Land Use, Transportation and Air Quality (LUTAQ)

Model Description, Findings and Recommendations

May 25, 2006

Southern Nevada Regional Planning Coalition

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The LUTAQ Project

Two years ago, representatives of the municipal entities and resource management agencies in Southern Nevada began a project to improve their ability to integrate land use, transportation and air quality (LUTAQ) planning. The goal of the project was to develop a computer model for examining the potential effects of changes in land use and transportation planning on air quality, traffic congestion, and other quality of life factors. The LUTAQ Working Group developed the model, used the model to analyze a range of development strategies, and made the model available to the planning entities and agencies in Southern Nevada. This report describes the model and the Working Group's use of the model to analyze planning alternatives.

Model Description

The LUTAQ model represents the links between population, transportation infrastructure, land use characteristics such as density, and air pollution generated by traffic for the region as a whole. The mathematical equations and parameters at the heart of the model were developed in close cooperation with SNRPC and member entity staff, and were calibrated with historical data.

Model Use

The model is a tool to examine "what if…?" scenarios at the regional level. Users can test changes in three land use characteristics that are a function of land use design (housing density, average number of trips made per person per day, and the average distance per trip), and two characteristics of the transportation system (the percent of travel satisfied by public mass transit and traffic flow). Output graphs show the effect of changes in these characteristics on air pollution, population, and costs associated with the policies. The model does not specify how the input characteristics should be changed; it displays the expected effects if the characteristics change.

Policy Analysis

The LUTAQ Working Group tested a wide range of scenarios corresponding to real changes being proposed by or discussed among planners in the region. They started by examining the projected effects of maintaining that status quo, that is, continuing to develop land and the transportation system as they are currently being developed. Next, they examined a range of densification scenarios, mixed-use scenarios, transit scenarios, and finally, combinations of densification, mixed use and transit changes.

Key Findings

1. *Maintaining the status quo will mean significant increases in traffic congestion and air pollution.*
2. *Densification alone makes things worse.*
3. *Reductions in "Distance per Trip" and the "Number of Trips" are required for any significant improvement.*
4. *We need to increase our use of mass transit and alternative modes of transportation.*
5. *A combination approach of densification, mixed use and transit changes will:*
   - Keep time in traffic from increasing beyond present levels.
   - Keep air pollution consistently within (below) EPA standards.
   - Avoid a decrease in the rate of population growth.
   - Reduce overall costs below the status quo scenario by avoiding the loss of federal transportation subsidies.

Recommendations

Significant improvements in traffic, air quality, and other factors require a combination of strategies. Based on model outcomes and best management practices the Working Group suggests the following as realistic and achievable general policy targets for the SNRPC and its member entities in the Las Vegas Valley:

Table 1. LUTAQ Recommendations

General Policy Targets, Percents

Factor	Core	Non-Core
Housing Density:	increase—0% to 190%	increase—0% to 70%
Distance per Trip:	reduce—30% to 50%	reduce—10% to 50%
Number of (vehicle) Trips:	reduce—10% to 20%	reduce—20% to 30%
Transit/Alternative Mode use:	Increase—50% to 160%	Increase—50% to 80%
Traffic Flow increase:	Increase— 1% to 1.5%	Increase—1% to 1.5%

Core Area Policy Targets

Factor	Current Value	Target Value
Housing Density (units/acre):	2.1	up to 6
Distance per Trip (miles):	6	reduce to 3 - 4
Number of (vehicle) Trips:	3	reduce to 2.5 – 2.7
Transit/Alternative Mode use (%):	3.3	increase to 5 – 8.5
Traffic Flow increase (%):	none	1% to 1.5%

Non-core Area Policy Targets

Factor	Current Value	Target Value
Housing Density (units/acre):	4.7	up to 8
Distance per Trip (miles):	9	reduce to 4.5 - 8
Number of (vehicle) Trips:	3	reduce to 2.1 – 2.5
Transit/Alternative Mode use (%):	3.3	increase to 5 – 6
Traffic Flow increase (%):	none	1% to 1.5%

Introduction

Purpose of the project

The purpose of this project was to improve the ability of Southern Nevada agencies and government entities to integrate land use, air quality and transportation planning. The main project activities were developing and facilitating the use of a computer simulation model for decision-making.

LUTAQ: A model to examine the potential effects of Land Use and Transportation changes on Air Quality, traffic congestion and other quality of life factors.

Mission statement:	Integrate Land Use, Transportation, and Air Quality issues into plans for development in the Las Vegas Valley.
Land Use:	The term “land use” in this project refers to the **intensity**, **location** and **mixture** of different kinds of land uses throughout the Las Vegas Valley.

Approach

Use a group model building approach to develop a system dynamics simulation model for evaluating land use policies.

Purpose of the model

The model was used by the LUTAQ Working Group and will continue to be used by SNRPC member entities and agencies as tool for analyzing possible policy options.

Model Development and Use

The LUTAQ model was developed over a 24 month period by members of the LUTAQ Working Group in collaboration with a modeling team from the UNLV Department of Environmental Studies. The Planning Directors designated 20 upper level staff members of the entity planning departments and agencies to constitute the LUTAQ working group. They were drawn from different disciplines and included land use planners, air quality modelers, and transportation planners. Group members participated in specifying the model purpose, clarifying the problem definition, identifying the model structure, and quantifying the relationships between variables. Group members also helped set the model parameters. Quantification was done “behind the scenes” by the consultants. When the model was complete, the Working Group used the model to test a set of policy scenarios corresponding to real changes being proposed by or discussed among planners in the region.

Working Group members have been trained in the use of the model and are available to assist Planning Directors and SNRPC Board members in using the model. Entity staff also has the ability to use the model on an ongoing basis. One potential application of the model is as a means for the member entities to communicate land use policies and consequences to leaders and decision-makers.

Background

What is a system dynamics model?
A system dynamics model is a computer tool for evaluating the potential consequences of policy decisions. It consists of a set of variables and equations that represent cause-and-effect relationships in the real world. Models are based on the principles of system dynamics, an approach for studying the behavior of complex systems that was first developed by Massachusetts Institute of Technology Professor Jay Forrester in the 1950's. System dynamics models help us examine the way a system changes over time. The model is 'validated' by assessing its ability to replicate the historical behavior of certain outputs. Once validated, a model can be used to test how a "virtual system" would react to policy interventions, and thus help decision-makers compare the effects of different policy alternatives before they are implemented in the "real world."

System dynamics models can be updated easily, either by adjusting the structure of the model to incorporate details of the system (e.g., adding an ozone sector), or parameter values can be adjusted as more studies are completed and the system is better understood and quantified.

What the LUTAQ model is and is not
The LUTAQ model represents the land use and transportation system that affects air quality and other quality of life indicators in the Las Vegas Valley. It shows the effects that changes in regional-level land use and/or transportation policies will have on time in traffic, air pollution, and population in the region.

- The model **is** regional in nature, specific to the Las Vegas Valley and based on the characteristics of the "whole" area. It is designed to test "what if…?" scenarios at the regional level. It is factual—based on real numbers and conditions found here in the Las Vegas Valley! It has been calibrated with historical data and prepared in close cooperation with SNRPC and member entity staff.

- The model **is not** designed to analyze or develop detailed strategies to implement policies. It is assumed that the model will be used to create regional-level, broad-based policy recommendations and that the implementation of the policies will be left to each entity. The model is not designed to analyze any individual project or even specific planning area—it is a regional model.

Model Description

Model Structure

The model divides developed land in the Las Vegas Valley into two areas: an urban core and a non-core area as shown conceptually in Figure 1. The urban core approximately represents Downtown Las Vegas and the Strip—an elongated transportation corridor along which development might have relatively high densities. The non-core area represents existing suburban areas surrounding the core plus any new development beyond the core.

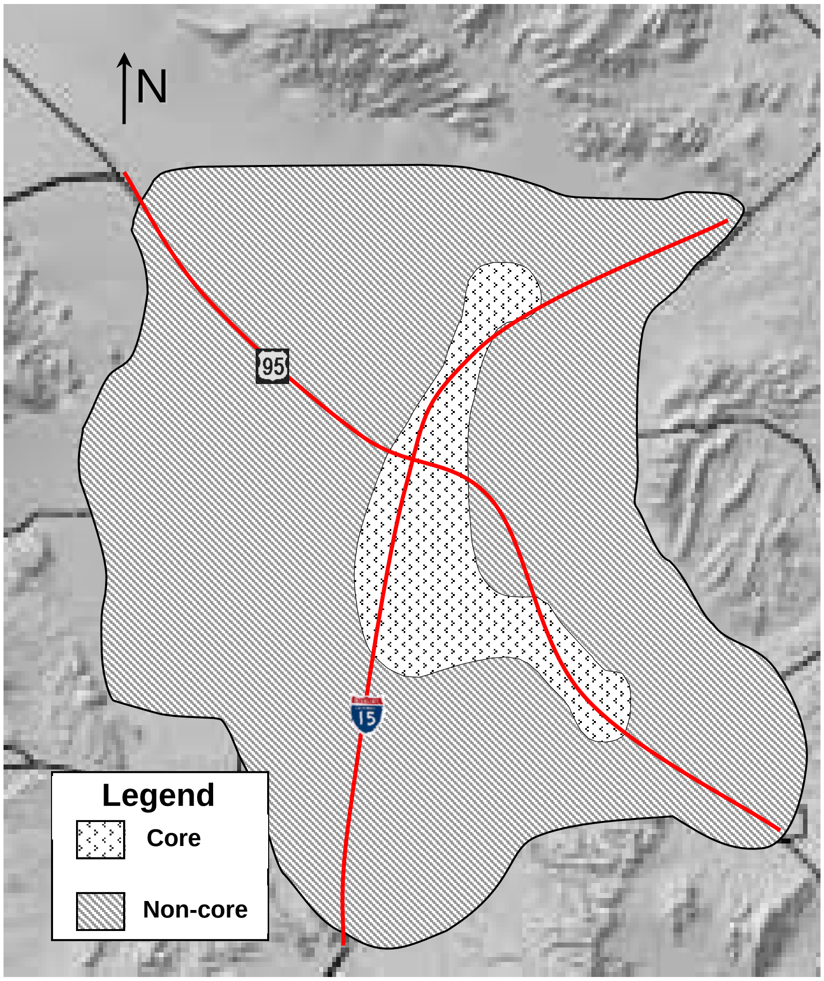


Figure 1. Map of Core and Non-core areas
Conceptual map of areas in the Las Vegas Valley considered to be core and non-core for the purposes of the LUTAQ model.

The model assumes that new development takes place in two ways. Land in the urban core can be "redone" or converted from its current state, and land that is currently vacant can be added to the non-core area as it is developed.

At the start of the model simulation, we begin with today's values of dwelling unit density, average distance per trip, average number of trips per day, and transportation characteristics for both urban core and non-core areas. The model allows you to apply different values of density, land use and transportation characteristics to all or some of the new development in each area beginning in 2005. You can design a different policy package for the core and non-core areas and you can specify how much of each area the policy will apply to. Then the model plays out the effect of those policy changes over the next 30 years.

Model Sectors: Function and Importance

The LUTAQ model contains over 300 hundred variables linked together by mathematical equations. These variables and equations are organized into five major sectors and four sub-sectors that are linked as shown in Figure 2.

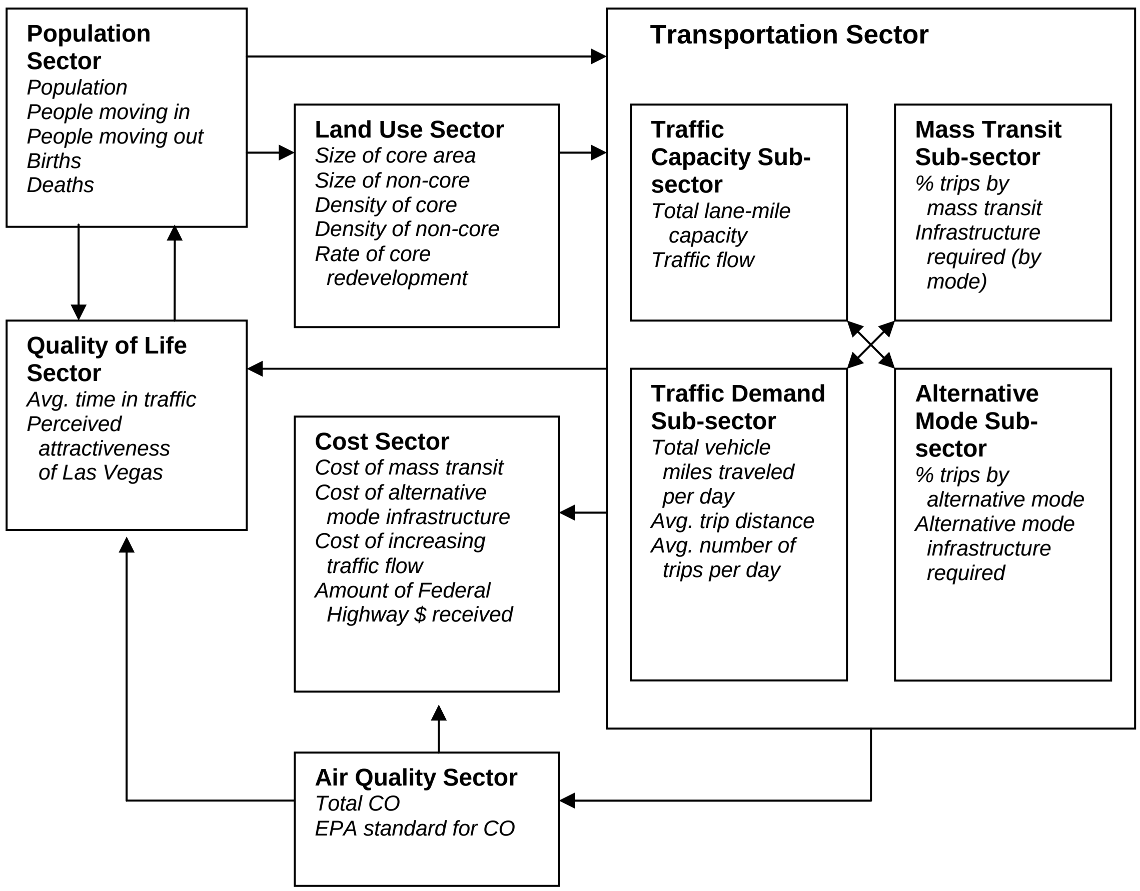


Figure 2. LUTAQ Model Sector Diagram
Key variables in each sector are in *italics*.

<u>Population and Land Use Sectors</u>

The population and land use sectors of the LUTAQ model work together to track the number of people living in four land areas, each of which is subject to a different land use policy, as well as the overall total population. The four areas are:

- The core area developed under old policy
- The core area redeveloped under new policy
- The non-core area developed under old policy
- The non-core area developed under new policy

The total amount of land in the core area is fixed for the 30-year modeling period. Thus, as areas of the core are redeveloped, the core area subject to the old policy shrinks, and the core subject to the new policy grows by the same amount. The total amount of land in the non-core subject to old policy is fixed, but the amount of non-core land subject to new policy is unlimited. The total quantity of land available within the BLM disposal area boundary is included for reference.

Policy ‘levers’ in the Land-Use Sector allow non-core areas to be developed and core areas to be redeveloped according to a different set of land-use related characteristics. These characteristics include the *average number of housing units per acre,* and the number of persons per dwelling unit is included as a constant. These variables are used to calculate the population capacity of each category.

The populations in each area increase and decrease by in- and outmigration, and by births and deaths. The in- and outmigration rates change according to the relative attractiveness of Las Vegas as a place to live, calculated in the Quality of Life Sector.   Population growth is allocated to existing areas with excess capacity in the following order: core area subject to old policy, core area subject to new policy, and non-core area subject to old policy. Population growth that cannot be accommodated by excess capacity drives new development in the non-core area (subject to new policy).

The nature of land use can affect an individual’s travel by personal vehicle. Mixing compatible residential, retail, and commercial uses can reduce the average distance per trip, and the average number of trips per day. Land-use policy can encourage (or discourage) mixed-use development, and thus affect the average number of trips per day per person, and the average distance traveled per trip. The LUTAQ model treats these variables as ‘input’ variables -- that is, they can be manipulated for redeveloped areas of the core area, and newly developed non-core areas.

Why aren’t the land use input variables more specific?
Mixed-use development has many components, can take many forms, and can be accomplished under many different policy scenarios. While the Southern Nevada Regional Planning Coalition (SNRPC) facilitates collaboration among the member entities to address regional issues, it does not dictate policy for implementation by the local governments. For this reason, the LUTAQ working group chose to test the impacts of altering average distance per trip, and average trips per person per day in areas of new development and redevelopment on air quality and traffic congestion. Should the SNRPC choose to recommend ‘targets’ for these variables (and other mass-transit related variables), it would then be up to the individual entities to develop complementary land use policy that best fits their situation.

<u>Transportation Sector</u>

The Transportation sector is divided into four sub-sectors: traffic capacity, traffic demand, mass transit infrastructure, and alternative mode infrastructure. The traffic capacity sub-sector tracks the capacity in vehicle miles traveled per day for each area, based on the average amount high and low speed lane-miles associated with each acre developed. The traffic capacity sector includes an input variable that can increase capacity by taking actions to increase traffic flow (such as synchronized traffic signals, fewer curb cuts per mile, turnout lanes, etc.)

The Mass Transit and Alternative Mode sub-sectors allow the percentages of trips taken by public modes other than cars to be manipulated. The model assumes that different levels of ridership on public mass transit require different types of transit infrastructure. The model considers three types of transit infrastructure: local buses, express buses, and rail. Figure 3 illustrates the assumptions built into the model regarding the level of ridership and the mix of transit infrastructure required. Figure 3 was developed based on an examination of the relationship between public mass transit ridership and the infrastructure mix in a number of major metropolitan areas in the U.S. When model users set a desired or target level of mass transit ridership, the model looks up the mix of transit infrastructure required, and uses the result to estimate the cost of achieving that level of ridership.

The traffic demand sector calculates the number of vehicle miles traveled each day, based on the population of each land area (from the population sector) and the average number of trips and the average distance per trip (from the land use sector). The total trips per day is then reduced by the percentage of travel by mass transit, and the remainder is used to calculate relative congestion (volume of traffic/traffic capacity), and in-turn, average speed.

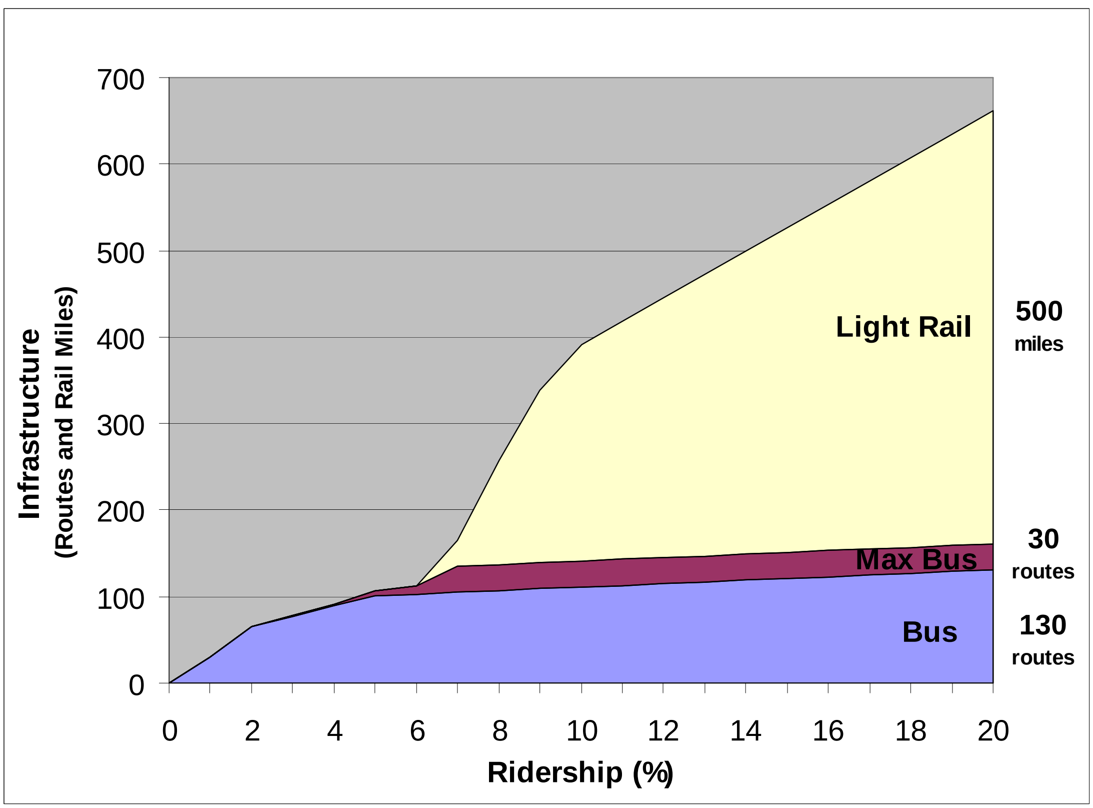


Figure 3. Mass Transit Infrastructure and Ridership
Approximate mix of types of infrastructure required to achieve a given level of public mass transit ridership.

Air Quality Sector

The Air Quality Sector calculates the average quantity of carbon monoxide released into the Las Vegas metropolitan area air shed each day. The quantity is based on the total number of vehicle miles traveled and the average amount of carbon monoxide emitted by a vehicle of a given vintage at a certain speed. The Federal standard used to assess attainment for carbon monoxide is included in this sector.

Why only carbon monoxide?
Carbon monoxide, ozone, and fine particulate matter are the principal pollutants of concern in the Las Vegas metropolitan area. For several reasons, the LUTAQ working group chose carbon monoxide as a ‘proxy’ for all forms of air pollution.

Quality of Life Sector

In the Quality of Life Sector, the relative attractiveness of Las Vegas as a place to live is calculated using three variables: average time in traffic per person per day, air quality, and a factor that accounts for all other ‘quality of life’ factors combined. Average time in traffic per person per day is calculated from average speed (from the Transportation Sector), average distance traveled, and number of trips per day (from the Land Use Sector). Air quality is the average quantity of carbon monoxide emitted into the air per day (from the Air Quality Sector). The variable that accounts for all other ‘quality of life’ factors is a function of the population.

Cost Sector

The cost sector calculates to the capital cost, and the operations and maintenance (O&M) costs of the mass transit and alternative mode infrastructures, and traffic flow enhancements. The capital and O&M costs of mass transit depend on the quantity of infrastructure in each ‘mode’: route bus, rapid transit bus, and light rail. A ‘mode share’ table returns the necessary quantity of each to achieve the target rider-ship (input variable in the Transportation Sector). The cost sector also accounts for the loss of Federal Highway funds in years that the quantity of carbon monoxide exceeds the Federal standard for attainment.

Causal relationships
The LUTAQ model was constructed by beginning with the variables that measure the problematic trends (air quality and traffic congestion), and then working backwards to understand what causes the problem. The string of causes that contribute to a problem is called a ‘causal chain’. These causal chains often connect back to themselves, forming what is referred to as a ‘feedback loop’. A high-level causal loop diagram of the LUTAQ model is depicted below (Figure 4).

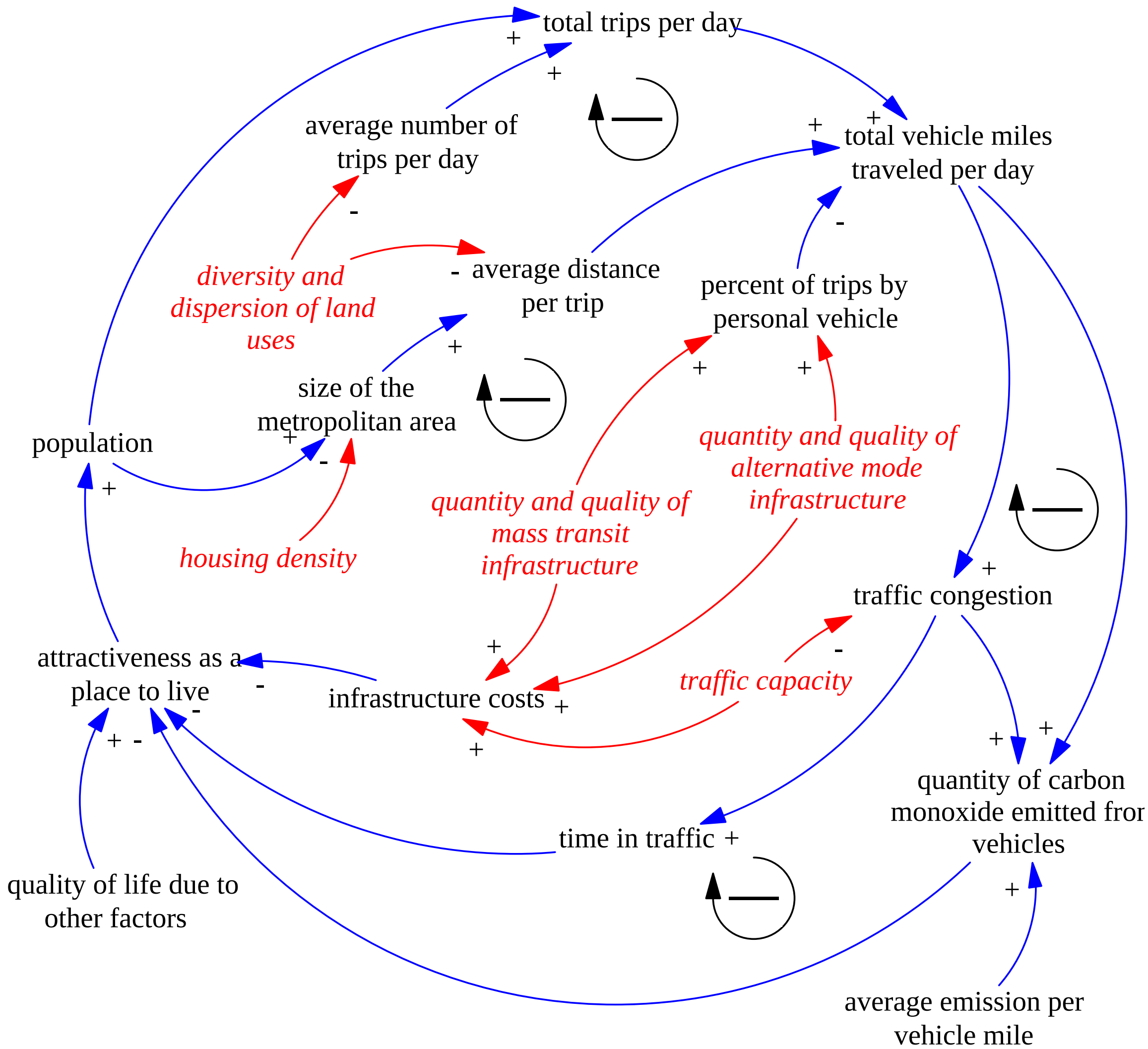


Figure 4. LUTAQ Model Causal Loop Diagram

The causal loop diagram depicts the causal relationships that exist between the variables. The sign at the arrowhead indicates the direction in which one variable is affected by another. Where the sign is positive (+), the change is in the same direction. For example as the population increases (and all else is constant), the total number of trips per day increases. However, the direction of change also works in the opposite situation (e.g. if population were to decrease, total number of trips per day would also decrease). Where the sign is negative (-), the change is in the opposite direction. For example, as time in traffic increases, the attractiveness of Las Vegas as a place to live decreases.

The feedback loops in the LUTAQ model can be summarized as follows: as population increases, so does the number of trips take per day. This in turn increases the total vehicle miles traveled per day. This results in increasing traffic congestion and air quality, which both reduce the attractiveness of Las Vegas as a place to live. Declining attractiveness increases out migration and decreases in migration, thus slowing (or even reversing) population growth. With no intervention, population growth will slow as air quality and traffic congestion get worse.

However, intervention can alter the outcome. In the causal loop diagram, opportunities to affect the outcome are depicted in italics. These illustrate that changing land-use characteristics, and transportation infrastructure can offset increasing demand. The LUTAQ model, by linking variables with mathematical equations allows for the quantitative assessment of the trends in ‘output variables’ (air quality and traffic congestion) that result from manipulation of the ‘input’ variables (land use characteristics and transportation infrastructure).

Data: Sources, Accuracy, Uncertainty

Many of the variables used in the model are either constants (such as the average number of persons per household), or vary over time. Variables that change over time can also be ‘constants’ (such as the quantity of land in the BLM disposal area), or can change according to the dynamics of the model (such as the number of persons living in the non-core area). In the latter case, a starting value is needed.

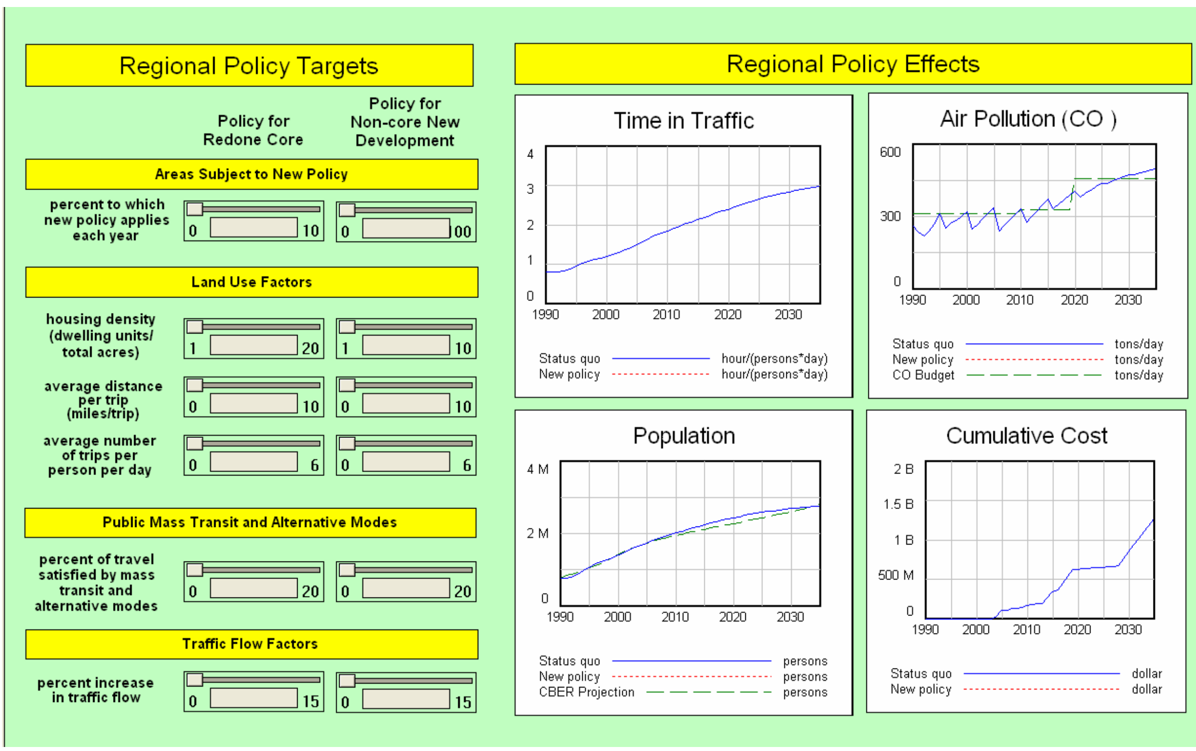
Where a constant or a starting value was required, the LUTAQ modeling team obtained a value from an appropriate source and documented where the information was obtained. This information is contained both within the model, and in the technical documentation.

The information needed to calculate values for certain variables, such as how time in traffic affects one’s perception of attractiveness, does not exist. In such cases, the LUTAQ team conducted ‘thought experiments’ as a group to derive a reasonable range of responses. These were then used to identify an estimated value used in the model. Where this was the case, the variables are so documented.

How to Use the Model

Figure 5 shows the policy input and output screen. The twelve slider boxes under **Regional Policy Targets** are the inputs or decision variables the model user can change. The labels to the left of the slider boxes are the names of the decisions or policy variables. Taken together, the two columns of slider boxes represent a policy scenario or set of decisions. You can change any number of boxes for a scenario. The first column is the set of policies that apply to redone land in the urban core area. The second column is the set of policies that apply to new development in the non-core area. The right side of the screen, **Regional Policy Effects**, shows the result of running a new policy scenario.

Figure 5. LUTAQ Model Policy Input and Output Screen



Policy Inputs

To set values for any decision variable, you can either move the slider bar until the value you want appears in the center box or type the value directly into the box. If you do not change a value, it remains at the current value, shown in the box below the slider. The numbers at each end of the slider bar show the minimum and maximum values possible for the variable.

What is happening in the model when you move a slider bar?

Moving a slider bar changes the value of an input variable from the default value (displayed at the starting position of the 'slider') to the new value (displayed when the slider bar is set to a new position). When the model is then run, it simulates the effect of the new value on the system.

For each area (core and non-core), you can set values for any one or combination of the following policy variables:

1. *percent of the area to which the new policy applies each year*
   You can choose how much of the land in the urban core is redone under the new policies each year and how much of the new development in the non-core area will be subject to the new policies. In the urban core, up to 10 percent of the land can be redone in accordance with the new policy each year. If you leave the value at zero, new policies will not apply to any land in the core area and changes you make in the rest of the column will have no effect on the output graphs.

2. *housing density*
   Density is measured in dwelling units per total acres. You can choose the increase or decrease density. The new values will apply only to the redone urban land or new development in the non-core area.

3. *average distance per trip*
   Average distance per trip is a measure of how far residents need to travel to school, work, shopping, recreation and other services. Average distance per trip can be changed by land use design. For instance, a greater degree of mixed-use development would likely reduce the average distance per trip.

4. *average number of trips per person per day*
   The number of trips per day is also a reflection of land use characteristics. Again, a higher degree of mixed use is likely to increase the ability of residents to combine trips and therefore reduce the total number of trips per day.

5. *percent of travel satisfied by mass transit and alternative modes*
   The percent of travel satisfied by modes other than personal vehicles can be affected by a number of factors including: availability of public mass transit infrastructure or bicycle/pedestrian routes, frequency of service, types of mass transit available, design of the transit system relative to travel destinations, and cost of mass transit relative to personal vehicle use. The model does not specify these design details; it shows the expected outcomes if percent of travel was changed by any means.

6. *percent increase in traffic flow*
   Traffic flow can be affected by a number of land use and transportation design considerations. These include the number of curb cuts on major streets, turnout lanes, and other factors.

Running the Model

To run the model, first click on the "SET" icon on the bar at the top of the screen, shown in Figure 6. The slider boxes will show the current values. Make any changes you want to make to policy variables. To simulate the new policy scenario, click on the running man symbol on the bar at the top of the screen (Figure 7). The model uses the new input values to calculate the values of variables in the entire model. The model runs for 45 years (1990-2035).

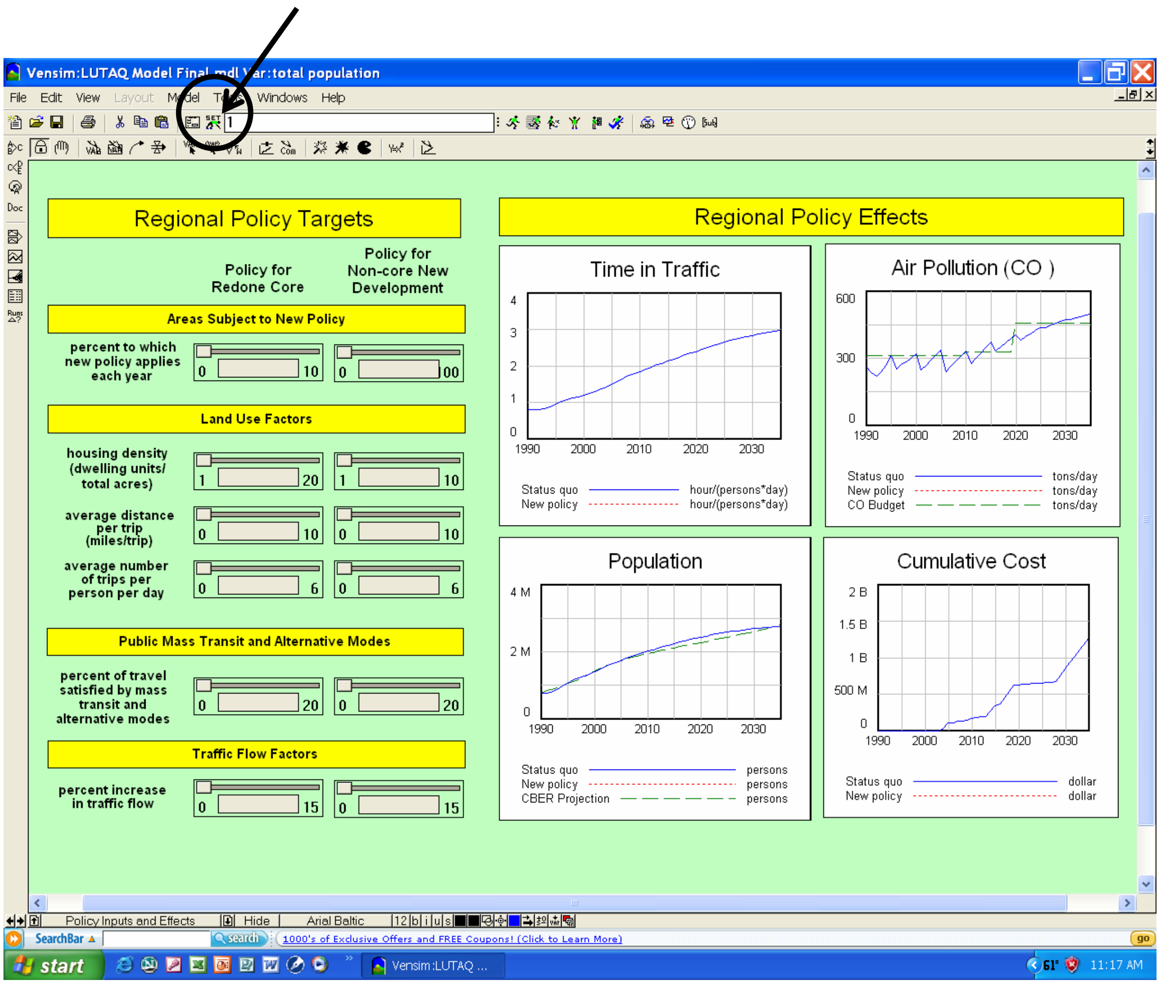


Figure 6. Use SET Icon to change policy variables

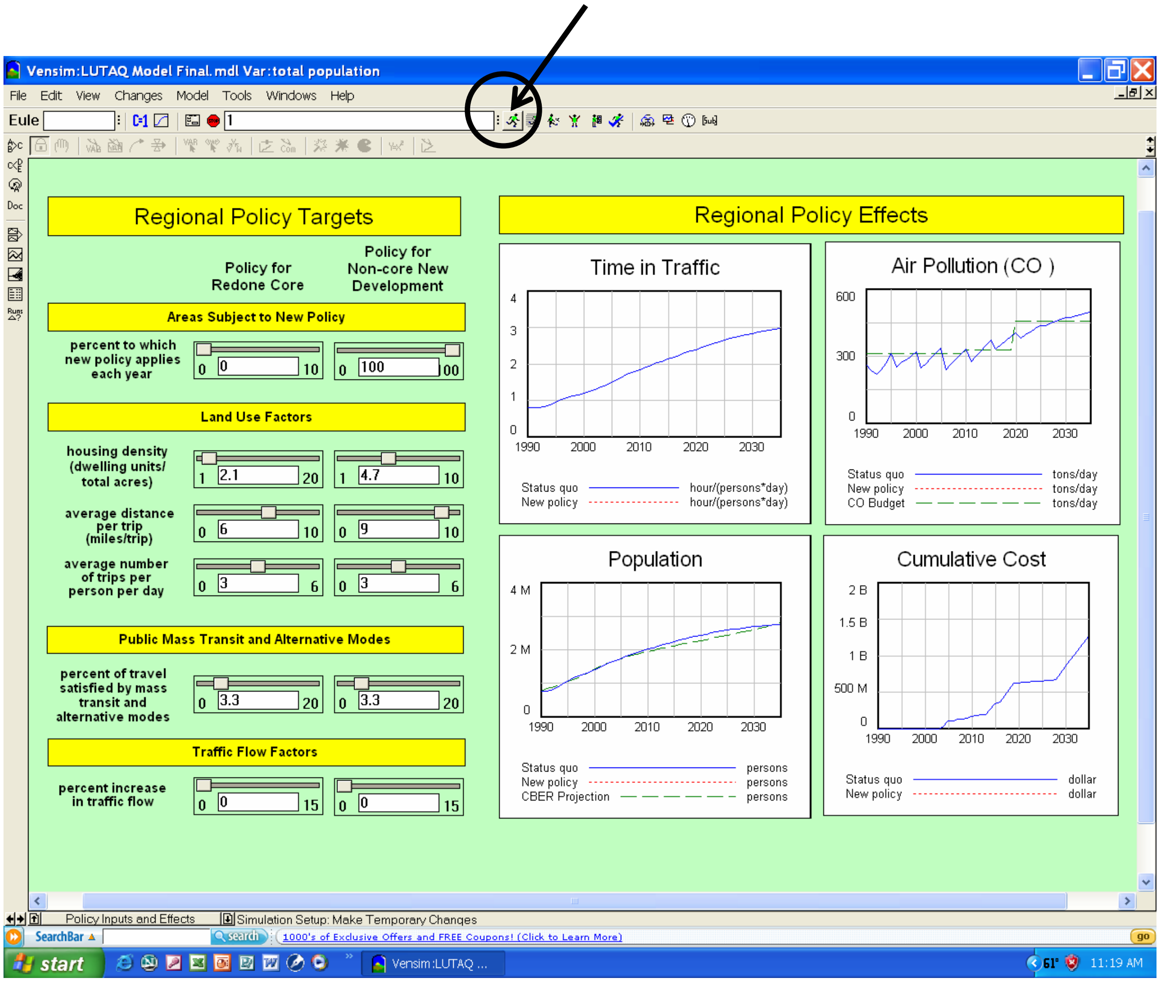


Figure 7. Click Running Man Icon to run the model

Model Output Graphs

At the end of the simulation, the output graphs on the right-hand side of the input and output screen (Figure 5) show the effects of the policy on four key variables: Time in Traffic, Air Pollution, Population, and Cumulative Cost. The blue, or solid lines shown on the graphs in Figure 5 represent the results of maintaining the status quo, which is, taking no action different from current policies. This “Status quo” line is used to compare whether proposed policy changes improve the situation or make it worse than it would otherwise have been.

<u>What the graphs represent</u>

1. Time in Traffic

Time in Traffic represents the average number of hours spent per person per day in traffic for all travel. A policy scenario that improves Time in Traffic would be one where the output line is below the “Status quo” line.

2. Air Pollution

The Air Pollution graph shows the projected amount of carbon monoxide (CO) in tons per day generated by personal vehicle traffic. The green, or dashed line represents the CO budget for the region set by the U.S. EPA. The CO budget line is shown as a reference. Each year the actual amount of CO is above the CO budget, the region stands to lose its federal subsidy for transportation (currently $80 million per year). Air pollution is calculated as a function of number of vehicle miles traveled and average CO emissions per mile, which is a function of average traffic speed. A policy scenario with a favorable outcome is one that keeps the CO emissions below the budget line.

3. *Population*

   The Population graph shows the total resident population of the Las Vegas valley. The green, or dashed line shows the population projection made by the UNLV Center for Business and Economic Research (CBER).

4. *Cumulative Cost*

   The Cost graph includes the cost of any federal subsidies lost due to violations of the EPA CO budget, plus the additional cost of any land use or transportation policies.

Relationship between the model and "real life"

<u>How does the model assist in the decision-making process?</u>
SNRPC staff and the consultants have built a high-level model that represents the ways in which the Las Vegas Valley functions. Model users can simulate the effects of changes in land use and transportation policies and practices. Policy and spending changes can be tested for effectiveness with no significant costs to the community. Policy "packages" can be compared with one another to evaluate their relative merits to determine the best scenario to be brought forward for implementation.

<u>What tools or processes are available to achieve a given effect?</u>
First, the model does not inhibit, preclude or direct the policies of any entity or group. Where the model is most useful is in predicting outcomes for major changes in the way that the community develops and travels. The model provides limited guidance about the specific mechanisms for achieving any particular set of policy alternatives. The specific ways that any entity might implement any particular alternative package is left completely to that entity.

For illustration, the LUTAQ Working Group identified some of the tools and processes that could be used to change policy variables:

Housing Density (the number of dwelling units per acre)

Tools for affecting density include:

zoning density, mixed-use design, redevelopment, use conversions, building heights, yards, and local street widths.

Average Distance Per Trip (trip length)

Tools for affecting distance per trip include:

mixed use, location of services and employment near residential areas (live/work/play designs), through streets, urban design, pedestrian orientation, travel barriers (zone walls), common access, and redevelopment.

Average Number of Trips Per Day (how many trips each person makes)

Tools for affecting number of trips per day include:

mixed use, location of services and employment near residential areas (live/work/play), technology, urban design, travel barriers (zone walls), common access, pedestrian orientation, redevelopment, fewer yards.

Percent of Travel Satisfied by Mass Transit and Alternative Modes (how each trip is taken—bus, rail, Max, Monorail, bicycle, walking, etc.)

Tools for affecting mass transit ridership include:

mixed use, location of services and employment near residential areas (live/work/play), facility availability, station access (quantity and location), travel time, personal costs, parking fees, technology, urban design, travel barriers (zone walls), common access, pedestrian orientation, redevelopment.

Percent Increase in Traffic Flow (how smoothly/quickly traffic moves)

Tools for affecting traffic flow include:

Mass Transit and Alternative Mode infrastructure, High Occupancy Vehicle lanes, mass transit lanes, freeway improvements, one-way road couplet's, fewer curb-cuts, traffic signal coordination, mixed use, location of services and employment near residential areas (live/work/play), technology, urban design, travel barriers (zone walls), common access, pedestrian orientation, redevelopment.

Policy Analysis

The purpose of the LUTAQ project was not only to develop the model, but also to use the model to develop regional land use and transportation policy guidelines that would most effectively achieve desired regional outcomes for transportation, air quality, and other quality of life factors. After validating the model, the LUTAQ Working Group used the model for extensive analysis of all the policy variables. The group tested each of the variables individually and in combinations representing policy scenarios that were being proposed by or discussed among planners in the region. For each test, the group asked, "if we could change this parameter, or set of parameters in this direction, what effect would it have on a regional level?"

The group began by examining the status quo. They simulated the model using current land use and transportation development practices to the year 2035 to show what we can expect if we do nothing different from what we are doing now. This provided a baseline against which to compare the relative effects of other policy scenarios. Next, they examined the effect of increasing the density of dwelling units across a range of densities and with different areas of focus (core area, non-core area, and valleywide). Third, the group tested different mass transit scenarios. Fourth, they focused on land use design, testing a range of mixed-use scenarios. Finally, they tested combinations of strategies to find a set of "best management practices."

Policy Goal

In evaluating different policies, the group was seeking to satisfy the following criteria:

- Maintain population growth at or above projected levels.
- Keep time in traffic at or below current levels.
- Maintain air pollution below the EPA budget.
- Minimize costs.

Status Quo

The **Status quo** scenario represents the general trends expected in the output variables if we do nothing different from what we are currently doing. That is, if we assume no land in the core area is redone, all new development is subject to existing land use and transportation policies, densities remain the same, travel characteristics of people across the valley stay the same, and transportation infrastructure simply maintains current ridership levels, we can expect the output variables to behave as shown in Figure 8.

Figure 8. Status Quo Model Results
Input values and model results for the Status quo, or baseline scenario.

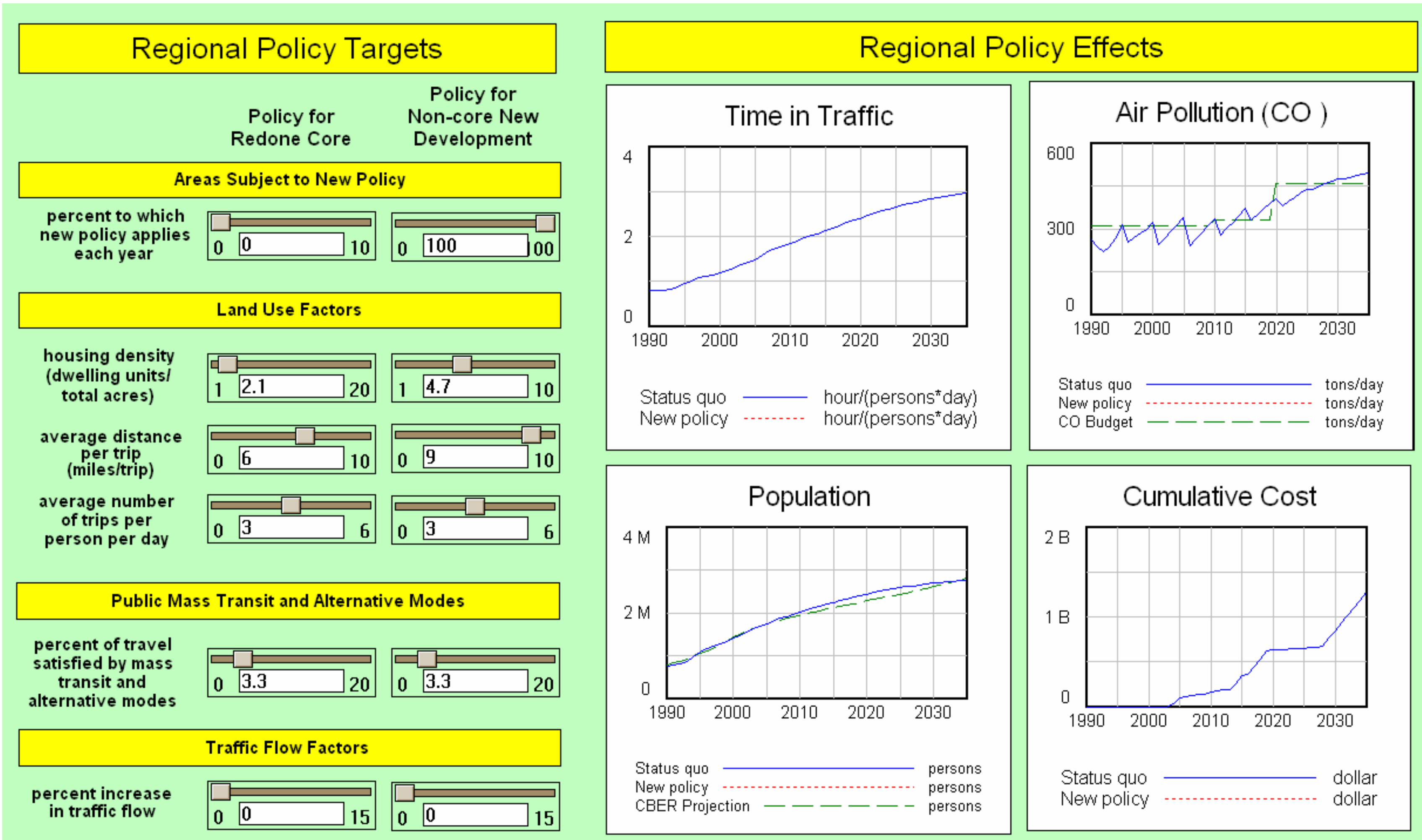


Figure 8 shows that if we do nothing differently, we can expect population to continue growing at roughly the same rate, time in traffic per person per day to roughly double in the next 30 years, and air pollution to rise and exceed the CO budget for a significant number of years. Without incurring any costs of implementing new policies, the cumulative cost of doing nothing differently could be over 1 billion dollars in federal transportation subsidies that would be lost when air pollution exceeds federal standards.

Densification Scenarios

The first set of policy scenarios analyzed follow the conventional wisdom about how to improve traffic and air quality problems in Las Vegas. When asked how they would solve these issues, many people suggest increasing housing densities.

Densification 1 "Urban Center": Increase density moderately and only in the core area

> This corresponds to a vision of the metropolitan area as having a dense urban core surrounded by non-urban area with existing residential densities. In this alternative, it was assumed that 2.5% of the core area is redone each year and the density was raised from 2.1 dwelling units per acre to 6 dwelling units per acre. This moderate increase might represent a situation in which apartment buildings with one or two floors are gradually replaced with higher density units and a few high-rise developments are added. All other policy inputs retain their existing values. Figure 9 shows that this policy results in moderately higher time in traffic, approximately the same population growth until 2020 when it reaches a plateau, and marginally worse air quality.

Densification 2 "Urban Center": Increase density significantly and only in the core area

> In this scenario, 5% of the core area is redone each year with a much higher density of 12 dwelling units/total acres. This represents relatively rapid development of multi-story buildings in the urban core. All other land use design and transportation parameters remain the same across the valley. Density remains the same in non-core areas. Figure 10 shows that an aggressive focus on density alone in the core causes time in traffic to climb dramatically. Population growth reaches a plateau due to time in traffic and worsening air quality.

Densification 3 "Non-core Multifamily Development": Apply increased density policy to only 50% of new development in the non-core area

> This scenario corresponds to a situation in which half of new development has a higher density of 8 dwelling units per total acres and half is developed under current densities (4.7 units per acre). This scenario increases time in traffic and air pollution moderately (Figure 11), but less than aggressive densification in the core.

Densification 4 “Urban Center and Non-core Multifamily Development”: Increase density somewhat in both core areas and non-core new development.

Increasing density moderately in both core and non-core areas has an effect similar to the previous scenarios (Figure 12).

Densification 5 “Townhouse densities”: Increase density modestly in urban core and significantly in non-core new development.

In this scenario, single family or low-density residential dwellings in the urban centers would be replaced with higher density townhouse or multifamily dwellings at a slow rate while any new development in the non-core area would be constructed at a townhouse density of 8, rather than the current 4.7 dwelling units per acre. The effects are similar to all previous density scenarios (Figure 13).

Figure 9. Densification 1: Moderate density increase only in core area

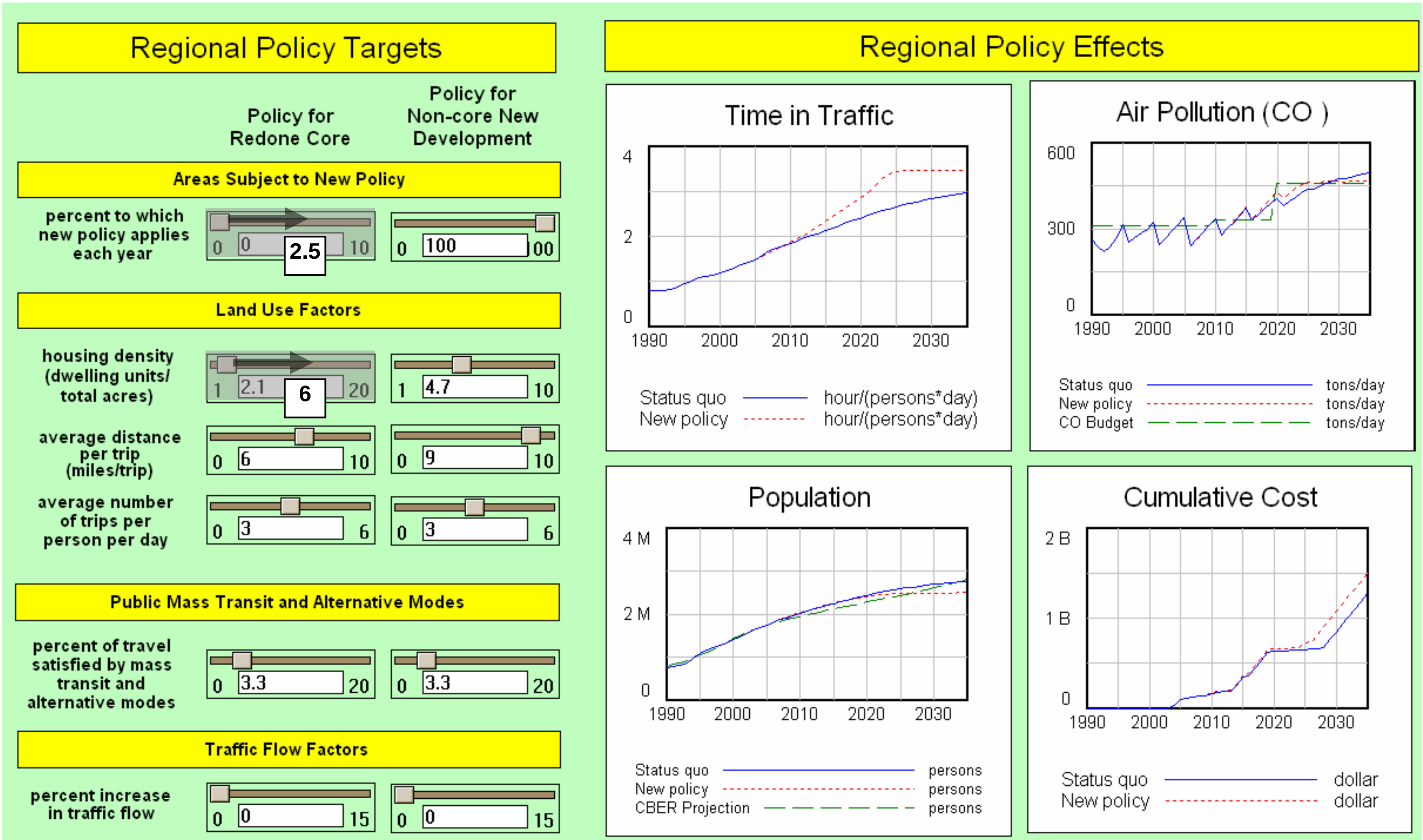


Figure 10. Densification 2: Significant density increase only in core area

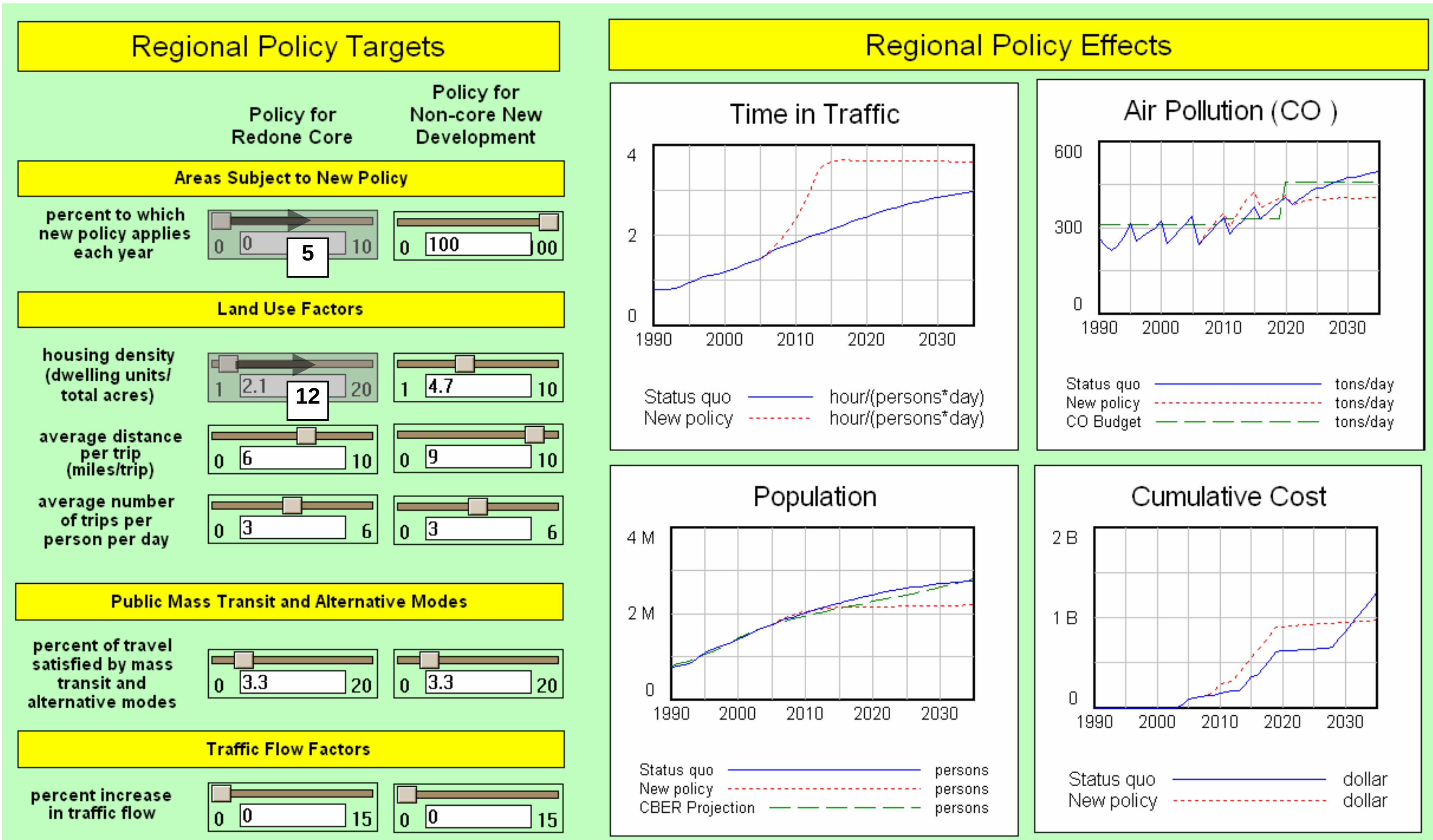


Figure 11. Densification 3: Increase to multifamily density in half of new development only.

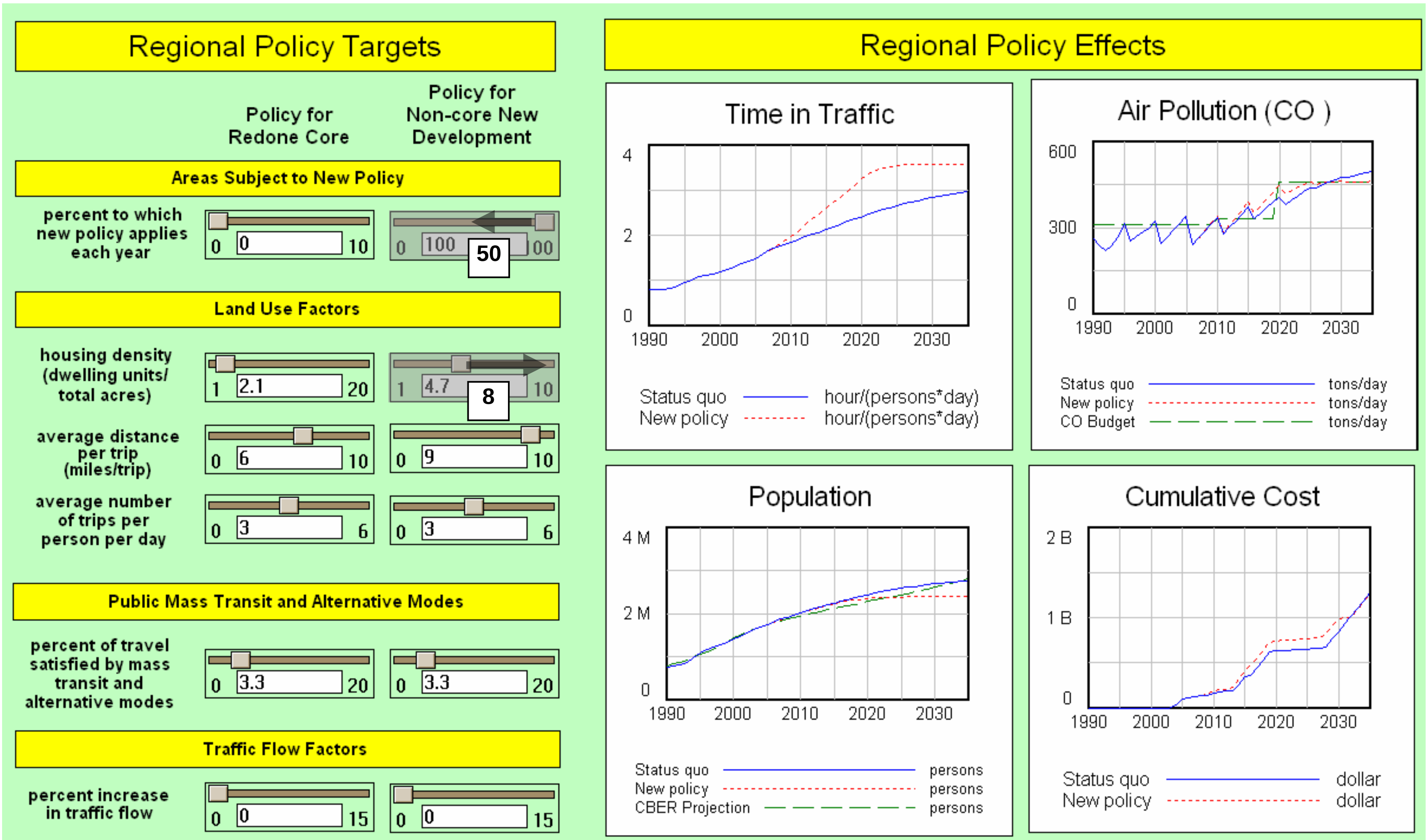


Figure 12. Densification 4: Moderate density increases in both core and non-core.

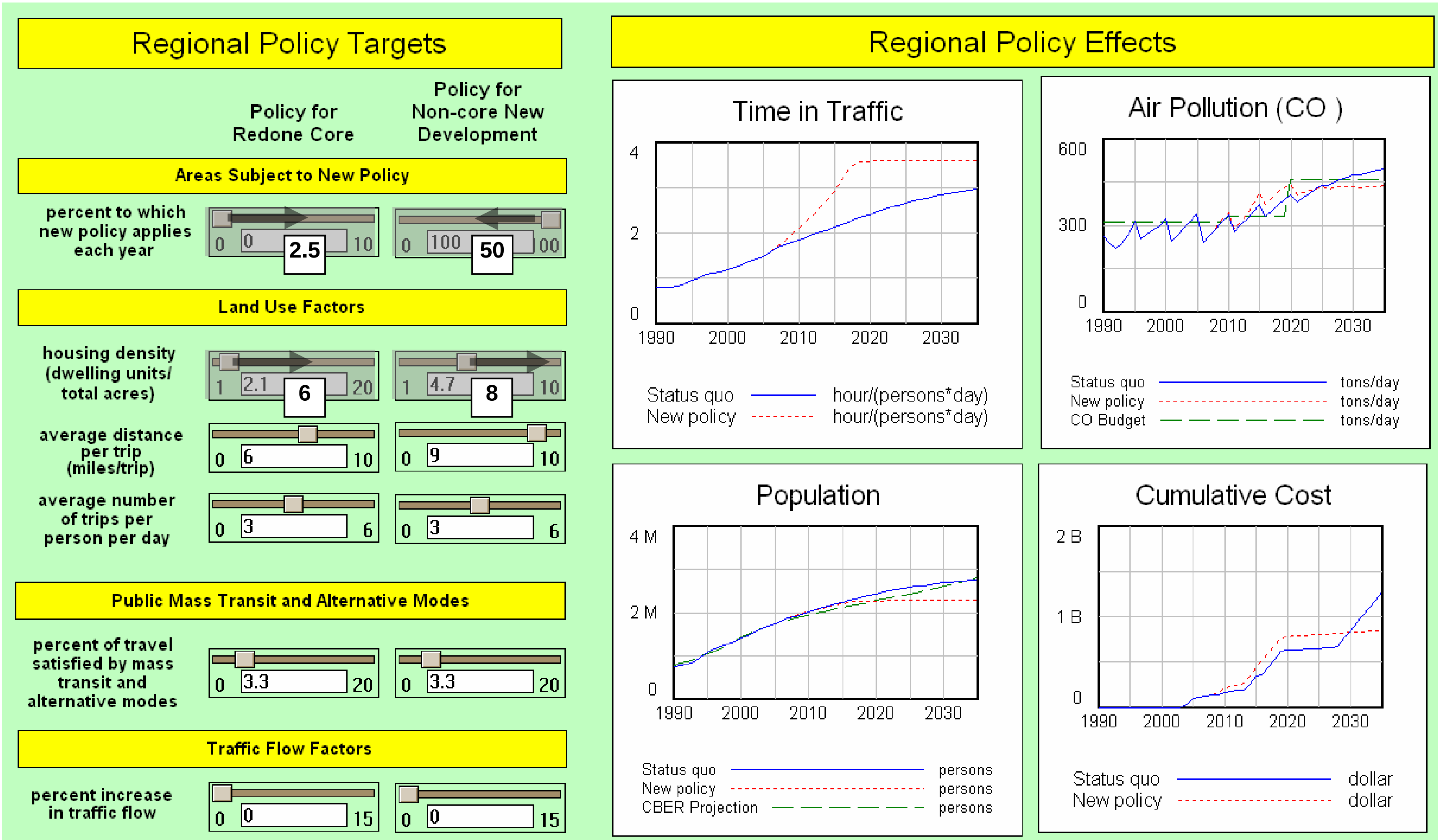
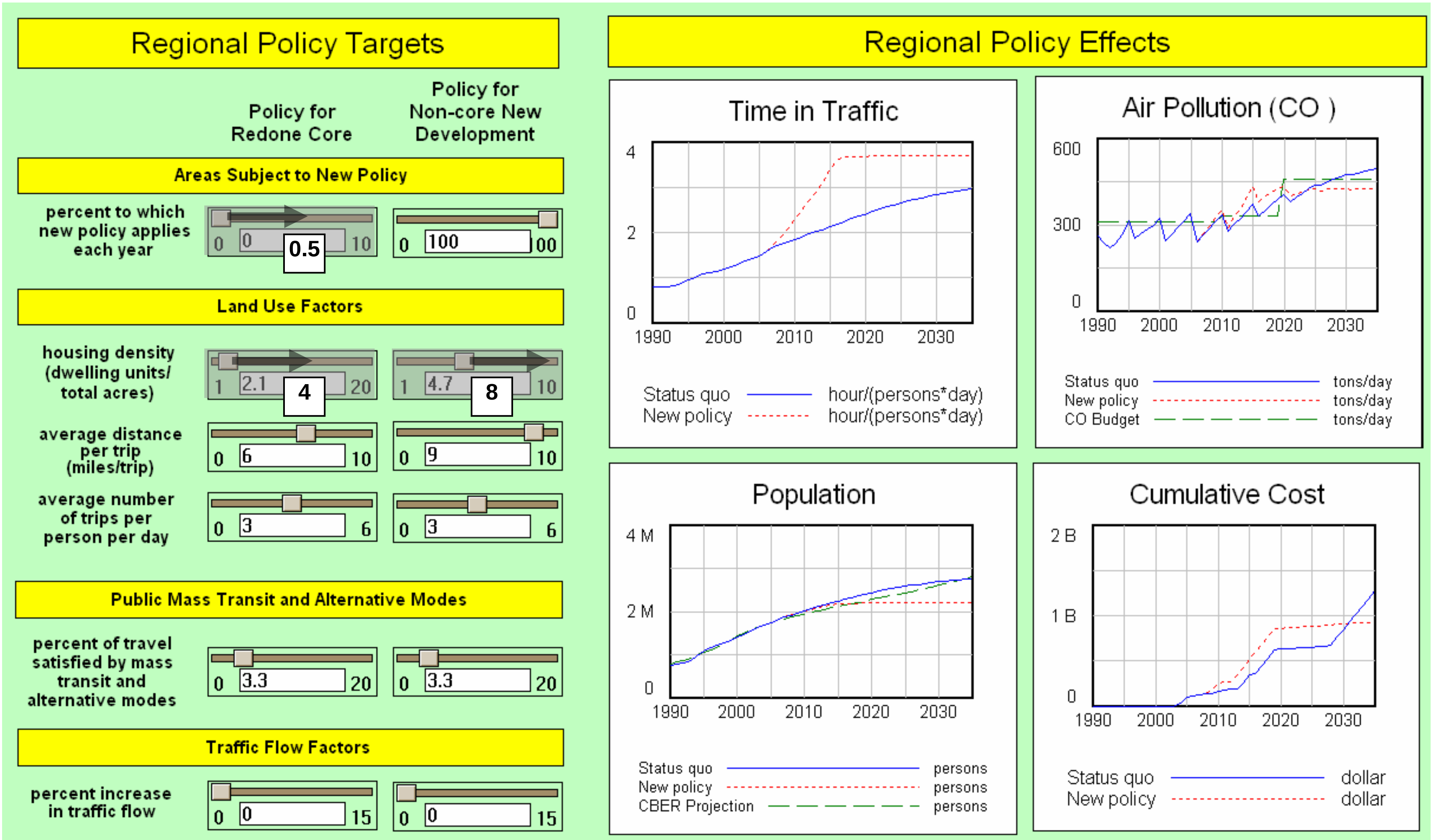


Figure 13. Densification 5: Density increases primarily in non-core new development



Mixed Use Scenarios

Mixed-use scenarios focus on changes in land use design that would affect the average number of trips made per person per day and the average distance per trip. Both factors can be decreased by making destinations such as schools, work, and shopping more integrated and closer to one another. The following set of scenarios show that even modest decreases in number of trips and distance per trip can have dramatic effects.

<u>Mixed Use 1: Increase proximity of destinations in core area only</u>

The first scenario focuses on the core area only. It tests what would happen if we were able to reduce trip distance by half in the core area. This scenario would represent the development of an urban area with residences, shops, and services in close proximity, as is the case in many cities with a long history of evolution. Some have referred to such urban mixed use as "Manhattanization". Figure 14 shows that focusing on the core area alone, and only on promoting shorter trip distances yields only modest improvements in traffic congestion and air quality.

<u>Mixed Use 2: Increase proximity of destinations in non-core area only</u>

The second land use scenario focuses on the non-core area only, and only on decreasing the average distance per trip. The graph (Figure 15) shows the test of two values. New policy 1 reduces trip distance from 9 miles/trip to 4.5 miles/trip; New policy 2 reduces trip distance by only one mile, from 9 to 8 miles/trip. Both values improve all policy criteria.

<u>Mixed Use 3: Increase proximity of destinations in core area only</u>

The next scenario is similar to the previous one, but changes the number of trips per day instead of the distance per trip. Figure 16 shows that any decrease in number of trips is beneficial. It also shows that similar outcomes can be achieved by different means, that is, by changes in either trip distance or number of trips.

<u>Mixed Use 4 and 5: Decreases in both trip number and distance in both areas</u>

Scenarios 4 and 5 reduce both land use design factors in both the core and non-core areas. These scenarios represent comprehensive designs promoting mixed-use development. Scenario 4 represents a very modest change from the status quo: 1 mile reduction in average trip distance, and less than 10% reduction in the average number of trips per day. Scenario 5 represents a more aggressive change: a 50% reduction in trip length and nearly 20% reduction in trips per day. While scenario 5 yields a dramatic improvement in policy criteria, scenario 4 shows that even modest changes can produce significant improvements.

Figure 14. Mixed Use 1: Increased proximity in core area

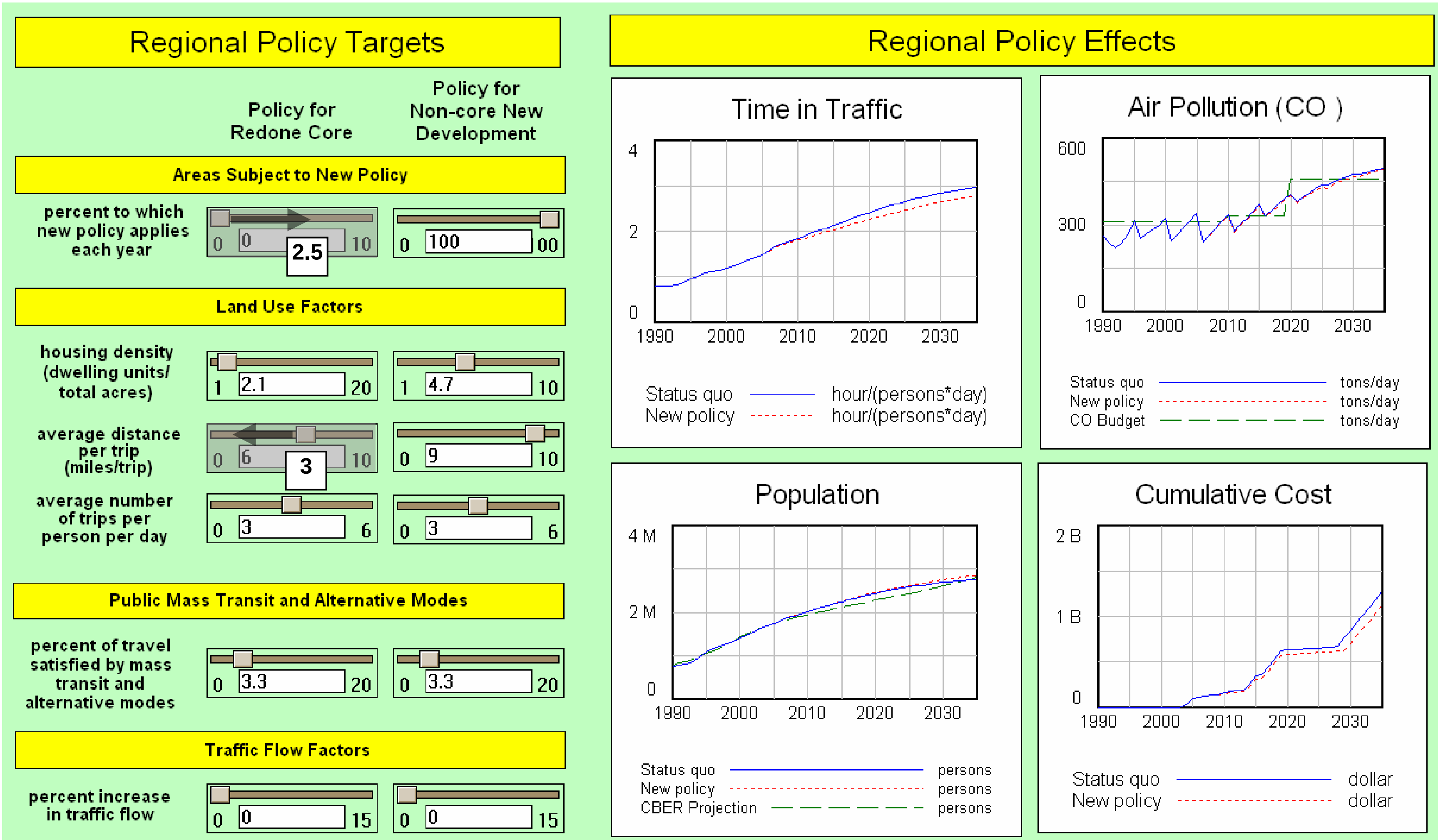


Figure 15. Mixed Use 2: Increased proximity in non-core area, showing multiple values of distance per trip

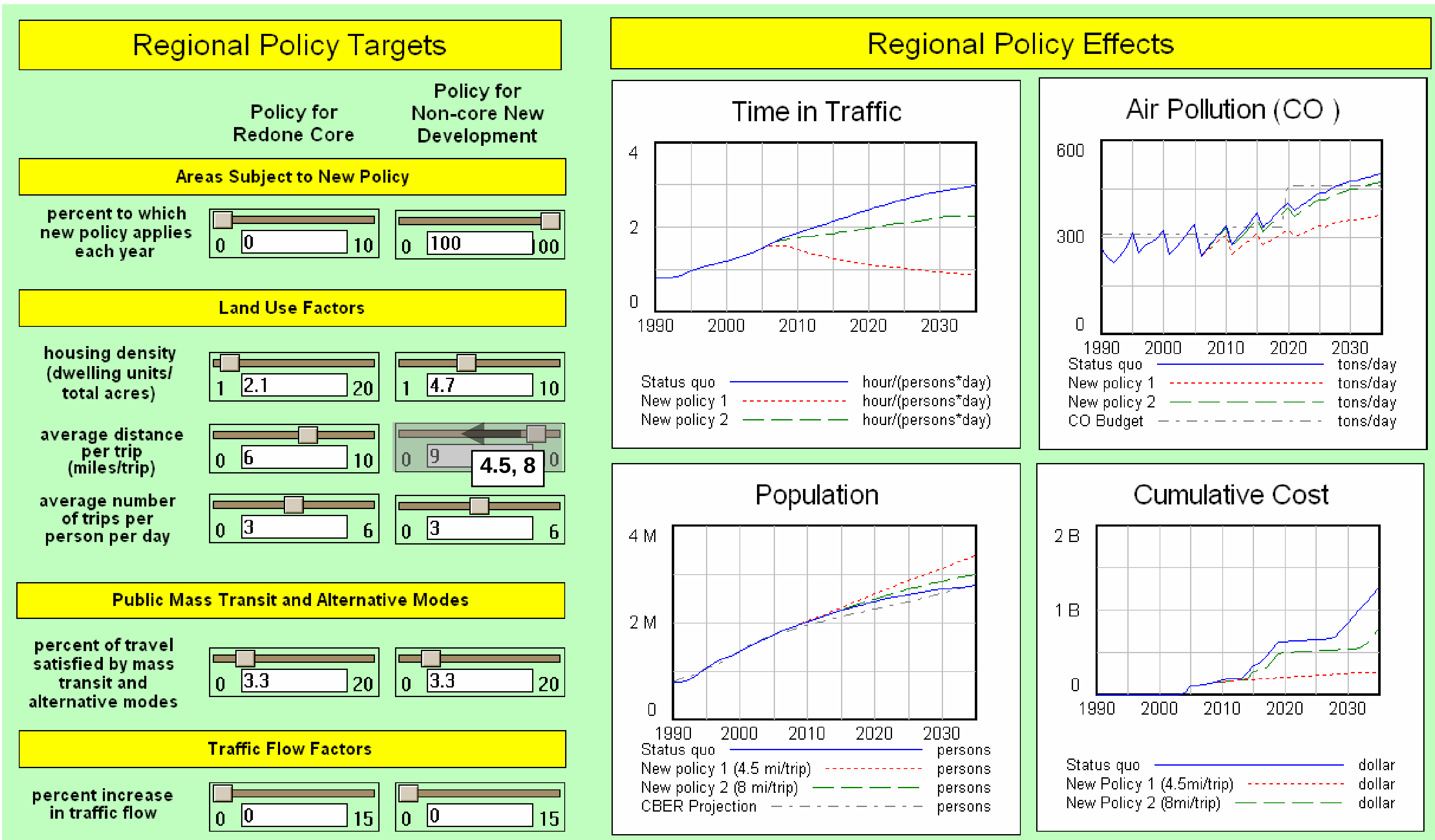


Figure 16. Mixed Use 3: Increased proximity in non-core area, showing multiple values for number of trips

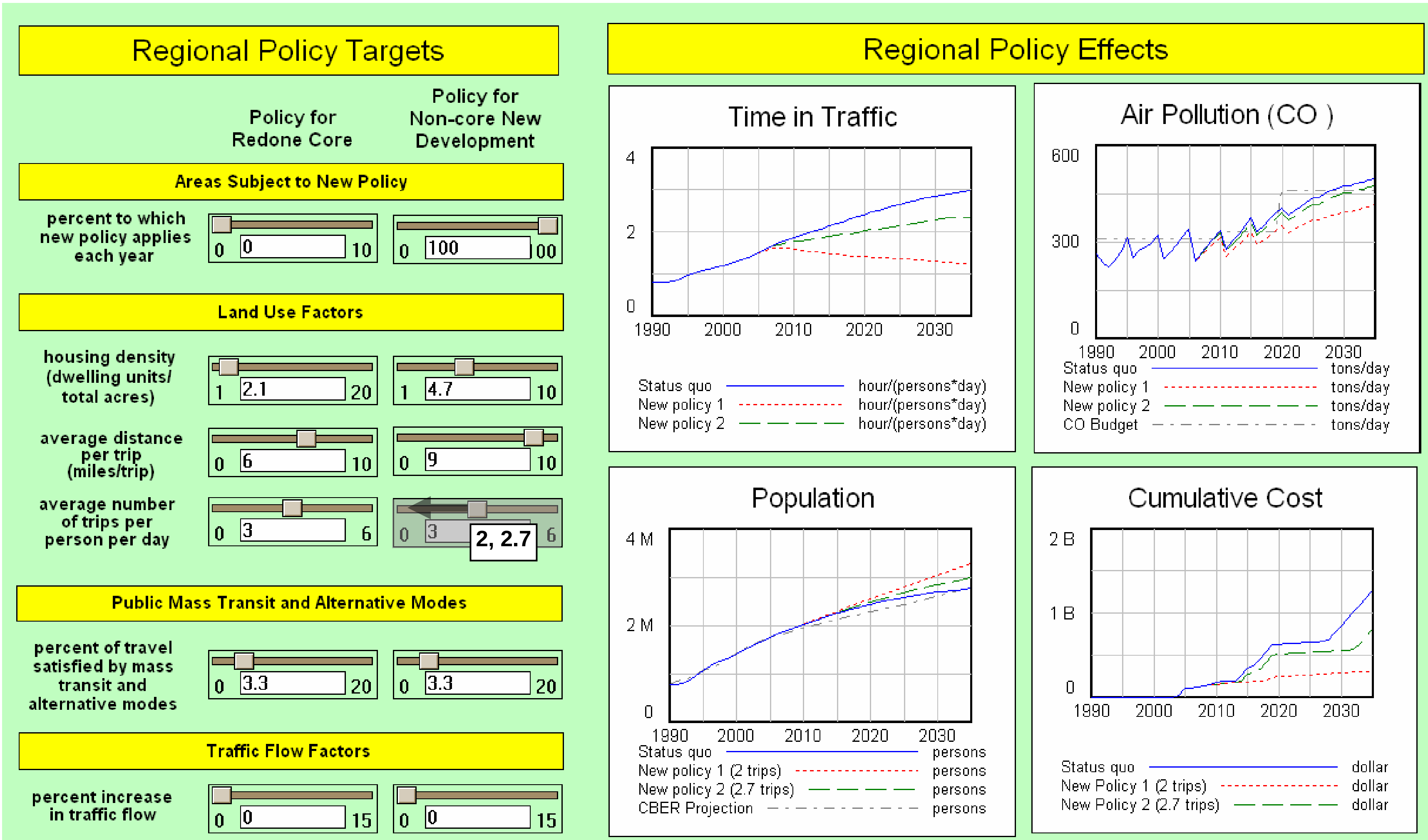


Figure 17. Mixed Use 4: Small changes in both areas

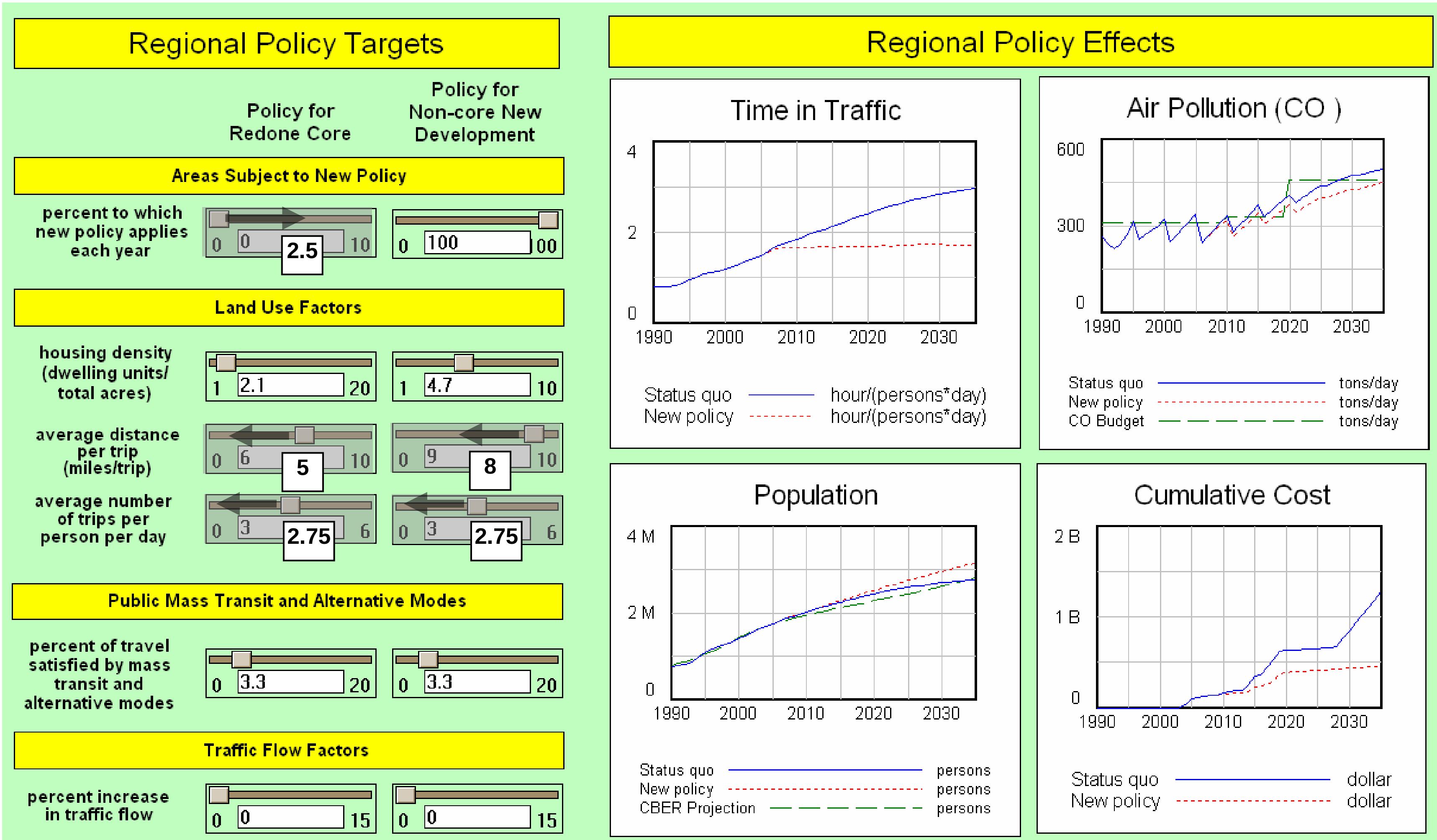
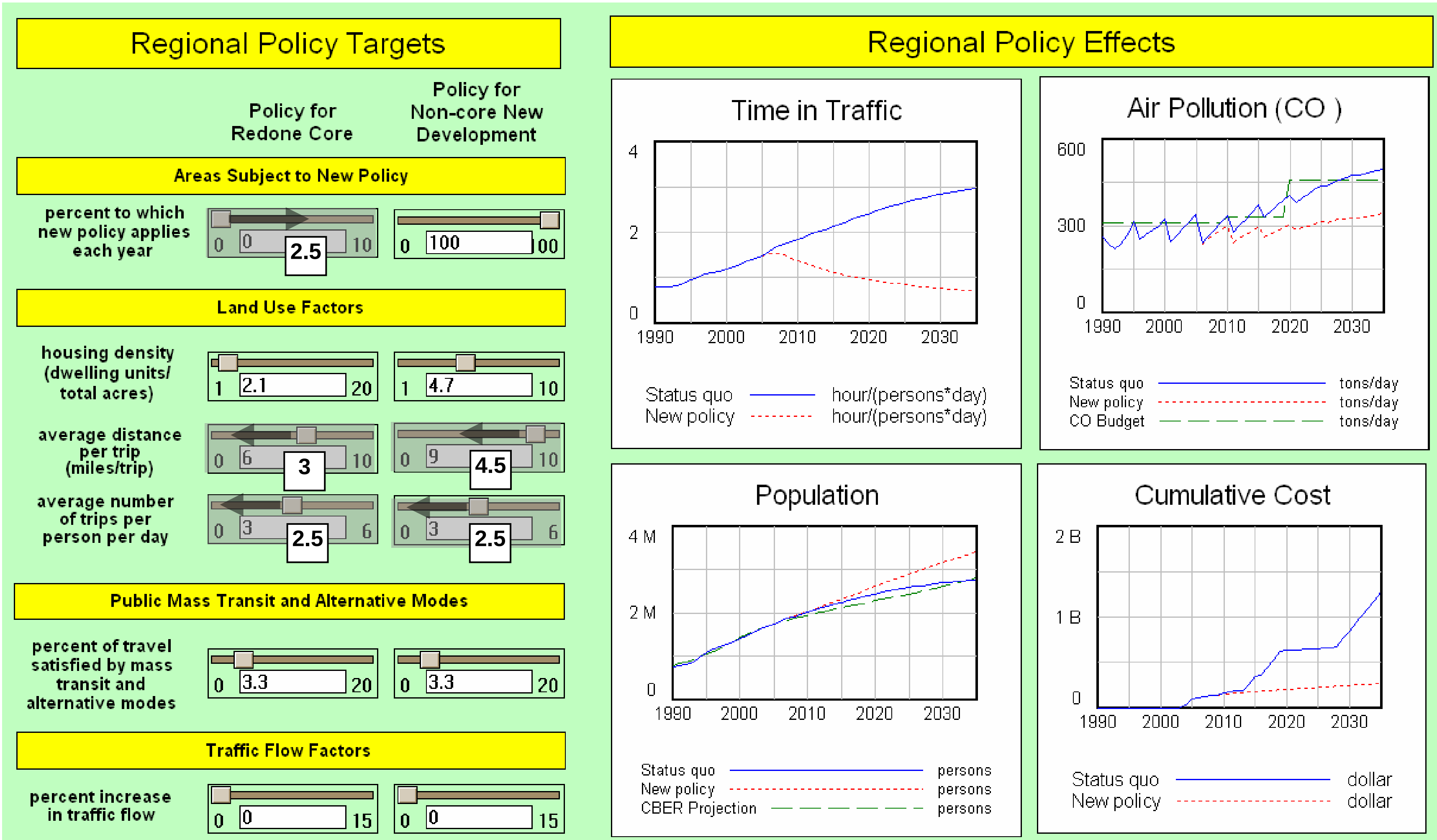


Figure 18. Mixed Use 5: Moderate changes in both areas



Transportation Scenarios

Transportation scenarios focus on increasing the percent of travel on public mass transit and alternative modes. Figures 19-23 show the results of five scenarios testing different configurations of public mass transit infrastructure.

Transportation 1: Core focus, 10% ridership

> This scenario represents an intensification of transit infrastructure in the core area. Achieving a relatively high 10% ridership would require a mix of types of infrastructure including local buses, rapid buses, and rail. This scenario represents a situation where the system would serve primarily residents in the core area (holding other factors such as density constant). As Figure 19 shows, this scenario generates almost no improvement in policy criteria, but carries a high cost, due to the expense of adding rail infrastructure.

Transportation 2: Non-core focus, 6% ridership

> Scenario 2 tests an increase in ridership in the non-core area alone. This represents a transit system with a strong focus on buses, both local and express, serving primarily residents away from the center of the valley. Figure 20 shows that this improves the policy criteria more than a core-focused system, but still shows only modest gains.

Transportation 3, 4, and 5: Valleywide focus, with different levels of ridership

> The next three scenarios combine the first two scenarios in a more realistic way. Since the transit system serves the whole valley, it should be considered as a whole. These scenarios test different levels of ridership, which correspond to different amounts of infrastructure. Scenario 3 shows the effect of a small increase in ridership, such as might be achieved by expanding the current local bus system. The effect of the local bus improvements is minimal, however. Scenario 4 tests a greater increase in ridership. Increasing core area ridership from 3.3 to 8.5 percent, and non-core ridership from 3.3 to 6 percent, would require a system that includes a small amount of rail but focuses largely on the express, or MAX buses. It represents an integrated system that might include park-and-ride facilities to bring non-core residents to the core area transit facilities. The results are similar to Scenario 2. Finally, Scenario 5 tests an integrated system with an aggressive increase in ridership. The gains in policy criteria are similar to the previous scenario, but the cost is high due to the cost of rail that would be needed.

Figure 19. Transportation 1: Moderate to high increase in ridership in core area only

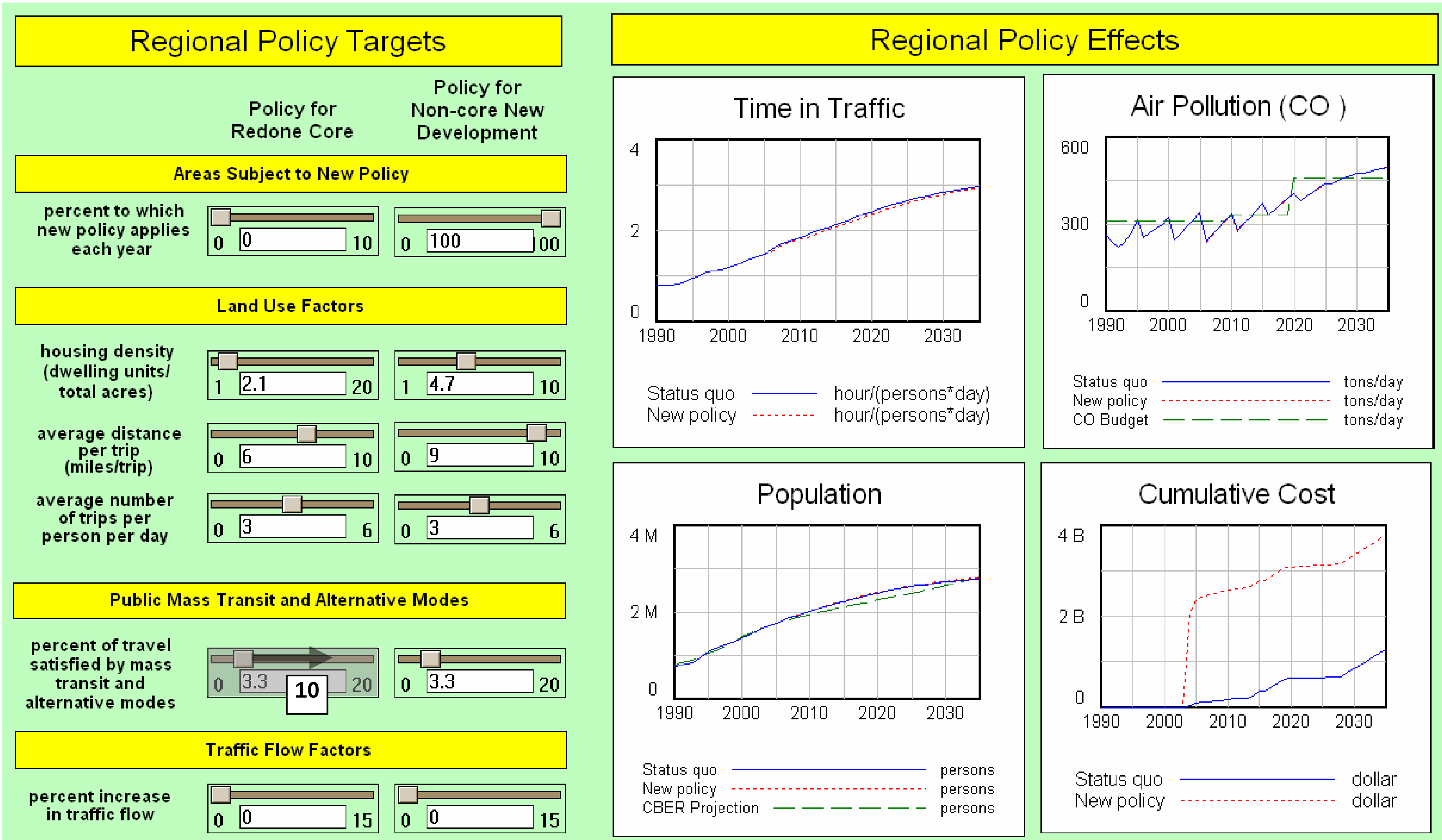


Figure 20. Transportation 2: Moderate increase in ridership in non-core area only

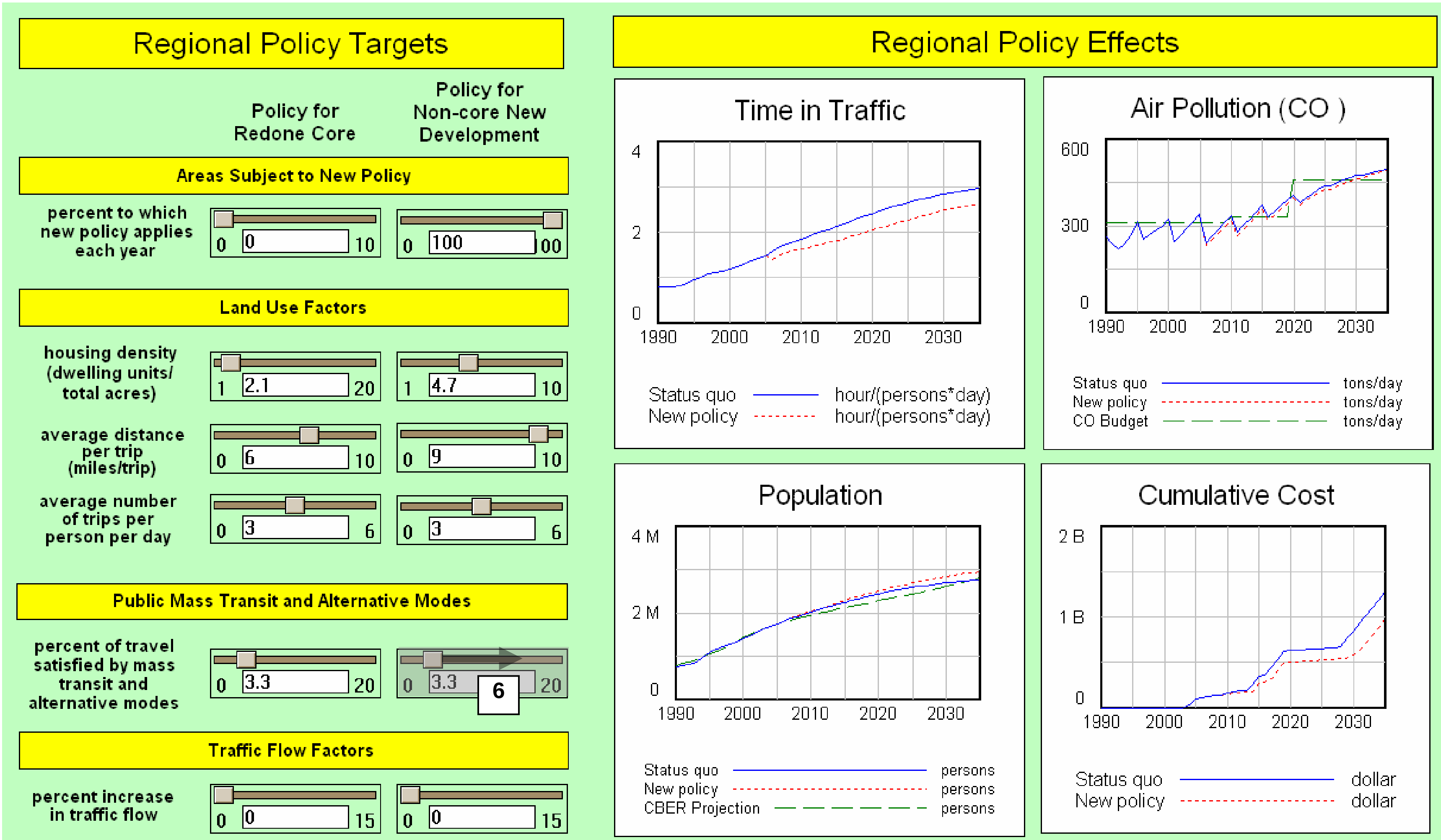


Figure 21. Transportation 3: Minimal increase in ridership valleywide

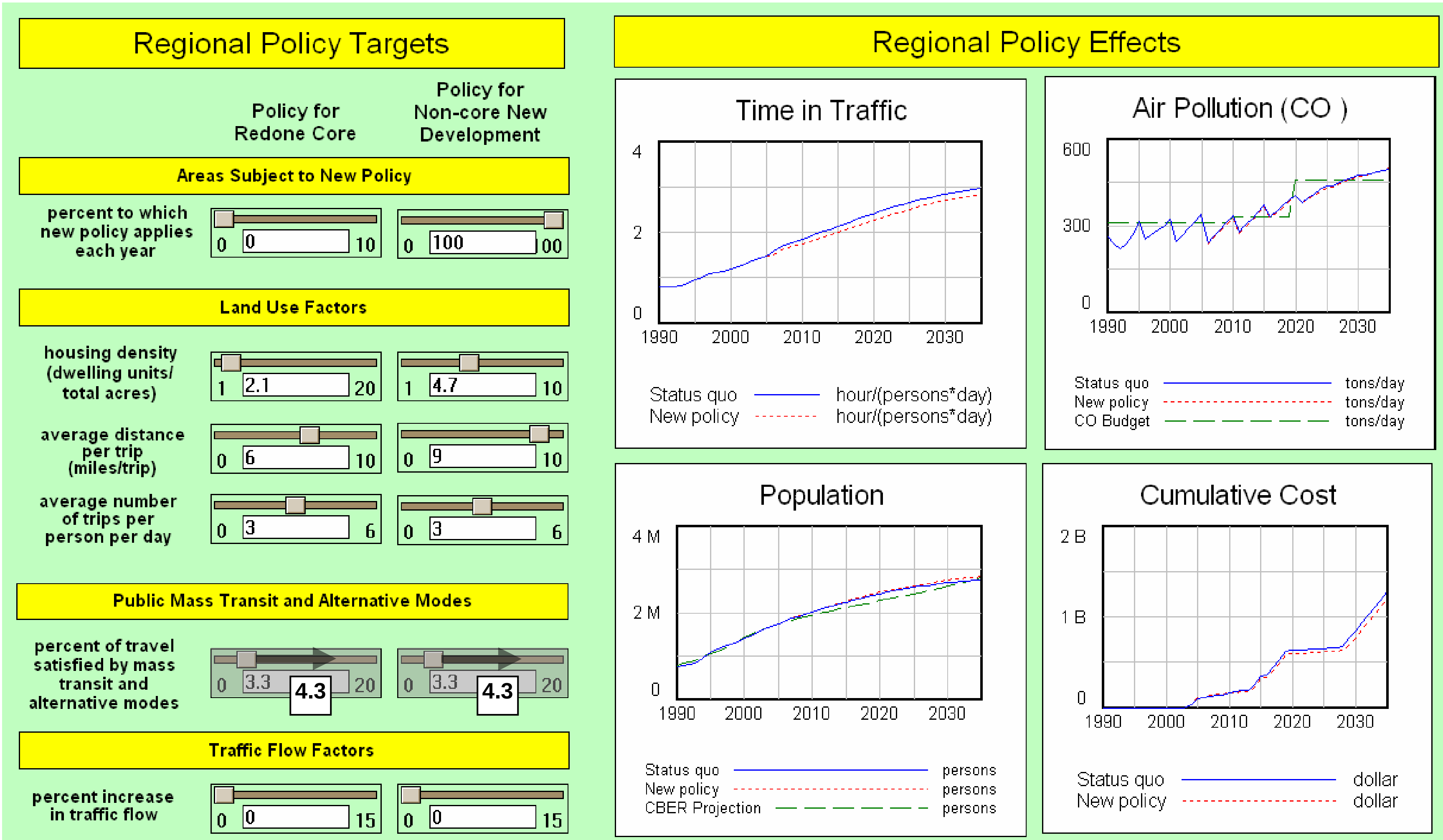


Figure 22. Transportation 4: Aggressive increase in ridership valleywide

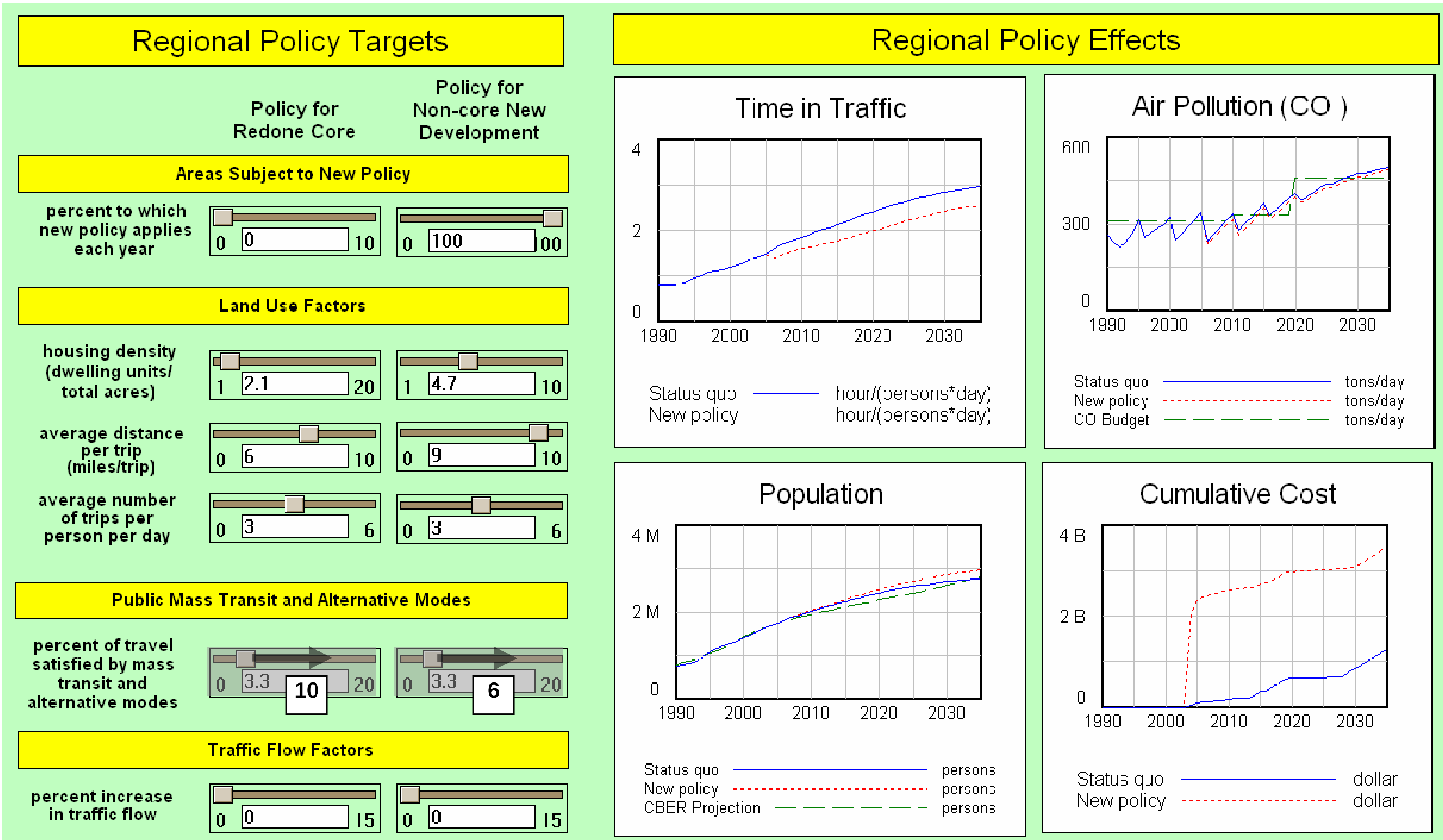
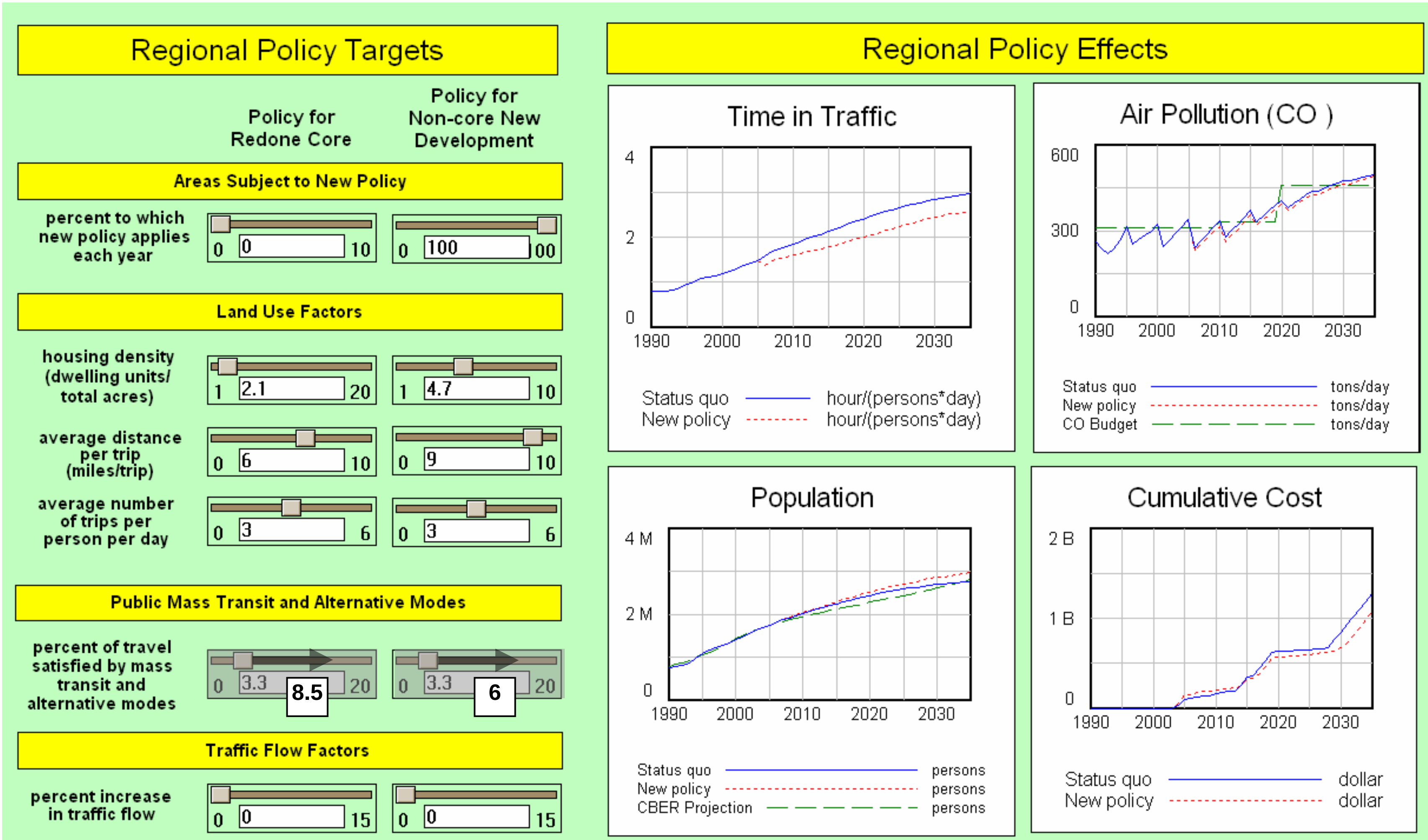


Figure 23. Transportation 5: Moderate increase in ridership valleywide



Combination Scenarios

Testing the effects of each of the policy variables individually showed clearly that you cannot just change one thing. Instead, achieving significant improvements in traffic, air quality, and other factors requires a combination of strategies. The group tested a number of combinations and found two that represent realistic policy scenarios that met the policy criteria. The group proposed that these scenarios represent “best practices” for integrating land use, transportation, and air quality planning.

Figures 24 and 25 show the details and results for the two scenarios, labeled:

<u>Best Practices Combination 1: Modest changes across the board</u>

<u>Best Practices Combination 2: Moderately aggressive strategies</u>

Both combinations assume that density will increase. In the first combination (Figure 24), density doubles in the core, and increases by 50% in non-core new development. Distance per trip decreases by 2 miles in the core and 1 mile in non-core new development. Average number of trips decreases by less than 10% in the core and by 30% in the non-core new development. These changes in trip distance and number of trips could be achieved by promoting new developments on the edge of the metropolitan area with a high degree of mixed use, and increasing the integration of uses in the core. Combination 1 assumes modest investments in transit infrastructure to increase ridership by 50%. As Figure 24 shows, Best Practices Combination 1 dramatically improves time in traffic over the status quo projection, yielding almost no increase from current values. Air pollution stays below the EPA budget throughout the model run period, and population growth shows a small increase above projected status quo levels.

Best Practices Combination 2 represents a more aggressive change in land use and transit policies. Density is nearly tripled in the core and doubled in non-core new development.   Distance per trip is reduced by half across the valley, and the number of trips is reduced by approximately 20%. Transit infrastructure is increased as in Transportation Scenario 5. This combination has the greatest positive effect on all policy criteria. Time in traffic decreases below the status quo projection, air pollution is well below the EPA budget, population growth continues at a strong rate, and costs increase less than in the status quo scenario.

Figure 24. Best Practices Combination 1: Modest changes across the board

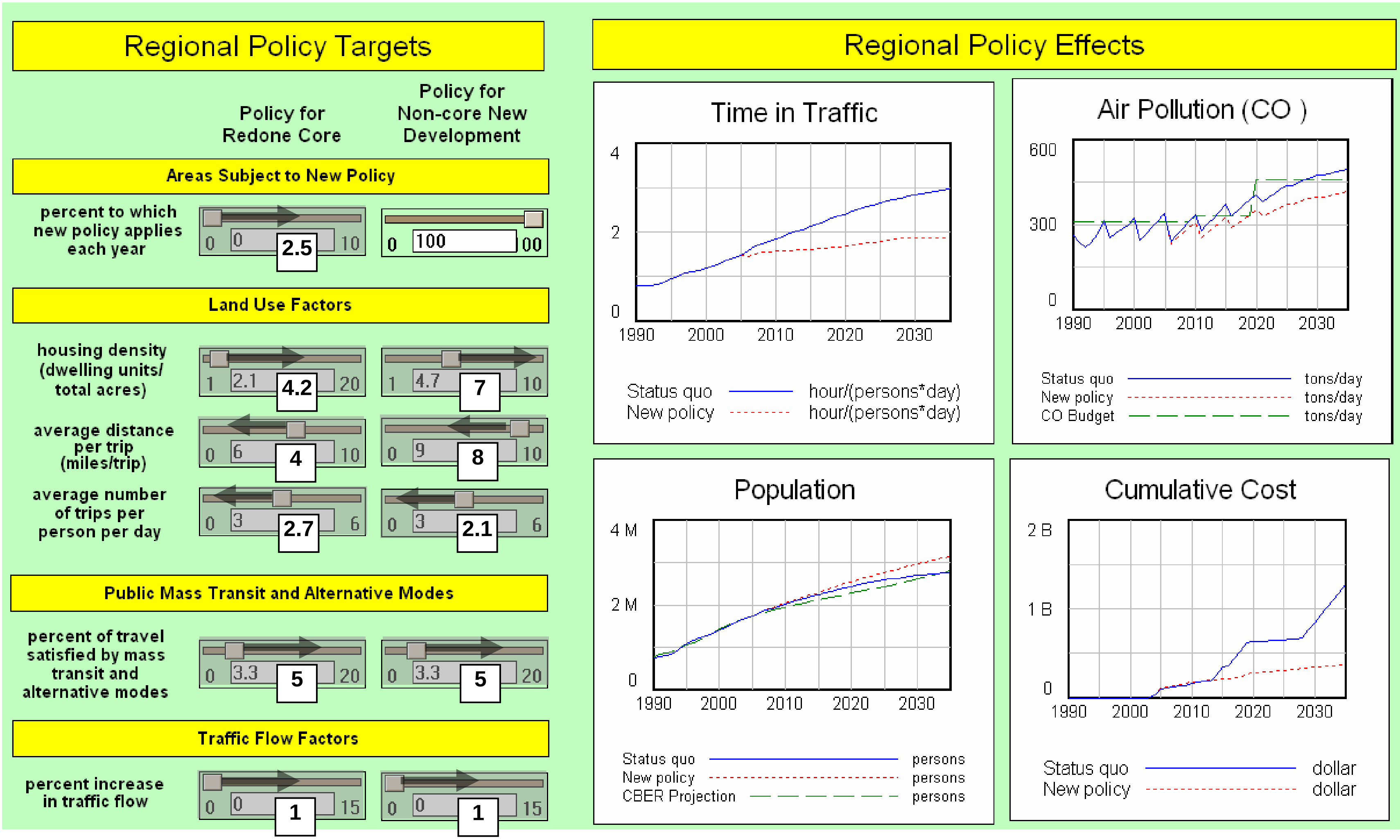
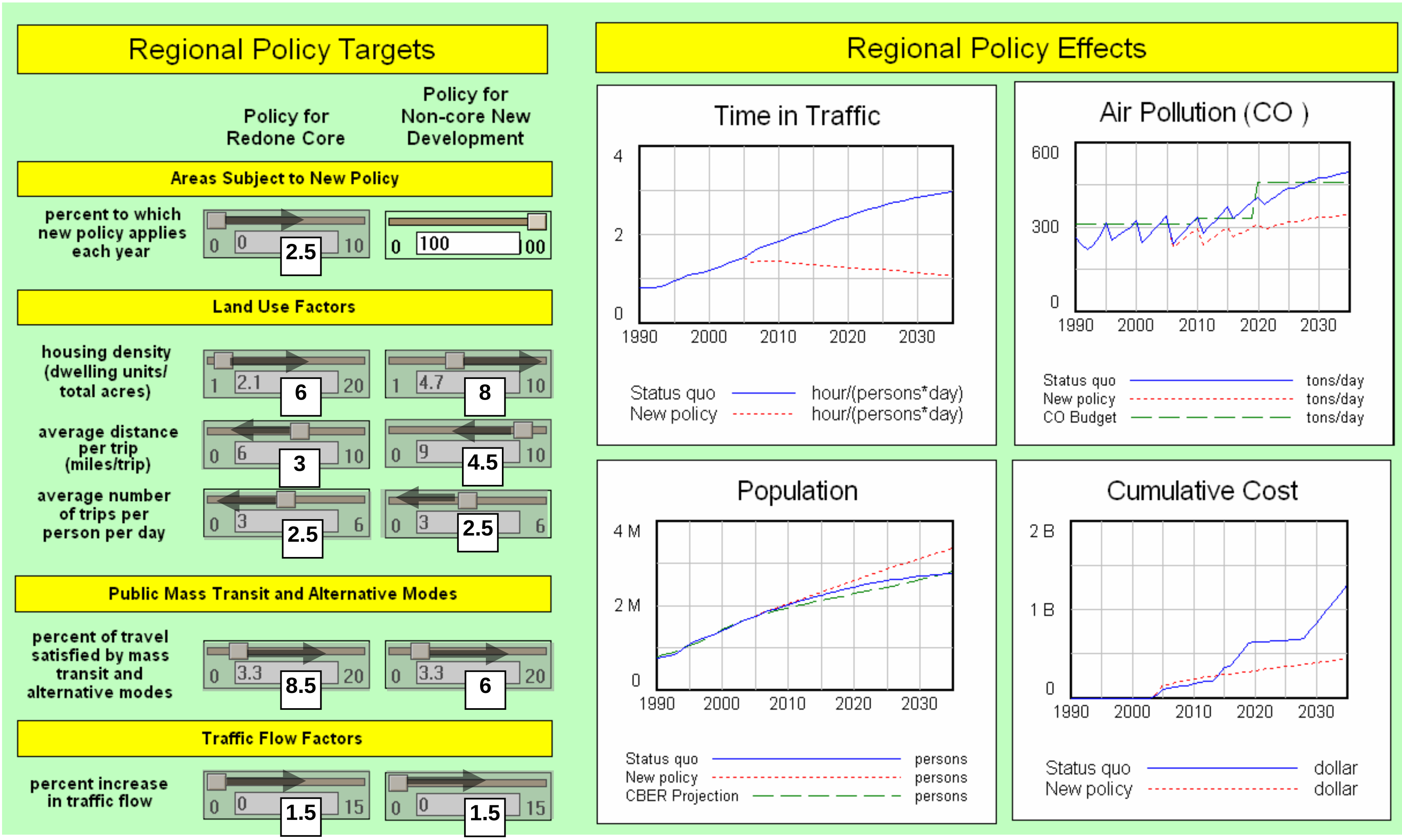


Figure 25. Best Practices Combination 2: Moderately aggressive strategy



Summary and Discussion

Use of the LUTAQ model for policy analysis produced several key findings.

First, it underscored the general sense that if we do not change the way we develop land and the transportation system; several aspects of quality of life in the valley are likely to get worse.   While most people who have lived in Southern Nevada for any length of time would probably agree that traffic and air pollution are "getting worse", the LUTAQ model helps quantify the magnitude of the problem. The model shows that maintaining the status quo will mean significant increases in traffic congestion and air pollution (Figure 8). More specifically, if land use and transportation development continue according to current trends, the Las Vegas Valley can expect the following:

- Traffic congestion will increase to the point that time spent in traffic per person per day will approximately double by 2035.
- Air pollution levels will continue to exceed EPA standards regularly.
- Even though maintaining the status quo will not incur new policy costs, we can expect to lose a significant amount of federal transportation subsidies due to air quality violations.

Second, it showed that densification alone (at any level and in any area) makes things even worse than if we simply maintained the status quo. Because recent efforts to change land use strategies have focused on increasing the density of dwelling units, the LUTAQ group tested a range of densification strategies. All the runs tested showed that if we focus on increasing density alone (Figures 9-13), we can expect:

- Time in traffic will increase rapidly in the next decade to more than double its current value.
- Air pollution levels increase above status quo levels for the next 10-15 years.
- Population growth will level off because the combination of traffic congestion and poor air quality will reduce the desirability of the Valley as a place to live.
- Costs increase above the status quo levels for the next 10-15 years, then level off as the stagnant population stops the rise in air pollution.

Finally, the model analysis showed there are ways to achieve the policy goals that do not require extreme changes in land use and transportation design. The most powerful tool for reducing congestion, maintaining air quality within EPA standards, maintaining population at projected levels, and minimizing costs, is a combination of land use design and transportation infrastructure that increases density moderately, reduces the average number of trips per day and distance per trip, and shifts even a small percentage of travel from cars to public transportation. Both of the Best Practices Combinations met and exceeded the policy criteria. While the level of effort needed to implement the more aggressive strategies may be unrealistic, the analysis showed that even modest changes could lead to significant improvements.

Combination 1, with modest changes to all policy inputs (Figure 24):

- Keeps time in traffic from increasing beyond present levels.
- Keeps air pollution consistently below EPA standards.
- Avoids a decrease in the rate of population growth.
- Reduces overall costs below the status quo scenario by avoiding the loss of federal transportation subsidies.

As the LUTAQ Working Group noted during the model building as well as the model analysis phase, Land Use, Transportation and Air Quality are linked in critical ways. Changes in one part of the system cannot be made without consequences in other parts of the system. For instance, the model demonstrates that any increase in density has detrimental effects on traffic and air quality. Such increases may be necessary, however, to keep housing development economically viable as the price of land increases. What this analysis shows is that other factors in the system can balance the negative consequences of one factor, such as densification, to achieve an overall desirable outcome.

Appendix

External Review Report

29 September 2005

Technical review of the LUTAQ model

The LUTAQ model is a System Dynamics model for simulating feedbacks among land use policy, population size, transportation, and air quality in the Las Vegas valley over the next several decades. The model was developed at UNLV by a group led by Prof. Krystyna Stave, using Ventana Systems' Vensim® modeling software. Professor Stave has asked Ventana to conduct a technical review of the model and this report details the findings of that review.

The model allows users to define new housing density and transportation infrastructure characteristics for future redevelopment of parts of the urban core, and for newly developed land area in the Las Vegas valley. Based on these choices, the model estimates the effects over time on traffic congestion, air quality, and net population growth, as well as the costs of the transportation infrastructure.

Our review included the following checks: (i) consistency of units of measure in all equations, (ii) algebraic and typographical correctness of each equation, (iii) conservation of land and people throughout the simulation, (iv) logical calculation sequence in each submodel, (v) proper use by each submodel of information from other submodels, and (vi) sensible magnitudes of output under all allowed input values. At the same time we took note of areas where the model was correct but where the same logic could be expressed more clearly or easily.

The model has two particularly elegant features. First, the model avoids overwhelming the user with geographic minutia by simply defining four categories of land: urban core under status quo policy, urban core under a new policy, new development under the status quo, and new development under a new policy. That framework is sufficient to explore aggressive or moderate pursuit of a variety of potential policies, allowing experimentation with many management philosophies in an easily used framework. Second, the model uses a simple but effective abstraction of how a growing population will distribute itself among the land categories over time. This ensures that simulation outcomes conform to what is physically possible.

The details assumed in the model appear to be well-researched and well-founded. Three examples are (i) research across many US municipalities used to derive the model assumption about how the number of public transporation routes serviced affects public transportation ridership, (ii) input from local government experts on the relationships among road infrastructure decisions and traffic characteristics such as average speed, and (iii) use of the widely-accepted CBER population growth forecast to represent the effects on population growth of all factors not included in the model itself. While no forecast is guaranteed to be correct, the CBER forecast is well established as a basis for policy planning in Las Vegas, and so this choice makes LUTAQ consistent with prior expections in aspects of population growth outside the model scope.

The intended model assumptions and dynamics have been correctly expressed in the modeling software. In the roughly 300 equations in the model we found 2 technical errors, neither of which were able to affect results by more than a few percent. These have been pointed out to the modeling team and corrected. We also discovered one approximation that could have been made more precise, but after discussing it with the modeling team, we concur that the additional model complexity required to improve it would not be worthwhile given its almost unnoticeable impact on model outputs.

Ventana has identified to the LUTAQ modeling team two primary areas for potential improvements. First, we have recommend further research to clarify and document which model parameters have the most direct influence on the key relationships between congestion, air pollution, and population growth, as an initial step toward broader research on this important aspect of the model. Second, we have recommended several stylistic improvements that will make the model code easier to maintain and modify in the future.

In conclusion, the approximations and abstractions chosen for the model are appropriate to the model's purpose and to its current stage of development, and the technical expressions of those choices are executed correctly.

Dan Goldner, Lead Consultant
Ventana Systems, Inc.

About Ventana Systems, Inc.

Ventana was founded in 1985 to help organizations make better decisions by advancing the standards of modeling technology and practice. A small, expert group, Ventana's consultants have backgrounds in modeling, psychology, economics, engineering, operations research, and the physical sciences, each with from ten to more than thirty years' experience. Ventana® models inform high-stakes decisions in the world's most admired organizations, including Boeing, General Motors, Hewlett-Packard, IBM, the US Department of Energy, and the Federal Aviation Administration. Ventana's tools, including patented techniques to aid error detection, error prevention, and rapid comprehension of complex results, have been collected in the Vensim® dynamic modeling environment. First released commercially in 1991, Vensim has become the software of choice for thousands of analysts, consultants, and researchers. Ventana also provides the Vensim Personal Learning Edition free of charge to students of modeling worldwide. Ventana is based in Harvard, Massachusetts. For more information, please visit www.ventanasystems.com.