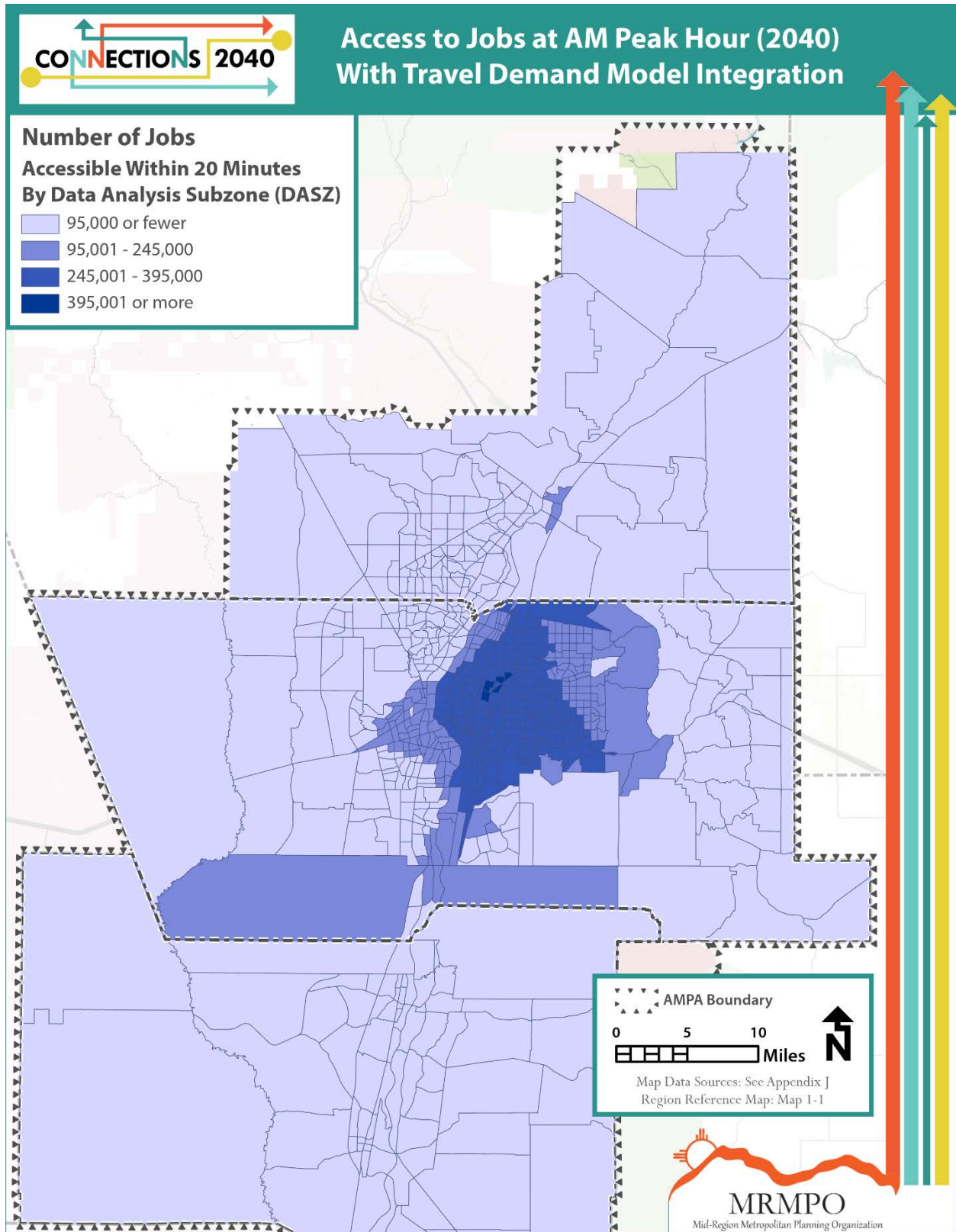


Figure H-2: Access to Jobs with Travel Demand Model Integration

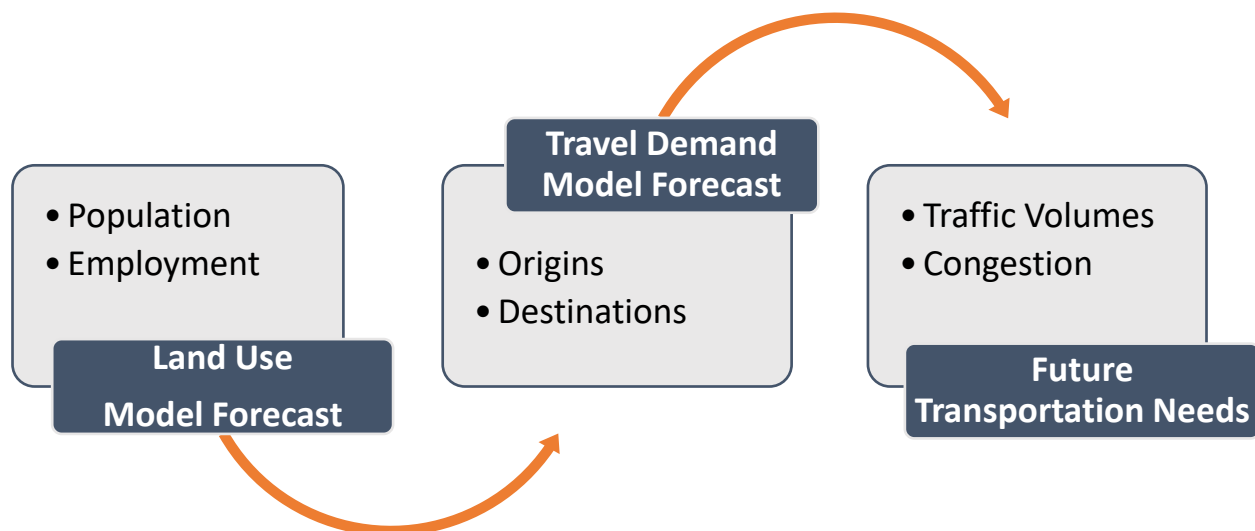


Land Use Forecasting Methods

Introduction

Federal transportation legislation mandates a planning process that links transportation with land use, and MRCOG has responded to this call with a commitment to integrated planning. As such, the Mid-Region Metropolitan Planning Organization (MRMPO) operates a locally customized implementation of the UrbanSim land use model to forecast the spatial distribution of people and jobs moving into and within the region. The UrbanSim land use model is integrated with the Cube travel demand model which means that the modeling framework allows land use decisions to impact future congestion, which in turn impacts future land use. The socioeconomic forecast serves as the primary input to the travel demand model in order to forecast future travel demand, which then informs decisions related to future transportation infrastructure needs. This section describes how land use is forecast and the integration of the land use model and the travel demand model.

Figure H-1: Land Use and Travel Demand Modeling Framework



UrbanSim Overview

UrbanSim is a microsimulation land use model designed for analyzing the potential effects of land use policies and infrastructure investments on the development and character of the region. The modeling system relies upon a data-driven, transparent, and behaviorally-focused methodology that is designed to attempt to reflect the interdependencies in dynamic urban systems, focusing on the real estate market and the transportation system, and on the effects of individual and combinations of interventions on patterns of development, travel demand, and household and job location. UrbanSim has become the operational modeling approach for a variety of metropolitan areas in the United States and abroad, and is actively used by planning organizations in Austin, Chicago, Denver, Detroit, Honolulu,

Phoenix, Minneapolis, Salt Lake City, San Diego, San Francisco, Eugene-Springfield, Seattle, and Paris among others.

UrbanSim works by simulating the interactions among households, businesses, and developers within real estate markets. By modeling the real-world trade-offs between housing costs, accessibility, and various other amenities, UrbanSim predicts households' location choices. UrbanSim also replicates local employment dynamics, including a firms' location choices. Furthermore, the model simulates developers' choices of what kind of buildings to build, where, and when, and whether to redevelop existing properties. Land use policies constrain what developers can build, and transportation plans modify accessibility patterns, which influence the attractiveness of different locations for households and firms. These dynamics influence prices and rents and the market conditions for new development or redevelopment.

UrbanSim simulates changes by single year increments, and the results of one year provide the starting point for the next simulation year. This method closely replicates the way that urban areas evolve, year over year, with mismatches between the supply and demand of housing and jobs. Typically, metropolitan areas see only a small fraction of the housing stock added in a given year. Development of real estate proceeds slowly in response to rapid changes in demand, leading to swings in vacancy rates and prices, and to the commonly observed booms and busts in real estate cycles.

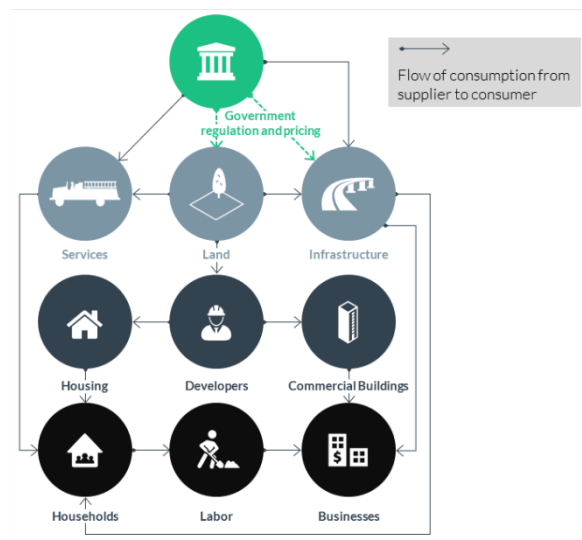
Key conceptual underpinnings of UrbanSim include:

- Representation of individual decisions made by households, employers, people and jobs.
- Representation of the supply and characteristics of land and of real estate development.
- A dynamic perspective of time, with the simulation reacting to changing conditions year to year.
- The use of real estate markets as a central organizing focus, with consumer choices and supplier choices explicitly represented, as well as the resulting effects on real estate prices. The relationship of households or employers to real estate tied to specific locations provides a simple accounting of space and its use.
- The use of Multinomial Logit Models to represent the choices made by households, employers and developers (principally location choices).
- Integration of the urban simulation system with existing transportation model systems, to obtain information used to compute accessibilities and their influence on location choices, and to provide the inputs to the travel models.

Model System Design

In the UrbanSim model, buildings are located on parcels that have particular characteristics such as value, land use, and developable area. Local municipalities set policies that regulate the use of land, through the imposition of zoning or through pricing policies such as development impact fees. Municipalities also build infrastructure, including transportation infrastructure, which interacts with the distribution of activities to generate patterns of accessibility at different locations that in turn influence the attractiveness of these sites for different consumers. Households have particular characteristics that may influence their preferences and demands for housing of different types at different locations. Businesses also have preferences that vary by industry and size of business (number of employees) for alternative building types and locations.

Figure H-2: Households and Employer Interactions within Real Estate Markets.



UrbanSim predicts the evolution of households, employers and their characteristics over time, using annual steps to predict the movement and location choices, the development activities of developers, and the impacts of governmental policies and infrastructure choices. The land use model is interfaced with MRMPO's travel model system to deal with the interactions of land use and transportation. Access to opportunities, such as employment or shopping, are measured by the travel time or cost of accessing these opportunities via all available modes of travel. See the travel model integration section for details.

MRMPO uses exogenous regional employment and population forecasts as control totals, meaning that these are inputs that are not predicted directly by UrbanSim or MRMPO. The University of New Mexico Bureau of Business and Economic Research (UNM-BBER) uses a macroeconomic model to predict short term future employment by sector which is supplemented by MRMPO using a long-term employment forecast from Regional Economics Modelling Inc. (REMI) to create a regional employment control total. The University of New Mexico Geospatial Population Studies (UNM GPS) develops county level population projections using the cohort component method which relies on predicting births, deaths and migration that is used as a population control total.

UrbanSim Inputs

- Employment data from New Mexico Department of Workforce Solutions and InfoGroup
- Household data merged from multiple U.S. Census sources and ESRI Business Analyst Online
- Municipal, County, Tribal and State land use plans and regulations such as zoning
- Undevelopable land, Federal land, Tribal land, and State land boundaries
- Congested travel times from the Cube travel demand model
- Parcel database supplemented with local data pertaining to land use, housing units, nonresidential square footage, year built, land value, and improvement value. Sources include County Assessors, local planning Geographic Information Systems (GIS) databases, CoStar, Metrostudy, and building permits issued for new construction.
- Average construction costs from RSMeans

UrbanSim makes extensive use of discrete choice models where individual households and employers choose buildings. First, multinomial logit models are estimated based on the variables that have proven to be statistically significant in explaining past behavior. For example, households that moved to the region in the last 5 years are evaluated based on the census tracts that they chose to move to. The estimated model then generates a probability that a particular household (based on income and other characteristics) will pick a particular housing unit (of different sizes, prices and other characteristics). In order to predict choices given the predicted probabilities, the choice algorithm uses a sampling approach. As illustrated in the figure below, a choice outcome can be selected by sampling a random number from the uniform distribution in the range 0 to 1, and comparing this random draw to the cumulative probabilities of the alternative housing units. Whichever alternative the sampled random number falls within is the alternative that is selected as the 'chosen' one. This algorithm has the property that it preserves in the distribution of choice outcomes a close approximation of the original probability distribution, especially as the sample size of choosers becomes larger.

The diagram illustrates the choice model process flow, organized into three main sections: Model Specification, Utility Equations, and Choice Process.

Model Specification: Shows a set of Chooser Attributes k (Submodel k) leading to a Chooser (n) and a Chooser (N) . The Chooser (n) is associated with a ChoiceSet $(n) = \text{Alternatives } j \dots J$.

Multinomial Logit Utility Equation (j) : The utility $V^n(j)$ is calculated as a function of coefficients β_{js} and variables X_{js} , plus interaction terms $\beta_{njs} X_n X_{js}$.

Multinomial Logit Probability Equation (j) : The probability $\text{Pr}^n(j)$ is calculated as the exponential of the utility $V^n(j)$ divided by the sum of exponentials of utilities for all alternatives j .

Choice Process: The cumulative probability ranges (e.g., 0 - .15, .15 - .40, 40 - .77, .77 - 1.0) are used to generate a random number. The random number is then mapped to a choice (e.g., .65 maps to the third choice, represented by a green circle). The choice is then mapped to the observation (n) .



CONNECTIONS 2040

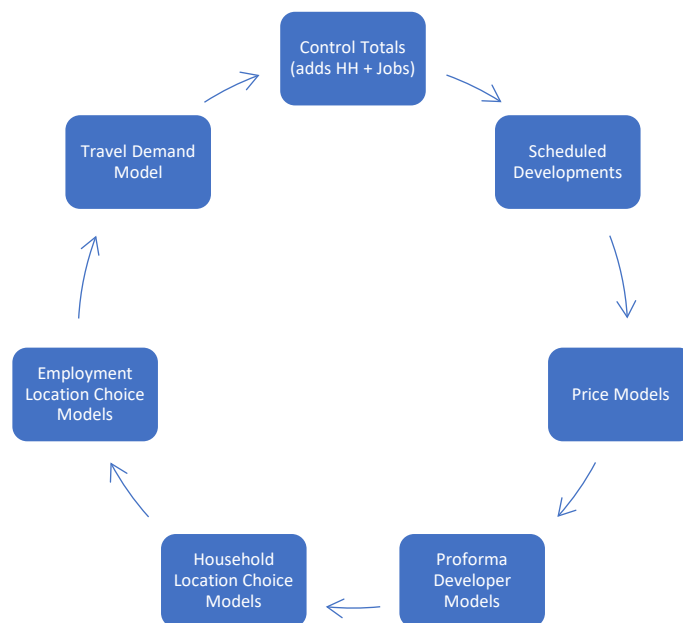
Figure H-4: Sample probability of a manufacturing firm locating on a particular parcel (yellow is high, purple is low)



Model Steps

Each simulation year follows the steps seen in Figure x. First, the control totals developed externally by UNM and REMI determine how many new households and jobs are introduced to the region. Next, the known scheduled developments are built. Next, the Price Models update real estate prices followed by the proforma and developer steps calculating costs of potential sites and then building new buildings that are profitable. Next, the Household and Employment Location Models place households and jobs into empty buildings based on the predicted attractiveness of each site. Finally, because the spatial allocation of people and jobs has been altered, the Travel Model is updated and calculates new congested travel times. The updated travel times will affect the next year's prices and location choices.

Figure H-5: Model steps in each simulation year



Developer Models

- **Scheduled Developments:** Known development projects that are either currently under construction or set to begin building in the near term are added to the simulation in the appropriate year. This allows areas of current growth to be seeded with real projects and updates the base year data from 2016 to current conditions.
- **Proforma:** Computes the costs and revenues of feasible development projects allowed by zoning and creates new buildings. Costs include: construction costs, demolition costs (if parcel is not vacant), financing costs, and parking construction costs. Using the modelled prices from the Price Models to estimate potential revenue of different developments, the most profitable development projects are built in each simulation year.

Price Models (Ordinary Least Squares Regression)

- **Commercial Price Models:** These models are segmented by office, retail, and industrial. Important estimation variables include: accessibility to workers (based on travel model outputs), year built, proximity to freeway exits, size of parcel or building, within 'key center', accessibility to other employers (clustering effect).
- **Residential Price Model:** Important estimation variables include: accessibility to jobs (based on travel model outputs), proximity to industrial sites (negative coefficient), income level of neighborhood, access to transit, year built, and access to retail or food services.

Location Choice Models (Multinomial Logit)

- **Employment Location Choice Models:** These models are segmented by employment sector. Important estimation variables include: commercial rent/price per square foot, size of parcel or

building, type of commercial building, year built, accessibility to other employers (clustering effect) and accessibility to workers.

- **Household Location Choice Models:** These models are segmented by income. Important estimation variables include: rent or price per residential unit, unit square feet, year built, accessibility to jobs (based on travel model outputs), access to transit, access to retail or food services, average household size of neighborhood, and income level of neighborhood.

Integrated Modelling Approach

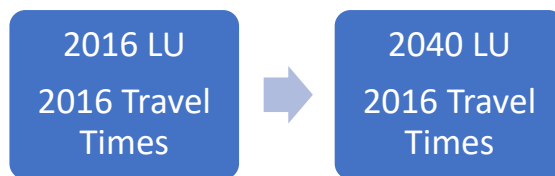
An integrated modelling approach that combines land use and travel demand improves the ability to reflect future conditions that are representative of the dependencies between housing and employment choices and congestion.

Without the travel demand model, the land use model uses only one set of travel times throughout the whole simulation, meaning that regional growth does not affect travel times and congestion does not affect future growth. In contrast, when the land use model runs interactively with the travel demand model, the travel times get updated every time the travel demand model runs. The interaction between the two models occurs every 5 years starting in the simulation year 2020 and concluding in 2040. With each iteration of the travel demand model, land use development patterns are modified because travel time is a factor when deciding where to build future development.

The following picture illustrates the differences between a traditional and an integrated model approach to predicting future land use.

Figure H-6: Traditional Approach vs. Integrated Approach to Modelling Land Use

Traditional Approach



Integrated Approach



The table below shows the differences in expected growth between the traditional modeling approach and the integrated approach. The travel demand model results are based on a “no build scenario”, in which the base 2016 roadway network remains static in order to create a true comparison between the two runs.

Table H-1: Forecast Differences by County when Applying an Integrated Model Approach

County	Jobs	Households
Bernalillo	0.13%	1.45%
Sandoval	-1.25%	-3.60%
Valencia	-2.99%	-4.97%
Torrance	-4.74%	-7.35%

All counties except Bernalillo County show a declining share of growth within an integrated modeling framework. This reflects the decreased access to key destinations from surrounding counties when future congested travel times are introduced. As congestion levels rise, Valencia, Sandoval and Torrance become less attractive for future development given that many trip purposes and in particular work commutes are destined for Bernalillo County.

Integration between the land use and travel demand models is a more realistic approach to forecasting. By allowing the models to interact we are able to better simulate real world decision-making as we know that issues of congestion and travel times to common destinations often play a role in where households and employers chose to locate.

Target Scenario

The Target Scenario is a “what if” scenario and therefore requires adjustments from the trend model assumptions in order to simulate an alternative. These adjustments within the UrbanSim model help us understand how policy changes may affect future regional growth. Key guiding principles of the Target Scenario goals include: 1) support premium regional transit, 2) invest in activity centers and transit-oriented development, 3) balance housing and jobs, and 4) preserve and protect the character of rural areas.

The three specific components that are adjusted to create the Target Scenario are: 1) zoned capacities within key centers and along future transit corridors, 2) policy incentives for development in key centers and transit corridors, and 3) reduce attraction of new development within greenfield and rural areas. Therefore, the baseline assumptions of the UrbanSim model were adjusted in the following manner:

- The zoned densities for parcels in key centers or transit corridors were increased to encourage density in areas served by transit.
- Revenues of commercial development in westside key centers and transit corridors were increased to help balance jobs and housing west of the river.
- Revenues of residential development in eastside key centers and transit corridors were increased to help balance jobs and housing east of the river.
- Revenues of residential and commercial development in Valencia County key centers were increased to encourage density where appropriate.
- Revenues of greenfield development were decreased (“greenfield” is approximated by selecting parcels that do not currently have municipal sewer service) to preserve the rural character of outlying areas.

Assumptions and Limitations of UrbanSim

UrbanSim is a model system, and models are abstractions, or simplifications, of reality. Only a small subset of the real world is reflected in the model system, as needed to address the kinds of uses outlined above. Like any model, or analytical method, that attempts to examine the potential effects of an action on one or more outcomes, there are limitations to be aware of.

- *Boundary effects are ignored.* Interactions with adjacent metropolitan areas pose modeling difficulties due to boundary effects. For example, MRMPPO does not model interactions with Santa Fe even though residents of the Mid-Region work in Santa Fe or vice-versa.
- *Zoning regulations are assumed to be binding constraints on the actions of developers.* Parcels are constrained by their zoned densities with the exception of the known scheduled developments which are always built, and approved master planned areas which are updated to reflect the intended uses and densities shown in the plans.
- *UrbanSim is a regional land use model and results should not be used at a parcel level.* While UrbanSim is a microsimulation model, results are intended to be aggregated to larger geographies such as DASZs in order to avoid the inaccuracy inherent at the parcel level.

- *Behavioral patterns are assumed to be relatively stable over time.* The UrbanSim model assumes that behavioral patterns will not change dramatically over time. Models are estimated using observed data, and the parameters reflect a certain range of conditions observed in the data. If conditions were to change dramatically, such as fuel prices tripling and continuing to increase, it is probably the case that fundamental changes in consumption behavior, such as vehicle ownership and use, would result.

Methodologies for Select Maps

Map: Land Classifications with Trails

Displays local trails with layers of the 2016 National Land Cover Database (NLCD). The NLCD serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation. NLCD provides spatial reference and descriptive data for characteristics of the land surface such as thematic class (for example, urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover. NLCD products are created by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of Federal agencies led by the U.S. Geological Survey. ¹

Map: Animal Collisions by Type

2012-2016 wildlife vehicle collision data, supplied by...

Map: Crucial Habitat Assessment Tool (CHAT)

The New Mexico Crucial Habitat Assessment Tool (NM CHAT) is a web-based map tool with spatial information on the conservation of animals, plants, and their habitats across New Mexico. It is designed to aid landscape-level planning and is intended for industry, natural resources managers, conservation practitioners, and the public to identify priority habitat (See Data for details.). The CHAT website is a collaboration between New Mexico Dept. of Game & Fish and Natural Heritage New Mexico, Museum of Southwestern Biology at the University of New Mexico. Data on species and habitats was provided by Playa Lakes Joint Venture, New Mexico Environment Department Surface Water Quality Bureau, U.S. Fish and Wildlife Service, and the Museum of Southwestern Biology at the University of New Mexico.²

Map: UHI and Tree Canopy in the Albuquerque Metro Area

Environmental Justice Index scores per census tract were derived from American Community Survey 2014-2018 5-year Estimates on percent of tract population with incomes below the Federal Poverty Level, and of ethnicities other than those reported as “White, non-Hispanic.” These populations are those required by federal law to be considered in assessments of environmental justice. Using the Jenks “natural breaks” classification system to minimize the average deviation from the class mean while maximizing the deviation from the means of the other groups, and five classes in each variable, a score from 1 to 5 was assigned to each percentage range, then summed to produce an index score with values from 2-10 representing relative concentrations of both populations. The “Urban Heat Severity” layer was provided by the Trust for Public Land as part of the Bernalillo County Greenprint process, and shows where Urban Heat Islands and high percentages of impervious surface overlap in the County. Generated from LANDSAT Satellite Sensory Data using an average of 6 scenes collected on: June 9th 2014; June 16th 2014; July 18th 2014; June 3rd 2015; June 19th 2015; and August 15th 2015, raster cells were given values ranging from 3-5 defining the degree of heat above the +1.25 F above-average threshold, and combined using a sum with the NLCD impervious surface estimates. The final results were created by doing a statistical natural breaks classification on the summed result, with those scoring higher being assigned a priority value of High (4) or Very High (5). The “Tree Canopy” layer was provided by the Nature Conservancy for the Albuquerque area, mapped from 4-band, 1-meter resolution aerial photographs captured in the summer of 2016 by the National Agriculture Imagery Program (NAIP), and

¹NLCD 2016 Land Cover (CONUS), <https://www.mrlc.gov/data/nlcd-2016-land-cover-conus>

² About New Mexico Crucial Habitat Assessment Tool, <http://nmchat.org/about.html>

digitized using a Classification and Regression Trees (CART) classifier and hand-digitized training data in Google Earth Engine (GEE). To derive the “Priority Areas for Intervention”, a 1-5 score for percent tree canopy and severe heat cover was derived for each tract (using the same natural breaks method described above), then summed with the Environmental Justice Index score to identify tracts where low tree canopy cover and high to very-high heat area combine with high percentages of populations in poverty. Research suggests that poverty is a relevant indicator of vulnerability to extreme heat, and so these tracts make logical priority locations for new tree plantings and other heat-reduction interventions.

Map: FEMA 100-year Floodplains in the Region

Depicts areas with a 1% annual chance of flooding according to the Flood Insurance Rate Map (FIRM) program of the Federal Emergency Management Agency, and low water crossing points where “When Flooded, Turn Around, Don’t Drown” caution signs are located around the region. These signs were purchased and distributed through a partnership of the New Mexico Dept. of Homeland Security and Emergency Management and the New Mexico Floodplain Manager’s Association.³

Map: WUI Areas in the Region

Wildland Urban Interface (WUI) and Intermix areas of the region. Data provided by the U.S. Forest Service Data Archive.⁴

Map: Alternative Routes Along the Local Network

Depicts road network density in five classes of local lane miles per half-mile grid cell.

Map: Environmental Justice Index

Environmental Justice Index scores per census tract were derived from American Community Survey 2014-2018 5-year Estimates on percent of tract population with incomes below the Federal Poverty Level, and of ethnicities other than those reported as “White, non-Hispanic.” These populations are those required by federal law to be considered in assessments of environmental justice. Using the Jenks “natural breaks” classification system to minimize the average deviation from the class mean while maximizing the deviation from the means of the other groups, and five classes in each variable, a score from 1 to 5 was assigned to each percentage range, then summed to produce an index score with values from 2-10 representing relative concentration of both populations.

Map: Access to Transit and EJ Populations

Combined with the EJ Index (see Map 9-1 methodology above), and using the MRMPO’s Transportation Access Model tool, contours were generated representing the area that can be reached by walking from each bus stop for 5 and 10 minutes at an average speed of 3 miles per hour along the transportation network (including trails). Population and demographic statistics for each service area were then generated from 2014-2018 American Community Survey 5-year Estimates (prorated by linear frontage areas).

Map: Percent Tree Canopy Coverage

Using a digital tree canopy layer provided by the Nature Conservancy for the Albuquerque area, a

³New Mexico TADD Signs story-map,

<https://www.arcgis.com/apps/MapJournal/index.html?appid=13d7a67071a5465e91ed01ceaad25433>

⁴New Analyses Reveal WUI Growth in the U.S. <https://www.nrs.fs.fed.us/data/wui/>

percent canopy cover for each census tract was calculated and symbolized in five classes using the Jenks “natural breaks” classification system to minimize the average deviation from the class mean while maximizing the deviation from the means of other groups. The canopy was mapped from 4-band, 1-meter resolution aerial photographs captured in the summer of 2016 by the National Agriculture Imagery Program (NAIP), and digitized using a Classification and Regression Trees (CART) classifier and hand-digitized training data in Google Earth Engine (GEE). Using the above described EJ Index, tracts with scores of 9 or above are highlighted for comparison.

Map: Access to Open Space and EJ Populations

Using the MRMPO’s Transportation Access Model tool, contours were generated representing the area that can be reached by walking from points surrounding each publicly accessible park or open space in 5 or 10 minutes along the transportation network (including trails). Population and demographic statistics for each contour area were then generated from 2014-2018 American Community Survey 5-year Estimates (prorated by linear frontage areas). Map displays the above described EJ Index census tract scores and highlights tracts with scores of 9 or above.

Map: Transit Access to Healthcare

Using the MRMPO’s Transportation Access Model tool, contours were generated representing the area that can be reached by bus service from each healthcare facility in 15, 30, and 45 minutes along the transportation network’s existing bus routes. Population and demographic statistics for each service area were then generated from 2014-2018 American Community Survey 5-year Estimates (prorated by linear frontage areas). Map displays the above described EJ Index census tract scores and highlights tracts with scores of 9 or above.

Overview of REMI Policy Insight +

REMI PI+ is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to wage, price, and other economic factors.

The PI+ model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the model. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Wages, Prices and Costs, and (5) Market Shares. The blocks and their key interactions are shown in Figures 1 and 2.

REMI Model Linkages (Excluding Economic Geography Linkages)

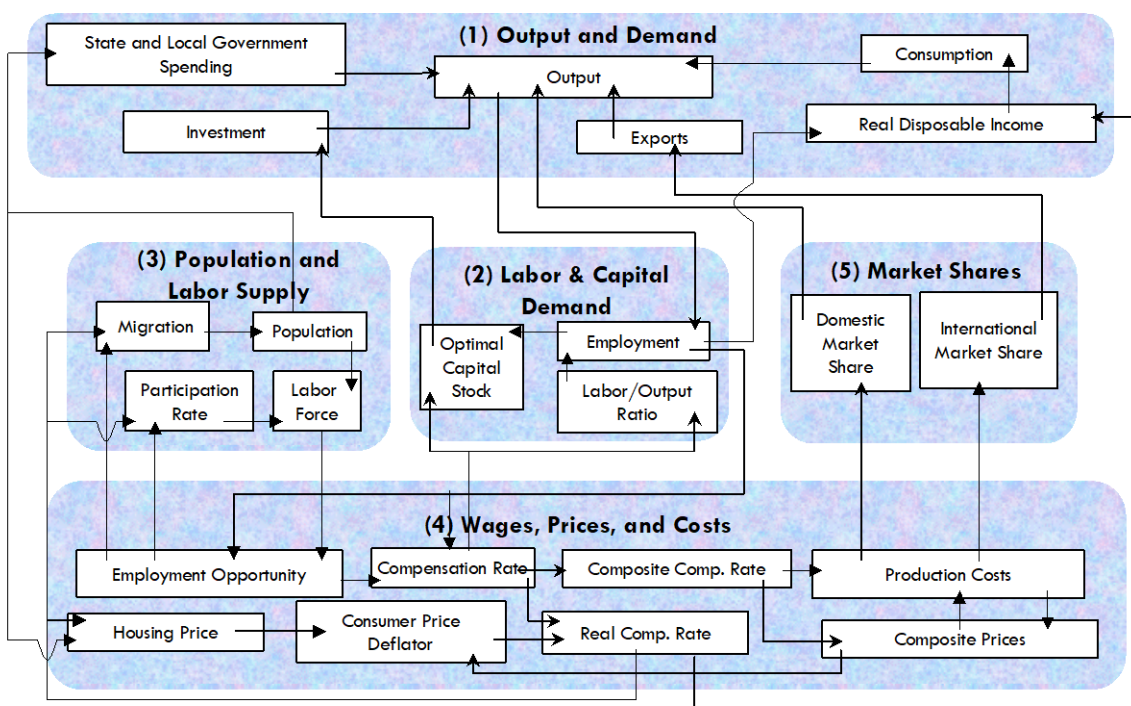


Figure 1

Block 1. Output and Demand

This block includes output, demand, consumption, investment, government spending, import, product access, and export concepts. Output for each industry in New Mexico is determined by industry demand in the state and its trade with the US market, and international imports and exports.

For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities and population. Input productivity depends on access to inputs because the larger the choice set of inputs, the more likely that the input with the specific characteristics required for the job will be formed. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

Block 2. Labor and Capital Demand

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

Block 3. Population and Labor Supply

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age and gender, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after tax compensation rate. Migration includes retirement, military, international and economic migration. Economic migration is determined by the relative real after tax compensation rate, relative employment opportunity and consumer access to variety.

Block 4. Wages, Prices and Costs

This block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the wage equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods and services. These prices measure the price of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs of distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of output in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by cost of labor, capital, fuel and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas and residual fuels.

equations. The proportion of local, inter-regional and export markets captured by each region is included in the Market Shares block.

Overview of REMI TranSight


$$\text{PI}^+ + \text{Travel Demand Data Integration} = \text{TranSight}$$

TranSight takes the methodologies involved with PI+ and goes one step further to integrate economics with travel demand modeling. TranSight allows for the ability to test alternative transportation changes and observe the short and long-term impact on jobs, income, population, and other economic variables. In addition, it integrates data on emissions, safety valuation factors, and other transportation related data based on national standards and customized to local regions and subareas.

Inputs from Travel Demand and Other Sources

TranSight takes four pieces of data from travel demand models. These are number of trips, VMT (vehicle-miles traveled), VHT (vehicle-hours traveled), and interregional travel patterns. With this data, as well as external parameters on emissions and efficiency, the model is able to calculate benefit-cost outputs as well as economic valuations. Much of the workings of this process come from the relative differences of trips, VMT, and VHT against each other under different project scenarios and interregional trade relationships inside of the model.

User-Costs from Transportation (i.e. Travel Externalities)

TranSight performs benefit-cost calculations of agency- and user-costs based on the travel demand data and parameters from public sources on the value of emissions, safety considerations, operating costs, and the value of lost/saved time due to projects:

- The model determines *emissions* by scaling the VMT. Logically, it follows that more VMT means more emissions, as more miles means more opportunity for carbon, NOX, SOX, and other pollutants to make their way into the local atmosphere. The model also adjusts for different rates of emissions at different system speeds. The model assigns values to these emissions from the EPA's PART5 and MOBILE6b models.
- As with emissions, TranSight scales *safety* costs based on VMT. The model includes a figure for the number of accidents and fatalities per million VMT and, hence, more VMT means more of each of the latter. On the other hand, the user can modify this accident parameter if a project makes safety improvements to a network. While somewhat morose, the model has a value for accidents and fatalities included inside of it, too, based on the National Safety Council's value of lost productivity and capital damage from accidents.

- *Operating costs* are similar in TranSight. Namely, more VMT means more spending on fuel and “wear ‘n’ tear” to vehicles. However, as with emissions, the model adjusts for overall system efficiency (in fuel and oil consumption), where greater efficiency eventually will reduce operating costs. The model then takes these savings—for instance, a \$500 savings on gasoline purchases means more money in consumers’ pockets—and then feeds them back into general consumption in the rest of the regional economy.
- The *value of time* in the model is similar, but it relies on VHT and trips instead of VMT. The model divides VHT by trips, so that higher VHT/trips means a higher average travel time for a venture. Then, multiplying this ratio between baseline and alternative, TranSight figures out the time saved/lost and assigns it a value. One hour of time “stuck in traffic” is equal to 50% the average wage rate of a region in the model, per the U.S. DOT’s recommended value for the same, and this goes into the benefit-cost analysis, as well.
- The model adds these values together, as well as the construction, finance, and operations costs, and puts them into the benefit-cost calculator. From there, given user specifications for a discount rate and analysis, TranSight produces a benefit-cost ratio (BCR).

Transportation Cost Matrices (i.e. “Effective Distance”)

Transportation upgrades and downgrades reduce the economic “effective distance” between areas for trade and commerce. “Effective distance” is an economic concept of the *de facto* distance between two nodes in terms of time and economic costs. Typically, the initial distance is one, while changes in the transportation network make things effectively closer or further away, changing this figure to greater than one (further) or less than one (closer) as proportions.

TranSight has three transportation cost matrices. These are for commuting time, the cost for transportation services, and for access to intermediate inputs and consumer goods. Using the same data as the benefit-cost portion of analysis, the model converts VMT, VHT, trips, and interregional into the matrix and into impacts on a regional economy:

- *Commuting costs* work on a similar process to travel time. They compare the average length of a trip (that is, VHT/trips) between different regions for commuting. From there, the model calculates a change in the effective distance between the regions for commuting purposes, with a number greater than one meaning an effectively further distance and a number less than one meaning an effectively closer distance. This takes account of improvements, but also rebound situations inside of the travel demand.

- *Transportation costs* come from two methodologies. The first is a measurement of system speed—explicitly, VMT/VHT. That is, fixed VMT would “enjoy” lower VHT under a higher overall system speed, which translates in the model into lower transportation costs. Additionally, the models includes commercial operations based on the above calculation, but including vehicular wear ‘n’ tear and wages to drivers and operators. Taking this, the model hopes to find a quicker “average speed” to engender improvements.
- *Accessibility costs* works like commuting costs, only on the inverse. For accessibility, the key formulation is trips/VHT for interregional trade. Here, the final valuation still comes down to the average length of each trip between each region. Shorter interregional trips mean greater access to consumer needs and intermediate goods in the model, which adds to the attractiveness of a region and its overall competitiveness. This eventually translates into the economic impacts of the model in the next section here.

Labor Access, Commodity Access, and Delivered Prices

PI* includes a handful of New Economic Geography concepts in its model structure, which shows the influence of spatial relationships and industry/labor clustering on economic development. TranSight takes that one step further in integrating it with real travel data. In continuation of this process, in starting with travel demand, TranSight takes the changes in effective distance (described above) and translates them into economic changes:

- *Labor access* is the quantification of labor pooling in the model. An example is more helpful. If a hospital is looking for a particular type of specialist in a city with a medical or university cluster (like Houston, TX or Boston, MA), then chances are they are going to be able to find an applicant with a close match to their needs in experience and education. This applicant will, thus, provide the hospital with high productivity and give them a competitive edge over other regions. Imagine, as well, a small hospital in a state like Wyoming—where they would have to, essentially, be much less selective with their hiring process. Labor access quantifies this effect in the model on a regional level. Decreased commuting costs from TranSight means greater labor access for an industry or a region, which will allow it to make “better” hiring decisions, expand productivity, and compete effectively.
- *Commodity access* is similar, except that it works with goods and services instead of workers. The model quantifies that a greater economic output means a greater diversity of goods and services available to businesses and consumers; therefore, they are able to find things either

more palpable to their tastes (consumers) or more ideally-suited to their productive process (businesses). From there, these intermediate goods lead to productivity advantages, larger market shares, and all the associated effects in the model.

- *Delivered prices* are an addition to the production costs concept in the model. There is a big difference between the “cost of production” (what it takes to roll a product off of the line) and the “delivered price” (what it actually costs to sell it on the shelf). The difference is, of course, transportation costs. A lower effective transportation distance between regions will reduce the delivered price, as it leaves the cost of production alone *ceteris paribus*, and lowers the transportation costs. This leads to similar productivity advantages, and makes regions more likely to trade with each other due to network changes.

“Market Share Effects” (i.e. Competitiveness Advantages)

The idea of a regional *market share* is particular to the REMI family of models, but it is one worth exploration in the context of TranSight’s integration with TDM. In block (5) of the model, there is an equation to estimate the “competitiveness” of each industry in each region based on its cost of production and transportation costs. From here, this determines the industries’ sales, and therefore their hiring decisions, investments, and other choices. This works its way back through the model to other factors like demography and government spending. For instance, lower costs of production in one region expands output, hiring, and eventually leads to economic migration to the region due to increased employment opportunity. TranSight follows this process (either positively or negatively) when estimating transportation’s influence in the economy.

Conclusion and Additional Resources

This section summarizes how TranSight brings PI⁺ together with travel demand models. It follows the process of the model and its methodology to start with “raw” TDM data to the point where it performs benefit-cost analysis (BCA) and economic impact analysis (EIA) for its user. This involves taking VMT, VHT, trips, and interregional patterns and translating them into social costs, transportation cost matrices, access indices, and eventually market share effects throughout the economy. Please see the REMI website at <www.remi.com>, or contact any REMI economist for further information.

Quick Guide to TranSight Parameters and Data Sources

TranSight, the dedicated transportation model of Regional Economic Models, Inc. (REMI), draws from external data sources for the purpose of integration with travel demand models (TDM). These sources

are public and transparent, and they outline the parameters internal to the model for performing economic analysis and benefit-cost analysis. The sources shown below serve as defaults and can be adjusted by the user to reflect alternative assumptions or data sources.

Parameter	Data Source
Emissions rates per VMT (five types: VOC, NOX, CO, SOX, PM)	United States Environmental Protection Agency (U.S. EPA) models: PART5 (SOX and PM) and MOBILE6b (CO, NOX, and VOC)
Social costs of emissions (five types: VOC, NOX, CO, SOX, PM)	McCubbin, Donald and Mark Delucchi, “The Social Costs of the Health Effects of Motor Vehicle Air Pollution.” Report 11 from <i>The Annualized Social Cost of Motor-Vehicle Use in the United States</i> . Institute of Transportation Studies. University of California-Davis, 1996.
Safety valuations (fatalities, injuries, and PDOs)	National Safety Council (which incorporates wage and productivity losses, medical expenses, vehicle damage, and risk adverseness) – <i>Estimating the Cost of Unintentional Injuries</i>
Historical Fuel Prices	Energy Information Administration (EIA)
Historical Fuel Efficiency	Energy Information Administration (EIA)
Value of lost leisure time due to travel and delay	• <i>Highlights of the 2001 National Household Travel Survey</i>, Bureau of Transportation Statistics, U.S. Department of Transportation, BTS-0305, 2003. • <i>Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey</i>, Federal Highway Administration, U.S. Department of Transportation, 1999, <i>2001 National Transit Database</i>. • <i>The Value of Saving Travel Time: Departmental Guidance for Conducting Economic Evaluations</i>, U.S. Department of Transportation, April 19, 1997. • These are the prefabricated estimates of occupancy of leisure time values—FHWA recommends 50% of the median hourly wage as the hourly value of lost/gained leisure time
Occupancy rates	<i>See the category for leisure time</i>