

The logo consists of a stylized graphic on the left, composed of a black square with a white diagonal line and a yellow curved shape overlapping it. To the right of the graphic, the word "TranSight" is written in a bold, sans-serif font, with "Tran" in black and "Sight" in yellow. To the right of "Sight" is the text "v4.0" in a smaller, black, sans-serif font.

TranSight v4.0
Model Documentation

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Overview of the Model

REMI TranSight integrates leading travel-demand and transportation forecasting models (such as TranPlan, TransCAD, TP Plus, EMME/2, and HERS) with REMI PI+. While stand-alone transportation models produce forecasts of travel-demand response to a proposed transportation project, TranSight provides a more complete perspective by predicting the full array of economic and demographic effects that will result from completing the project. It translates the key outputs generated by the transportation models into a series of cost and amenity variables that can be incorporated into a single-region or multi-region impact analysis, as driven by the powerful PI+ engine, which is also the core of REMI's PI+ model. The output of this process shows such key economic indicators as employment by industry, output, and value added by industry, personal income, population, and many more.

TranSight allows the user to specify the financial dimensions of an upgrade to the transportation infrastructure, including expected construction costs, financing, and annual operation/maintenance costs. In addition, it calculates several *indirect* types of costs and benefits that may ensue from the project, including changes in safety, emissions, operating costs, and transportation costs. Some of these computations require user input regarding construction, finance, and operations, while others use the output from travel-demand model scenarios. Collectively, this information is transferred into PI+, which produces multi-year forecasts of economic and demographic trends under the transportation upgrade, and compares them with a baseline forecast. In capturing the full effects of the project, TranSight can assist governments in determining whether allocating funds to a particular transportation upgrade is a winning proposition relative to funding other policy initiatives.

The model structure is represented pictorially in Figure 1 below, which reveals both the components of the model and the manner in which information flows between them. Outputs from the transportation model are combined with built-in cost parameters and project-specific information to produce values for policy variables designed to simulate the project's direct impact. The PI+ engine processes these results to generate comprehensive forecasts of the project's macroeconomic effects.

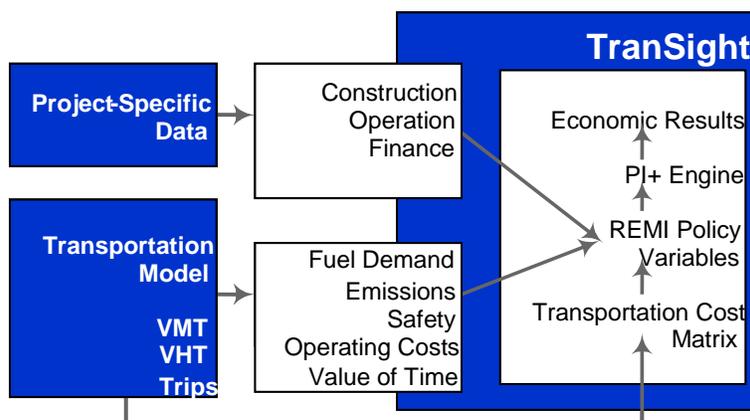


Figure 1. Model structure of TranSight

Detailed Model Description

This section first describes the mechanism by which TranSight receives and processes its input. Following this are subsections that describe the various costs and benefits that are incorporated into TranSight's assessment of a transportation project.

Model Inputs

The inputs to the modeling process stem from three sources:

- output from travel-demand model simulations
- project-specific information
- nationwide studies by government agencies and localized studies specific to the regions being modeled (as available)

Although transportation models vary significantly in structure and content, they all produce estimates of vehicle miles traveled (**VMTs**), vehicle hours traveled (**VHTs**), and vehicle **Trips** under different scenarios involving modifications to one or more elements of the transportation network. Models that handle multiple modes of transportation will produce **VMT** and **VHT** by mode, as well as vehicle **Trips** for each defined highway and public transit mode. Other models may report miles and hours traveled within each of several geographic areas, which can be incorporated into TranSight's multi-regional framework. Because transportation-model outputs often vary (for example, highway **VMTs** may be subdivided across different vehicle types and/or times of day), TranSight was designed with sufficient flexibility to handle a diverse range of data dimensions, which allows REMI to customize the model for individual clients. Much of this variation is due to differences across the various travel-demand models, but various transportation departments or other users may configure the same modeling package differently.

TranSight regions can correspond to states, counties, user-specified sub-county areas, or aggregations thereof, provided that travel-demand data is available for each desired region. This information is necessary as a basis for quantifying the improvements in commuter, transportation, and accessibility costs that result from the decrease in "effective distance" achieved by the transportation upgrade. The concept of effective distance essentially captures the distance decay effect through which the frequency of **Trips** between regions A and B is inversely related to the distance between them.

Even though the vast majority of **Trips** begin and end within the same region, cross-regional **Trips** involve a greater number of hours and miles per trip. The travel-demand model's region-to-region breakdowns of hours, miles and **Trips** are directly transferred into TranSight to calculate the change in effective distance between each pair of regions.

Among inputs not derived from travel demand models or public transit data, many parameters (such as pollutant emission rates and accident costs) are assigned default values from national sources such as the Institute of Transportation Studies and Federal Highway Administration, although the client can revise these with locality-specific estimates. While in certain cases the national figures are reasonable proxies for localized regions, the geographic variability of other factors such as accident rates and fuel prices makes local customization more vital. You must enter other TranSight inputs,

such as those characterizing construction expenses and project financing, because of their specificity to the simulation.

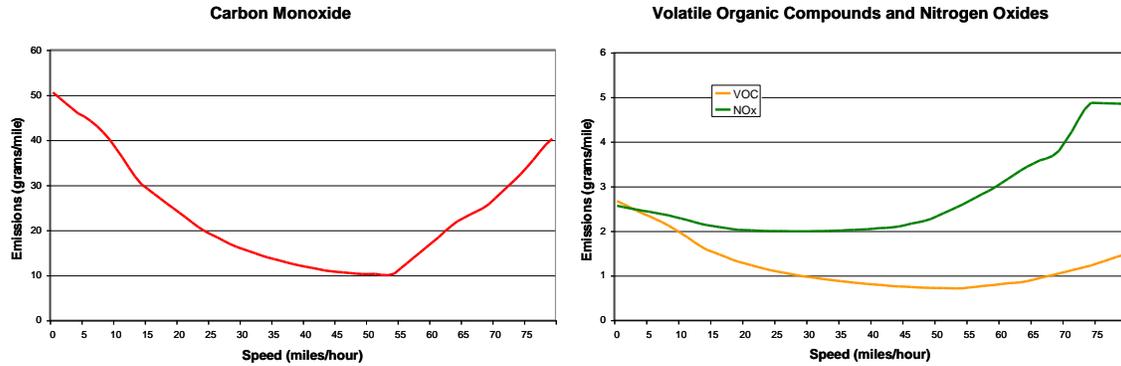
Costs and Benefits

Each of the following subsections focuses on a direct effect, describing the cost calculation performed by TranSight and the manner in which the cost enters the PI+ analysis. Note that one or more of these costs may be excluded from the simulation prior to running TranSight, at the user's discretion. For greater discussion of the theoretical underpinnings of modeling these costs in TranSight, please consult Appendix A.

Emissions Costs

While transit upgrades can reduce emissions by drawing motor vehicles off the road, highway enhancements typically induce increased traffic, which causes greater emissions of harmful pollutants. In TranSight, changes in emissions costs are computed from three sets of inputs. First, for each of five primary pollutants (carbon monoxide, nitrogen oxides, sulfur oxides, particulate matter, and volatile organic compounds), TranSight specifies rates per vehicle-mile. We assume constant emissions rates for transit modes, but for motor vehicles (autos and trucks) we assume variable rates for each potential vehicle speed from 0 to 80 miles/hour. The emissions rate for some motor vehicle pollutants depends on travel speed, and declines up to a certain threshold speed, at which point emissions begin to increase (see Figure 2 below). For other pollutants, the emissions rate remains fairly constant over all speeds. The rates are differentiated across each mode of transport.

TranSight uses motor vehicle emissions rates obtained from two prominent models developed by the EPA: PART5 (for SO_x and PM) and MOBILE6b (for CO, NO_x, and VOCs). These models rely on assumptions regarding the age distribution of the US motor vehicle fleet, fuel characteristics, locally relevant operating conditions, and the effects of inspection and maintenance programs to establish average emission rates for each multiple-of-five speed between 10 and 65 mph. To derive rates for all speeds from 0 to 80 mph, the process of Lagrange interpolation was applied to the EPA's rates. Figure 2 illustrates for three of the five pollutants (CO, NO_x, and VOCs) how emission rates progressively improve and then worsen as travel speed increases. For the remaining two pollutants under consideration (SO_x and PM), emissions rates remain constant over all speeds at the levels estimated by the EPA. Given the likelihood of tightening emissions regulations, technological improvements, and gradual conversions from internal combustion to electric engines, TranSight enables the user to enter differing (likely lower) emissions rates for each forecast year.



Emissions rates for various speeds (source: EPA's PART5 and MOBILE6b)

The second matrix of inputs represents the cost per gram of each of the five pollutants under consideration, which, like the emission rates, can vary from year to year. TranSight is packaged with default emissions costs that are based on a study by McCubbin and Delucchi, who quantify the health effects of vehicle pollution per **VMT** in the average urban area and the nation as a whole.¹ These costs are used for both motor vehicle and public transit modes, as the health impacts of a gram of pollutant are identical regardless of the source. The user may modify these cost parameters based on conditions endemic to the region being modeled; for example, emissions costs tend to be higher in congested urban areas since pollutants tend to have more potent health effects nearer the source. The final set of inputs is simply total vehicle miles traveled under the baseline and alternative (i.e., with the transportation project in place) scenarios, disaggregated by mode of travel. Combining the three inputs produces total emissions cost figures for each of the five pollutants, as illustrated in the following equation. TranSight performs this calculation separately for each mode specified in the model.

$$\Delta EC = \sum_j \left((ER_j^{alt} \times CPG_j^{alt} \times VMT^{alt}) - (ER_j^{base} \times CPG_j^{base} \times VMT^{base}) \right)$$

where

ΔEC = Change in total emissions cost (\$)

ER_j^{alt} = Emissions rate for pollutant j (gram/mile) under the alternative scenario

ER_j^{base} = Emissions rate for pollutant j (gram/mile) under the baseline scenario

CPG_j^{alt} = Emissions cost per gram for pollutant j (\$/gram) under the alternative scenario

CPG_j^{base} = Emissions cost per gram for pollutant j (\$/gram) under the baseline scenario

VMT^{alt} = Vehicle miles traveled under the alternative scenario

VMT^{base} = Vehicle miles traveled under the baseline scenario

¹ McCubbin, Donald, and Mark Delucchi, "The Social Cost of the Health Effects of Motor Vehicle Air Pollution." Report 11 from *The Annualized Social Cost of Motor-Vehicle Use in the United States*. Institute of Transportation Studies. University of California-Davis. 1996.

The change in emissions cost relative to baseline levels enters into the PI+ engine as a non-pecuniary amenity that accrues to workers and their dependents.² These costs then proceed to influence private decision-making by households in accordance with the tenets of the new economic geography, as articulated by Fujita et al.³ and applied to regional macroeconomic modeling by Fan, Treyz and Treyz.⁴ This theory emphasizes the geographic location decisions of firms, demonstrating how improved access to intermediate inputs and a diversely skilled labor force can provide incentives for industries to cluster and agglomerate. But in addition to these business effects, households may be motivated to migrate closer to cities, where access to a broader array of consumer goods and potential employers may counterbalance dis-amenities such as higher crime rates, traffic, and air pollution. As a consequence, a transportation project that effectively reduces emissions costs may stimulate in-migration to urban regions, and TranSight will capture this dynamic over the course of the forecast period.

Safety Costs

Upgrading a highway or transit line can improve safety on the transportation network, but to the extent that usage increases, the frequency of accidents can increase. Since the number of accidents is directly proportionate to vehicle miles traveled, the transportation model's role in assessing net **VMT** changes is pivotal for TranSight's computation of cost impacts. TranSight permits annual mode-specific rates for each of three accident consequences: fatalities, injuries, and property damage only (PDO). The model is pre-packaged with default highway accident rates based on national averages reported by the Federal Highway Administration; the user can modify these rates if local-specific data are available. For transit modes, the model includes default accident rates that are derived from nationwide US Department of Transportation data.⁵

TranSight also provides default cost-per-accident figures for each transportation mode, broken down by accident consequence. These are based on National Safety Council figures that incorporate wage and productivity losses, medical and administrative expenses, motor vehicle damage, and a willingness to pay to reduce safety risks.⁶ Additionally, a different set of costs can be entered for each forecast year, for example, to reflect rising insurance premiums or health care costs. The cost calculation mirrors that performed for emissions costs, taking the following form for each mode:

$$\Delta SC = \sum_j \left((AR_j^{alt} \times CPA_j^{alt} \times VMT^{alt}) - (AR_j^{base} \times CPA_j^{base} \times VMT^{base}) \right)$$

where

$$\Delta SC = \text{Change in total safety cost (\$)}$$

² Lieu, Sue and G. I. Treyz, "Estimating the Economic and Demographic Effects of an Air Quality Management Plan: The Case of Southern California." *Environment and Planning*, 24 (1992): 1799-1811.

³ Fujita, Masahisa, Paul Krugman, and Anthony J. Venables, *The Spatial Economy: Cities, Regions, and International Trade*. Cambridge, MA: MIT Press, 1999.

⁴ Fan, Wei, Frederick Treyz, and George Treyz "An Evolutionary New Economic Geography Model." *Journal of Regional Science* 4 (2000): 671-695.

⁵ Bureau of Transportation Statistics, *National Transportation Statistics 2001*.

⁶ National Safety Council, *Estimating the Cost of Unintentional Injuries*.

AR_j^{alt} = Accident rate for accident consequence j (accident/mile) under the alternative scenario

AR_j^{base} = Accident rate for accident consequence j (accident/mile) under the baseline scenario

CPA_j^{alt} = Safety cost per accident for accident consequence j (\$/accident) under the alternative scenario

CPA_j^{base} = Safety cost per accident for accident consequence j (\$/accident) under the baseline scenario

VMT^{alt} = Vehicle miles traveled under the alternative scenario

VMT^{base} = Vehicle miles traveled under the baseline scenario

As with emissions costs, changes in safety costs are transferred into the PI+ engine as adjustments to the non-pecuniary amenities that impact individual welfare. Even for people not involved in accidents, the prevailing local accident rate along with associated insurance and medical costs can influence the relative attractiveness of living and/or working in a particular region. Changes in these variables may stimulate migration into or out of the region. But the migratory impact of safety costs might conceivably be outweighed by other factors set in motion by the transportation project; for example, a new highway might make driving less safe, but it also improves access to attractive commodities and employers, which might trigger in-migration despite the attendant risks. By computing the magnitude of all these costs, TranSight can predict how they balance out to yield a net impact on economic migration and other economic factors.

Operating Costs

Increased travel stimulated by a highway upgrade forces increased out-of-pocket spending on vehicle operation and maintenance. In TranSight, vehicle operating expenditures represent an opportunity cost in the form of foregone spending on other consumption goods and services. TranSight comes packaged with default pre-tax fuel prices based on recent region-specific historical trends (as reported by the Energy Information Administration), and both federal and state excise tax rates applicable in the modeling region. You can modify these prices and tax rates for each region in each forecast year, in case you anticipate a particular time trend, tax change, or geographic variation.

The total post-tax fuel price is applied to a miles-per-gallon figure that is appropriate to the average speed prevailing on the region's transportation network. TranSight contains a table of speed-specific mpg parameters (for speeds from 0 to 80 mph), which allows for variation in gas mileage from year to year. While tightening fuel efficiency regulations and improving technology should increase average mpg over time, the increasing prevalence of trucks and sport-utility vehicles may dampen this trend somewhat. Finally, TranSight multiplies per-mile fuel spending by the change in **VMTs** predicted by the selected transportation model, to compute total expenditures on gasoline. The fuel cost parameters can vary by motor vehicle type (i.e., cars versus trucks) in order to reflect three important phenomena: the price differential between regular gasoline and diesel fuel, the difference

in the federal excise tax on regular versus diesel, and the considerably different fuel efficiency exhibited by cars and trucks over the range of possible average network speeds.

The change in fuel expenditures is computed for each vehicle mode as follows:

$$\Delta FE_i = \left(\left((FP_i^{alt} + FEDTAX^{alt} + STATETAX_i^{alt}) \times \frac{VMT^{alt}}{MPG_s^{alt}} \right) - \left((FP_i^{base} + FEDTAX^{base} + STATETAX_i^{base}) \times \frac{VMT^{base}}{MPG_s^{base}} \right) \right)$$

where

ΔFE_i = Change in fuel expenditures for region i (\$)

FP_i^{alt} = Pre-tax fuel price for region i (\$/gallon) under the alternative scenario

FP_i^{base} = Pre-tax fuel price for region i (\$/gallon) under the baseline scenario

$FEDTAX^{alt}$ = Federal excise tax (\$/gallon) under the alternative scenario

$FEDTAX^{base}$ = Federal excise tax (\$/gallon) under the baseline scenario

$STATETAX_i^{alt}$ = State excise tax for region i (\$/gallon) under the alternative scenario

$STATETAX_i^{base}$ = State excise tax for region i (\$/gallon) under the baseline scenario

VMT^{alt} = Vehicle miles traveled under the alternative scenario

VMT^{base} = Vehicle miles traveled under the baseline scenario

MPG_s^{alt} = Typical fuel efficiency at speed s (miles/gallon) under the alternative scenario

MPG_s^{base} = Typical fuel efficiency at speed s (miles/gallon) under the baseline scenario

In addition to these fuel-related expenditures, TranSight contains a non-fuel operating cost parameter that captures maintenance and repair costs associated with vehicle “wear-and-tear.” As with fuel costs, non-fuel operating costs can differ between cars and trucks; default values based on analogous parameters in other travel demand models are included in TranSight. The change in non-fuel expenditures is calculated for each vehicle mode as follows:

$$\Delta NFE_i = (NF_i^{alt} \times VMT^{alt}) - (NF_i^{base} \times VMT^{base})$$

where

ΔNFE_i = Change in non-fuel expenditures for region i (\$)

NF_i^{alt} = Non-fuel spending per mile for region i (\$/mile) under the alternative scenario

NF_i^{base} = Non-fuel spending per mile for region i (\$/mile) under the baseline scenario

VMT^{alt} = Vehicle miles traveled under the alternative scenario

VMT^{base} = Vehicle miles traveled under the baseline scenario

The change in fuel costs is modeled as a change in Consumer Spending on Gasoline and Oil, while the change in non-fuel operating costs is captured as a change in Consumer Spending on Transportation services. In both cases, the spending change has an equal and opposite effect on household expenditures on other goods and services. For example, decreased expenditures on gas or auto maintenance due to declining vehicle miles traveled allows for shifting of personal disposable income toward other consumption commodities. The reallocation of the savings by consumer category is proportionate to baseline consumer spending on those categories of goods and services. By providing households more latitude on how to spend their income, projects that reduce vehicle operating costs ultimately benefit consumers in the model.

Value of Time

Time spent in transit has an opportunity cost in terms of the more desirable or productive activities foregone by the traveler. In this respect, a transportation network improvement benefits individuals to the extent that it reduces average travel time per trip. For each mode, TranSight bases the value of leisure time saved by the transportation upgrade on the resulting reduction in hours per vehicle-trip multiplied by the average vehicle occupancy rate. Accounting for vehicle occupancy rates is critical since all passengers reap the benefits of shortened travel times. It is particularly important when examining substitution between public transit and motor vehicles, since transit vehicles naturally have considerably higher passenger capacity. The average time savings are then multiplied by the portion of **Trips** under the alternative simulation conducted for leisure purposes. For convenience, TranSight is packaged with default leisure percentages⁷ and vehicle occupancy rates⁸ culled from federal surveys.

Finally, these total time savings are multiplied by a dollar valuation of leisure hours, which is benchmarked to 50% of the average wage rate to be consistent with methodology recommended by the U.S. Department of Transportation. REMI tailors this figure to the modeled region's wage and applies it to both peak and off-peak hours, which again accords with standard DOT procedure despite overlooking time-differential rates of congestion.⁹ The same dollar valuation is applied to leisure time in all modes, since there is no justification for valuing leisure time spent in buses or trains differently than leisure time in cars. Mathematically, TranSight calculates the savings in leisure time for each mode as follows:

$$\Delta LT_i = (VHT_i^{alt} \times VOR_i^{alt} \times \%L_i^{alt} \times VL_i^{alt}) - (VHT_i^{base} \times VOR_i^{base} \times \%L_i^{base} \times VL_i^{base})$$

where

$$\Delta LT_i = \text{Change in leisure time value for mode } i \text{ (\$)}$$

⁷ *Highlights of the 2001 National Household Travel Survey*, Bureau of Transportation Statistics, U.S. Department of Transportation, BTS-0305, 2003.

⁸ *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Federal Highway Administration, U.S. Department of Transportation, 1999; *2001 National Transit Database*.

⁹ *The Value of Saving Travel Time: Departmental Guidance for Conducting Economic Evaluation*. U.S. Department of Transportation. April 19, 1997.

VHT_i^{alt} = Vehicle hours traveled on mode i under alternative scenario

VHT_i^{base} = Vehicle hours traveled on mode i under baseline scenario

VOR_i^{alt} = Vehicle occupancy rate for mode i (persons/vehicle) under alternative scenario

VOR_i^{base} = Vehicle occupancy rate for mode i (persons/vehicle) under baseline scenario

$\%L_i^{alt}$ = Percentage of **Trips** for leisure purposes on mode i under alternative scenario

$\%L_i^{base}$ = Percentage of **Trips** for leisure purposes on mode i under baseline scenario

VL_i^{alt} = Value of leisure time on mode i (\$/hour) under alternative scenario

VL_i^{base} = Value of leisure time on mode i (\$/hour) under baseline scenario

As with other cost changes described above, these time savings enter the PI+ engine in the form of increased non-pecuniary amenities to individuals. Even though leisure travel time reductions produced by transportation projects rarely translate into direct financial benefits for households, they do enhance the comparative attractiveness of a region, which is likely to stimulate in-migration. People will be drawn to an area that has diminished its transportation network congestion in relation to neighboring areas, all else being equal. Improved commuting efficiency may also entice workers by providing access to a greater cross-section of potential employment opportunities, thereby further encouraging inward migration.

The Transportation Cost Matrices

Transportation upgrades can reduce the “effective distance” between two locations by facilitating a more efficient flow of labor and goods between them. Within the TranSight framework, the effective distance implicitly enters the calculation in three distinct matrices: commuter costs, transportation costs, and accessibility costs.

Commuting Cost

The commuter cost matrix reflects changes in commuting time (measured in hours per commuter trip) between and within modeling regions, which result from completion of the transportation improvement. Since infrastructure expansions should unambiguously reduce travel time by increasing route and mode options, these savings can be translated into an economic impact based on the change in network-wide travel speed and the resulting reduction in average commute time. These savings are assumed to accrue entirely to firms.

TranSight derives the region-to-region changes in commuter time from transportation model output of changes in the **VHT**/trip ratio for each mode. Since the cost matrix expects a single coefficient value, TranSight calculates a weighted average of time savings across all modes, where each mode’s weight is its percentage of total system vehicle hours traveled. Finally, this average time savings is divided by 8 hours to scale them to the length of a typical workday. Note that the commuting time changes with respect to the baseline simulation can vary across forecast years, to allow for dynamic response to the transportation improvement over time. The model calculates

commuter cost savings for each combination of regions i and j (with $i=j$ implying within-region savings) via the following formula. It should be noted that the transportation cost change is calculated relative to a baseline value of 1, with a positive ΔCC actually representing an *increase* in commuter costs and a negative value indicating a cost decline.

$$\Delta CC_{ij} = 1 + \frac{1}{8} * \sum_k \left[\left(\%H_k^{alt} * \frac{VHT_{ij}^{alt}}{trips_{ij}^{alt}} \right) - \left(\%H_k^{base} * \frac{VHT_{ij}^{base}}{trips_{ij}^{base}} \right) \right]$$

where

ΔCC_{ij} = Change in commuter costs between regions i and j (hours)

$\%H_k^{base}$ = Percent of **VHT** between i and j traveled on mode k : baseline scenario

VHT_k^{base} = Vehicle hours traveled between i and j on mode k : baseline scenario

$trips_k^{base}$ = Vehicle **Trips** traveled between i and j on mode k : baseline scenario

$\%H_k^{alt}$ = Percent of **VHT** between i and j traveled on mode k : alternative scenario

VHT_k^{alt} = Vehicle hours traveled between i and j on mode k : alternative scenario

$trips_k^{alt}$ = Vehicle **Trips** traveled between i and j on mode k : alternative scenario

$$\%H_k^S = \frac{VHT_{ij}^S * Occ * CCRatio}{\sum_{ij} VHT_{ij}^S}$$

where

$\%H_k^S$ = Percent of **VHT** between i and j traveled on mode k : scenario S

VHT_k^S = Vehicle hours traveled between i and j on mode k : scenario S

Occ = Vehicle occupancy on mode k

$CCRatio$ = Commuting costs mode ratios for mode k

Whereas the commuter cost matrix captures time savings for off-the-clock work-related **Trips**, the transportation cost matrix displays time savings for on-the-clock business travel and transport of goods. As with commuter costs, transportation costs can vary among regions as well as across forecast years. Thus, a new or expanded highway connecting two regions may have substantial impacts on transport costs between them, but also smaller secondary effects on costs between other regions as traffic patterns shift in response to the new alternative. The intertemporal differences can capture the cumulative impact of business development that occurs along the new highway or near a

new public transit station, which may steadily increase congestion and thereby increase average travel times.

If no **Trips** data is available, TranSight uses the following equation for determining the change in commuter cost:

$$\Delta CC_{ij} = I - \left\{ \frac{I}{2} * \left[I - \frac{\frac{\sum VMT_{ij}^{base}}{ij}}{\frac{\sum VHT_{ij}^{base}}{ij}} \right] \right\}$$

where

ΔCC_{ij} = Change in commuter costs between regions i and j

VMT_k^{base} = Vehicle miles traveled between i and j on mode k : baseline scenario

VHT_k^{base} = Vehicle hours traveled between i and j on mode k : baseline scenario

VMT_k^{alt} = Vehicle miles traveled between i and j on mode k : alternative scenario

VHT_k^{alt} = Vehicle hours traveled between i and j on mode k : alternative scenario

Transportation Cost

TranSight quantifies transportation cost savings from the difference between the alternative and baseline scenarios in the ratio of **VMT** to **VHT**. This approach captures the offset between shorter travel times and additional miles traveled, both of which are likely consequences of an upgraded transportation infrastructure. In other words, the principal driver of cost savings is the change in average travel velocities on the region’s road network, which reduces the effective distance between sellers and their markets. TranSight computes the transportation cost savings parameters as follows:

Because the baseline values are in the numerator, a cost change parameter greater than 1 implies a cost increase relative to the baseline case, whereas ΔTC_{ij} less than 1 suggests cost savings to the commercial and industrial sectors due to the transportation project. Thus, the value of 1 would indicate that the transportation improvement has a neutral impact on transportation costs, with the degree of deviation from 1 being associated with the magnitude of the cost effect.

The formula applies exclusively to miles and hours of road-based travel, under the simplifying assumption that goods and services are not transported on public transit modes such as light rail and buses.

$$\Delta TC_{ij} = \frac{(VMT_{ij}^{base} / VHT_{ij}^{base})}{(VMT_{ij}^{alt} / VHT_{ij}^{alt})}$$

where

ΔTC_{ij} = Change in transportation costs between regions i and j

VMT_{ij}^{base} = Vehicle miles traveled between i and j : baseline scenario

VHT_{ij}^{base} = Vehicle hours traveled between i and j : baseline scenario

VMT_{ij}^{alt} = Vehicle miles traveled between i and j : alternative scenario

VHT_{ij}^{alt} = Vehicle hours traveled between i and j : alternative scenario

Accessibility Cost

The final cost matrix bridges business and consumer interests by reflecting the value of increased accessibility to intermediate inputs and consumer goods afforded by the upgraded transportation system. While widened roads may only marginally improve accessibility, other infrastructure upgrades such as new bus routes, highways, or commuter rail lines may yield notable decreases in accessibility costs. In particular, expansions of network capacity facilitate greater flow of inputs to production, which augments the variety of available goods and thereby enhances regional productivity, particularly for industries with heavy dependence on intermediate inputs and transportation.

As with the preceding two cost matrices, accessibility costs are entered for each pair of modeled regions in each forecast year. TranSight contains two approaches to measuring these costs, which are difficult to quantify by nature of their intangibility. The first assumes that accessibility costs explain the residual bias toward local purchases that cannot be accounted for by the transportation cost differential between local suppliers and their more distant competition, and is used when the **VMT** to **Trips** ratio is constant or when no **Trips** are entered. From this perspective, accessibility further shrinks the effective distance beyond what transportation costs might suggest, which can be measured in terms of increased speed on the network. Thus, accessibility cost changes are merely a scaled-down additive counterpart to the transportation cost changes calculated via the formula above.

$$\Delta AC_{ij} = 1 - \left[\frac{1}{2} * (1 - \Delta TC_{ij}) \right]$$

where

ΔAC_{ij} = Change in accessibility costs between regions i and j

ΔTC_{ij} = Change in transportation costs between regions i and j

The second approach assumes that increased accessibility results from a greater number of delivery **Trips** within a given time period, which allows firms to access a more diverse array of potential

inputs to production, and is used when the **VMT** to **Trips** ratio is constant or when there is no correlation. This interpretation is embodied in the equation below, which draws upon road vehicle data exclusively (under the assumption that public transit does not serve as a channel for transporting intermediate inputs):

$$\Delta AC_{ij} = \frac{(Trips_{ij}^{base} / VHT_{ij}^{base})}{(Trips_{ij}^{alt} / VHT_{ij}^{alt})}$$

where

ΔAC_{ij} = Change in accessibility costs between regions *i* and *j*

$Trips_{ij}^{base}$ = Vehicle **Trips** between *i* and *j*: baseline scenario

VHT_{ij}^{base} = Vehicle hours traveled between *i* and *j*: baseline scenario

$Trips_{ij}^{alt}$ = Vehicle **Trips** between *i* and *j*: alternative scenario

VHT_{ij}^{alt} = Vehicle hours traveled between *i* and *j*: alternative scenario

TranSight has the unique ability to pass these three cost matrices directly into the PI+ engine, where they impact economic and demographic trends through different channels. Reduced commuting times are assumed to improve labor productivity, since firms can access more suitable employees from the widened labor pool, while individuals can find jobs that are better matches for their specific attributes. This ultimately decreases production costs, while influencing economic migration by altering relative wage rates by region. Decreases in transportation costs lower the delivered prices of products, which are computed as the sum of the commodity's cost at its origin and the distance-related cost of transferring the commodity to its destination. These price changes translate into lower input costs for producers and into benefits for consumers. Finally, improved accessibility costs diminish production costs due to improved access to well-suited factor inputs, and also indirectly influence the location decisions of households via the economic migration module.

All of these effects cascade into other macroeconomic variables because of the interlinkages built into the model. As a consequence of affecting commodity and labor access indices, transportation projects can have secondary effects on regional wages, employment, delivered prices, and market shares, among other variables. Importantly, an improvement in a region's transportation infrastructure can yield localized benefits in costs and productivity which can increase its competitive position vis-à-vis surrounding regions. But at the same time, the project can create spillover effects in those neighboring regions, particularly on labor and capital inputs that are drawn from those areas.

Construction and Financing

The project construction costs and financing do not enter the model through the travel demand data. Instead, the user enters this data directly into their respective scenarios (Design and Construction, Operation and Maintenance, Funding).

Construction Costs

Governments incur the costs of building, financing, and maintaining a transportation upgrade over the lifetime of the project. While the construction process represents an expense from the government's perspective, it also represents demand that stimulates increased employment and production of intermediate inputs by the private sector. Both of these aspects are included in TranSight's modeling framework. In TranSight, the user enters projected construction costs and projected operation and maintenance (O&M) costs in dollar form for each of the forecast years, in accordance with the annual work schedule of the transportation upgrade under consideration. The operation and maintenance costs heavily depend upon the nature of the undertaking. Public transit requires significant operating costs and replacement of depreciated equipment, as contrasted with road improvements that may only require periodic pavement and shoulder maintenance.

TranSight translates these expenditures into demand policy variables. First, contracts with construction firms to implement the transportation project are reflected in increased final demand for the construction industry, which naturally flows through into sales, employment, demand for intermediate inputs (based on the I-O table), and other variables. TranSight also passes operations and maintenance spending into final demand for construction. The model uses endogenous trade-flow shares (based on a gravity-model approach) to allocate this demand to increased sales by the construction industry in both the specified region and other defined regions, including residual regions comprising the "rest of US" and the "rest of world."

Financing

Governments may utilize a number of different mechanisms to finance transportation projects. The instruments they choose (whether a single funding source or a "cocktail" of sources) can have varying effects on the region's economy, depending on market characteristics and the demand responsiveness of the individuals bearing the burden of the tax or spending changes. From a regional fiscal-balancing standpoint, some sources (such as previously budgeted transportation spending and federal highway grants) can be regarded as essentially costless. In contrast, targeted tax hikes, spending reallocations, and bonds directly alter the government's bottom line, in addition to producing indirect fiscal effects through inducing dynamic behavioral responses by households and firms. To perform a comprehensive assessment of a project's impact, it is imperative to balance the economic benefits the project generates with the costs (both direct and indirect) borne by the region's taxpayers and businesses. TranSight is designed with such a holistic perspective in mind.

TranSight enables you to invoke several different sources of funding for the transportation project under consideration. Any of five types of taxes—sales, gas, consumer (including income), property, and business—may be hiked relative to their baseline levels. These increases are entered as changes in amounts collected (i.e., incrementing total tax receipts by a specified dollar amount). The tax changes can vary by region (for multi-regional models) and year to capture their real-world timing and geographic incidence.

On the spending side, when project-related outlays (excluding those funded by federal money) exceed the budgeted allotment for transportation construction, obtaining the additional funds from

other budget categories carries an opportunity cost. To capture this, TranSight enables you to input the reductions in non-dedicated government spending (i.e., not budgeted for transportation) necessitated by funding the project. These reductions may be entered on a yearly basis for both the state and local levels, since funding may be shared across the two levels of government. They can also vary by region (in multi-regional models) since financial responsibilities for large projects may be apportioned differentially across regions. In case the spending takes the form of annual payments against a bond, TranSight provides a built-in calculator that can convert the bond's parameters (amount, interest rate, and maturity) into annualized payment obligations.

When entering spending figures, you should omit any project expenditures drawn from the existing transportation budget. TranSight assumes that those funds would have been spent on other transportation-related projects, making them costless for any specific transportation project from a governmental accounting perspective. Similarly, the user should exclude from the analysis any federal grants allocated to the project since they are viewed as exogenous and non-transferable (hence, there is no opportunity cost associated with applying them to the transportation upgrade). Land acquisition costs are excluded from construction spending because economic value stems from improvements to land, not from portfolio transactions involving land. However, these acquisition costs must be included in the financial tabulation to the extent that the associated funding derives from non-dedicated, non-federal sources.

Appendix A: Theoretical Foundations

This Appendix discusses the economic theory of modeling the effects of transportation infrastructure improvements. It includes greater depth of detail on the theoretical considerations underlying TranSight, as well as some description of alternative approaches not incorporated into TranSight's methodology. For ease of reference, the Appendix is subdivided into topics that correspond to sections in the main body of the document.

Emissions Costs

Transportation expansions such as lane additions or new roads can produce two countervailing effects on the amount of pollutants emitted by motor vehicles. The increased capacity of the road network is likely to increase traffic volumes, thereby raising vehicle miles and (by logical extension) emissions. But studies have demonstrated that emission rates for many pollutants decline up to a certain speed (a threshold which is different for each polluting chemical), meaning that if the upgrade increases average traffic speed to a level that remains below the threshold, emissions among cars that would have traveled in absence of the upgrade may decrease.¹⁰ By contrast, for highway projects, this emission rate effect generally produces *higher* emission levels since the prevailing speed exceeds the threshold at which pollution rates begin to worsen, so the volume and rate effects reinforce one another.¹¹ A balancing of these effects depends critically upon the average speeds before and after the project's completion, and upon the proportion of induced additional cars infused into the system following the upgrade.

Substitution effects must also be addressed, particularly when the transmission project involves the development or improvement of alternative forms of transportation, such as commuter rail or buses. New train or bus lines may, for matters of convenience or expense, entice drivers to switch modes of transportation and thereby reduce total emissions. A complete analysis of demand for marginal quantities of public transit requires consideration of relative prices, attitudes toward transit, and distance from proposed station locations to population and business centers, among other factors. To the degree that individuals respond to their alternatives and switch from private cars to public transit, emissions will be correspondingly reduced.

Ideally, an analysis of a transportation project's effect on emissions would quantify changes from three sources: direct emissions in motor vehicle exhaust, road-dust particulate matter, and pollutants released by gasoline stations, refineries, vehicle manufacturers, and other businesses impacted by changes in vehicle miles or the number of vehicles on the road. But the bulk of health effects from transportation improvements are attributable to five pollutants: carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), particulate matter (PM), and volatile organic compounds (VOCs). Therefore for purposes of simplicity, TranSight focuses on quantifying the emissions rates and associated health costs of these pollutants, which is consistent with the EPA's approach.

¹⁰ Note that emission rates may also vary by fuel type (e.g., premium, regular, or diesel) and engine size, but speed appears to be the principal determinant.

¹¹ U.S. Environmental Protection Agency. *Mobile5b, fleet average, low altitude, including NLEV and Heavy Duty Vehicle (2004) Standards*. 14 September 1996.

As described by Delucchi, there are three steps to obtaining estimates of health cost impacts from motor-vehicle emissions: 1) converting changes in emissions to changes in air quality, 2) converting these air quality changes to changes in physical health effects, and 3) converting health effects to changes in economic welfare.¹² The first step typically involves invoking models of atmospheric dispersion and chemistry to test the effect of a marginal change in emissions. The second stage of the process requires development of exposure-response functions for each pollutant and for each potential health effect (ranging from asthma and headaches to mortality). These functions measure the change in incidence of adverse health effects with respect to changing doses of a particular pollutant, and have been estimated in a number of epidemiological and clinical studies.

The final step is to place monetary valuations on the incidence of the various health maladies caused by motor-vehicle emissions. Ideally, this would involve evaluating all potential impacts of emissions-induced health problems, such as lost work days and leisure activities, lower productivity, medical expenses oriented toward treating the illness, and pain and discomfort. Because these can be difficult to measure, many studies concentrate on mortality impacts and attempt to quantify the value of life. This valuation of life can entail surveying people about their willingness to pay for alternative levels of safety (i.e., reduced risk of mortality) or examining wage differentials between occupations regarded as equal other than the associated risk of injury or death.¹³ These studies often use discount rates that place greater weight on near-term deaths resulting from emissions, and also may assign lesser “value of life” to the elderly people who have greater probability of dying from pollution-related maladies (this “value of life” is unrelated to that used in Safety Costs).

Safety Costs

As with emissions costs, the net impact on safety costs of an expansion in transportation infrastructure is indeterminate. Additional road capacity will induce a combination of incremental demand (i.e., **Trips** that would not have been taken in absence of the upgrade) and shifts in existing demand (i.e., **Trips** that are re-routed onto new roads, which may decrease travel distance). The tradeoff between these two phenomena partially depends on the nature of the project. For example, a one-lane expansion of an arterial road may just induce re-routing of **Trips** onto the newly widened road, whereas a two-lane widening of a previously underused bypass highway may increase **Trips** by delivery vehicles. As another example, adding carpool lanes to existing highways may decrease vehicle miles despite the additional car-carrying capacity. Finally, new or upgraded public transit induces substitution away from private motor vehicles and thereby unambiguously reduces accident volumes, although transit vehicle accidents can have severe consequences.

The principal travel-demand models generate vehicle miles traveled and vehicle hours traveled across multiple dimensions, including time period (e.g., peak versus off-peak and A.M. versus P.M.) and year. This array of output enables differential, user-specified accident rates across these dimensions, which allows the modeling to better reflect real-world conditions in which per-mile

¹² Delucchi, Mark. *The Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991: Summary of Theory Data, Methods, and Results*. Institute of Transportation Studies. June 1996. Publication No. UCD-ITS-RR-96-03(01).

¹³ Greenwood, M. J, G.L. Hunt, D.S. Rickman, and G.I. Treyz “Migration, Regional Equilibrium, and the Estimation of Compensating Differentials.” *American Economic Review* 81, (1991): 1382-1390.

accidents are more numerous during rush periods. Incorporating the time dimension permits accident rates to move over time in response to anticipated changes in traffic congestion, perhaps due to projected regional shifts in population or business development.

Because of the vastly divergent costs associated with accidents that produce fatalities, injuries, or merely property damage, it is important to obtain accident rates broken down by the accident's consequences. Disaggregating by accident type captures the significantly higher incidence of "property damage only" (PDO) accidents relative to more serious types, thereby translating into a more accurate tallying of true cost changes. Ideally, accident rates by type would be subdivided further by road type and by speed of travel; for example, widening a highway may facilitate smoother traffic flow at higher speeds, which typically lowers aggregate accident rates but increases the percentage of higher-cost fatality-causing accidents. However, these data are rarely available in practice.

Converting accident rates into costs requires a full valuation of the economic consequences. This may incorporate a variety of items, including medical expenses, lost productivity at work, vehicle repair and replacement costs, police and emergency response expenses, the cost to society of uninsured motorists, and pain and suffering inflicted upon the victims. Although related to accidents, the opportunity costs for drivers delayed by other peoples' accidents are discussed in the section concerning the value of time. While many accident costs are monetary and easily tabulated (such as repair costs and lost production at work), others (such as "pain and suffering" and lost participation in non-market activities) may be more difficult to quantify. Because not all harm is compensated by the culpable driver (or his insurance company), some costs can be regarded as externalities--for example, increased insurance premiums to cover the damage caused by uninsured drivers.

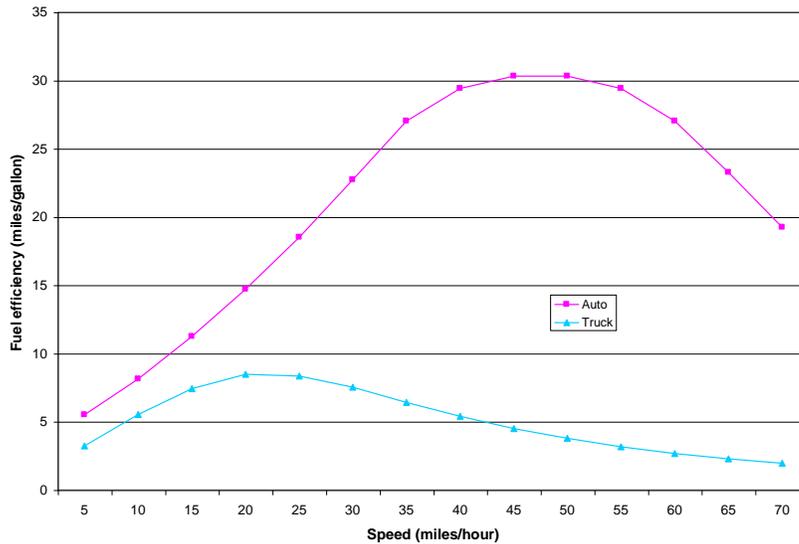
Operating Costs

Improvements to the transportation infrastructure produce indirect effects on spending by households and businesses to operate and maintain motor vehicles. In particular, construction of major new roads in growing population centers can induce increased fuel consumption, to the extent that the additional **VMTs** derive from incremental **Trips** rather than re-routings of existing **Trips**. Similarly, the added miles necessitate additional spending on vehicle maintenance and repair, since cars and trucks endure greater "wear-and-tear" within a given timeframe. These higher out-of-pocket expenses represent opportunity costs, since less disposable income is available for discretionary spending on desired goods and services.

In contrast, mass transit projects cause expenditures on vehicle operation to decrease as individuals substitute car **Trips** with bus and train **Trips** for both commuting and leisure purposes. Naturally, the magnitude of this effect hinges upon elasticities of substitution between private vehicles and public transit. The introduction or extension of high-occupancy vehicle lanes also reduces vehicle operation costs as car depreciation is diluted across participants in a carpool. Regardless of the type of transportation upgrade under consideration, the valuation of changes in vehicle operation costs is straightforward since the commodities being consumed are priced in the

marketplace—namely, the retail price of gasoline, and the cost of vehicle maintenance that is contingent upon mileage.

Just as with the other costs associated with transportation projects, the directionality of the response of fuel and maintenance expenditures may be ambiguous. Widening a road is likely to increase demand, which would suggest increased fuel consumption. However, the upgrade increases the average speed of vehicles that would have utilized the road regardless, which (depending upon the speed levels in question) may diminish fuel consumption since miles/gallon for automobiles tends to improve up to a threshold of around 50 miles per hour. On the other hand, fuel efficiency for trucks tends to peak at much lower speeds, meaning that increased traffic velocities would induce greater fuel consumption by trucks for the majority of road types. These facts are demonstrated below in Figure 4, which shows fuel mileage at various travel speeds for cars and trucks. Clearly, the proportional breakdown of road use by vehicle type (cars, trucks, and buses), along with the proportion of new travelers relative to ones who would have traveled in absence of the project, are critical in assessing the aggregate impact on operating expenditures.



Fuel efficiency of autos and trucks at various speeds (source: Los Angeles MTA)

Value of Time

While more difficult to measure than other benefits of transportation projects, the gains in personal utility associated with reductions in “vehicle hours traveled” (VHTs) can be substantial. For commuters traveling to work, improvements in the efficiency of the transportation network cause time savings as well as a reduction in traffic-induced stress. These benefits may be particularly significant when commuter-oriented upgrades such as high-occupancy lanes or light rail lines are installed, although merely widening an existing highway also yields savings by expediting traffic flow toward business centers. Naturally, the upgrade can also shorten travel times for leisure **Trips**, which effectively makes the surplus time available for other activities. Although leisure **Trips** may be less valued from a productive standpoint, they comprise a large portion of total travel, meaning that

projects that boost average speeds can furnish considerable savings across all households in the region.

The total value of travel time can be conceptualized in several different ways. At the most fundamental level, it can be regarded as the willingness to pay to not spend the necessary minutes in transit—that is, to have travel time reduced to zero. The desire to minimize travel distance (and the associated time) is an important component of the location decision for both households and firms, as they consider various potential commuting or delivery distances in light of their time allocation preferences and comparative valuation of various activities. But while real estate costs are generally higher in major population centers (where access to consumer goods and clients is greater) than in less dense areas, this differential is naturally not only a function of the “price of convenience” but also of other factors such as land scarcity; thus, the value of travel time cannot be obtained directly from such disparities.¹⁴

Taking another approach, as adopted by Delucchi, the process of valuing travel time can be subdivided into two aspects: the opportunity cost (in terms of the value of foregone activities) and the hedonic cost (the pleasure or displeasure derived by the individual from the driving experience itself). In terms of opportunity costs, those that are priced in the private sector may be valued monetarily. For example, savings in truck rental costs, fuel, and driver wages due to quicker completion of deliveries can be tabulated in a straightforward manner, while productivity gains associated with less time spent in traffic may also be estimated.¹⁵ These savings can be quantified with the aid of the Transportation Satellite Accounts (produced by the U.S. Bureau of Economic Analysis), which estimate the value of transportation activities by industry and commodity.

More difficult to ascertain are non-monetary externalities that accrue from both commuter and (especially) leisure travel. Such costs include the hedonic utility of travel (whether positive or negative) as well as unpaid activities foregone and the risks of involvement in an accident. As these cannot be valued directly, most researchers have relied upon surveys in which people are presented with hypothetical choice situations through which they can indicate their willingness to pay to decrease travel time. In general, the non-monetary costs associated with travel time (and particularly with delays due to traffic congestion and nearby accidents) can be treated as a function of vehicle occupancy, the opportunity cost of time, average speed, and the hedonic attributes of travel (that is, the pleasure or discomfort derived from driving or riding).

The Transportation Cost Matrices

“Effective distance” is the mechanism through which the theory of economic geography enters the decision-making processes of economic agents in TranSight. It can be imagined as the geographic distance between two centers of economic activity, adjusted for the efficiency of multi-modal transportation between them. Hence, improvements in the transportation infrastructure reduce effective distance between two locations and consequently increase their interaction, in terms of the

¹⁴ Transportation Research Board – National Research Council. *Economic Implications of Congestion: NCHRP Report 463*; Glen Weisbrod, Donald Vary, George Treyz, 2001.

¹⁵ Delucchi, *ibid.*

flows of labor, intermediate inputs, and end-use commodities. In general, as effective distance increases, the costs that deter economic activity rise through an exponential process called “distance decay.” The rate of change by economic sector of the distance decay curve (known as the distance decay parameter, β) captures both the increased deterrence and the variable impact on flows by sector.

For businesses involved in transporting goods, shorter travel times for their delivery vehicles translate into savings on fuel, wages, and perhaps vehicle and inventory costs. Furthermore, traveling sales personnel can potentially reach more clients during business hours. Although these savings can stem directly from additional roads, which provide quicker alternative routes between popular destinations, they can also result from widened roads, public transit networks, or enhanced traffic control systems, which can diminish congestion and lower accident rates.

As stipulated by the theory of economic geography (which is integrated into the PI+ model), both firms and households obtain benefits from policies that expand their access to variety in labor, intermediate inputs, and end-use goods. Transportation upgrades may facilitate the commute of workers to a more distant job whose characteristics are more closely aligned with the worker’s personal attributes. From the perspective of firms, the project can provide access to a broader and more diverse labor market, enabling the hiring of more suitable workers. Thus the project may induce over time a better match between employers and employees, by expanding the pool of preferred jobs accessible to a given commuter, and the pool of preferred workers accessible by firms.¹⁶

Economic geography also assumes that markets are characterized by monopolistic competition, meaning that goods and services are non-homogeneous. Therefore, all economic agents derive incremental utility from the ability to choose from a wider array of alternatives. By facilitating interactions among a more diverse set of buyers and sellers, transportation upgrades can broaden the scope for market transactions. Businesses can find better matches for their needs in the intermediate input markets, while households can purchase more varied goods and services.

¹⁶ Weisbrod, Glen, and Frederick Treyz “Productivity and Accessibility: Bridging Project-Specific and Macroeconomic Analyses of Transportation Investments.” *Journal Of Transportation And Statistics*, 1.3, 1998: 65-79.