NCHRP Project 20-83(06):
Effects of Socio-Demographics on Travel Demand

Impacts 2050 User Guide

March 20, 2013

Table of Contents

1. Introduction

1.1 What is *Impacts 2050*?

Impacts 2050: demographic scenario analysis tool is a menu-driven spreadsheet model that state and regional transportation decision-makers can use to investigate how socio-demographic factors in a region might impact travel demand over time. It is a model to investigate what could happen under logically consistent demographic, economic and development scenarios. It is not a forecasting model, as the focus is on breadth of scope and flexibility of assumptions, rather than on short-term accuracy spatial detail.

The scenario analysis tool integrates two elements:

1. A system dynamics model that represents regional links between population, land use, employment, transport supply, and travel behavior; and

2. Scenarios representing visions of possible futures.

1.2 What is the scenario analysis tool designed to do?

The scenario analysis tool is a *strategic* model. Its purpose is not to produce detailed forecasts of travel behavior, rather the tool is intended to illustrate a range of future scenarios that could occur in a given region under a range of different assumptions. *Thus, the tool is intended to complement rather than replace existing travel demand forecast models in a given region.*

The scenario analysis tool is designed to be run with multiple scenarios, and is therefore *fast* and easy to run. Furthermore, it predicts the path taken over time into the future, rather than making forecasts for a single end-state. This approach allows rapid, ‘hands on’ analysis of multiple alternative futures.

The scenario analysis tool is designed to address a wide range of ‘what if’ questions that a region may be confronted with, for example:

- Socio-demographic questions: what if the aging of the population causes the typical retirement age to increase?

- Land use questions: what if there was a large shift in preference towards urban locations?

- Employment questions: what if technological changes lead to increased job creation rates?

- Transport supply questions: what would happen if no new roads were built in the next 30 years but population growth continues?

- Travel behavior questions: what happens if the gas price doubles?

The scenario analysis tool is able to address such a wide range of questions by integrating the socio-demographic, land use, employment, transport supply and travel behavior sectors in a system dynamics approach. This approach accounts for the relationships between these sectors over time, and for the impact of feedbacks within the system, for example population increase could increase congestion, which if not alleviated could lead to more people leaving the region over the longer term.

As a tool for long-range planning, the emphasis of the scenario analysis tool is on producing qualitatively accurate representations of how different variable relationships will evolve over time, rather than numerically accurate forecasts for one particular sector.

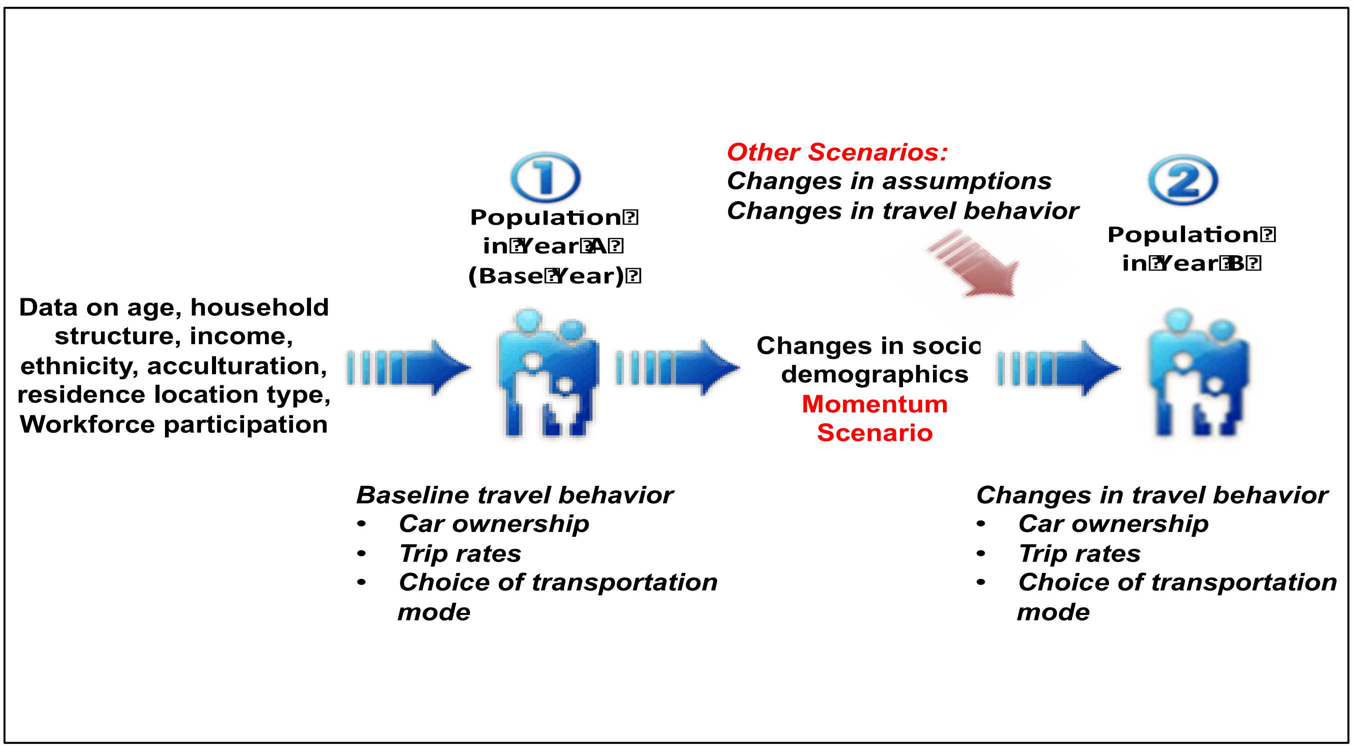
The scenario analysis tool incorporates a detailed treatment of the socio-demographic and transportation sectors, but is not intended to provide detailed spatial forecasts, with the spatial dimension being represented by three aggregate area types.

1.3 How does the scenario analysis tool work?

The scenario analysis tool uses a *system dynamics* approach to understand the relationships between population factors and travel demand, and the ways in which these relationships might change over time.

The heart of the model is the socio-demographic sector. To predict changes in this sector over time, the tool first profiles the base year population across a range of attributes that are associated with travel behavior. It then evolves this population over time, simulating transitions from one category of in each of these attributes to another category. The impacts on travel behavior are calculated in terms of car ownership, trip rates and choice of transportation mode. Changes in expected transitions can be tested as scenario variables. This process is illustrated in Figure 1.

Figure 1: Evolving the Population over Time in Travel Impacts 2050



The scenario analysis tool models the following changes in five sectors:

- Socio-demographics: changes in age and household structures, acculturation and employment status, household income, and area type of residence location.

- Travel behavior: changes in car ownership, work and non-work trip rates, work and non-work mode choice (car, transit, bike, walk).

- Employment: changes in the number of jobs by retail, service, and other categories in urban, suburban, and rural area types.

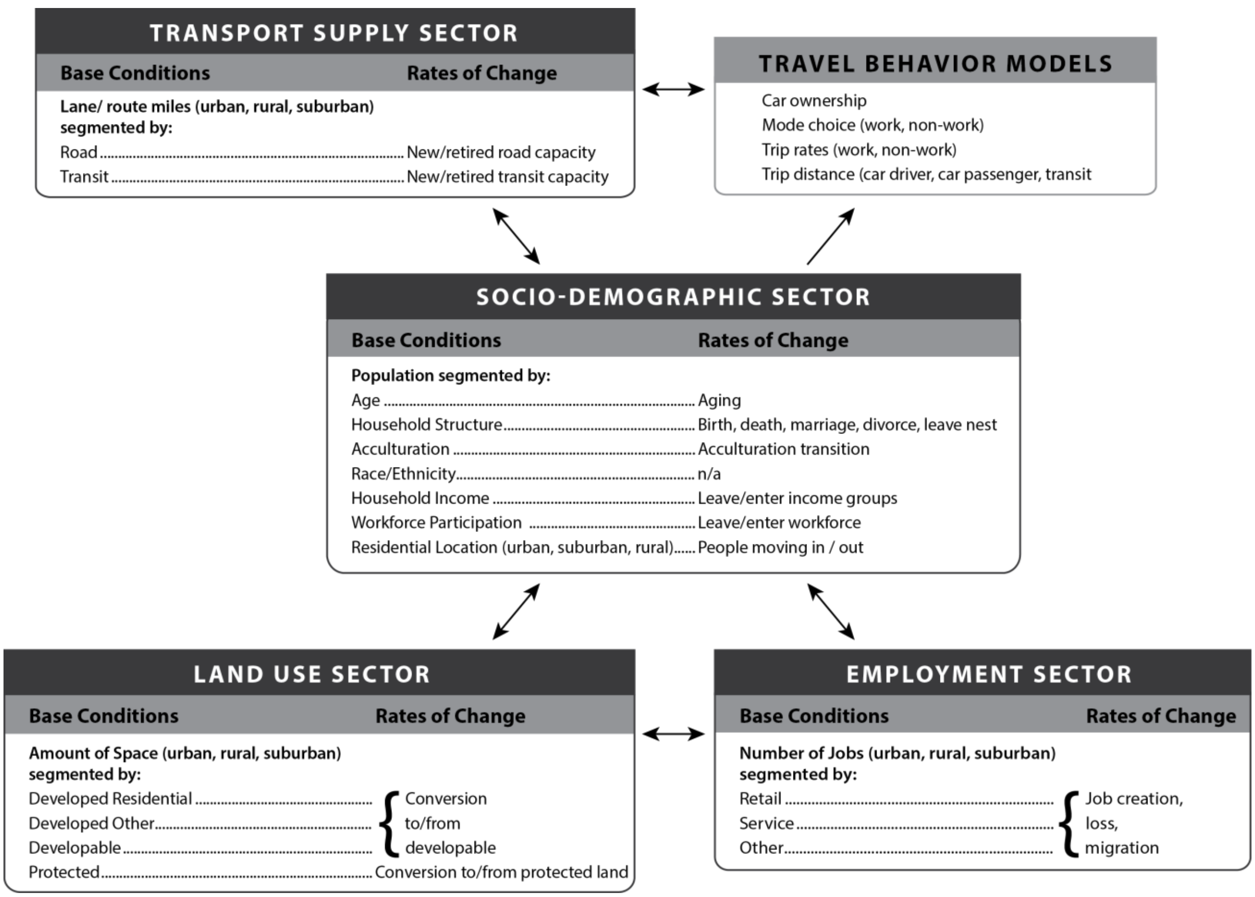
- Land use: changes in the amounts of commercial, housing, developable and protected space in urban, suburban, and rural area types.

- Transport supply: changes in the amounts of freeway, arterial capacity, and regional transit service (bus, rail) in urban, suburban, and rural area types.

The socio-demographic sector is modeled in the greatest detail as understanding the impact of changes in this sector on travel demand is the main objective of this study.

For each of these sectors, information is assembled to define the *base conditions*, then then changes over time are represented by specifying *rates of change*. The inter-relationship between the five sectors is illustrated in Figure 2.

Figure 2: Travel Impacts 2050 Model Structure



In system dynamics terminology, *stocks* are defined for each sector. Initially these define the *base conditions*, and then these stocks change over time according to the rates of change and inter-relationships between the sectors represented in the model. The stocks represented in the model are population, the number of lane/route miles, amount of space and the number of jobs.

The Travel Behaviour models represent a sub-model of the socio-demographic sector, rather than a separate sector. This sub-model predicts the levels of demand for transport given the distribution of population across the segments represented in the socio-demographic sector.

1.5 Structure of this guide

Chapter 2 explains how to install and navigate the tool.

Chapter 3 describes how to specify the base data for the region for the 2000 base year, which the model uses as the starting point for simulating the future. For Atlanta, Boston, Detroit, Houston and Seattle base data has already been input.

Chapter 4 explains how the model scenario can be specified. Four pre-specified scenarios are available, and this Chapter briefly summarizes how each of the four scenarios has been specified. The chapter also explains how the user can easily create their own scenario using one of the four pre-specified scenarios as a starting point.

Chapter 5 explains how to run the scenario analysis tool, and how the tool can be run to make a series of related scenario runs.

Chapter 6 explains how the model output can be analyzed. It describes the detailed simulation output that is produced for half year intervals from 2000 thru to 2050, as well as the summary output that is automatically generated and how custom plots can be created from the simulation variables.

Chapter 7 describes three components of the model that the user would not modify for most scenario runs, specifically demographic transition rates derived from analysis of PSID data, the demographic seed matrix taken from analysis of 2009 NHTS data, and the travel behaviour models that have been estimated from the 2009 NHTS data.

2. Installing and Navigating the Tool

2.1 Installing the Tool

The scenario analysis tool is delivered in a zip file containing two components:

- NCHRP_Impacts_2050_V1_8.xlsm: The spreadsheet scenario analysis tool
- NCHRP_Impacts_2050_V1_8.pro: The simulation model

To install the tool, and open it for the first time, the user simply needs to:

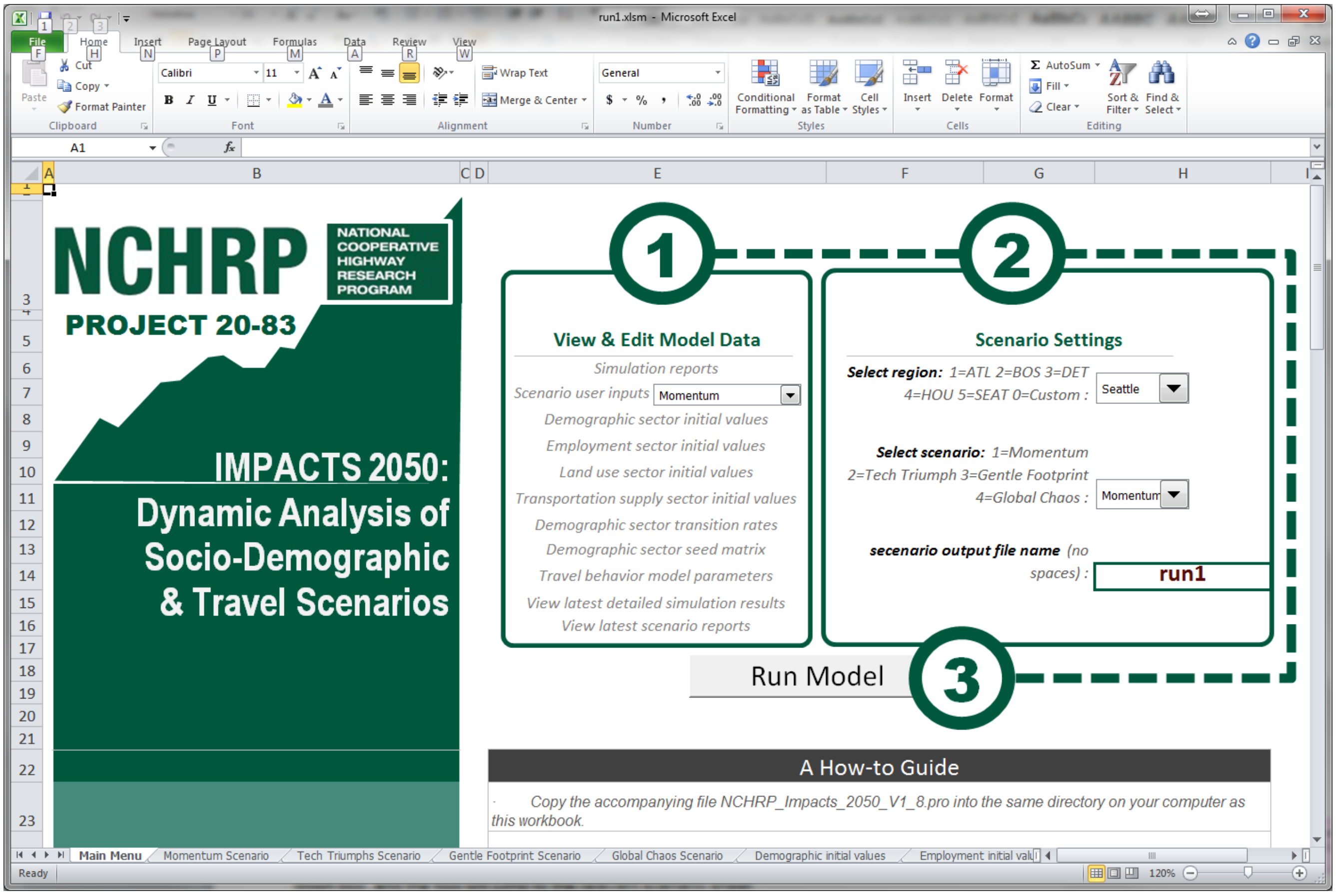
1. Copy the 'NCHRP_Impacts_2050_V1_8.pro' file to the same directory location as the spreadsheet.
2. Rename the 'NCHRP_Impacts_2050_V1_8.pro' file as 'NCHRP_Impacts_2050_V1_8.exe' (the file is delivered using the .pro extension as many email systems will not accept files with the .exe extension).
3. Open the spreadsheet. If prompted by Excel, select 'Enable Content' or 'Enable Macros' so that the imbedded macros can run.

When the tool is run, Excel calls the .exe file which runs the simulation model for each ½ year interval thru to 2050. The simulation results are output to a .csv file which is then read back in by the tool ready for analysis.

2.2 Navigating the Tool

The tool has been set up so all sheets can easily be navigated via the 'Main Menu' sheet which will appear when the spreadsheet is opened. The navigation options are illustrated in Figure 3.

Figure 3: Main Menu Navigation Options



The user can navigate to all sheets in the workbook by clinking on the links given in box ①. To navigate to a scenario user input sheet, simply select one of the four scenarios from the drop-down box, and the tool will jump to the relevant scenario sheet.

To navigate back to the Main Menu sheet, simply click on the 'Return to Main Menu' button highlighted in red at the top left of the other sheets.

3. Defining Base Data for the Region

Four sets of data must be specified to define the year 2000 base conditions for the simulation region:

- Demographic data
- Employment data
- Land use data
- Transport supply data

Data has already been entered into the tool for the Atlanta, Boston, Detroit, Houston and Seattle regions. For set the model up for any other region, termed a *custom* region in the scenario analysis tool, the following sections describe the sheets in the spreadsheet where inputs need to be made for each of each of these four sets of data.

The region to which the model is applied can be an MPO region or an entire state. To run the model at the state level the user simply needs to assemble the required base data at the state level.

The following sub-sections describe the demographic, employment, land use and transport supply data that the user needs to define the base conditions for a custom region.

Once the base year data for a custom region has been defined, the user should save the spreadsheet with a different name before making runs for different scenarios.

In the following sheets, cells that are highlighted in yellow are base year region-specific values that users need to specify to start the simulation with appropriate year 2000 values for a specific region. The other cells that are highlighted in orange are the basic structural parameters of the model. Although the values in these orange cells can be changed by the user, it is recommended not to change them unless the user has a good working understanding of the model and wishes to test the effects of making different structural assumptions.

3.1 Demographic data

The demographic data is specified on the 'Demographic initial values' sheet. The stock variable is total population in the region, which is broken down across a range of dimensions.

Base year region-specific inputs

To define the base demographic data for the region, the user needs to enter the following information into the cells highlighted in orange in column B.

Table 1: Base Demographic Data

Dimension	Units	Categories
Age	Persons	0-15, 16-29, 30-44, 45-59, 60-74, 75+
Household type	Persons	single without children, couples without children, single with children, couples with children
Acculturation group/race	Persons	Combination of (a) foreign-born <20 years in US, foreign-born 20+ years in US, native-born and (b) Hispanic, Black, Asian, White/other
Household income band	Persons, bands in 2009 US$	$0-$34,999, $35,000-$99,999, $100,000 up
Employment status	Persons	in workforce (including those looking for employment), not in workforce
Area type	Persons	urban, sub-urban, rural

The first six of these dimensions should sum across categories to give the same total population figure.

For the five pre-defined regions, 2000 base data for these dimensions has been defined from 2000 Census data.

A ‘couple’ is defined as either married or co-habiting partners (but not, for example, two non-related adults). ‘Children’ can be up to age 30 if they are the couple’s own children.

The area type information is defined at the Census tract level. For each tract, the number of jobs per square mile and the number of residents per square mile is calculated. The area types are then defined as follows:

- Urban areas have at least 4000 jobs/mile^2 or 10,000 residents/mile^2 inside the tract
- Suburban areas are areas that do not qualify as Urban, and have at least 500 jobs/mile^2 or 1,000 residents/mile^2 inside the tract
- Areas do not qualify as Urban or Suburban are classified as Rural areas.

Thus the base demographic data starts at the detailed Census tract level, and then aggregates this information up to three area types.

More information on the socio-demographic sector is provided in Chapter 4 of the interim report.

3.2 Employment data

The employment data for the region is specified on the ‘employment initial values’ sheet. The stock variable is number of jobs, which should sum to the total number of persons in the workforce given on the ‘Demographic initial values’ sheet. Note that the workforce totals include persons looking for employment.

Base year region-specific inputs

To specific inputs for a “Custom” region, the user needs to enter the job totals into cells B4:B12 highlighted in yellow, for the nine combinations of area type (urban, sub-urban, rural) and employment type (retail, service and other).

The source for this data for the five example regions is the Longitudinal Employer-Household Dynamics data from the U.S. Census Bureau, 2002.

Other inputs

In cells B15:G23 are base commute patterns, specifying the fraction of residents in each area type who work in each area type. (E.g. 95% of employed urban area residents also work in the urban area.) These base values are adjusted during the simulation to take account of changes in job demand and supply in the different area types.

In cells B26:B28, the user can modify the employment sector delays which specify the length of time it takes for the stock of jobs to adjust during the model simulation in response to changes in inputs from the other sectors. Three delay values are specified:

- **Job creation**: jobs created in the region by new companies moving to the region, new companies starting up and existing companies adding jobs.
- **Job loss**: jobs lost in the region by companies leaving the region, going out of business or downsizing.
- **Job migration**: jobs changing location within the region, e.g. moving from urban to sub-urban areas.

In general, these delays do not need to be modified by the user, because it is possible for the user to specify multiplies on these rates using rows 44-46 of each of the scenario pages. (The “rates” are inversely proportional to the delays, so a higher multiplier on the scenario sheet will give a shorter delay.) One exception: the user can effectively “turn off” the dynamics of the employment sector by specifying very long delays (e.g. 10,000 years) on this sheet

In cells B33:D41 are the weights on the employment attraction functions used for each of the nine employment categories. The weights specify the relative attractiveness of job demand/supply index, commercial space demand/supply index and road mile demand/supply index on the attractiveness of the nine employment types. The weights should always sum to one across each row.

In cells B45:D65 are the values of the attractiveness functions for job demand/supply index, commercial space demand/supply index and road mile demand/supply index. The graph plotted to the right of these cells illustrates the shape of the attractiveness functions.

As mentioned above, the values for the employment attractiveness function are highlighted in orange, meaning that these are structural relationships in the model, and can be left as they are unless the user wishes to test the effect of using different functions.

Chapter 7 of the interim report provides more detail on how these attractiveness functions are specified, and presents a flow diagram illustrating how the employment sector operates.

3.3 Land use data

The land use data is specified on the ‘land use initial values’ sheet. The stock variable is land use in square miles.

Base year region-specific inputs

If the user wishes to use a new Custom region, the area in square miles for the twelve combinations of area type (urban, sub-urban, rural) and use-type (residential, non-residential, developable and protected) must be specified in cells B4:B15. The definition of urban, sub-urban and rural is as per Section 3.1 above.

For the five example areas, the values were calculated using the base year population and employment figures along with the assumed land required per household and per job (see below). It would be possible to use more detailed parcel data and other GIS-based land use information to possibly obtain more accurate estimates of these values, but that was not done for this project.

Other inputs

Cells B18:B22 are the base values for the land use sector delays, which form exogenous inputs to the model. In general, these delays do not need to be modified by the user, although it is possible to do so in order to test different response times for this sector. The user can effectively "turn off" the dynamics of the land use sector by specifying very long delays (e.g. 10,000 years) on this sheet

The base densities of housing developments areas are given in cells B26:E28, for different household types in each of the three area types. Similarly, the densities of different non-residential development types in each of the three area types are specified in cells B32:D34. The most typical way of changing these for a particular scenario are to use rows 49 and 50 of the scenario sheets, which allow scenario-specific multipliers to be applied to these base densities.

Finally, the fractions of developable land available for residential and non-residential development are specified for each of the three area types in cells B38:C40. Note that each row may sum to more than one.

Chapter 6 of the interim report provides more detail on how the land use sector is modeled, including a flow diagram illustrating how the land-use sector is modeled, the interactions with other sectors, and how the user defined inputs operate.

3.4 Transport supply

The transport supply data is specified on the 'Transp. supply initial values' sheet. The stock variable is lane miles for highway and route miles for transit.

Base year region-specific inputs

If the user wishes to use a new Custom region, the number of lane miles for freeways, arterials and other highways in urban, suburban and rural areas must be specified in cells B4:B12, and the total route miles for the rail and bus transit modes specified in B13:B14.

To generate the lane miles inputs, data on total centerline miles has been assembled, which is converted into lane miles by multiplying by the average number of lanes per highway type. The user can input the centerline mile totals for their region into cells L4:L12, and if they wish to modify the average number of lanes per highway type this data can be edited in cells J4:J12. The lane miles values in cells B4:B12 will then be automatically calculated as the product of these two columns. (Otherwise, if the user has direct data on lane-miles, these can be input directly into cells B4:B12)

The source for these data for the five example regions was the National Transit Database of the Federal Transit Administration, 2002.

Note that the road supply is much more important for the operation of the model than the transit supply, as currently in the model the relative demand and supply for transit does not have any feedback effects on the other sectors, while the relative demand and supply for road capacity can affect the attractiveness for new employers and new residents.

Optional inputs

In cells B17:B20, the user can modify the delays in years for road and transit capacity to be added and retired, which are exogenous inputs to the model. Rather than changing these values, the user can specify scenario-specific multipliers on these rates using rows 54-57 on each of the scenario input sheets. (The “rates” are inversely proportional to the delays, so a higher multiplier on the scenario sheet will give a shorter delay.) The user can effectively “turn off” the dynamics of the transport supply sector by specifying very long delays (e.g. 10,000 years) on this sheet

Cells B24:D26 allow the user to modify the average road capacities in vehicles/hour per lane for the nine possible road and area type combinations.

Similarly, cells B30:C32 allow the user to modify the average transit capacities in passengers per hour per route for bus and rail for the three different area types.

Cells B35 and B36 give one-way peak hour fractions for work and non-work trips respectively, to translate the daily demand from the travel demand models to AM peak hour demand, as it is the relative peak hour road supply and demand that is used to determine the effects of road congestion.

Finally, cells B40-B51 give the fraction of trip distances that are driven on roads within each area type. For example, it is assumed that Surburban-to-Urban commutes are 30% on Urban area roads, 70% on Suburban area roads, and 0% on Rural area roads. As the model does not use explicit networks or traffic assignment, these fractions give the approximate usage of different types of roads for different types of trips.

Chapter 8 of the interim report provides more detail on how the rates of change in the transport sector are modeled, including a flow diagram that illustrates how the sector is modeled, including interactions with the other sectors, and how the user-defined inputs operate.

4. Defining the Model Scenario

The model is intended to be a scenario-analysis tool, and so has been setup so that different scenarios can be easily specified and tested. Four scenarios have been pre-specified, and any of the four pre-specified scenarios can be used as a starting point for making a particular scenario run.

The four pre-specified scenarios are:

- Momentum scenario
- Tech Triumphs scenario
- Gentle Footprint scenario
- Global Chaos scenario

To make modifications relative to the default values for each scenario, the user simply edits the *scenario multipliers* which are applied as modifiers to the base rates. So a multiplier of 0.5 means using half of the base rate, a multiplier of 1 means using the base rate without adjustment, and a multiplier of 2 means doubling the base rate.

To help highlight which scenario multipliers have been changed, the cells containing the scenario multipliers change color as the values are changed. The cells turn increasingly green for scenario multiplier values above one (higher rates), and increasingly red for scenario multiplier values below one (lower rates). Yellow shading indicates no change from the base rates.

Scenario multipliers can be specified at five years intervals from 2000 thru to 2050. The simulation is run for ½ year increments, and so for ½ year points other than those where scenario rates are specified, values are determined by interpolating linearly between the rates defined at the 5-year points either side.

Chapter 10 of the interim report explains how the four scenarios have been specified, and presents a table showing scenario factors have been translated into impact thru the variables represented in the model. It is the impacts of the scenarios on the model variables that are specified on the four scenario sheets of the scenario analysis tool. As Chapter 10 of the interim report makes clear, the impact of the four different scenarios in terms of model inputs is open to debate. For this reason, the four scenario sheets make explicit how the scenarios have been specified in terms of the model variables, and allow the user to modify the default scenario assumptions to test the impact of alternative assumptions.

The four pre-specified scenarios are described in the following sections, and then the sections go on to explain how the scenarios have been specified as modifiers to the base rates and variables in the model. The explanations should assist users who wish to set up alternative scenarios, or investigate the sensitivity of the simulation results for their region to the set of default assumptions made to specify each of the scenarios.

4.1 Momentum scenario

The momentum scenario is described as follows. The current state of the country in 2050 would still be recognizable to a visitor from the 2000s. Change is based on population dynamics, and we have not experienced any major shifts in demographic, economic, or technology trends. Nor have there been major policy shifts, as the two political parties have held firm to positions and divided government remains a feature of national politics. Travel demand and funding have changed a bit more. Commute travel has decreased somewhat, thanks to telework. People are still on the roads a fair amount for shopping and personal business, but congestion levels are manageable. Federal gas taxes have risen a few times, but not enough to keep up with the increases in fuel economy. As a result, with less federal funding many states have had to increase their own funding streams if they want to maintain their existing road network.

The 'Momentum Scenario' sheet shows how the study team have specified this scenario in terms of the transition rates and variables used in the model. To specify the momentum scenario, the base transition rates and variables are used without modification as this scenario represents a continuation of current trends, except for four changes to the 2005 rates to take account of the recent economic downturn:

- A 20% increase in the rate at which individuals leave the workforce, and a 10% reduction in the rate at which individuals enter the workforce; and

- 50% increases in the rate at which individuals enter the lowest income group, and leave the highest income group.

The modifications are specified for 2005 only, and therefore these scenario multipliers are assumed to return the base rates by 2010, and thereafter remain fixed at the base rates thru to 2050. These modifications to the 2005 scenario multipliers to take account of the recent economic downturn have also been applied for the other three scenarios, however as described below these scenarios represent other changes to the scenario multipliers which come into play after 2010.

4.2 Tech Triumphs scenario

The Tech Triumphs scenario is described as follows. Technology has saved us from ourselves. While the United States faced some difficult challenges in the 2010s, many of these have been mitigated by innovations that helped us live longer, reduce our carbon footprint, connect our world, and travel more easily and safely. Autonomous vehicles have changed how people travel, and data-intensive communications technology has also affected how much people travel. Commute travel has declined, since a high proportion of office workers now work from home, and fewer people live near their jobs since their physical presence is seldom required. Much socializing also takes place virtually, and many weekly necessities are delivered to peoples' doors. The travel that does take place tends to be faster, cheaper, and more convenient than ever.

The 'Tech Triumphs Scenario' sheet shows how the study team have converted the ten scenario variables into modifications to the model variables specified via the scenario multipliers. The scenario multipliers incorporate the following changes from 2010 onwards:

Socio-demographic sector

- *Death rate* reduces due to longer lifespan and better general health due to health care technology, good environmental conditions.

- *Birth rate* increases due to increased optimism about the future.

- *Marriage rate* reduces as individuals opt to delay marriage due to 'virtual' living.

- *Divorce rate* increases due to increased choices and flexibility in living arrangements.

- *Empty nest rate* increases as increased opportunities allow young people to move out.

- *Leave workforce rate* reduces because home-working allows people to delay retirement.

- *Enter lowest income group rate* reduces because of high rate of economic growth.

- *Enter highest income group rate* increases because of high rate of economic growth.

- *Foreign in-migration rate* reduces as desire to re-locate to US falls as workers find jobs in their home countries.

- *Foreign out-migration rate* increases due to increase in demand for technology workers and open immigration policies.

- *Domestic migration rate* and *intra-regional migration rate* both reduce as technology allows people to work from anywhere and economic activity diffuses from population centers.

- *Death rates, birth rates, marriage rates, divorce rates, empty nest rates and space per household rates* by income group are all assumed to remain at base levels, under the assumption that the benefits of technology favor those with higher incomes and so current levels of inequality persist.

Travel behavior sub-sector

- *Fuel/energy price* reduces due to improved energy technology and efficiency.

- *Shared car fraction* reduces due to high income growth.

- *No car fraction* reduces because move to suburbs leads to higher car ownership.

Employment sector

- *Job creation rate* increases and *job loss rate* reduces because growing economy helps businesses and jobs.

- *Job move rate* increases because technology allows people to work from anywhere leading to a diffusion of activity away from population centers.

Land-use sector

- *Residential space per household* increases due to lower densities.

Transport supply sector

- *Road vehicle capacity per lane* increases because intelligent vehicles can use the road space more efficiently.

- *Transit passenger capacity per route* increases because technology leads to greater transport efficiency.

4.3 Gentle Footprint scenario

The Gentle Footprint scenario is described as follows. After droughts and 'super storms' began plaguing the United States in the 2010s, both public consciousness and political will began shifting toward taking more serious action to slow climate change. While it was too late to curb the rise in carbon concentration in the atmosphere, the United States has made surprisingly good progress in adopting a variety of means to reduce energy consumption. Many lifestyle changes that might once have been considered radical are now mainstream. Federal, state, and local governments have responded by shifting their focus to investments that support public transit, walk and bicycle modes, rather than cars. Most cities and suburbs have good networks of bicycle lanes, and transit systems have expanded while the size of the road network has barely budged in 20 years. High-speed rail has been built in a half-dozen corridors, and it captures a healthy percentage of travel between those cities.

The 'Gentle Footprint Scenario' sheet shows how the study team have converted the ten scenario variables into modifications to the model variables specified via the scenario multipliers.

Socio-demographic sector

- *Death rate* reduces due to longer lifespan and better general health due to healthier lifestyles, good environmental conditions.
- *Birth rate* reduces because concern about the environment leads to smaller household sizes.
- *Enter lowest income group rate* increases, and *enter highest income group* reduces, together these two effects work to increase the proportion of the population in the lowest income group hence representing increasing economic equality.
- *Foreign in-migration rate* increases because environmental technology businesses require technology workers, and 'back to basics farming' requires migrant labor.

Travel behavior sub-sector

- *Fuel/energy prices* are raised to encourage use of alternative energy sources.
- *Shared car fraction* increases because car sharing is encouraged.
- *No car fraction* increases because better public transit options are available.
- *Work trip rate* and *non-work trip rate* are both reduced because travel becomes more expensive.
- *Car passenger mode share* increases because cars are used more efficiently.
- *Transit mode share* increases because better public transit systems are available.
- *Walk/bike mode share* increases due to higher land-use densities, improved bicycle lane network.
- *Car trip distance* decreases because car use is reduced.

Land-use sector

- *Residential space per household* and *non-residential space per job* both reduce due to increased densities.

- *Land protection* increases because a greater value is placed on undeveloped land.

Transport supply sector

  - *Road capacity addition* reduces because investment in new road capacity is reduced.

  - *Transit capacity addition* increases due to increased investment in public transit.

4.4 Global Chaos scenario

The Global Chaos scenario is described as follows. The past few decades have challenged Americans' general optimism, and the world has become a far different and more difficult place. Several trends intersected to bring about this distressing 'new normal': the increasing impact of climate change, financial instability at a global scale, and a new isolationism. The results, which affect not only the United States but most of the world, are heightened insecurity, lower life spans, and chronic conflicts. Widespread unemployment means that far fewer people are on the roads and transit systems. With state and local governments collecting relatively little revenue, they have a hard time maintaining the existing infrastructure or responding to crises like returning travel to normal after a major storm. Walking and cycling are far more popular now, but generally out of necessity than choice, and those with cars often make extra money on the side as gypsy cabs.

The 'Global Chaos Scenario' sheet shows how the study team have converted the ten scenario variables into modifications to the model variables specified via the scenario multipliers.

Socio-demographic sector

- *Death rate* increases due to lack of focus on health care and poor environmental conditions.

- *Birth rate* reduces because of reduced optimism about economic conditions.

- *Marriage rate* reduces because of reduced optimism about economic conditions.

- *Empty nest rate* reduces because economic chaos results in adult children living with their parents.

- *Leave workforce rate* reduces due to later retirement.

- *Enter workforce rate* reduces due to poor economic conditions, with bigger reductions from 2030 than the reductions to the leave workforce rates.

- *Leave lowest income group rate* reduces, and *enter lowest income group* increases, as people shift into the lowest income group due to poor economic conditions.

- Similarly *leave highest income group rate* increases, and *enter higher income group* reduces, as people shift out of the highest income group due to poor economic conditions.

- *Foreign in-migration rate* decreases due to increased border controls and stricter visa restrictions.

- *Foreign out-migration rate* increases due to stricter visa restrictions and increased deportation.

- *Domestic migration* reduces because there is less relocation activity as opportunities dwindle irrespective of location.

- *Low income impact on death rate* increases because the increase in death rates is even higher for lower income groups.

- All other income variations on birth, death, marriage, divorce, leave empty nest, and space per household rates remain at base year rates, i.e. base year levels of difference with income group persist.

Travel behavior sub-sector

- *Fuel/energy price* increases because of global supply instability.

- *Shared car fraction* increases because there is more car sharing.

- *No car fraction* increases because poor economic conditions lead to a fall in car ownership.

- *Work-trip rate* falls due to lower employment rates.

- *Non-work trip rate* falls due to depressed economy.

- *Car passenger share* increases due to increased car sharing.

- *Walk/bike share* increases following reductions in car ownership.

Employment sector

- *Job creation rate* reduces due to low economic growth.

- *Job loss rate* increases due to low economic growth.

- *Job move rate* reduces due to reduced job opportunities.

Land-use sector

- *Land protection* is reduced because less value is placed on protected land.

Transport supply sector

- *Road capacity addition, transit capacity addition, road lane mile capacity* and *transit route mile capacity* rates are all reduced due to very low investment in transport capacity.

5. Running the Tool

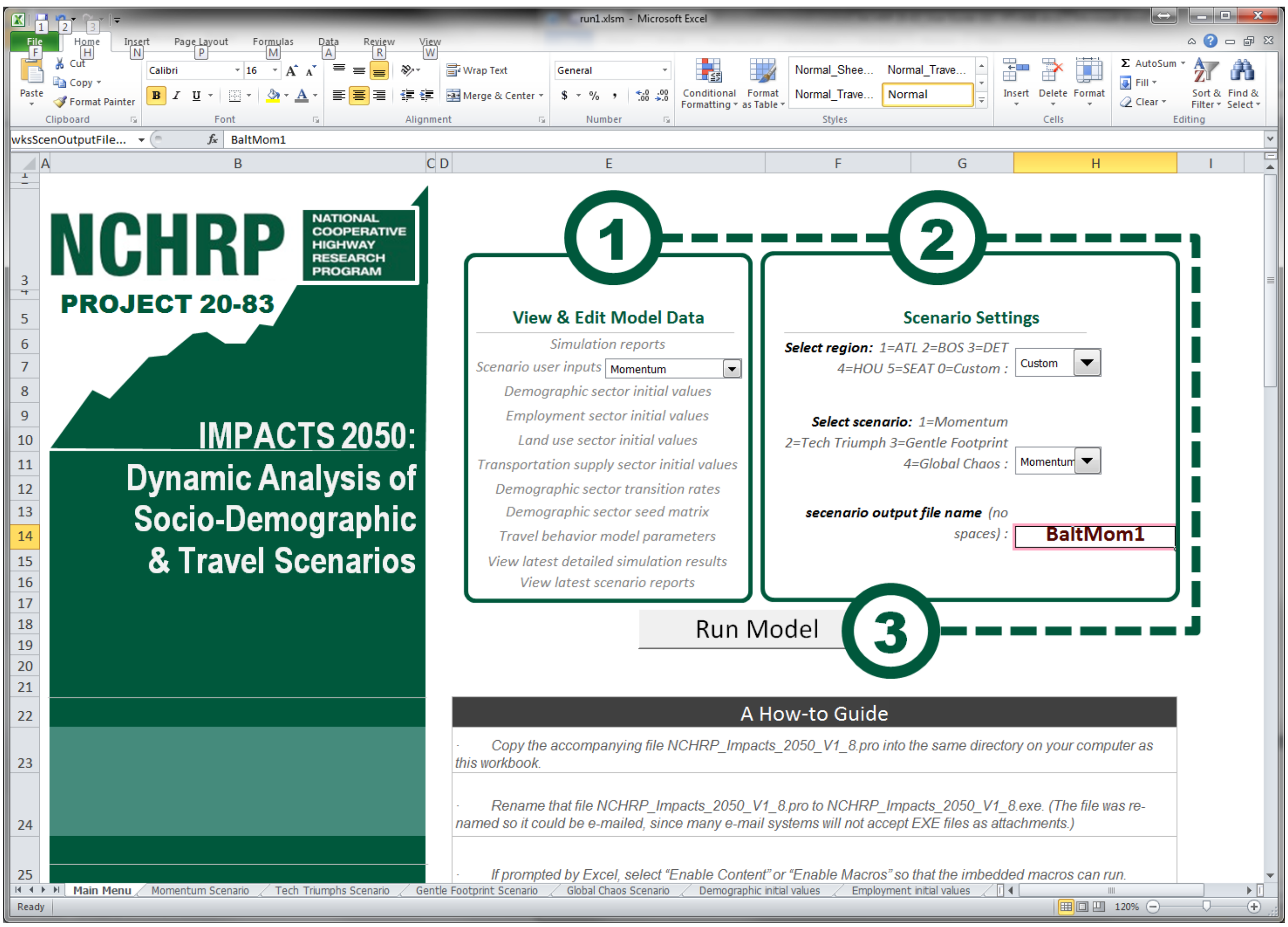
Once base data for the region has been defined (if running for a custom region), and any modifications to the standard scenario inputs have been specified, the scenario analysis tool is ready to be run.

To run the tool, the user simply needs to follow these steps from the 'Main Menu' tab:

1. Under box ②, select the region from the first drop-down box, and the scenario from the second drop-down box.
2. Enter the scenario output file name in the in the input cell at the bottom of box ②. Note that the scenario output file name cannot contain any spaces.
3. Click the 'Run Model' button to run the simulation.

This process is illustrated in Figure 4.

Figure 4: Running the Scenario Analysis Tool



In the example given in Figure 4, the user has specified base year data for their region (Baltimore) as per Chapter 3, and has selected 'Custom' from the region drop-down. The scenario is 'Momentum', selected from the scenario drop-down. The scenario output file name is 'BaltMom1'.

Then to run the simulation, the user simply clicks the 'Run Model' button. In order to run the simulation, the spreadsheet outputs a series of .dat files which specify the base year stocks by sector, the scenario user inputs, the parameters in the travel demand model, the demographic seed matrix, the demographic transition rates and the scenario user inputs. The spreadsheet then calls the accompanying 'NCHRP_Impacts_2050_V1_8.exe' executable, which reads in the information from the *.dat files and runs the simulation over ½ year increments from 2000 thru to 2050. The program runs in a console window which indicates the year being simulated and then closes when the simulation is finished. The program creates a .csv file as output, which uses the scenario output file name.

Once the simulation is complete, the spreadsheet automatically reads in the simulation results from the .csv file, copies it to the 'Simulations Results' sheet, updates the summary results table and graphs on the 'Simulation Reports' sheet, brings the 'Simulation Reports' sheet to the user's screen, and saves the output to the new spreadsheet named using the specified scenario output file name. So in the example given in Figure 4, a spreadsheet named 'BaltMom1.xlsm' is created.

When the output spreadsheet is created all of the sheets are copied across, not just the output sheets. This means that the resulting spreadsheet contains full documentation of the base data used to make the run, as well as the scenario inputs and any other changes that were specified. The macros are also copied across, so it is possible to use the output spreadsheet to specify the next scenario run following exactly the same procedure. This functionality is useful if the user wants to make a series of related scenario runs where the 2nd scenario is specified by making modifications to the 1st scenario, the 3rd scenario is specified making the modifications to the 2nd scenario, and so on. This functionality facilitates exploratory analysis to investigate the sensitivity of model results to particular scenario inputs.

6. Analyzing the Model Output

The scenario analysis tool automatically generates two sets of output to allow the user to analyze the simulation results. First, a simulations report sheet that presents pre-specified tabulations and plots, and also enables the user to specify their own plots. Second, the detailed simulation results offering full flexibility for more detailed analyses. These two sets of outputs are described in the following sub-sections.

6.1 Simulation Reports

Once the simulation has been run, the scenario analysis tool will automatically present the 'Simulation Reports' sheet.

At the top left of the 'Simulation Reports' sheet, a table is presented which summarizes the simulated change in the socio-demographic characteristics of the region's population over the forecast period, and predicted changes in travel behavior. **Figure 5** illustrates the summary results generated for the Atlanta region under the Momentum scenario.

Figure 5: Summary of Table of Population and Travel Behavior

Year	2000	2010	2020	2030	2040	2050
Population	4,247,982	5,307,832	6,450,259	7,593,777	8,712,643	9,850,329
Percent under age 16	23%	22%	22%	22%	23%	23%
Percent over age 60	11%	14%	17%	19%	19%	20%
Percent in single households	13%	19%	22%	23%	24%	25%
Percent in HH w/children	63%	63%	62%	61%	60%	60%
Percent immigr. > 20 yrs in US	2%	5%	7%	9%	9%	8%
Percent immigr. < 20 yrs in US	8%	8%	7%	6%	5%	4%
Percent White/other	61%	60%	58%	57%	56%	55%
Percent Hispanic	6%	8%	9%	10%	11%	11%
Percent Black	29%	27%	26%	25%	25%	25%
Percent Asian	3%	5%	7%	8%	8%	9%
Percent low income group	31%	32%	34%	34%	33%	33%
Percent high income group	18%	19%	22%	25%	26%	27%
Percent in workforce	51%	44%	38%	35%	33%	32%
Percent non-car-owning	3%	3%	3%	4%	4%	4%
Percent car-sharing	21%	20%	21%	21%	21%	21%
Avg. car-occupancy- Work	110%	110%	110%	110%	110%	110%
Transit mode share- Work	0.02	0.02	0.02	0.03	0.03	0.03
Walk/bike mode share - Work	5%	6%	6%	6%	6%	7%
Avg. car-occupancy- Non-work	1.81	1.75	1.75	1.75	1.75	1.75
Transit mode share- Non-work	0.9%	1.0%	1.1%	1.2%	1.2%	1.2%
Walk/bike mode share-Non-work	12.9%	13.1%	13.4%	13.6%	13.7%	13.8%
Work trips/capita per day	0.59	0.50	0.43	0.39	0.37	0.36
Other trips/capita per day	2.92	3.02	3.14	3.20	3.23	3.24
Auto VMT/capita per year	9,902	7,924	6,596	5,664	4,986	4,453

Under the Momentum scenario, a significant increase in the population of the Atlanta region is predicted between 2000 and 2050, with an increase in the population aged over 60 and a corresponding reduction in the percentage of the population in the workforce. These demographic changes result in reductions in the work trip rate per capita, but increases in the other trip rate per capita.

In addition to the summary table presented in **Figure 5**, the spreadsheet creates 14 predefined plots that show how the simulation results evolve over time. Each plot is generated as both a line graph and a stacked area graph where the dimensions sum to 100%. The plots that are generated are summarized in Table 2.

Table 2: Summary of Predefined Plots

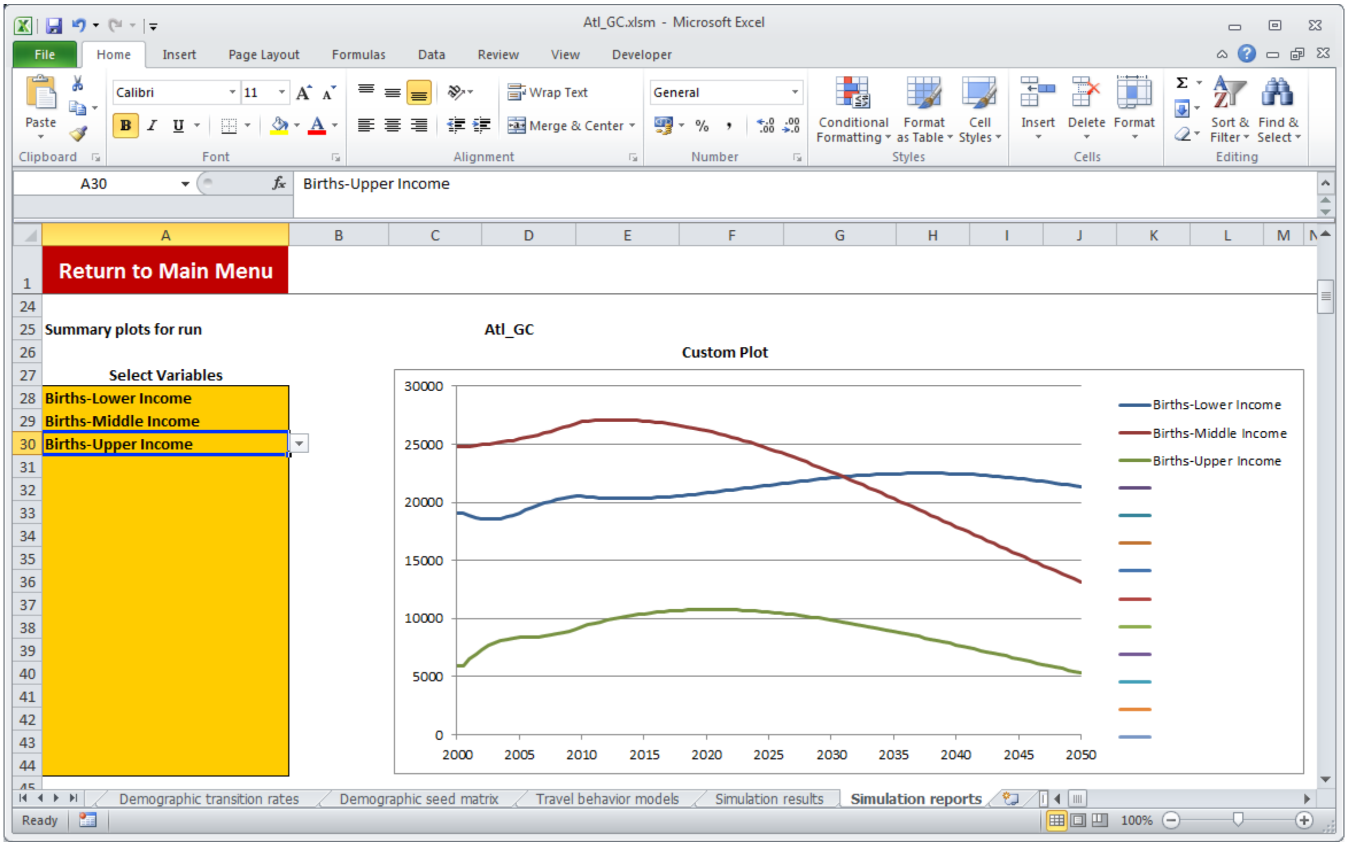
Plot Title	Sector	Dimensions
Demographic Transitions	Socio-demographic	Empty nest First child Divorces Marriages Births Deaths
Population by Age Group	Socio-demographic	0-15 16-29 30-44 45-59 60-74 75+
Population by Household Type	Socio-demographic	Couple with kids Single with kids Couple without kids Couple without kids
Population by Race/Ethnicity (summed across acculturation levels)	Socio-demographic	Hispanic Black Asian White/other
Population by Acculturation Level (summed across race/ethnicity)	Socio-demographic	Born in the US Foreign-born- In the US >20 yrs Foreign-born- In the US <20 yrs
Population by Income Group	Socio-demographic	Upper Income Middle Income Lower Income
Population by Workforce Participation	Socio-demographic	Not in workforce In workforce
Population by Residence Area Type	Socio-demographic	Rural area Suburban area Urban area
Jobs by Area Type and Sector	Employment	Rural area, other jobs Rural area, service jobs Rural area, retail jobs Suburban area, other jobs Suburban area, service jobs Suburban area, retail jobs Urban area, other jobs Urban area, service jobs Urban area, retail jobs

Land by Area Type and Land Use	Land use	Rural area, protected land Rural area, developable land Rural area, residential land Rural area, non-residential land Suburban area, protected land Suburban area, developable land Suburban area, residential land Suburban area, non-residential land Urban area, protected land Urban area, developable land Urban area, residential land Urban area, non-residential land
Road Lane Miles by Area Type and Road Type	Transport supply	Lane miles, rural area, local roads Lane miles, rural area, arterials Lane miles, rural area, freeways Lane miles, suburban area, local roads Lane miles, suburban area, arterials Lane miles, suburban area, freeways Lane miles, urban area, local roads Lane miles, urban area, arterials Lane miles, urban area, freeways
Population by Car Ownership Level	Travel behavior	No car Share car Own car
Daily Trips by Purpose	Travel behavior	Work trips Non-work trips
Daily Trips by Mode	Travel behavior	Walk/bike trips Transit trips Car passenger trips Car driver trips
Foreign and Domestic Migration	Socio demographic	Domestic out-migration Domestic in-migration Foreign out-migration Foreign in-migration

The spreadsheet also allows the user to create custom plots that plot the evolution of any of the stock variables represented in the simulation. The variables to be included in the plot can be selected from the drop down boxes available in Cells A28:A44, and up to 17 different variables can be plotted. The variables to be included in the plot should be selected working top-down in Cells A28:A44. In the example shown in Figure 6 below, a custom plot has been created to examine the variation in the number of births by income group over the simulation period.

Two custom plots are created, a line graph (as shown in Figure 6 below) and a stacked area graph, which is plotted to the right of the line graph.

Figure 6: Custom Plot: Births by Income Group over Simulation Period



6.2 Simulation Results

The detailed simulation results are plotted on the 'Simulation results' tab, while appears immediately to the left of the 'Simulation reports' tab. Providing the user with the detailed simulation results gives the user full flexibility to analyze changes in any of the stock variables in the model over the simulation period.

A total of 1504 variables are given in the detailed simulation results. The variables appear as rows, and the columns give the year, with results given for every ½ year period from 2000 thru to 2050. The variables are named in Column A. The first variable given in row 2 is the total population.

7. Other Parts of the Model

Three other sheets are defined in the model. The expectation is that the inputs in these sheets would not be modified under most scenarios, nonetheless they are described here briefly so the user can understand how they are used in the model, and for those users who wish to change these inputs.

7.1 Demographic Transition Rates

The ‘Demographic transition rates’ sheet contain the transition rates that define how the people in the region will transition over time between the different categories of the socio-demographic variables. The transition rates define how the population will transition from one ‘state’ to another, and are therefore fundamental to the simulation of the socio-demographic sector.

Two of the transition rates are structural, as they depend only on the passing of time. The first of these are aging, where the population transitions from one age cohort to the next. The model assumption is that working with 15 year cohorts one fifteenth on the people who survive transition into the next cohort. The second of these is acculturation transition. As a person’s ethnicity and place of birth (foreign or native) do not change during their lifetime, the only transition that applies to Acculturation is related to how long people have lived in the US. The model assumption is that each year one twentieth of the foreign-born persons transitions to the ‘greater than 20 years’ category.

Transition rates other than aging and acculturation were determined from analysis of the Panel Survey of Income Dynamics (PSID). The PSID data allowed individual rates of change to be determined for the individual categories comprising each socio-demographic variable. Rates of change were determined from the three most recent pairs of waves, 2003 versus 2005, 2005 versus 2007 and 2007 versus 2009. Note that there was very limited data for the transit rates among immigrants, so the same rates in the table for the foreign-born groups apply to all of the four race/ethnicity categories.

The resulting transition matrix is given on the ‘Demographic transition rates’ sheet. For each possible combination of age group, ethnic/acculturation group and household type, the following base transition rates are defined:

- death rate/year
- birth rate/year
- marriage rate/year
- divorce rate/year
- leave nest-single rate/year
- leave nest-couple rate/year
- empty nest rate/year
- enter low income group rate/year
- leave low income group rate/year

- enter high income group rate/year
- leave high income group rate/year
- enter workforce rate/year
- leave workforce rate/year

To test the impact of changes to these base transition rates, the user can specify reductions or increases relative to the base rates using the scenario multipliers defined on the scenario sheet.

Immediately below the base transition rates matrix, the base demographic delays are given in Cells B151:B156. The user can change the time period over which these processes take place by reducing or increasing the numbers of years over which these processes operate.

Next, in Cells C160:D165, rates are provided that determine, for changes in household type, the fraction of the resulting households where children are present. These rates are derived from analysis of the PSID data. The user could change these national values if they have data that provides alternative values for their region.

Base migration rates are given in Cells B168:B171. These migration rates are multiplied by the current population of the region. (The foreign migration rates are only multiplied by the current population who have lived in the US for less than 20 years, not the full population.) These rates are based on analysis of Census and ACS data over the years 2000 to 2010. Again, the user could change the default national values if they have better data that is specific to their region.

The final set of values presented on this sheet are the migration attractiveness functions. In Cells B177:D185, weights defining the relative attractiveness of three different measures that impact upon predicted migration levels are specified for different area types and migration types:

- job supply/demand index
- residential space supply/demand index
- road mile supply/demand index

The shape of the attractiveness functions for these three supply/demand measures are specified in Cells B189:D209. The graph plotted immediately to the right of these cells illustrates the shape of the attractiveness functions.

The inputs for the migration attractiveness functions are all highlighted with orange shading indicating that they should not be modified in most cases, unless the user wishes to change the basic assumptions of the model..

Section 4.2 of the interim report provides more explanation of how these different inputs operate, and presents flow diagrams illustrating how the socio-demographic sector transitions are modeled.

7.2 Demographic Seed Matrix

The 'Demographic seed matrix' tab contains the seed matrix this was generated from the 2009 National Household Travel Survey (NHTS) micro data. This seed matrix provides a description of the base population that is broken down into the 3 x 2 x 3 x 12 x 4 x 6 = 5184 possible combinations of the socio-demographic dimensions. The seed matrix is national, as there is not sufficient micro-data to define this multi-dimensional matrix at the regional level.

When the simulation is run for a particular region, this national seed matrix to converted into a regional matrix by applying an iterative proportional fitting (IPF) procedure. The marginal totals for each population dimension that are used to apply the IPF procedure are taken from the 'Demographic Initial Values' tab.

The values for the demographic seed matrix are highlighted in orange shading indicating that they should not be modified by the user in most cases (unless the user has a seed matrix from a very large sample representing their own region, such as PUMS/ACS micro-data..

7.3 Travel Behavior Models

The 'Travel behavior models' sheet specifies the model parameters that are used in the travel behavior models. In the scenario analysis tool, the travel behavior model is a sub-sector of the socio-demographics sector, predicting demand for travel as a function of the characteristics of the regional population at each point in time.

The travel behavior models were estimated from the full sample of the 2009 National Household Travel Survey (NHTS), including all add-on subsamples. The development of these models is described in more detail in Chapter 5 of the interim report. A summary of the travel behavior models is given below.

There are four travel behavior models, which are applied in the following order:

1. The Car Ownership Model was estimated using a multinomial logit (MNL) discrete choice model, and predicts the probability that an individual falls into one of three groups:

    a. 'Own car'. The person lives in a household where the number of cars is equal to (or greater than) the number of driving age adults, so each driving age adult can drive their own vehicle.

    b. 'Share car'. The person lives in a household that has one or more cars, but fewer cars than the number of driving age adults, so the at least two driving age adults may need to share a vehicle.

    c. 'No car'. The person lives in a household that has zero vehicles.

    The car ownership model parameters are defined in Cells B6:C31. Own car is the base alternative with zero utility, and so the parameters for 'share car' and 'no car' are interpreted as the differences in utility (attractiveness) relative to the own car alternative.

2. The Trip Rate Models were estimated as log-linear regression models, with dependent variable the number of trips plus one to avoid taking the log of zero for zero trip observations. The NHTS data includes all days of the week throughout the year, including weekends and holidays, and so the models give trip rates for what is truly an 'average day'. Two different models are applied:

    a. Work trips, which are trips to or from work, work-related or business activities.

    b. Non-work trips, are all other trips.

The parameters for the trip rate models are defined in Cells D6:E31.

3. The Mode Choice Models were estimated as MNL discrete choice models. Separate models were estimated for non-work, work and children's travel. Four modes are represented:

    a. Car driver.

    b. Car passenger.

    c. Transit.

    d. Walk/bike.

    The parameters for the mode choice models are defined in Cells F6:M31. For the non-work and work models, the model parameters are defined relative to the car driver base mode. For children travel, where car driver is not available, the model parameters are defined relative to the car passenger base mode.

4. The Trip Distance Models were estimated as log-linear regression models, with dependent variable the log of distance plus one to avoid taking the log of zero for zero distance observations. Three separate distance models have been estimated for car driver, car passenger and transit trips. There is no representation of transport supply for walk and bike modes in the simulation, and so there are no trip distance models for these modes.

    The parameters for the trip distance models are defined in Cells N6:P31.