Table of Contents

Go Back

A Model to Support Stakeholder Evaluation of Transportation Policy Options in Las Vegas, Nevada

Krystyna A. Stave and Richard E. Little[1]

Abstract

This paper describes a group model building process conducted to help a stakeholder advisory committee develop policy recommendations for a regional transportation agency. Over seven months, we worked with committee members and the transportation authority's technical staff to develop a strategic-level model. The model reflects the group's definition of the problem and collective understanding of the system. The group's goal was to improve traffic congestion, flow and air quality over a 25-year planning horizon at the lowest system cost. Their final recommendation included a mix of policies with an estimated cost of $2.5 billion that achieved the greatest air quality benefit and significantly reduced congestion and increased flow. Participants were very positive about the model-based process, saying it was faster and "less painful" than similar processes they had participated in. This paper discusses several issues including the role group model building played in the stakeholder involvement process, limitations of the model, constraints on the process and factors that were critical to the success of the process.

Keywords: transportation policy; air quality; traffic congestion; group model-building, public policy; public participation

Introduction and Problem Statement

Traffic congestion, transportation problems and air quality issues are concerns for metropolitan areas all over the world. Las Vegas, Nevada, one of the fastest growing metropolitan areas in the U.S., is no exception. In the last decade, the population has grown by approximately 5% per year, from 780,000 in 1990 to over 1.3 million in 2000 (CCA, 2000). Traffic congestion has increased significantly and traffic-related air quality has worsened. Air quality degradation affects human health in the region and also feeds back to affect the transportation system because of the connection between compliance with federal air quality standards and federal funding for transportation projects. If air quality does not meet federal standards, the Las Vegas region's $80 million per year of transportation funding is in jeopardy.

In December 2000, the Board of Directors of the Regional Transportation Commission (RTC) convened an advisory group of 30 system stakeholders. The group was to meet once per month for a year. Their charge was to make recommendations to the Board at the end of the year

---

[1] Assistant Professor and Graduate Research Assistant, respectively. Department of Environmental Studies, University of Nevada Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-4030 (E-mail for corresponding author Stave: kstave@ccmail.nevada.edu)

about how the RTC should address the region's transportation problem. The advisory group included elected officials, representatives of the business community and tourism industry, environmentalists, bus riders, other public agencies, and community residents. Participants had no particular knowledge of the transportation system other than their observations as system users.

After initial meetings discussing the way the transportation system worked and the group's perception of what constituted the transportation problem, we were brought in to facilitate a group model building process. We had a team of three people. One, with considerable public participation experience, served as a liaison with the advisory group; the other two were the modelers. One of the modelers facilitated the group model-building process with the advisory committee members and the other worked closely with the RTC technical staff. The group model-building process is discussed in greater detail in a companion paper in the *System Dynamics Review* (Stave 2002). This paper focuses on the model itself and the group's use of the model for policy analysis.

Figures 1, 2, and 3 below show the problematic trends in traffic congestion, system-wide average speed (an indicator of traffic flow) and average daily carbon monoxide generated by the transportation system. These provide the reference modes that define the transportation problem. Figure 1 shows congestion, measured as system-wide traffic volume divided by system-wide capacity steadily rising until it reaches approximately .8 in 2025. System-wide average speed (Figure 2) decreases from about 35 miles per hour in 2000 to 30 miles per hour in 2025. Carbon monoxide production also increases. The preferred trend, or goal, for congestion is to at least maintain congestion at its 2000 level of 0.5, what the RTC estimates is a "free-flow" condition, and if possible, find ways to decrease congestion below its present level. For system-wide average speed, the preferred trend would be to maintain the current speed, or if possible, increase it. Congestion and average system speed are measures of the ease of mobility in the region. Worsening congestion and flow are undesirable. They affect not only the quality of life of the region's residents, but also affect the local economy. Air quality has a somewhat different role in that worsening air quality can have direct consequences on the region through the loss of federal funding for transportation projects and a loss of autonomy over population growth and land use management. The region must maintain CO below the federal standard. These three trends both define the problem and set the criteria for measuring the effectiveness of potential solutions to be tested by the model.

Model Development

System Conceptualization

The group defined seven main problem dimensions (shown as circles in Figure 4) from their initial list of concerns and several key measures of each dimension (hexagons in Figure 4). We worked with a subgroup of eight participants to develop and refine a causal map of the system from which the modelers created a basic stock and flow model. At this stage, we worked

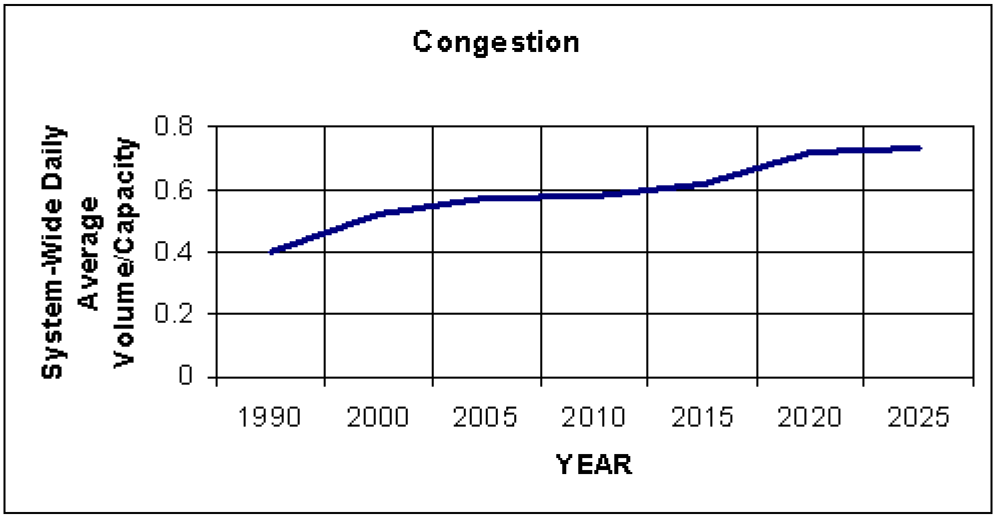

Figure 1. Reference mode for traffic congestion as indicated by system-wide average volume over capacity.

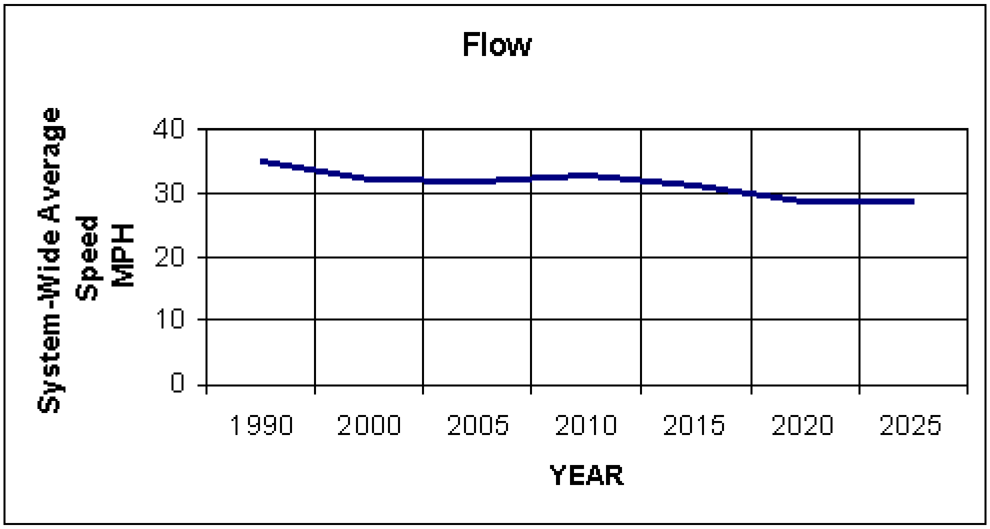

Figure 2. Reference mode for traffic flow, measured by system-wide average speed. Data and projections by RTC.

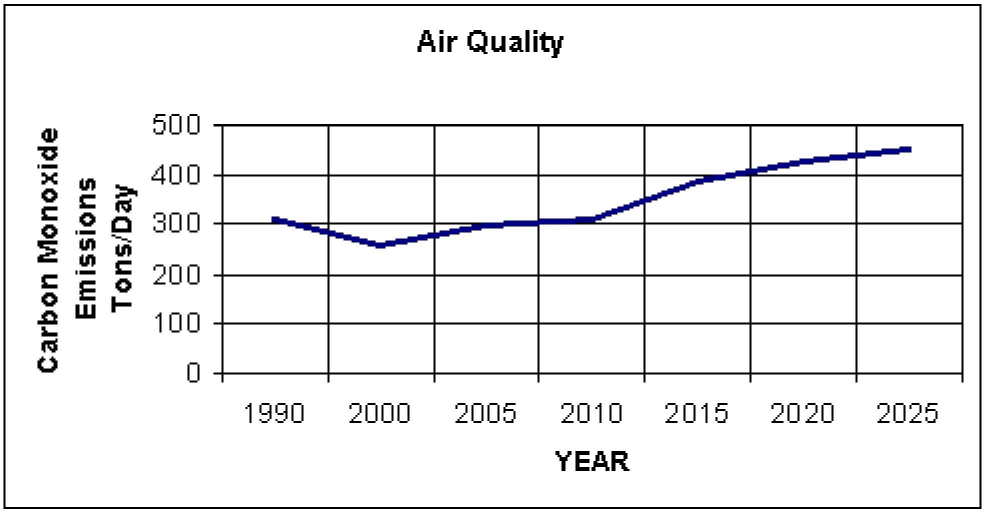

Figure 3. Reference mode for air quality as indicated by carbon monoxide emissions.

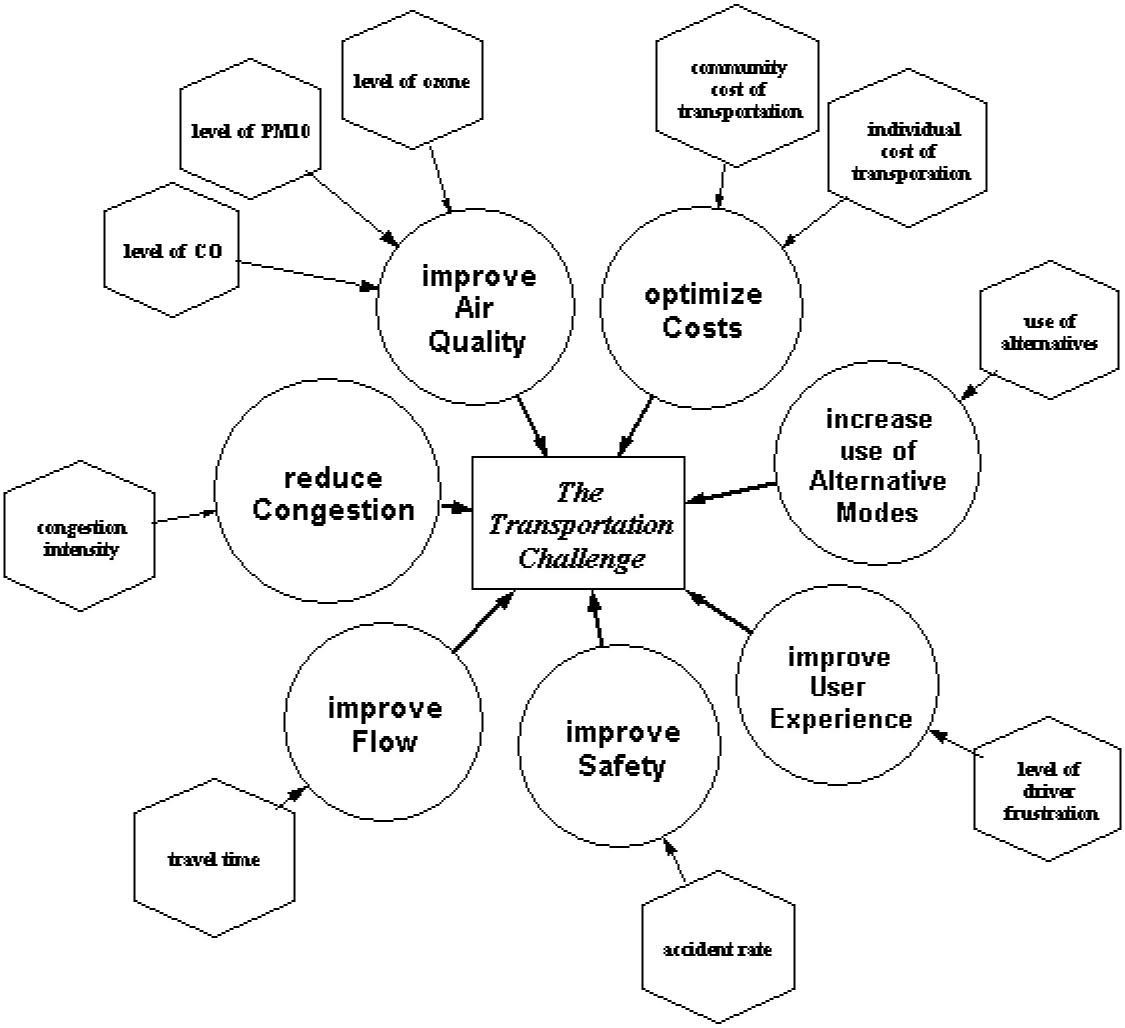

Figure 4. Initial definition of problem dimensions and measures (Stave 2002).

closely with the technical staff of the RTC to confirm the model structure and to determine values for system parameters.

In the course of discussions with the subgroup, full group and RTC technical staff, the seven dimensions were simplified to only four: congestion, flow, air quality, and cost. Figure 5 shows an overview of the model's causal structure.

System Structure

The model has seven subsectors containing 17 stocks as shown in Table 1. It was developed using Vensim® DSS (Ventana Systems 1988-2000a), and runs in Vensim® Model Reader (Ventana Systems 1988-2000b). Each subsector is represented on a different model

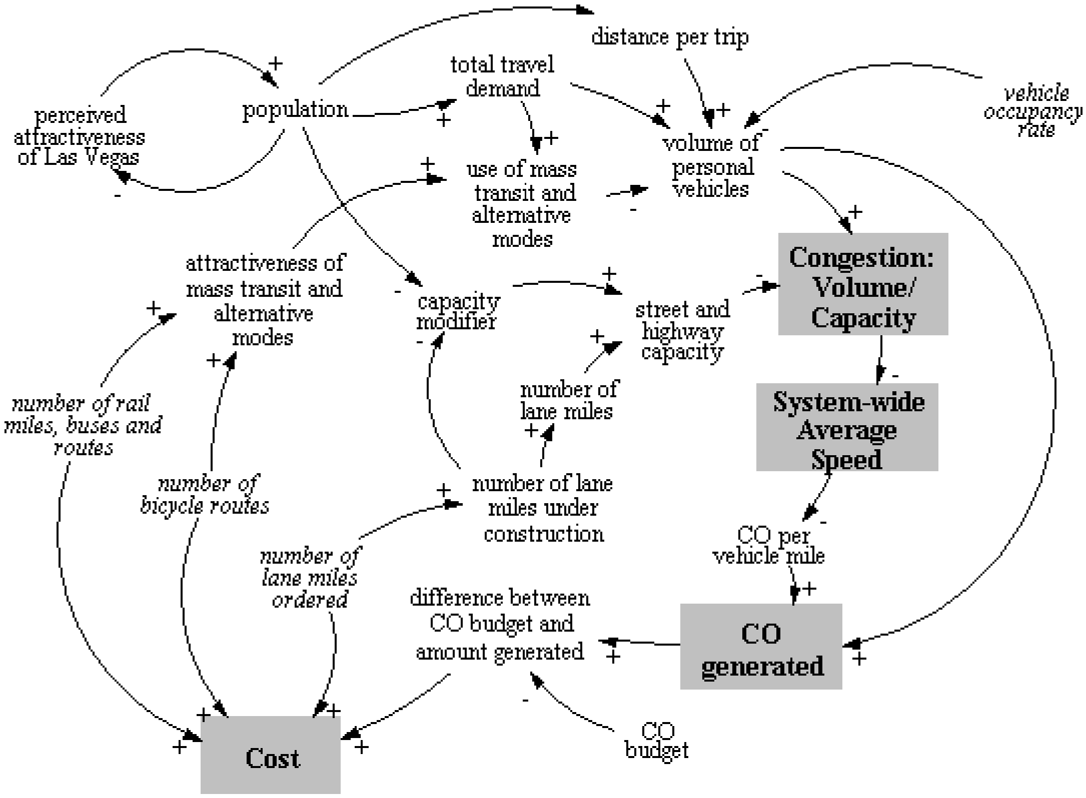

Figure 5. Overview of causal structure. Variables in italics represent policy options. Shaded boxes are output display variables (Stave 2002).

view. Figures 6 and 7 show the Demand and Capacity subsectors, respectively, for illustration. The model runs from 1990 to 2025, by year, with a time step of one day.

Table 1. Summary of RTC3 Transportation model structure.

Subsector	Stocks or Major Variables
Demand	Las Vegas Population (1 stock)
Capacity	Lane miles (6 stocks)
Mass Transit	Buses and Bus routes (4 stocks) Rail miles (2 stocks)
Alternative modes	Bicycle routes (1 stock)
Traffic management	Infrastructure (2 stocks)
Air Quality	Carbon Monoxide (no stock, calculated)
Cost	Cumulative cost (1 stock)

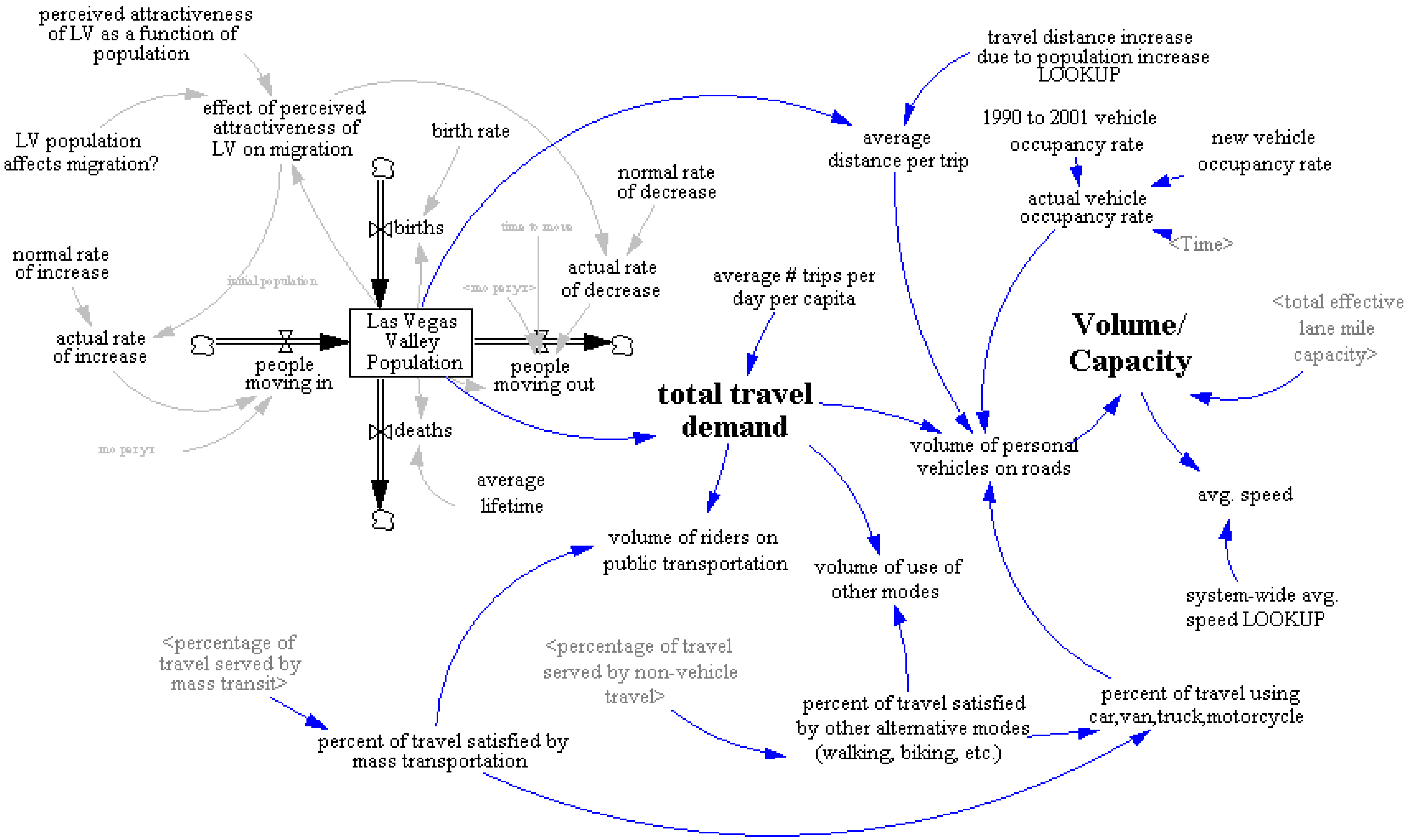

Figure 6. RTC3 Model – Demand Subsector

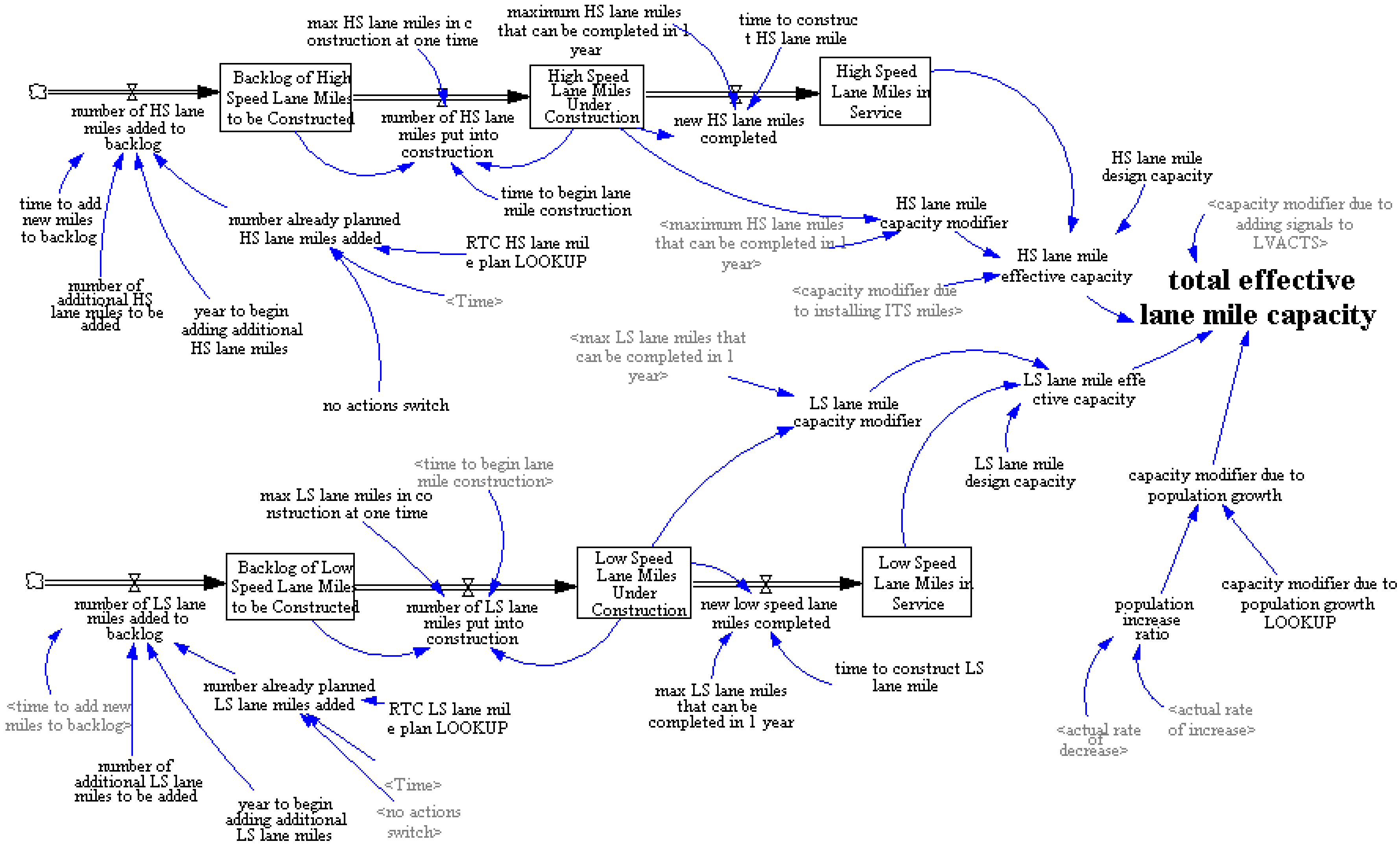

Figure 7. RTC3 Model – Capacity Subsector

Model Subsectors

Demand

The Demand subsector represents total travel demand as a function of population and average number of trips per capita. It calculates the volume of personal vehicles on roads, in vehicle-miles traveled, as the daily trips per capita times distance per trip, vehicle occupancy rate, and percent of travel using personal vehicles. Distance per trip is assumed to increase with population, representing the increasing spread of the metropolitan area.

Capacity

The Capacity subsector calculates the effective number of lane miles in the system. Effective system capacity is the total number of lane miles in service modified by friction factors due to population growth (which decreases capacity) and traffic management system infrastructure (which increases capacity). The model includes two kinds of lane miles – high speed lane miles such as freeways and major arterials, and low speed lane miles such as minor arterials and residential streets. The delay between the time that new lane-miles are ordered and put into service is represented by a chain of three stocks: backlog of ordered lane-miles, lane-miles under construction, and lane-miles in service.

Mass Transit

The Mass Transit subsector determines the total percentage of travel served by Citizens Area Transit (CAT) buses, Rapid Transit buses and rail. The amount of travel served by each of these modes is a function of their availability, which is the number of service hours for buses and number of miles in service for rail. The desirability of mass transit is limited in the model, based on studies done by the Texas Transportation Institute (TTI 2001) and communication with the RTC technical staff. Maximum possible mode share for regular buses is assumed to be 6%, for rapid transit buses, 5%, for rail, 6.5%, and for bicycle travel, 1.5% of total daily trips. The relationship between desirability and availability of mass transit was modeled with a lookup graph developed from RTC technical staff perceptions.

Alternative Modes

The Alternative Modes subsector accounts for the amount of travel served by bicycle routes.

Traffic Management

The traffic management subsector represents infrastructure that increases the capacity of the system by improving traffic flow. This model includes two kinds of traffic management infrastructure: intelligent transportation systems (ITS) and traffic signal coordination. This sector keeps track of the number of ITS signs in operation and the number of traffic signals connected to the Las Vegas Area Computer Traffic System (LVACTS) system. Traffic management infrastructure is assumed to increase lane-mile capacity.

Air Quality

Carbon monoxide is used as an indicator of overall Air Quality in this model. Carbon monoxide was chosen because it is the largest contribution of air pollution from the transportation system. The amount of CO generated each year by vehicles is calculated as a function of vehicle miles traveled in that year and the average CO contribution per vehicle mile, which fluctuates according to the average system-wide traffic speed. CO contributions per mile change every five years to reflect expected changes in vehicle fleet composition and improvements in emissions reduction technologies. CO was used as a proxy for all transportation-related air quality parameters. It was assumed that other vehicle-related parameters such as volatile organic carbons and nitrous oxides would follow similar trends and be affected similarly by policies.

Cost

The model calculates the total additional cost of the scenario each year and keeps track of the cumulative cost over the course of the simulation run. Costs in any given year are the total of capital costs incurred that year (for roads constructed, buses bought, or rail miles completed, for example) plus operational costs (per bus route, or for road maintenance), plus the cost of lost federal funding ($80 million) if CO produced by vehicle travel in that year exceeded the CO budget in that year. The output of the cost sector represents only the additional system costs. The Southern Nevada Regional Transportation Commission has established and budgeted for all capital and maintenance costs associated with all transportation expenditures through the year 2025.

Input/Output Interface

The model's custom input/output "dashboard" is shown in Figure 8.

Model Parameters

The data for this model came from the Regional Transportation Commission's technical staff. The Texas Transportation Institute's 2001 Urban Mobility Report (TTI 2001) provided background information about transportation issues in other parts of the U.S. that helped determine model equations. Specific data about Las Vegas came from several RTC about transportation demands of the resident and tourist communities (RTC 2000, RTC 1996 RTC 1995). In addition, the RTC collects data about transportation behavior to verify survey data and the predictions of modeling tools used by planning staff. Model parameters are based on data compiled from these RTC sources and personal communication with RTC technical staff.

Model Validation

Figure 6 shows the model output for the base run, a "do nothing beyond what is currently planned and funded" scenario. The output shows the same trends as shown in the reference mode graphs (Figures 1, 2, and 3). The first 11 years of the reference modes represent the historical trends and the next 14 years are the calculated projections. The output from the validation run shows a volume/capacity ratio that increases from .4 to .8 during the 25 year simulation run. This output matches the historical and predicted data for Southern Nevada. It supports the contention that the model contains the essential system structure responsible for generating the problematic behavior.

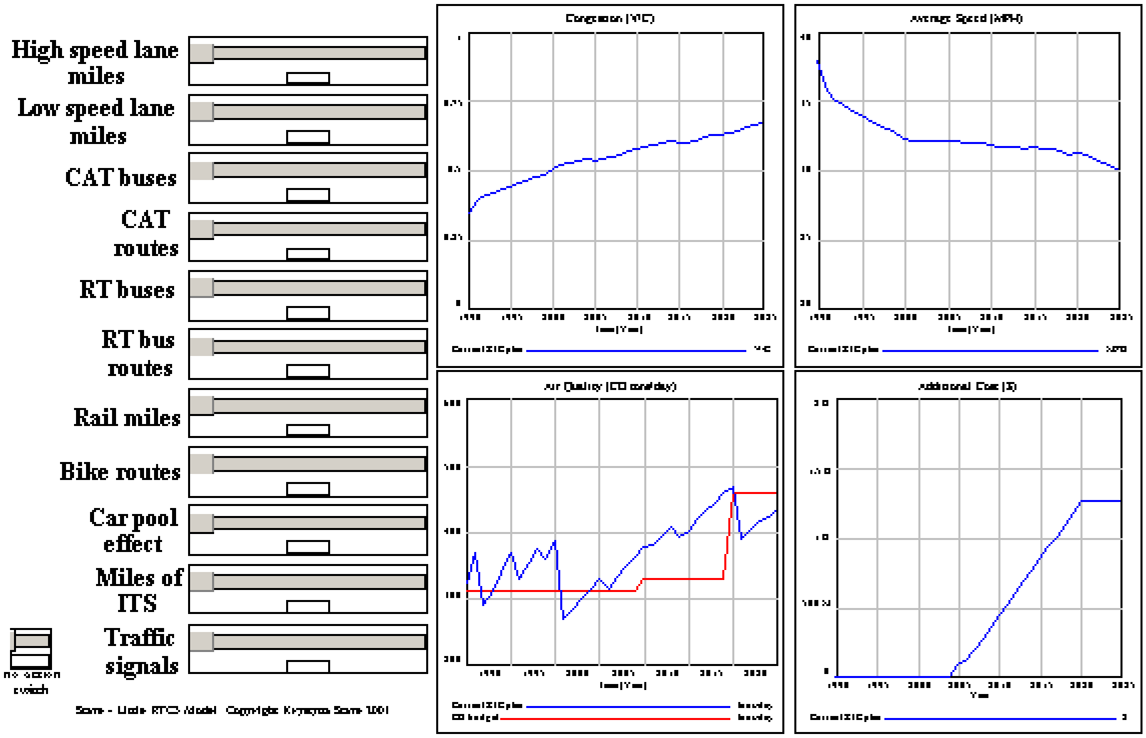

Figure 8. Input/output screen showing results of the base run scenario. The red line on the Air Quality graph shows the carbon monoxide budget, the daily average transportation-related amount Las Vegas is allowed to produce according to federal regulations.

Policy Analysis

The group first asked to see model output for each policy option separately , then ran a series of policy scenarios combining different policy levers. The key scenarios that were compared are shown in Table 2. The first scenario they ran was the validation scenario. This scenario is referred to by the RTC3 as the "current plan" because it represents the transportation planning and budgeting for the Las Vegas Valley through the year 2025. This plan includes an increase in roads, bus service, rail service, traffic management systems, and vehicle travel alternatives such as bike paths and car pooling. Because all of these improvements and additions are incorporated into the model, this scenario is run without any changes to the input variables. The additional costs of this scenario are approximately 1 billion dollars which result from the loss of federal funding tied to air quality violations.

Maximum Scenario – Needs Assessment

Throughout the RTC3 process the full group was presented with information about the transportation system as well as the planning efforts in place to address the system. One concept presented to the group was known as the "unfunded needs assessment," which presents all of the system upgrades that could be made, but which are not funded. In other words, the needs assessment is a wish list that would have to be paid for by local money that does not presently exist. This scenario (represented as Scenario 2 in Table 2) provided for system upgrades of all types, from additional lane miles to an increase in bus and rail service as well as traffic management systems and bike lanes. The only parameter that is not altered in this scenario is the vehicle occupancy rate or carpool effect, which is maintained at its current level.

The results of this scenario show significant improvements in congestion and air quality but with a cost in excess of 6 billion dollars, which the group considered to be politically prohibitive and unattainable. As a result, the RTC3 felt that the cost made the maximum scenario unacceptable.

Minimum Scenario – "Should Do

With such a high cost associated with the wish list of the needs assessment, the RTC3 wanted to generate a scenario that would provide the system with the basic necessities for improvement while maintaining the lowest cost. The variables and values for the "should do" scenario were the product of repeated model runs and associated deliberations, which provided new suggestion for model inputs and continued investigation of system structure and function. It was decided by the group that a "should do" scenario would involve the lowest cost system upgrades that would be considered as obvious necessities by the average voter or system user. The parameters selected, listed as Scenario 3 in Table 2, consisted of traffic management options, bike lane additions and an increase in vehicle occupancy, which represents an increase in car pooling.

The minimum scenario showed a cost of one billion dollars, the bulk of which comes from air quality violations. While the minimum scenario did not have as great an effect on congestion as the maximum scenario, the two scenarios were actually quite similar in the trends as well as the final outcomes. The maximum scenario ended with a system wide volume/capacity ratio of approximately .5 and the minimum scenario ended with a .55 volume/capacity ratio. Air quality was also similar, but the maximum scenario stayed below the violation limits for all but two years, while the minimum scenario exceeded the limits for 10 consecutive years.

The results of the minimum scenario provided the RTC3 with a considerable amount of information and feedback about the system as well as additional questions. After seeing the results of the minimum scenario and comparing them to the results of the maximum scenario the group wanted to understand why the results were so similar and yet the costs were so disparate. The group wanted to understand and develop a mid-level scenario that could achieve an improvement in the traffic system as well as an improvement in air quality compliance.

Mid level Scenario

Based on the comparison of the minimum and maximum scenarios, the group felt that a mid-level scenario should be developed, which addresses both traffic congestion and air quality, while still costing far less than the maximum scenario (Scenario 4 in Table 2). Additional roads, bus service and rail service were included in this scenario at reduced levels from the maximum scenario. Traffic management options, bike lanes and carpooling were all included at the maximum levels thought to be possible for the Las Vegas Valley.

The mid-level scenario demonstrated a volume/capacity trend that improved over the maximum scenario during the middle seven years of the run, and then slightly exceeds it towards the end. In the area of air quality both the mid-level and maximum scenarios show compliance for most of the model run, with almost identical time periods of violation near the end of the run, and then returning to compliance for the remainder of the run. The cost of the mid-level scenario is approximately 2.5 billion dollars.

Table 2. RTC3 Scenarios

				SCENARIOS				
Policy Lever	**Net Capital Cost per Unit**	**Net O&M Cost per Unit per year**	**Max Value**	1 **RTP** 2000-2025	**2 Needs**	**3 X "Should-do"**	**4 Y Mid-level**	**5 Z Needs + Carpool**
High speed Lane miles	$ 2 M/mi	$ 35,000/mi	1,000	608	850		425	850
Low speed lane miles	$ 1 M/mi	$ 35,000/mi	1,000	2243	0		0	0
CAT buses	$ 80,000/bus	—	500	199	455		225	455
CAT routes	—	$ 480,000/ route	100	24	15		7	15
RT buses	$ 180,000/bus	—	100	25	24		12	24
RT routes	—	$ 480,000/ route	30	5	4		2	4
Rail miles	$ 24 M/mi	$ 600,000/mi	250	6	80		19	80
Bike routes	$105,350/mi	$7,000/mi	1,000	462	400	300	400	400
Carpool effect	—	$35.4 M/1 person incr	1.65	1.32	1.32	1.4	1.4	1.4
Miles of ITS	$425,000/mi	$3,000/mi	200	130	20	70	70	20
Traffic signals	$ 250,000/ signal	$ 3,000/ signal	350	0	350	350	350	350
COST				**$1.5 B**	**$6 B**	**$1 B**	**$2.5 B**	**$5.5 B**

Policy Analysis Summary

The workgroup presented the five scenarios shown in Table 2 to the full group and suggested that the group recommend the Mid-level scenario. Members of the full group were concerned about the cost, so they made several suggestions for modifying the mid-level package. When none of their ideas decreased the cost without making air quality or congestion worse, they agreed to recommend the mid-level scenario. Figure 9 shows the output for all five scenarios.

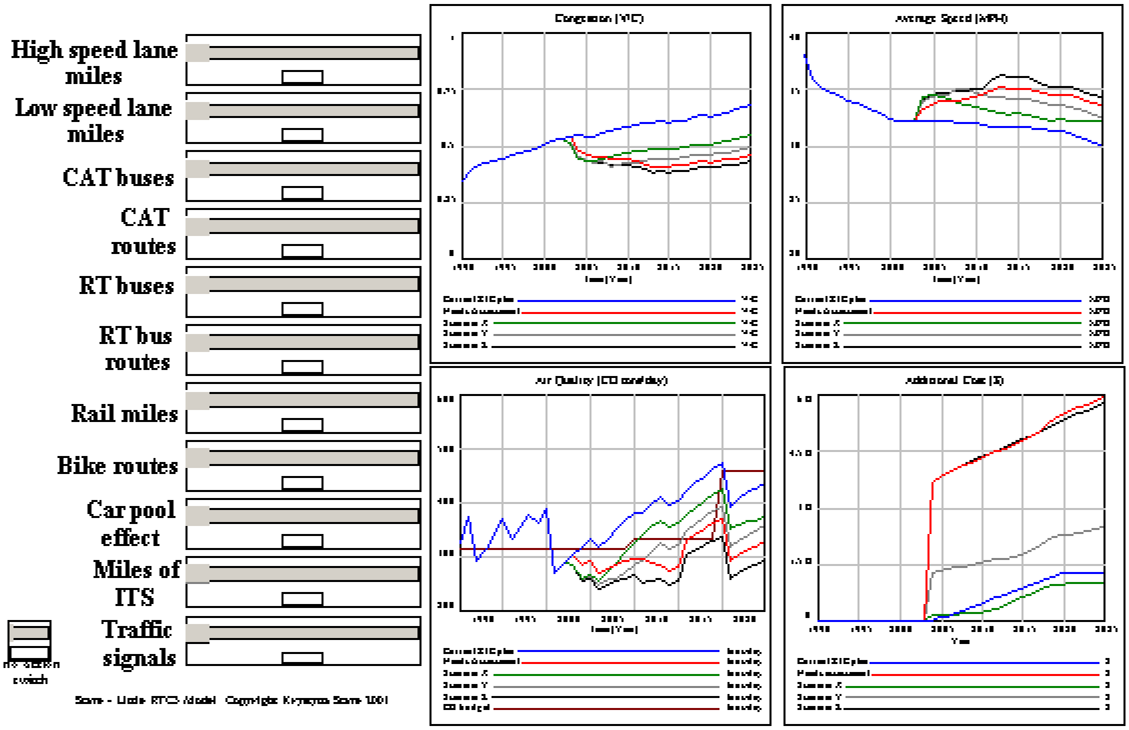

Figure 9. Results of policy scenario tests.

Discussion

This model is relatively simple. It reflects the charge of the advisory group and the limited time frame. The purpose of building and using the model was strategic problem-solving and education, not optimization or operational-level planning. The model served several purposes: to increase participant understanding of how the transportation system works, to organize a large amount of information, to build a shared basis for policy identification and evaluation among advisory group members, and to provide a tool for comparing the relative merits of suggested policy scenarios. Thus, although some system feedback is represented in the model, the most valuable feedback in this case was in the process, not the model. As the group used the model to test policies, they would respond to the output with discussions of how the result was generated and what effect different policies had. The members of the group were refining their knowledge of the system at the same time they were working with each other to develop a common idea about what to recommend. Stave (2002) describes in greater depth the role the model played in group discussions.

We had strong support from the RTC technical staff for developing this simplified model. Several members of the staff remarked they were very pleased to have a simplified tool for communicating the complexities of the system to others. They use models extensively for planning, but their models are much more detailed and are not useful for general communication. Even with the support of the technical staff, however, determining parameters for the simplified model was a challenge because the RTC works at a much more disaggregated level. For example, the RTC defines 12 different kinds of lane-miles. Summarizing these categories into the two we used in the model required decisions about how to combine the RTC categories in a way that was accurate, yet maintained important distinctions such as design capacity. In addition, some of the parameters we needed are uncertain. There is little information about the relationship between mode share and availability of mass transportation, for example. We had to rely on the perceptions of the RTC staff to generate this relationship. If we had had more time to develop the model, we would have confirmed the assumptions embedded in these lookup graphs with the advisory group participants.

Two major constraints on the level of sophistication of the model were the nature of the advisory group members and the limited time available for the entire process. The group members were all volunteer participants with other full-time jobs. Some participants were familiar and comfortable with computer models; others were familiar with but skeptical of models. Some had no familiarity with models but were curious, and others were suspicious or wary of any technology. Since it was important that the model be accepted by as many of the participants as possible, we had to keep the model relatively simple. In addition, the advisory group process was constrained to 12 months. Since we did not start working with the group until the fourth month, we had only seven months, meeting only 2-4 hours per month with the workgroup to develop a working model. The first several months were spent identifying the problem and developing the causal structure, which left only about ten weeks for development of the structural model and parameterization.

In spite of the model's simplicity and level of aggregation, the model and model development process served several key functions for the group. As described in Stave (2002), it provided a structure for organizing and connecting a large amount of seemingly unrelated chunks of information that were new to most of the group members, keeping track of where the process was going, setting boundaries for the types of policy options that were possible, documenting the activity of the group, and identifying and evaluating policy scenarios. The model provided a neutral framework for discussion and generated insight through behavior that was surprising to the group. One of the surprising findings was the importance of the vehicle occupancy rate, which can be influenced by carpool incentive programs. When the model showed that increasing the occupancy rate alone could have as much of an effect on the problem as the most expensive road-building and mass transit enhancement program, participants decided that even if carpooling might not be a popular idea, carpool incentives should be part of any policy scenario recommended. Perhaps the most useful insight was that, as one participant put it: "it is clear the best we are going to do is keep the system from getting worse." An RTC staff member said "people seem disappointed that they can't find the silver bullet, but I'm not. What this shows is there *is* no silver bullet" (Stave 2002). He felt that this made the group take the problem seriously and that it made them more committed to convincing others to take it seriously.

References

Clark County Assessor (CCA). 2000. url:http://www.co.clark.nv.us/assessor/Census.htm#Clark County Population.

Regional Transportation Commission (RTC). 1995. Las Vegas Regional Travel Demand Model Documentation Report Update 1995. Regional Transportation Commission of Southern Nevada. Government Center, Las Vegas, NV .

RTC. 1996. Las Vegas Valley Household Travel Survey.

RTC. 2000. Transportation Modeling Summary. Regional Transportation Commission of Southern Nevada, December 2000.

Stave, K.A. 2002. Using system dynamics to improve public participation in environmental decisions. *System Dynamics Review* 18 (2).

Texas Transportation Institute (TTI). 2001. The 2001 Urban Mobility Study. Texas Transportation Institute. Texas A&M University System. College Station, Texas.

Ventana Systems, Inc. 1988-2000a. Vensim® DSS32 version 4.2a. ©1988-2000a. Ventana Systems, Inc., 60 Jacob Gates Road, Harvard, MA 01451

Ventana Systems, Inc. 1988-2000b. Vensim® Model32 Reader version 4.2a. ©1988-2000b. Ventana Systems, Inc., 60 Jacob Gates Road, Harvard, MA 01451. Available from www.vensim.com.

Back to the Top