Lessons from LUTAQ: Building systems thinking capacity into land use, transportation, and air quality planning in Las Vegas, Nevada

Krystyna A. Stave and Michael Dwyer
Department of Environmental Studies
University of Nevada, Las Vegas

Abstract
This paper reports on the culmination of a two year project to facilitate "smart growth" planning in the Las Vegas, Nevada metropolitan area. Using a group model building process, representatives of key municipal entities and resource management agencies developed a 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 model and the process both contributed significantly to broadening systems thinking capacity in regional planning. The model supports system-based policy evaluation and the process created a common systems language among the more than 20 land use, transportation, and air quality planners in the group. The model represents regional links between population, transportation infrastructure, land use characteristics, and air pollution. Model analysis shows that the most powerful tool for achieving policy objectives is a combination of land use design and transportation infrastructure that reduces the average number of trips per day and distance per trip. This paper describes the model, results of the analysis, and effects of the group model building process on the participants.

Keywords: urban dynamics, urban planning, public policy, group model building, sustainable development, environmental management

Introduction

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.

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 contributed to model parameterization. Quantification was done "behind the scenes" by the consultants. The model was validated by the working group, technical experts in the planning, transportation, and air quality agencies, and external reviewers. 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. Over the 24 months, the LUTAQ Working Group met 35 times with each meeting lasting approximately 2 hours.

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 have 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.

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.

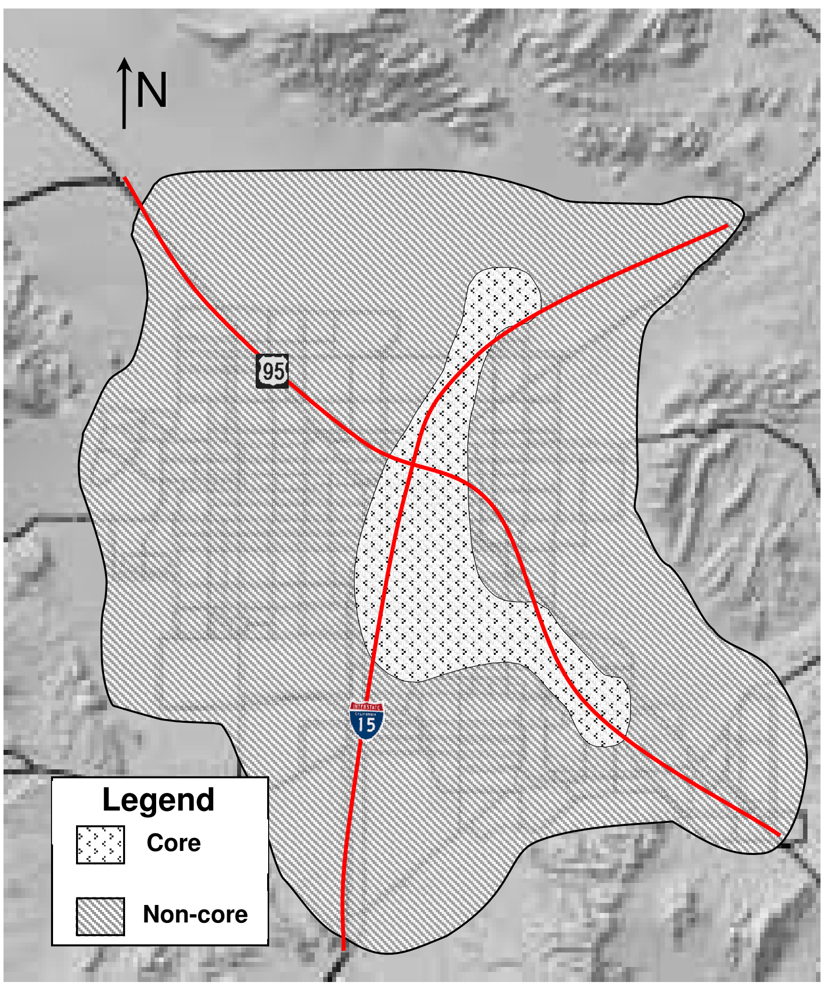


Figure 1. Map of Core and Non-core areas
Conceptual map of areas in the Las Vegas Valley considered to be core and non-core for the purposes of the LUTAQ model.

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.

The model simulation starts with 1990 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 the user 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. It allows a different policy package to be designed for the core and non-core areas. The simulation runs for 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 which are linked as shown in Figure 2.

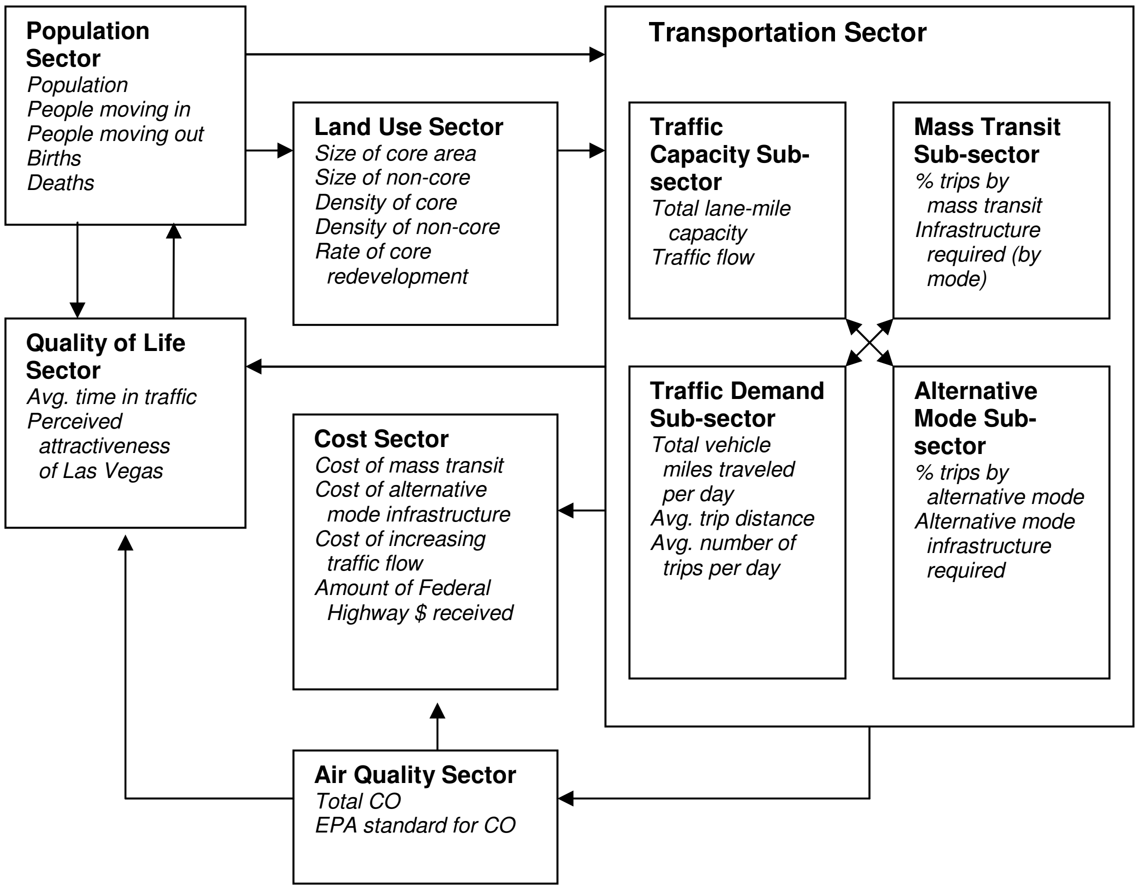


Figure 2. LUTAQ Model Sector Map
Key variables in each sector are shown in italics.

<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.

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, turn-out 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.

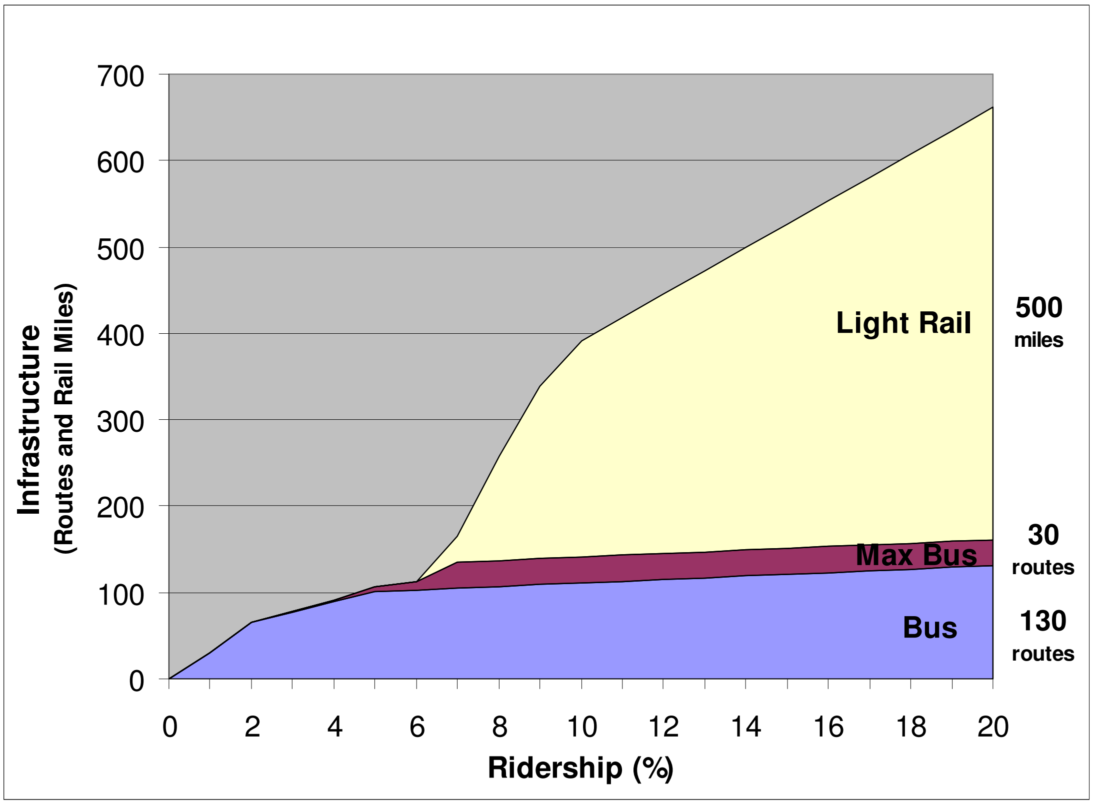


Figure 3. Mass Transit Infrastructure and Ridership
Approximate mix of types of infrastructure required to achieve a given level of public mass transit ridership.
The traffic demand sector calculates the number of vehicle miles traveled each day, based on the population of each land area (from the population 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.

<u>Air Quality Sector</u>

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. Carbon monoxide, ozone, and fine particulate matter are the principal pollutants of concern in the Las Vegas metropolitan area. Carbon monoxide was chosen as a 'proxy' for all forms of air pollution in the LUTAQ model because it is the pollutant most closely associated with the transportation system. Other automobile emissions behave similarly. Thus, if measures are found to mitigate carbon monoxide emissions, they can be expected to affect other emissions in the same direction. The Federal standard used to assess attainment for carbon monoxide is included in this sector.

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).

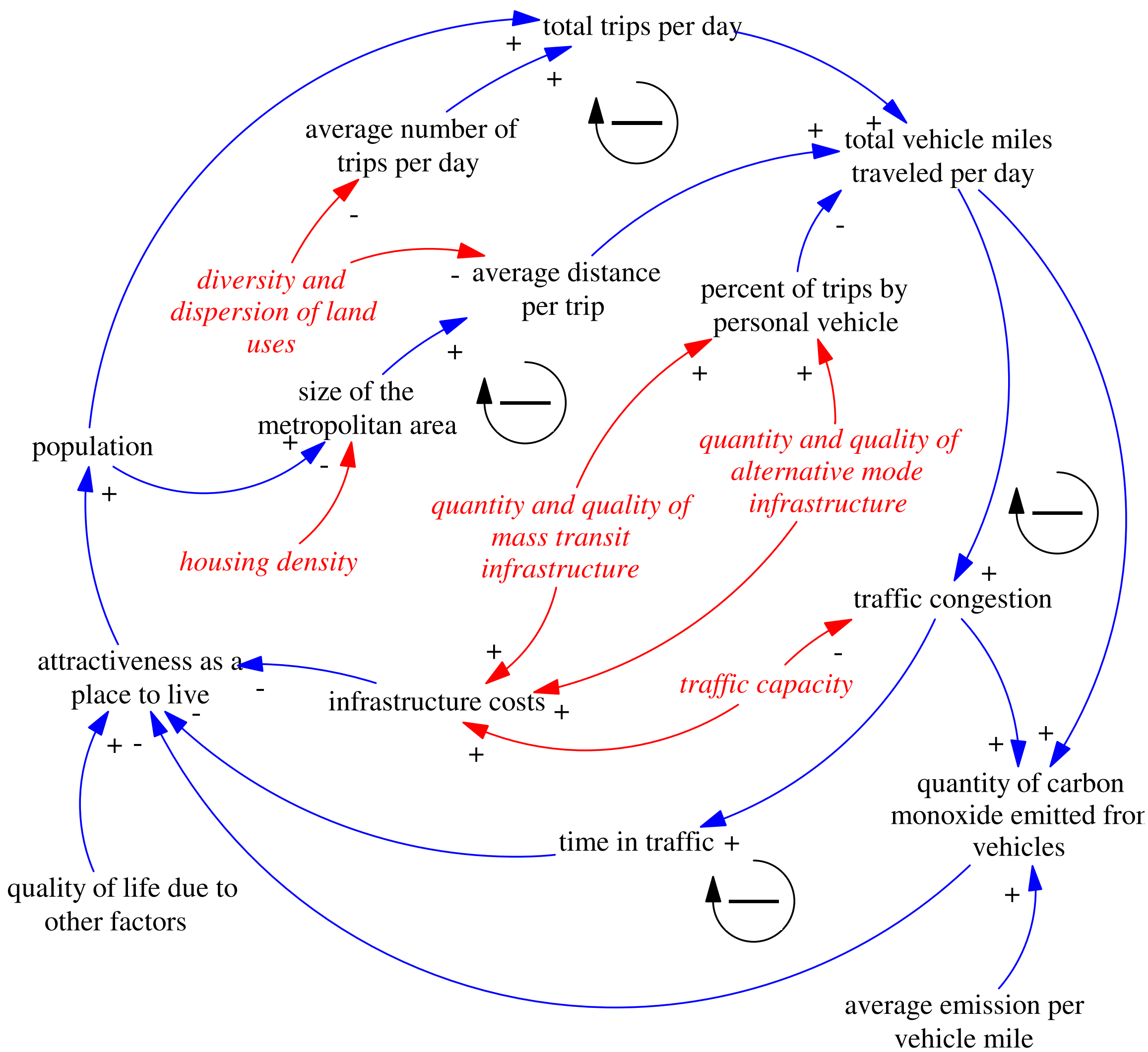


Figure 4. LUTAQ Model Causal Loop Diagram

The 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 outmigration and decreases inmigration, thus slowing (or even reversing) population growth. With no intervention, population growth will slow as air quality and traffic congestion get worse.

But 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.

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. 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. 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.

Validation Procedures

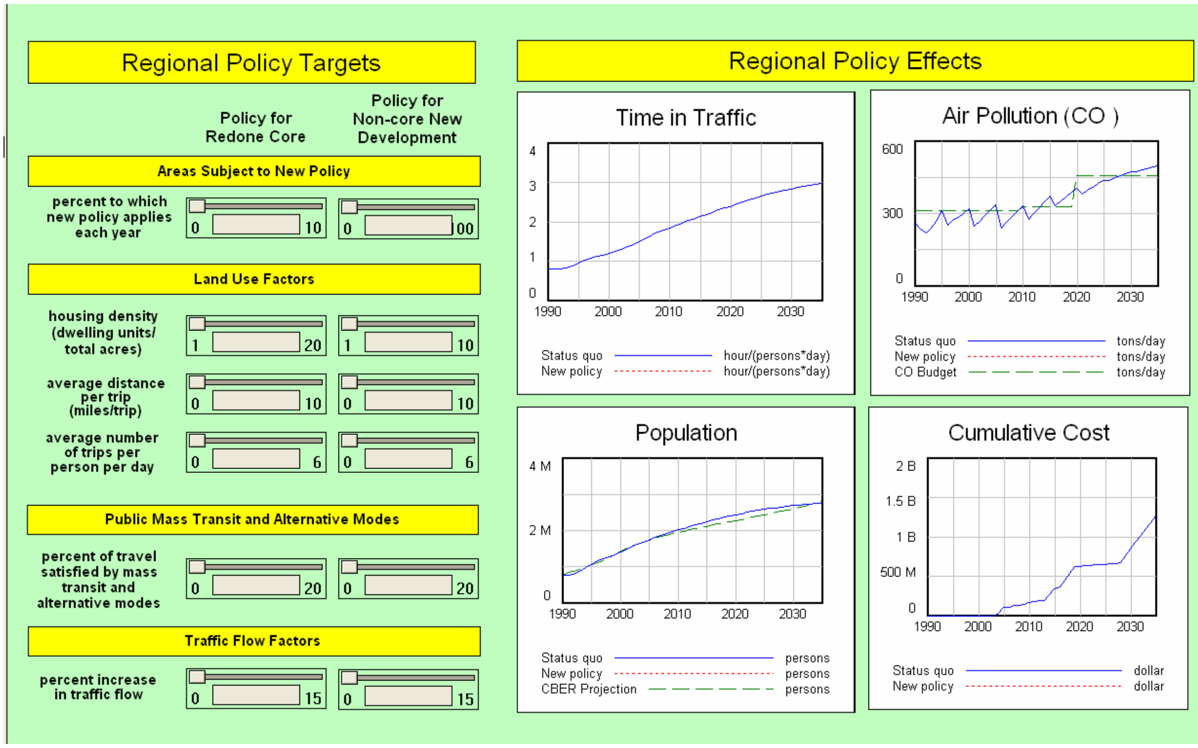
The model was subjected to several validation processes to ensure it represented the Southern Nevada Land Use, Transportation, and Air Quality system as accurately as possible for the indicated purpose. We considered the logical consistency of the model, the accuracy of the parameters, and the integrity of the model's structure.

Logical consistency was developed and tested in two ways. First, the causal relationships in the model were built in a group process that was transparent to all group members. Technical staff were consulted regarding any questions raised by the group about specific relationships. Technical staff were also consulted to determine the specific equations representing causal relationships. Second, the model output was compared with historical and projected trends. The values of all parameters in the model were rigorously researched and the sources of all the data are noted in the technical documentation. Technical staff confirmed the parameter values.

Using 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. 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

1. *percent of the area to which the new policy applies each year*

   Amount of land in the urban core that is redone under the new policies each year and amount of new development in the non-core area that 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 value is left at zero, new policies will not apply to any land in the core area and changes in the rest of the column will have no effect on the output.

2. *housing density*

   Density is measured in dwelling units per total acres. 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.

Model Output Graphs

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, that 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.

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.

Policy Analysis

The purpose of the LUTAQ project was not only to develop the model, but 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 tested each of the variables individually and in combinations representing policy scenarios that were being proposed by or discussed among planners in the region.

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 current practices and policies regarding land use design continue to be followed. That is, assuming 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, the output variables can be expected to behave as shown in Figure 6.

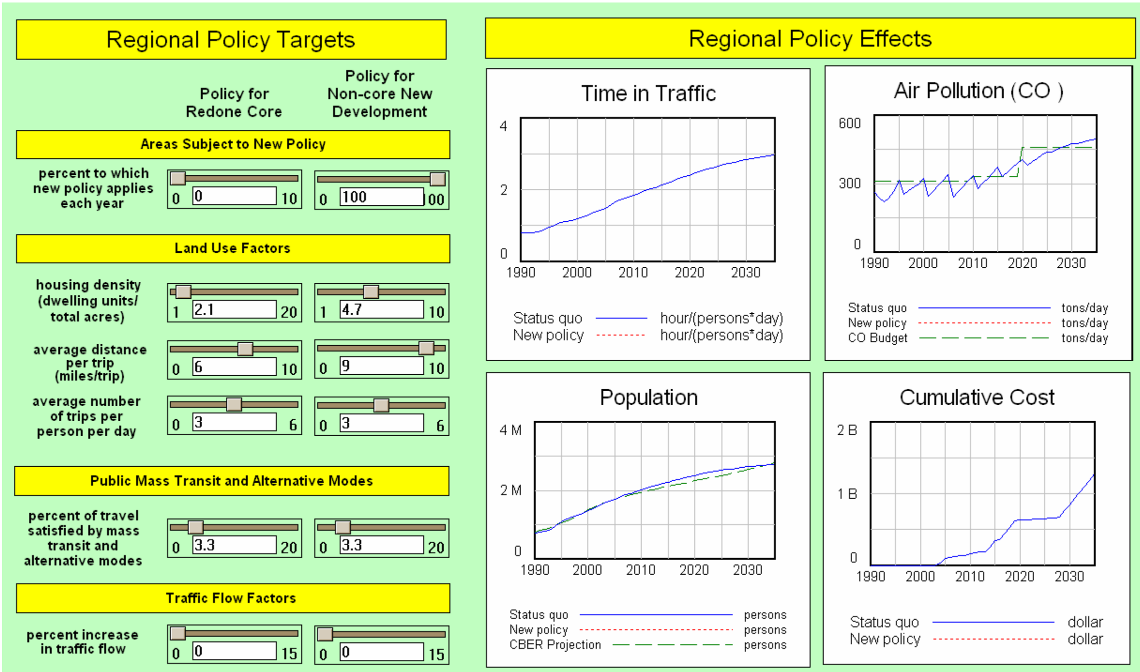


Figure 6. Status Quo Model Results
Input values and model results for the Status quo, or baseline scenario.

Figure 6 shows that if nothing is done differently, population will likely continue growing at roughly the same rate, time in traffic per person per day will roughly double in the next 30 years, and air pollution will 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 the group tested followed local "conventional wisdom" about how to improve traffic and air quality problems in Las Vegas. When asked how they would solve these issues, many people in the valley suggest increasing housing densities. The group tried a number of densification scenarios ranging from increasing density only in the core area (representing an increasing emphasis on creating more of an "Urban Center" in the valley) to increasing density only in new development (a shift to more multifamily and townhome development in outlying areas). All forms of densification made the key factors worse, as shown in Figure 7, representing a moderate increase in density in all areas in the valley.

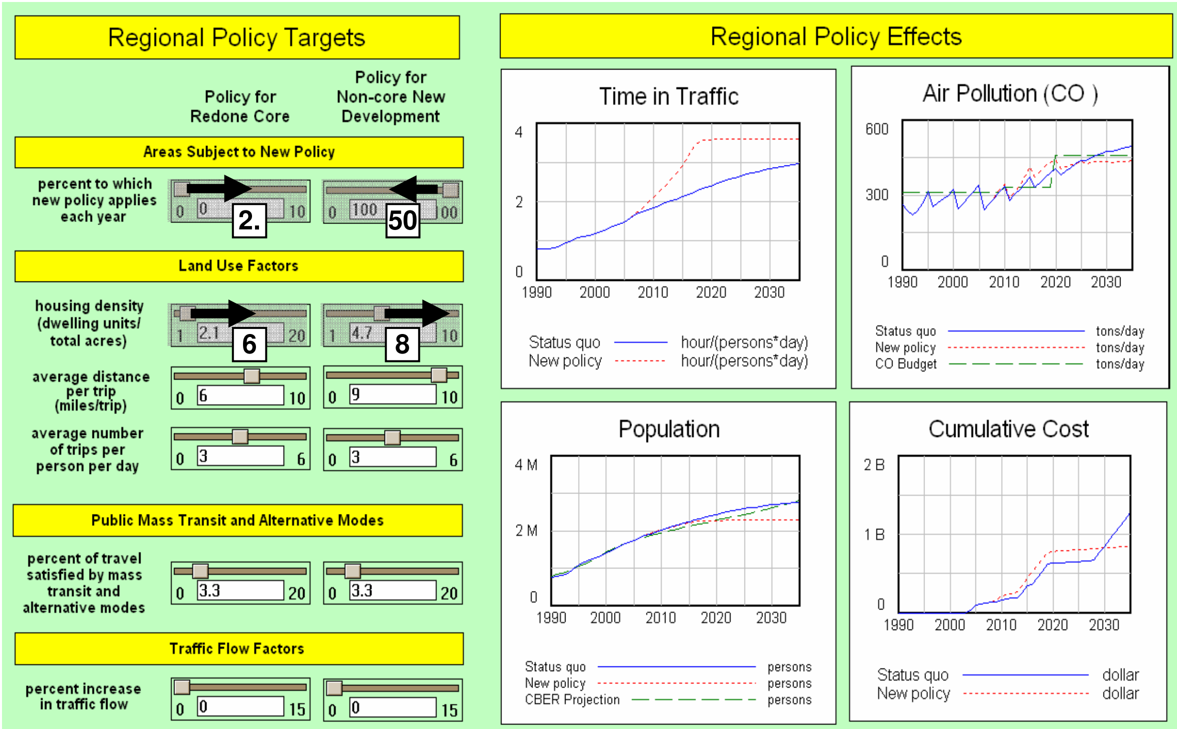


Figure 7. Moderate density increases in both core and non-core.

Mixed Use Scenarios

Mixed use scenarios focused 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 group tested a range of options in both core and non-core areas. All tests showed that even modest decreases in number of trips and distance per trip can have dramatic effects. Figure 8 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. Slightly more aggressive changes, shown in Figure 9, show the full impact of land use design on traffic congestion and air quality.

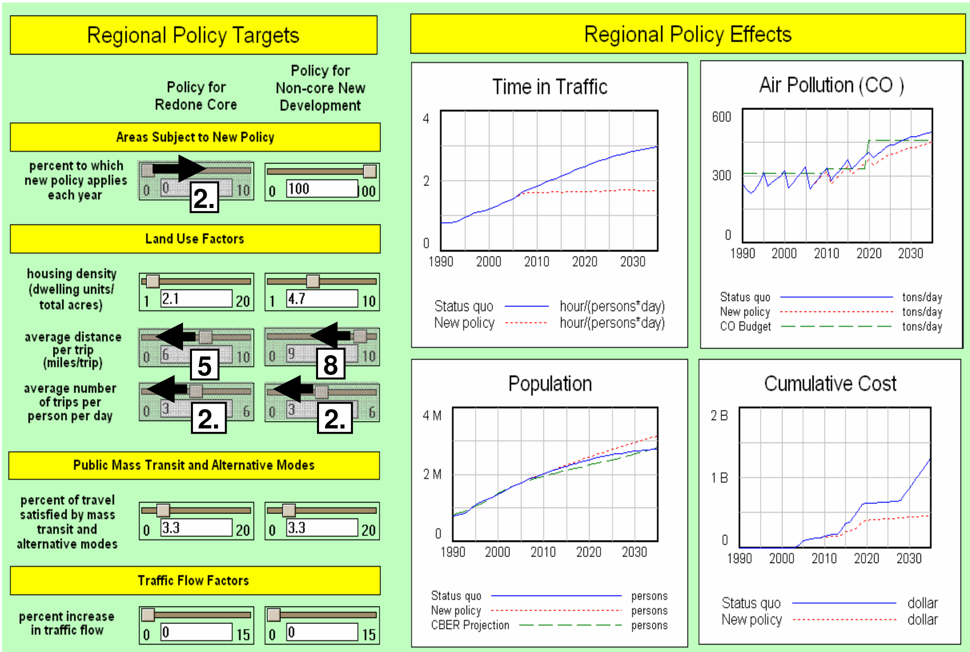


Figure 8. Small changes in both areas

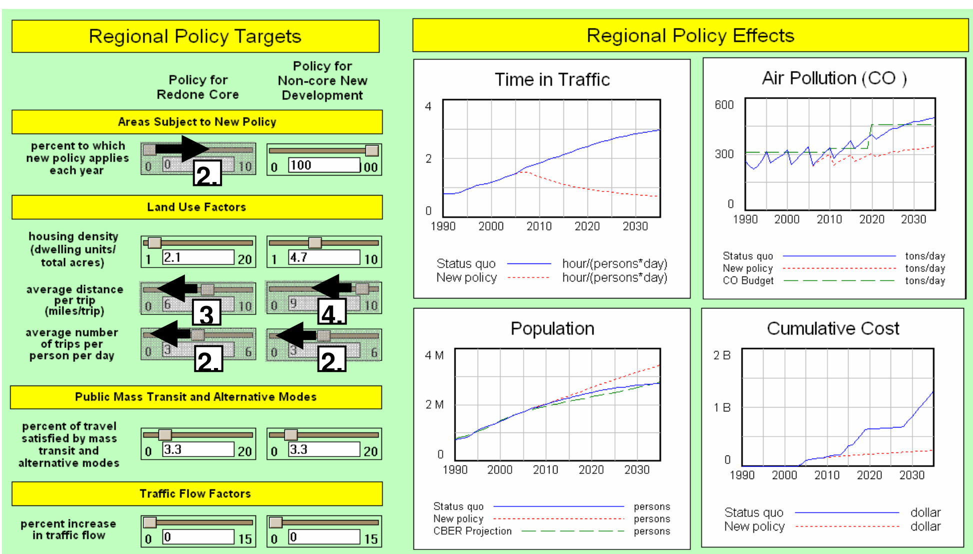


Figure 9. Moderate changes in both areas

Transportation Scenarios

Transportation scenarios focused on increasing the percent of travel on public mass transit and alternative modes. Figure 10 shows the results of moderate investments in express bus routes across the valley.

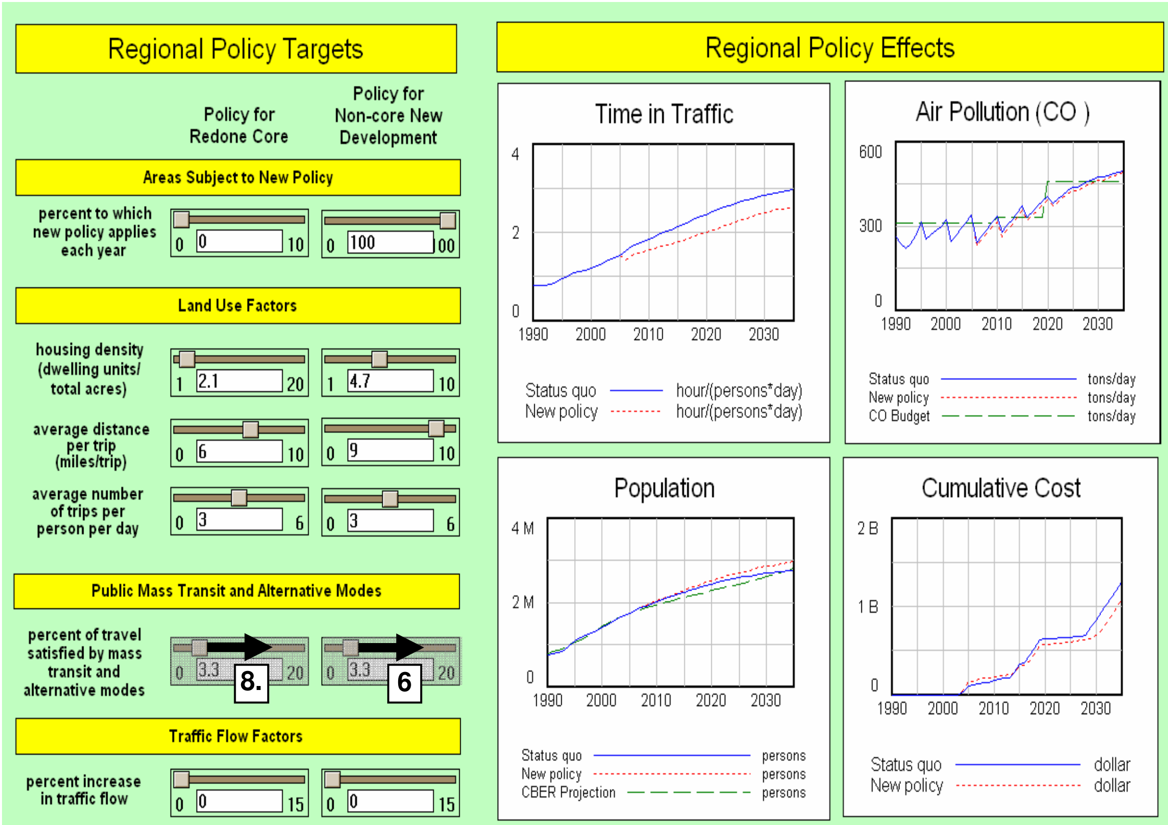


Figure 10. Moderate increase in ridership valleywide

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.

One represents modest changes across the board and the other represents more aggressive strategies. Both combinations assume that density will increase. In the first combination (Figure 25), 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. The first combination assumes modest investments in transit infrastructure to increase ridership by 50%. As Figure 11 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. 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.

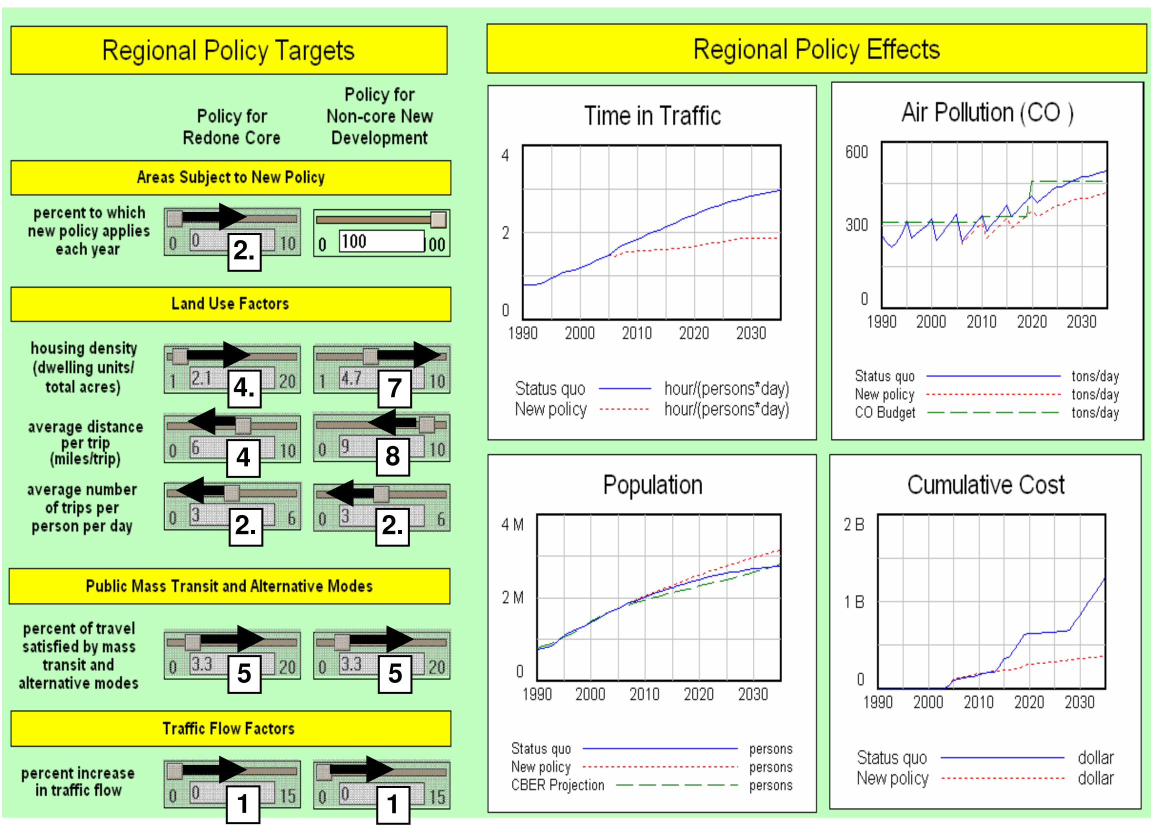


Figure 11. Best Practices Combination 1: Modest changes across the board

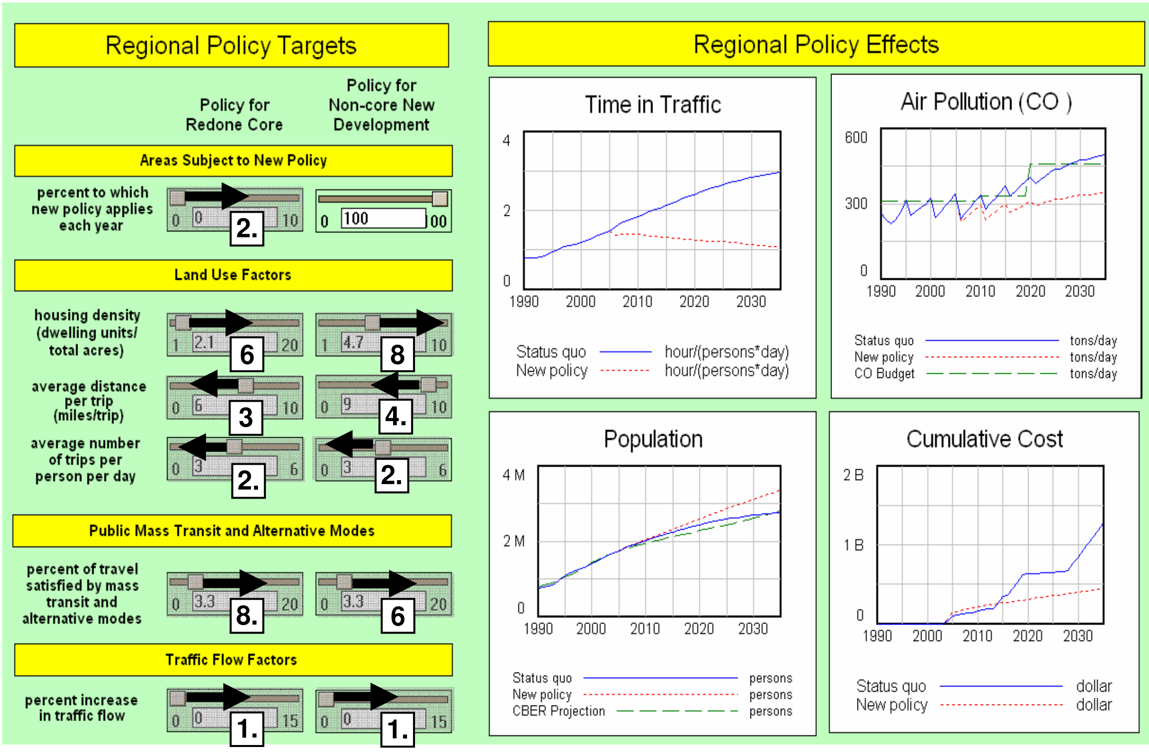


Figure 12. Best Practices Combination 2: Moderately aggressive strategy

Summary and Discussion

Use of the LUTAQ model for policy analysis produced several key findings. First, it underscored the general sense that if changes are not made in the way land and transportation system are developed, 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 9). 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 simply maintaining 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 focusing on increasing density alone leads to the following effects:

- 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 can lead to significant improvements.

Combination 1, with modest changes to all policy inputs (Figure 11):

- 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.

Benefits of Group Model Building

Most modelers would agree that the main goal of a modeling exercise is not the model, but the use of the model. For example, Rouwette *et al.* (2002) suggest that implementation of results and system improvement are primary goals of system dynamics interventions. There is a growing understanding, however, that the model building process can have significant benefits for the participants beyond, or perhaps even irrespective of, the model itself. One of the stated goals of this project was to better integrate land use, transportation, and air quality planning. The idea was that the model would be the means for the integration. But in this project, the process was at least as useful at improving integration as the model. The 20 or so regular participants in the group included land use planners, transportation modelers and planners, and air quality planners. In the beginning of the process, participants started out talking about the details of their parts of the system. Initial discussions of land use were focused on the subdivision level, spatial distributions of demographic and economic variables, and street networks. Transportation staff focused on the goal of reducing vehicle miles traveled and increasing mass transit ridership. At the same time, they complained that planning of large projects did not consider interrelated effects.

> "At the regional level, when they are considering a "big" project (1000 acres, for example), policy-makers never assess overall impact on traffic congestion and air quality – especially beyond the boundaries of the development – for example impact on under-designed roads that end-up being major ingress-egress to the development. The 'elected' people aren't making the connection between land-use and transportation and air quality. We are trying to get our elected officials to buy into ideas like increasing density along existing major transportation corridors."

By the end of the process, after working through causal diagrams of how their pieces fit together, the group was talking in a more unified way about the issues and their solutions. They shifted their perspective from their area of expertise to the system as a whole. They used concepts of feedback and interconnections to illustrate the points they made in discussions. And they were unified in their support for the model as a clear way to communicate the importance of the whole-system view to the elected officials and policy-makers. Group comments about the utility of the model include:

> "This shows that you can't simply do one thing, like increase residential density, and improve traffic congestion or air quality. You have to do a number of things all together."

> "This model is a worthwhile tool for communicating the issues to other people … and it's fun to use."

> "Most important message is: It is only by a combination of land use and transportation that we can achieve the three goals. This is what the model proves. We must use both. If you just use density – you won't get there."

> "I am really pleased with this model because planning has always been mostly an art for me. This links the pieces in a causal way. It quantifies the process. It puts science together with the 'coloring'."

"Some of the elected officials might say: We always knew this. The value of the model is:

1. It quantifies policy ideas and consequences
2. Lets us try out different parameters for 'investment' – and reveals the sensitivity of parameters. It tells you how to combine the variables to get what we want.

"It is flexible – If the elected officials don't like what we have done, they can work the model to come up with their own results."

The workgroup has developed the presentation that will be used to deliver the model to the Regional Planning Coalition board (to be presented in May 2006). The presentation includes a description of system principles and an overview of the model structure, as well as preliminary insights about the system that are emerging from the use of the model. The workgroup took the lead in developing the presentation, demonstrating that they understand the principles of seeing the system as a whole and accounting for feedback. Since the members of the working group report directly to the Planning Directors of the five municipal entities in the region or to senior level staff in the transportation and air quality management agencies, this fundamental increase in "systems thinking capital" is likely to have a greater long-term effect than simply the model itself.

References

Rouwette EAJA, Vennix JAM, van Mullekom T. 2002. Group model building effectiveness: a review of assessment studies. *System Dynamics Review* **18**(1):5-45

System Dynamics Review. 1997. Special Issue on Group Model Building. **13**(2):103-204

Acknowledgments

This project was funded by the Southern Nevada Regional Planning Coalition, the Southern Nevada Regional Transportation Commission, and the Applied Research Initiative of the UCCSN system with funds from the state of Nevada.