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Using a systems dynamics approach to determine what can be done to minimize ozone production

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Abstract

Ground level ozone is an air pollutant that affects people of all ages and origins in many urban areas including the Las Vegas Valley. The purpose of this study is to examine the best strategy to minimize tropospheric ozone generation through using a system dynamics approach via LUTAQ is used to formulate a solution to the reduction of ozone in the Clark County non-attainment area. By increasing housing density, decreasing average distance per trip, and decrease average number of trips per person per day is the most effective strategies to improving ozone levels in Las Vegas Valley.

Problem Statement

Clark County was designated as a noncompliance area by the EPA in July of 2004 when the Joe Neal station exceeded the 8-hour Ozone National Ambient Air Quality standard (Rogers, 2004: p.12B). Therefore Clark County is a non-attainment area for the air pollutant ozone. Clark County Department of Air Quality and Environmental Management (2004) reports, "Section 107(d)1(A)(i) of the Clean Air Act defines non-attainment as '*…any area that does not meet (or that contributes to ambient air quality in a nearby area that does not meet) the national primary or secondary ambient air quality pollutant...*" (p.1). This becomes an important issue because it poses health hazards to people in the valley and the cost of reducing ozone is currently estimated as high. When the county is not in compliance with the national standard, funding for the county is depleted. Ozone is a gaseous molecule that contains three oxygen atoms (O_3). It can protect earth from ultraviolet rays while it exists high in the atmosphere, or close to the ground, where it is the main ingredient of smog. Ground-level ozone is a product of reactions involving volatile organic hydrocarbons and nitrogen oxides in the presence of sunlight. I will be focusing on the layer of ozone in the troposphere more commonly referred to as ground level ozone. Ozone that is associated mostly with urban areas is an air pollutant referred to as ground level ozone, also known as "bad" ozone. O_3 usually occurs 50-100km from the city center but in some situations further downwind is where the peak may be found (Sillman, 1999).

The purpose of this study is to examine the best strategy to minimize tropospheric ozone generation through a system dynamics model. This pollutant is not given off from simply one source, it is caused by a chemical reaction of compounds given off from other sources and then released in the air. Smog is made up of natural atmospheric gases including ozone, nitrogen oxides, volatile organic compounds (VOCs), and particulate matter. According to the Environmental Protection Agency (USEPA, 2004a) cars release most of the VOCs and nitrogen oxides from the combustion in the engine. Other sources of NO_x and VOC include: large industry and combustion sources such as utilities, small industry such as gasoline dispensing facilities and print shops, consumer products such as paints and cleaners, off-road engines such as aircraft, locomotives, construction equipment, and lawn and garden equipment (USEPA, 2004a). On a hot summer day, such as we experience in Las Vegas, the sunlight reacts with the VOCs and nitrogen oxides released from cars and ozone is formed. Ozone makes a huge contribution, therefore is the main ingredient to the smog we experience in Las Vegas Valley. Thus on a summer day in Las Vegas where temperatures exceed 100 degrees Fahrenheit and with little to no breeze the smog is very heavy and visible to us even while we sit in the valley. Health risks to the people of the Las Vegas Valley may include: aggravation of the respiratory system, decline of lung function, stimulation of asthma, agitation and harm to cells that line lungs, and lasting lung damage. Children, elderly people, people who are very active outdoors, and people who suffer from a form of respiratory system disease are at the highest risk. In 2003 Clark County showed ten days of violation of the ozone standard and eight of those days were in the Las Vegas valley. A national air quality guide was established by the Environmental Protection Agency (EPA) that allows people to look up and assess the air quality of that day and who is at risk.

Background

Air Quality Regulations

The U.S. Environmental Protection Agency (1993) states, "The Clean Air Act is the comprehensive Federal law that regulates air emissions from area, stationary, and mobile sources. This law authorizes the U.S. Environmental Protection Agency to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment." This act was passed in 1970 to reduce pollution in each state on an individual basis. Later this act was amended because the country had failed in the effort to reduce air pollution so a revised edition needed to be introduced. So in 1977 new dates to achieve the NAAQS were to be set. Finally in 1990 the Clean Air Act was completely revised and for the better of humans and their environment. Under the new and improved Clean Air Act states do most of the work, because State Implementation Plans aim to reduce pollution in each state. This makes sense simply due to the fact that each state is more familiar with housing, geography, and industry at the local level. An example is each state will hold a hearing or fine a company who exceeds the set air quality standard. Each State Implementation Plan must be approved through the EPA because they are responsible for enforcing the Clean Air Act in the entire United States. Therefore the organization governs the amount of pollution in the air in the United States, thus each state must meet the EPA regulations. A state may make its laws more stringent, but can definitely not be weaker than the federal air quality standards.

Also more realistic deadlines were introduced in 1990 to reduce air pollution for states. In the previous law unrealistic deadlines were made and were impossible to meet so violation after violation occurred resulting in little to no success rate. The public has now been given the opportunity to participate and educate themselves more on the air pollutants that are out there and what they can do about them. And if they feel that regulation standards are not being met or if they have ideas they are encouraged to take part in hearings and participate in local programs.

Finally, companies are offered economic incentives to efficiently clean up air pollution at low costs.

These areas of the 1990 Clean Air Act Amendments were put in place to achieve the 8 hour ozone standard implemented by the EPA to reach each state on an individual basis. In 1979 0.12ppm was the limit measured in a one hour period, but by 1997 this limit was revised and 0.08ppm measured and averaged over an 8 hour period was the new standard. In general, the 8-hour national ambient air quality standard is more protective of public health and more stringent than the 1-hour standard, and there are more areas that do not meet the 8-hour standard than there are areas that do not meet the 1-hour standard (USEPA, 2003). Clark County has been designated a non-attainment area, thus the county must come up with a plan to comply with the new 8 hour standard. A large region in the southern portion of the county and Moapa and Apex Valleys are parts of Clark County that do not meet the new ozone standard. Figure 1 shows the Las Vegas non-attainment area does not fill up Clark County. The region of non-attainment exceeds over half of the area. After assessment by the EPA and Clark County the decision was made to not make the whole county one area. Even though it is smaller now it is still one of the largest non-attainment areas in the country covering 8,000 sq miles.

Ozone: What is it?

The U.S. Environmental Protection Agency (1993) clarifies, Nitrogen oxides make up nitrogen and oxygen that are highly reactive gases in amounts that may change. Nitrogen oxides accumulate mostly in the air above major urban areas such as cities in the layer most label as smog and form through a chemical reaction involving oxygen with a favor to high temperatures. Most nitrogen oxides are not only colorless, but one can’t smell them either. Motor vehicles, electric utilities, and other commercial, industrial, and residential sources that burn fuels are the main sources of nitrogen oxides.

Hydrocarbons which contain hydrogen and carbon, along with nitrogen oxides and sunlight reach to form ozone. These can be found in three different forms which such as gas, tiny particles, and droplets. Hydrocarbon pollution is produced when unburned or partly burned fuel is emitted from the motor as exhaust, and fuel is simply evaporated. Gasoline and diesel is the common power for most engines in vehicles which are hydrogen based. Therefore this pollution is found in a significant amount in typical urban areas where there is a surplus of motor vehicles and industrial processes.

Oxygen usually consists in the form of two atoms, but when it is found in a group of three, ozone is the compound. Ozone is found as a gas and can pose a threat because of the amount of danger it poses to the health of the environment. This pollutant is found once a chemical reaction has taken place it is not simply emitted from one source. These sources can include chemicals produced by chemicals found in products such as hair sprays, paints, gasoline, solvents and burning coal, and other fuels with the addition of sunlight.

Ozone Formation

STEP 1 $O_3 + h\upsilon + H_2O \rightarrow O_2 + 2HO\bullet$

Through the destruction of an ozone molecule can be how ozone forms. Ozone (O_3) is broken down when reached by ultraviolet light ($h\upsilon$), better known as sunlight. IT then has the option to form $2HO\bullet$, where "•" is a radical (a compound with an unpaired electron) which makes them very reactive.

STEP 2 $2HO\bullet + 2R\text{-}H + 2\,O_2 \rightarrow 2RO_2\bullet + 2H_2O$

Volatile organic hydrocarbons are represented as R-H in the equation above, where R in $2RO_2\bullet$ is the rest of the volatile organic hydrocarbon molecules. So, when volatile organic hydrocarbons are in the air from sources such as car exhaust, each OH and O_2 radical will react with them to form peroxy radicals.

STEP 3 $2RO_2\bullet + 2NO \rightarrow 2NO_2 + 2RO\bullet$

Nitrogen oxides (NO) are found in car exhaust. The radicals formed in STEP 2 will react with NO to form NO_2.

STEP 4 $2NO_2 + h\upsilon \quad 2NO + 2O$

NO_2 is broken down by hυ forming nitrogen oxides.

STEP 5 $2O_2 + 2O \rightarrow 2O_3$

Finally ozone is formed because of the oxygen formed in STEP 4 combined with the remaining oxygen in the presence of NO_2 which will make the product stable by removing excess energy. Since ozone requires NO, VOC, and sunlight STEP 3-5 will reoccur as long as NO is found in STEP 4(Washington State University in St. Louis Chemistry, 2004). As you can see ozone is created through the aid of two main precursors and these include NO_x and VOC's. In areas that are NO_x sensitive little difference is shown with response to VOC. However, in VOC sensitive areas, ozone decreases with increasing NO_x and increasing VOC. At the start of ozone formation VOC emissions establish the rate of first initial build up of ozone and NO_x emissions establish the full amount of ozone in an urban area (Sillman, 1999). Periods of 24h, 12h, and 6h begin to appear because, not only does ground level ozone need both precursors, it also needs sun radiation (Schlink, 2000). A natural process of ozone removal is referred to as

NO_x titration. This will take place when Nitrogen Oxide (NO) is emitted and then reacts quickly with Ozone (O_3) to create Nitrogen Dioxide (NO_2) or $O_3 + NO \rightarrow NO_2$. This reaction over powers $NO_2 + h\upsilon \rightarrow NO + O$ at night because the sun radiation is absent. Also a large amount of ozone may be removed in the early morning hours due to the large accumulation of the NO through out the night. In most urban areas this rate is minimal relative to ozone production. Titration takes a toll on ozone at night because there is no ozone formation. This process also dominates during winter because ozone production has slowed because of loss of some sun radiation (Shlink, 2000 & Sillman, 1999)

Ozone & Smog Relationship

The most important urban air pollution problem is photochemical smog. Hydrocarbons (HCs), their oxidation products, and oxides of nitrogen (NO_x), in a few hundred meters of air above our major cities, react in the presence of sunlight to produce strongly oxidizing compounds of which ozone is the most prevalent (Calvert, 1993). Therefore ozone is the main ingredient to smog that hovers over major cities. The chemical reactions that occur to form ozone also aid in formation of smog along with the chemicals and gases that are reacting and accumulating as well. As temperatures decrease, the chemical reactions are slowed and smog is seldom formed. When the sunlight is reduced or becomes absent ozone cannot form. Ozone and smog formation is thus a daytime phenomenon that occurs simultaneously.

Past efforts to Control Ozone

According to J.G. Calvert et al. (1993), "despite the major regulatory and pollution control programs of the past 20 years, efforts to attain the National Ambient Air Quality Standard for ozone largely have failed." With many in agreement in 1990 Congress passed a new set of Amendments to the Clean Air Act to accomplish more speedy improvement. Significant improvements have been made, but this by no means equals achievement. One important improvement is the production of lower emissions from motor vehicles through maintenance and increased technology from the manufacturer of motor vehicles. The methods that have been used have only been about half as effective in making improvements to urban air quality as they were designed to be. It is estimated that 39%, with three quarters of the increase in ozone in the troposphere, is due to human activity (Levy II, 1997). From July 11, 1995 through July 15, 1995 the highest O_3 levels were observed in Middle Tennessee during a period of air stagnation (Valente, 1998). This was 65 ppb over the regional average. When gentle winds and soaring solar radiation were observed during the study it produced an air stagnation event highly complimentary for photochemical ozone production resulting in the peak concentrations of ozone. Ozone (O_3) is prevalent in photochemical smog and most major cities have smog check stations to attempt to mitigate the contribution of hazardous compounds that are released into the air.

One of the most dominant sources of air pollution is motor vehicles. Presently in the United States motor vehicles are responsible for at least half of the smog-forming VOCs and nitrogen oxides (USEPA, 2004a). The EPA has required cleaner fuels, cleaner cars and inspection and maintenance programs on these vehicles. More people are driving more miles on more trips. In 1970, Americans traveled 1 trillion miles in motor vehicles, and we were expected to drive 4 trillion miles each year by 2000 (USEPA, 1993a).A study was performed in California in 1991 which identified 66,053 vehicles that revealed a lower number of vehicles accounted for a higher production of pollution. It is important to note that the gross polluters are not simply just the older vehicles, but in fact are all model years of vehicles. A gross polluter is a significant source of smog emissions. Beaton (1995) states, “The study found that the highest emitting 20% of the newest cars were worse polluters than the lowest emitting 40% of vehicles from any model year, even those from model years before the advent of catalytic converters”(p. 991). The study used two remote sensors at two separate urban locations that were designed to identify gross polluters or a significant producer of emissions. These sensors identified 58,063 polluting vehicles and 307 of them were pulled over and a voluntary Smog Check was administered. 126 vehicles of the original 307 which is equivalent to 41% displayed intentional alterations. Also 25% or 77 vehicles had flawed parts that was most likely not intentional. Each individual vehicle had official registration, but only a total of 8% or 25 vehicles passed the California Smog Check inspection (Beaton, 1995). It is evident that on-road emissions must be reduced in a more effective way.

Problems with the efforts

We must not focus all of the money and attention on new vehicles, but be aware of the facts of the study above and focus more attention and money on maintenance on vehicles that are of all ages, even if just a year old. An Environmental Protection Agency model argues that to replace an older vehicle with a newer vehicle, even if it is only one year newer it will produce lower emissions. If an older vehicle is replaced by a newer vehicle it is likely to only be beneficial if the older vehicle was a gross polluter.

Calvert et al. (1993) says, “The emission rates have not been reduced as to the extent that was expected. The number of miles driven in major urban areas has gone up, and the emission rate is the product of grams per miles and miles driven” (p.39). Notice Figure 2 which illustrates that on a per car basis, progress looks promising. But taken a more informed look the graph shows that vehicle miles traveled are increasing offsetting the progress of reducing the amount of vehicle emissions, even though today's car has about one half to one third the amount of NO_x emissions. Reducing emissions of ambient ozone precursors NO_x and VOC (and CO), is the the only way to minimize ozone (Sillman, 1999). This raises many health concerns and environmental concerns and is beginning to raise eyebrows in the Las Vegas Valley. As mentioned before Clark County was designated as a noncompliance area by the EPA in July of 2004 when the Joe Neal station exceeded the 8-hour ozone standard. As shown in Figure 3, fourteen stations located in Clark County monitor the amount of ground level ozone in the specific area. Figure 4 shows a graph of each of these stations exceeding the 8-hour standard in only one hour, thus being 85ppb. In Rogers (2004) article he states, "Clark County officials now have three years to submit an acceptable plan for curbing ozone. If they fail, the county could be forced to institute tougher controls on diesel equipment and vehicles, create ride-sharing programs, require the sale of cleaner-burning gasoline during the summer"(p.1a). Sillman (1999) states, "Reductions in VOC will only be effective in reducing ozone if VOC-sensitive chemistry predominates. Reductions in NO_x will be effective only if NO_x–sensitve chemistry predominates and may actually increase ozone in VOC-sensitive regions" p.)

Goal: Reduce Vehicle Miles Traveled

I hypothesize that since air quality can be reduced via number of vehicle miles traveled that for Las Vegas Valley the most effective land use and transportation strategies for reducing vehicle miles traveled will be increase housing density, decrease in average trip distance, and decrease in average number of vehicle trips per person per day. According to the EPA (Figure 6) the national average is 56% of all NO_x and 45% of all VOC is produced from motor vehicle emissions. Twenty five years prior to 1993, urban miles traveled in the United States increased by 100%. So the decrease in car emissions is offset by the in increase in miles driven (Calvert, 1993). According to the Clark County Department of Air Quality and Environmental Management (2004), “The Regional Transportation Commission of Southern Nevada (RTCSN, 2004) has published a comprehensive analysis of current and projected transportation needs. Travel demand models are used to estimate trips and vehicle miles traveled between calendar years 2000 and 2025” (p.12). Figure 6 illustrates that these travel demands are very high, even reaching into the 100,000’s on many road ways. And Table 6 is an indication of the increase of vehicle miles traveled on Clark County roads and the large increase of VMT soon to come. 2025 average weekly miles traveled is estimated to be 54,433,431 which is a significant increase from 32,908,107 average weekly miles traveled in 2004.

The air pollutant O_3 has increased, thus the amount of smog has increased in Clark County. Many stations around the county violate the national 8-hour standard set for the entire country. So not only is it posing health risk to people that live in the area, but is becoming costly since it is in violation of the federal standard. Now that awareness has been reached for the problem, direct possible solutions for the ground level ozone must be identified. According to Clark Counties Air Quality website the general public can take these measures to reduce ozone production (Tips to Reduce Ozone, 2004):

1. When at the gas station refrain from topping off the gas tank of your vehicle.
2. Fill up a vehicle with fuel after the sun has set.
3. Keep vehicle in good condition through regular maintenance such as oil changes and tune ups.
4. Reduce the amount of time the vehicle engine idles.

5. Reduce the number of quick accelerations once the vehicle is at a stop.
6. Travel fewer miles while in the vehicle or carpooling.
7. Use alternate modes of transportation such as bus, bike, or walking.
8. Don't use household products that contain volatile organic hydrocarbons.
9. Paint with only latex paint with a paint brush, no sprayers.
10. Mow the grass in when the sun is about to set and do this with electrical powered equipment rather than gasoline fueled.
11. Use only propane grill and electric starter when barbequing.

So since over half of these tips are related to motor vehicles in some sense the question develops for a possible solution to reduce the amount of emissions related to motor vehicles. Since NO_x is one of the two main precursors for ozone and is a compound found in motor vehicle emissions, it must be reduced. NO_x follows the same trend as ozone, thus no matter the amount of increase in NO_x ozone will increase as well.

To test my hypothesis I will be using a system dynamics model. Ford (1999) states System dynamics by definition is, "A method of analyzing problems in which time is an important factor, and which involve the study of how a system can be defended against, or made to benefit from, the shocks which fall upon it from the outside world." These models are designed for a general understanding. The reason for using a model is it is not feasible to test the actual problems and solutions in the real world. According to the Systems Dynamics Society (2004, p.1), "Feedback refers to the situation of X affecting Y and Y in turn affecting X perhaps through a chain of causes and effects. One cannot study the link between X and Y and, independently, the link between Y and X and predict how the system will behave. Only the study of the whole system as a feedback system will lead to correct results". This will be a computer model generated from research of the Las Vegas Valley that simulates the real world, since this is a problem that has been generated over time.

Method

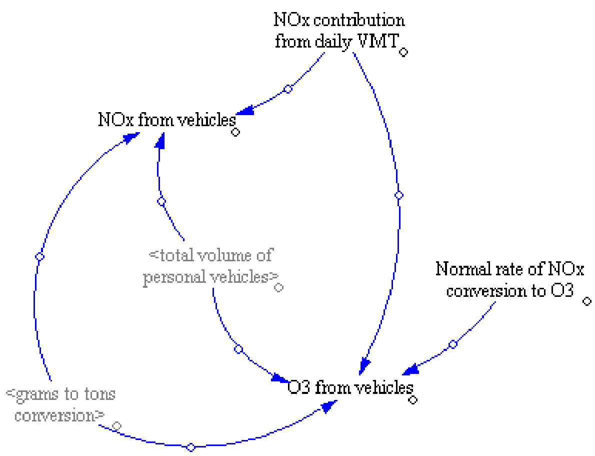
To determine the best land use and transportation strategies to reduce the amount of ozone in Las Vegas valley I used a beta version of the Land Use and Transportation changes on Air Quality (LUTAQ) model developed for the Southern Nevada Regional Planning Coalition (SNRPC) (LUTAQ Working Group 2005a). See Appendix 1 for more information. I made a minor modification to the model, adding a sector representing Air Quality to calculate the amounts of NO_x and O_3 as shown below. After adding the equations, I used the model to test land use policy options and project their effects on ozone production.

The modifications that I made to the model included the following equation:

Amount of NO_x [O_3] produced per day by personal vehicles (tons/day) = (0.4 grams NO_x [O_3]/ mile per passenger car) * (vehicle miles traveled per day) * ($1.1025*10^{-6}$ Tons/gram)

It is important to note that the vehicle miles traveled per day are dependent on various factors including population and miles traveled per person which the model already has determined. It is also important to note that the ozone ratio to NO_x is assumed as 1 to 1. The figure below is actual modification I made to the system and labeled the Air Quality Sector. Each factor flows into either NO_x from vehicles and O_3 from vehicles

Air Quality Sector



LUTAQ is a model to examine the potential effects of Land Use and Transportation changes on Air Quality, traffic congestion and other quality of life factors (LUTAQ Working Group 2005b). This model is designed to assume today's values for Las Vegas for the urban core area and the non-core area and extends to a 30 year limit. The model allows for changes to be made to some or all of the areas. These changes include:

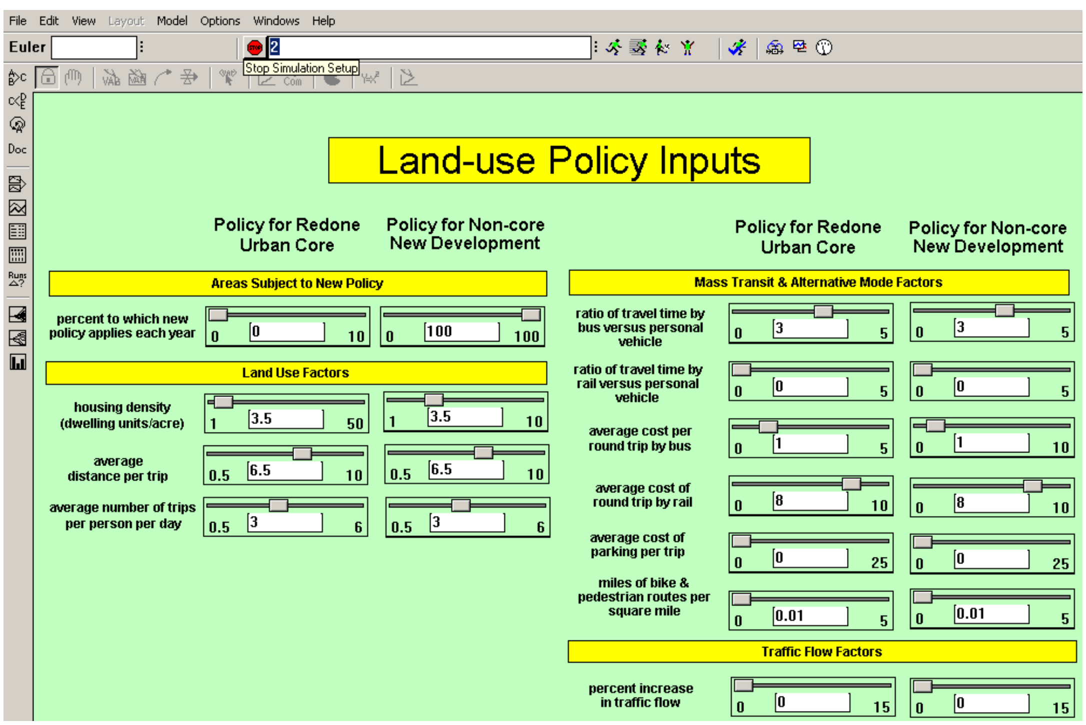
1. Housing density
2. Average trip distance
3. Average number of trips per day per person
4. Ratio of travel time by bus versus personal vehicles
5. Ratio of travel time by rail versus personal vehicle
6. Average cost per round trip by bus
6. Average cost of round trip by rail
7. Average cost of parking per trip

8. Miles of bike & Pedestrian routes per square mile.

Now that the Air Quality Sector was in place I set up three separate policy change runs. I changed a number of the factors above to different values only in the non-core area and the model developed graphs based on the changes. I then compared the decrease in NO_x and O_3 to the cumulative cost and by doing this I was able to determine if the changes were feasible or even much worth it.

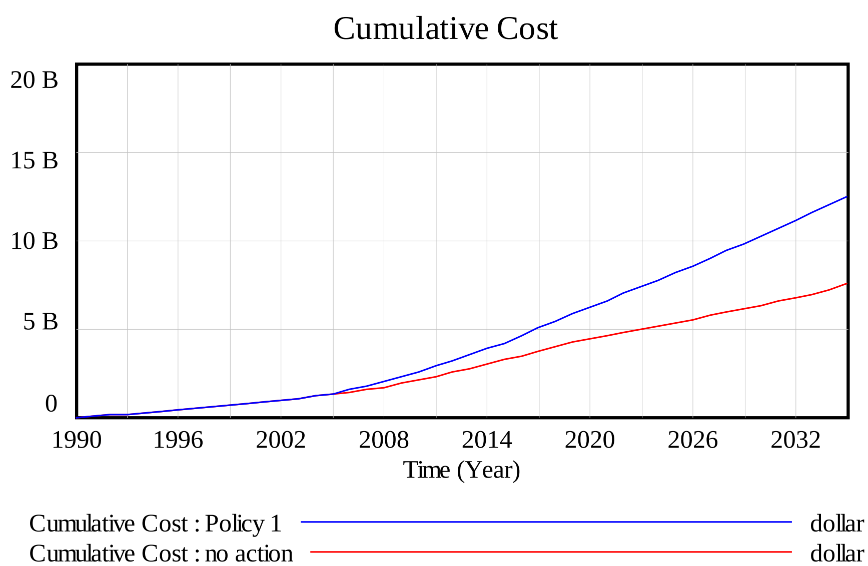
Results

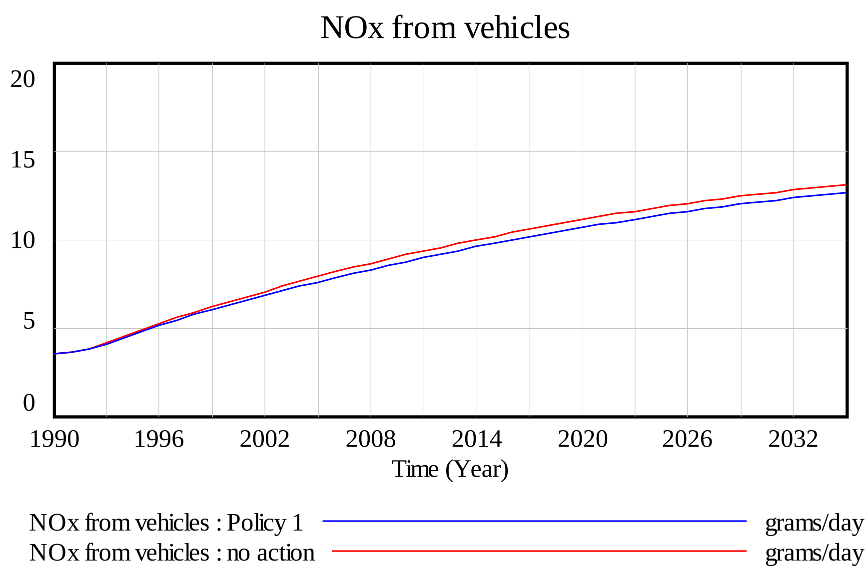
The figure directly below shows the original screen in the LUTAQ model. This screen represents the "no action" in each graph that is displayed in this section, which means that this is the direction in which Las Vegas is heading if nothing changes.



The graphs (A) below show the ratio of travel time by bus versus personal vehicle was reduced to 1, meaning that it would take the same amount of time to take the bus to a specific destination as it would a personal vehicle. The cost would jump to over 10 billion dollars which is higher than the no action plan denoted in red and the NO_x of grams/day would move down not by a significant amount.

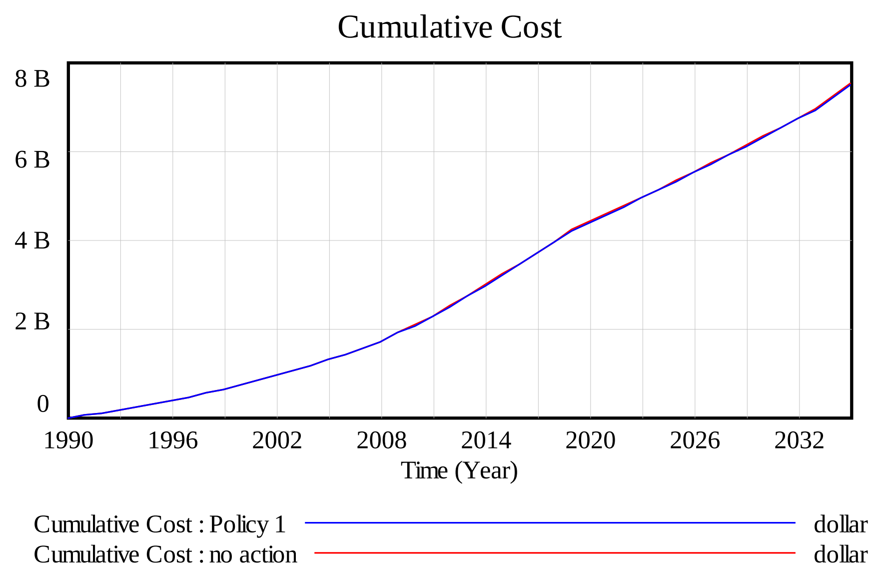
A)

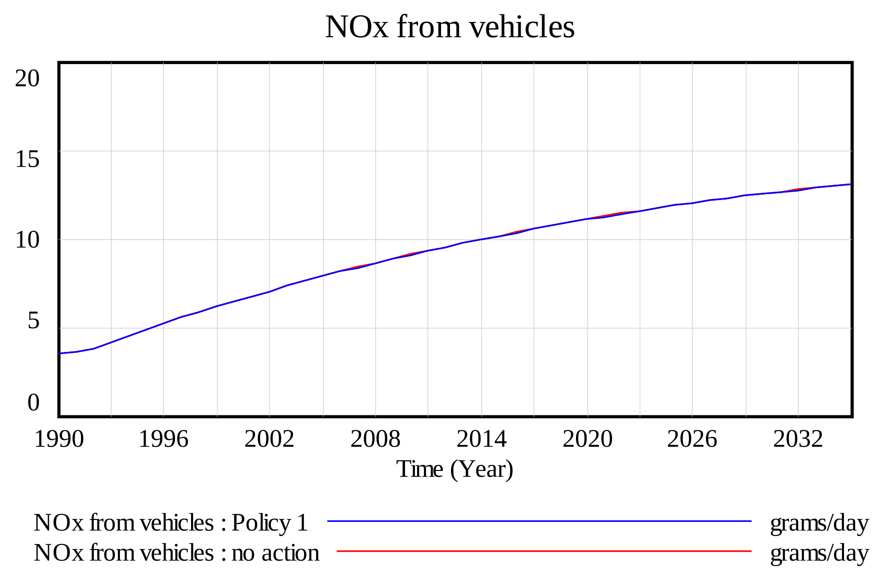




The two graphs (B) below represent reducing the average cost per round trip by bus to $0.50. Virtually no change is made between the cost and NO_x grams/day relative to the no action policy denoted in red. There is also no change when reducing the ratio of travel time by rail versus personal vehicle, average cost of parking per trip, and average cost of round trip by rail.

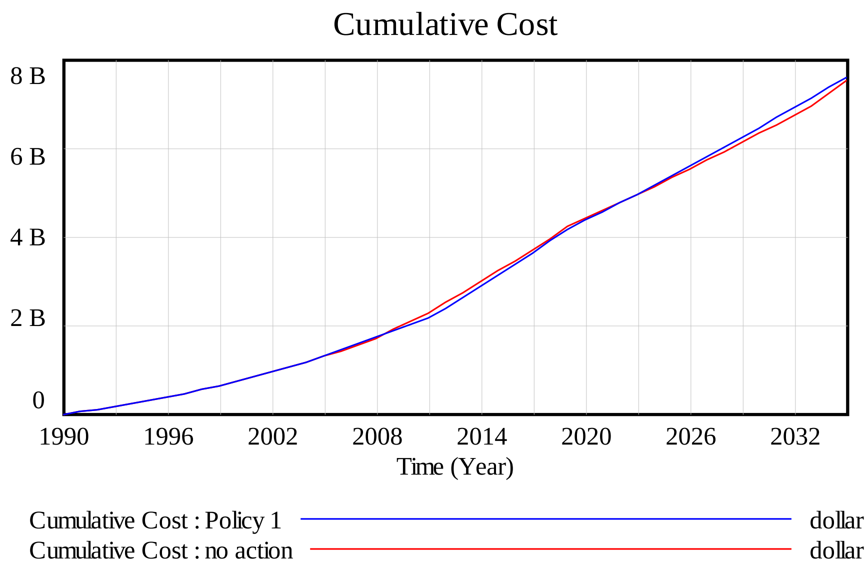
B)

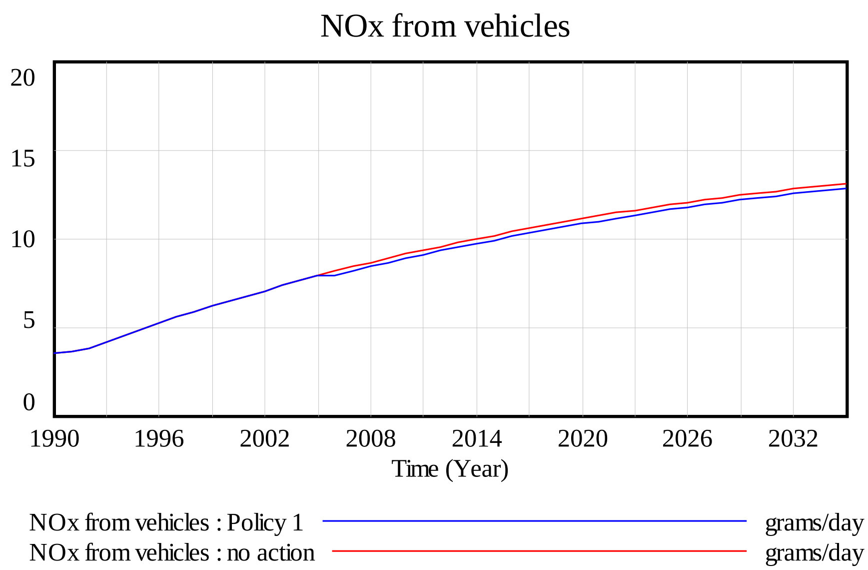




The graphs below (C) represent 5 miles of bike and pedestrian routes per square mile. There is a slight difference that can be noted in the cost and NO_x graphs. The cost is slightly raised and the NO_x is slightly decreased relative to the no action policy denoted in red.

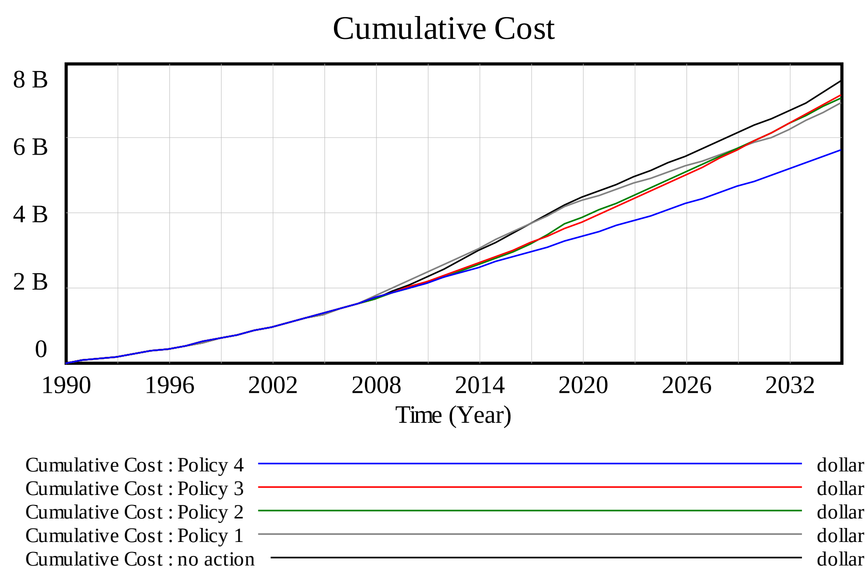
C)

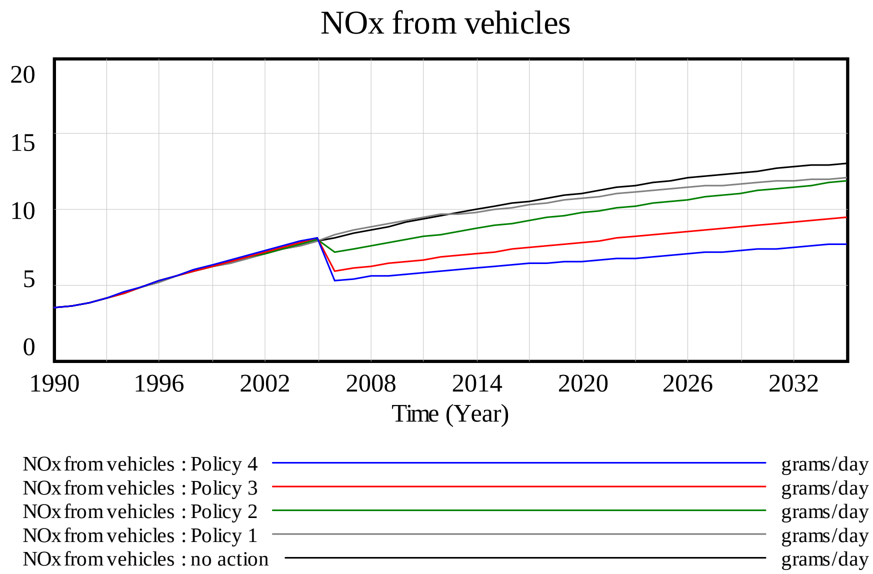




The two graphs (D) below represent four separate policies with one of the most reasonable solutions with cost in consideration to reducing the production of NO_x by only changing three values. Policy 1 represents a change in housing density with an increase from today to 4.5 dwelling units/acre. Policy 2 represents a change in average distance per trip with a decrease from today to 5 miles. Policy 3 represents a change in the average number of trips per person per day with a decrease from today to 1.5. And Policy 4 represents a change in all three factors with a 6 dwelling units per acre, 4.5 mile average trip distance, and 1.5 average number of trips per person per day.

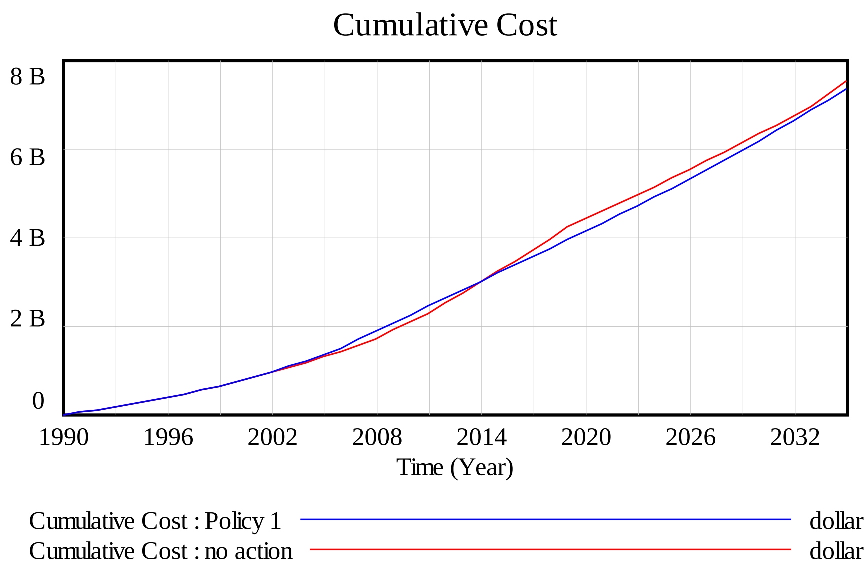
D)



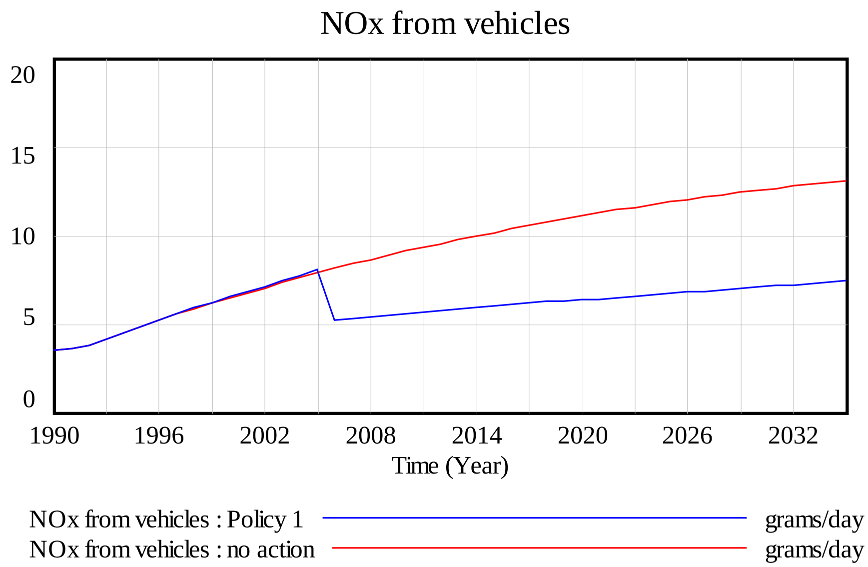


The graphs (E) below represent using the same numbers that were changed in Policy 4 but also making some changes such as, decreasing the ratio of travel time to 2 by bus versus personal vehicle, decreasing the average cost of round trip bus fare by $0.50, increasing the average cost of parking per trip to $10, and increasing to 5 miles of bike and pedestrian routes per square mile. There is little change in cost but a significant change in the reduction of the NO_x relative to the no action policy denoted in red.

E)



Cumulative Cost
8 B
6 B
4 B
2 B
0
1990
1996
2002
2008
2014
2020
2026
2032
Time (Year)
Cumulative Cost : Policy 1
dollar
Cumulative Cost : no action
dollar



NOx from vehicles
20
15
10
5
0
1990
1996
2002
2008
2014
2020
2026
2032
Time (Year)
NOx from vehicles : Policy 1
grams/day
NOx from vehicles : no action
grams/day

Discussion

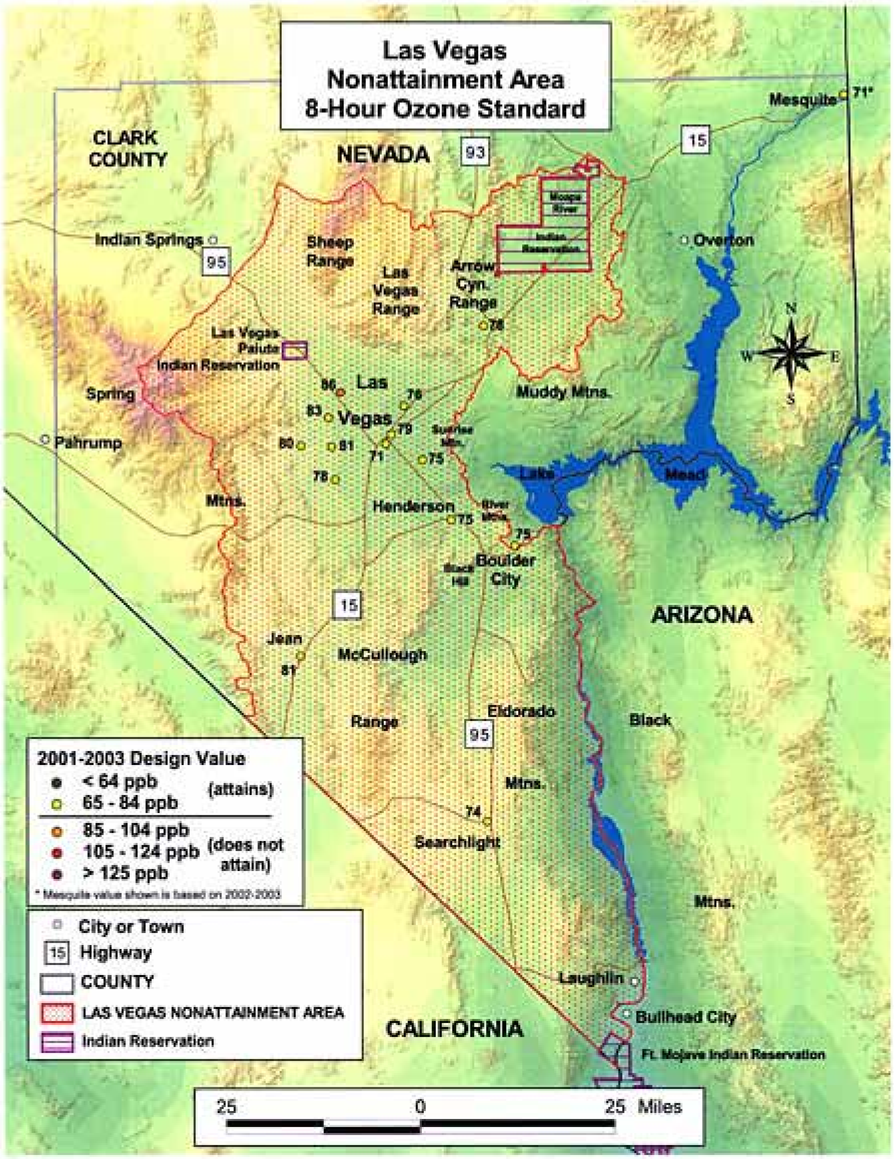
Ground level ozone is increasingly becoming a problem in the Las Vegas valley especially with the enormous amount growth it has experienced in the last decade alone. Therefore since the amount of people in the valley increasing so is the number of cars, therefore so is the amount of pollution, especially ground level ozone which makes up a huge portion of smog. Since ozone production is chiefly ruled by NO_x production the equations that I used to correspond, show as NO_x increases, ozone will increase as well. I hypothesized that for Las Vegas Valley the most effective land use and transportation strategies for reducing vehicle miles traveled will be increase housing density, decrease in average trip distance, and decrease in average number of vehicle trips per person per day. This is what my results show in the graphs presented. By increasing the housing density of the area people will live closer to their necessities and will no longer have to drive around a curvy housing complex just to exit and get to the store. This in relation will save them miles on each trip that they make during the day by having the ability to exit through a straight path. Also if their necessities are closer they are more apt to walk to where they need to go if it is more convenient for them, which in most cases it should be. Also in relation they will reduce the number of trips that are made in their cars due to land use strategies being better planned. This also is presented as the most cost effective way of reducing the amount of ozone produced in Las Vegas valley.

The model showed little to no difference when accompanied by changes in ratio of travel time by rail versus personal vehicle, average cost per round trip by bus, and average cost of round trip by rail. A small amount of reduction in NO_x when average trip parking cost was increased to the max of the allowable $25 and miles of bike and pedestrian routes per square mile also showed promising results in reducing ozone production in the non-core development area of the valley.

The LUTAQ model seemed to show the most promising results when housing density increased, average distance per trip decreased, average number of trips per person per day decreased, ratio of travel time by bus versus personal vehicle decreased, decreasing average cost of round trip by bus, average cost of parking increased, and miles of bike and pedestrian routes per square mile increased, which is shown in Results E. The reason the LUTAQ model didn't show very promising results for the alternative modes of transportation rather than the personal vehicles is because it is limited to the alternative modes we have now. Therefore the model figures that for example we have to make the CAT bus system more efficient than a personal vehicle. Obviously that is not very feasible and very costly at least. As of now LUTAQ doesn't take into consideration any proposed methods or ideas of attractive alternative modes of transportation.

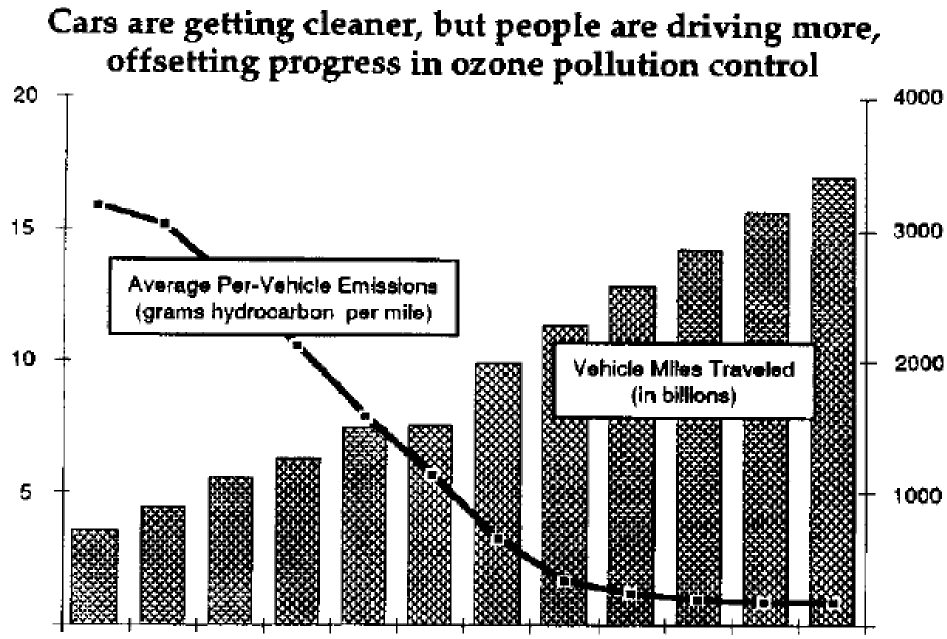
FIGURE 1:

Map of the Las Vegas, NV nonattainment area



(EPA, 2004b)

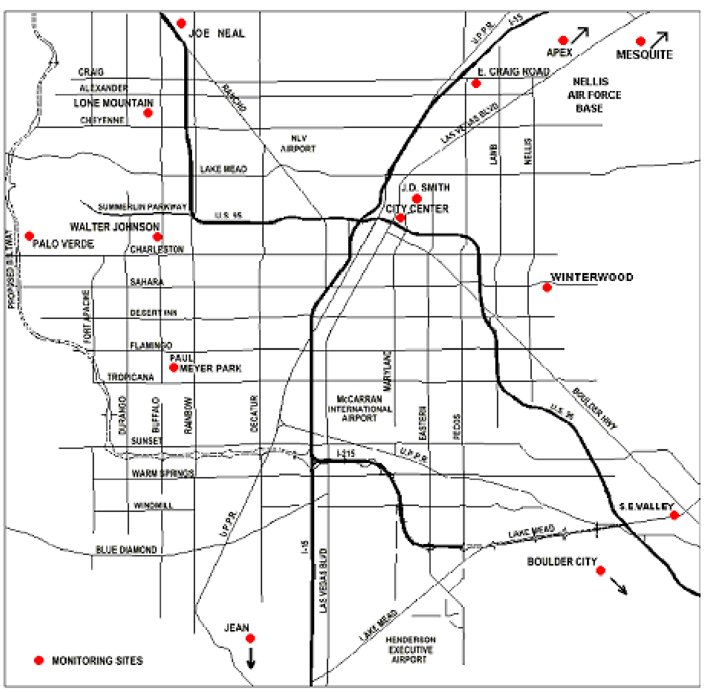
FIGURE 2:



(USEPA, 1993b)

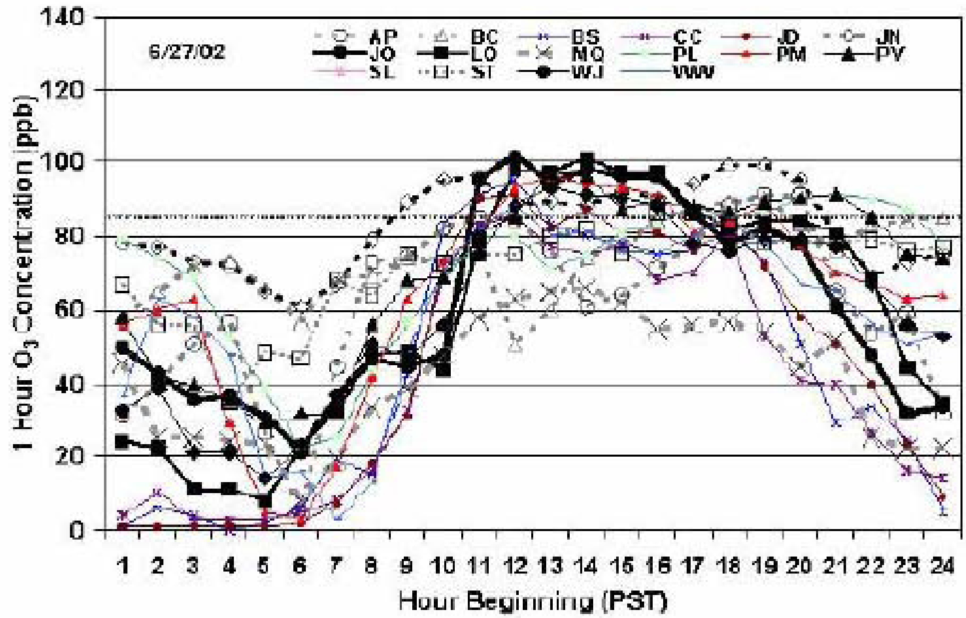
FIGURE 3:

Monitoring Sites



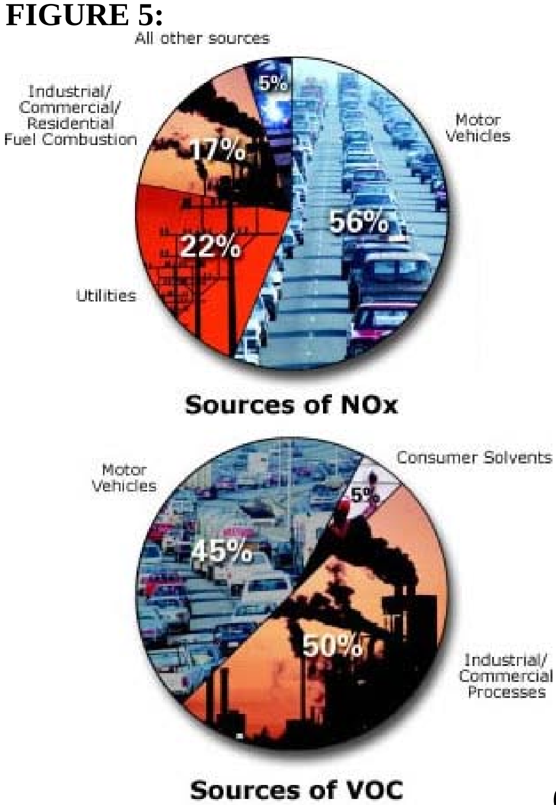
(Clark County Air Quality, 2004)

FIGURE 4:



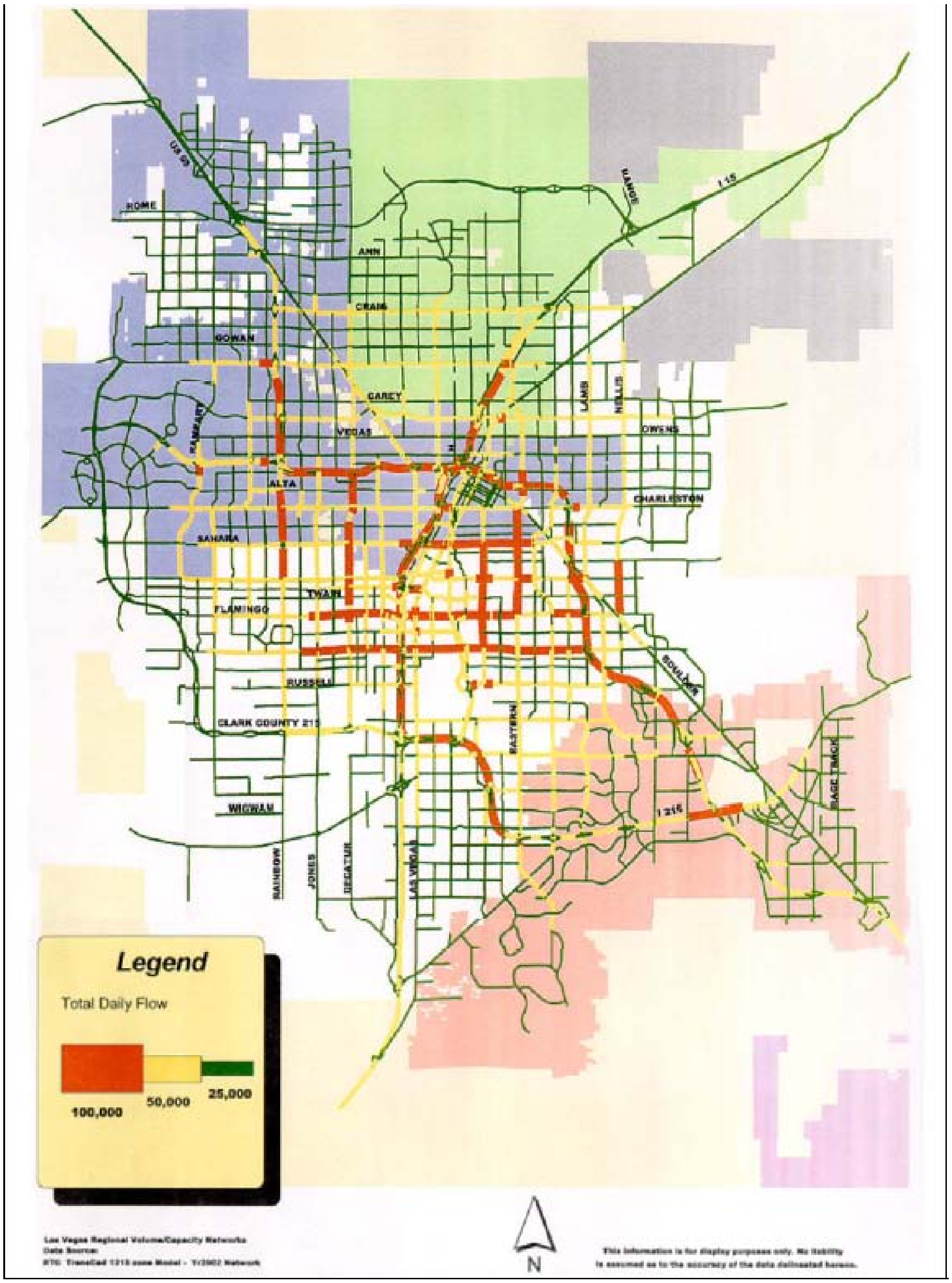
(Clark County Department of Air Quality and Environmental Management, 2004)

FIGURE 5:



(USEPA, 2004a)

FIGURE 6:



2002 Las Vegas Total Daily Traffic Flow
(Clark County Air Quality and Environmental Management, 2004)

TABLE 6:

	Average Weekly Vehicle Miles Traveled					
	2000	**2004**	**2005**	**2010**	**2020**	**2025**
Modeled Network VMT	**24,131**	**32,565,094**	**33,026,405**	**41,294,327**	**51,121,203**	**53,433,431**
Intrazonal VMT	**240,465**	**273,213**	**239,121**	**320,745**	**451,855**	**493,068**
Transit VMT	**66,900**	**105,800**	**196,700**	**196,700**	**197,800**	**197,800**
Total Average Weekly VMT	**24,438,571**	**32,908,107**	**33,462,226**	**41,811,772**	**51,770,858**	**54,124,299**
Source: Regional Transportation Commission						

(Clark County Department of Air Quality and Environmental Management, 2004)

References

Beaton Stuart P., Bishop Gary A., Zhang Yi, et al. (1995). On-Road Vehicle Emissions: Regulations, Costs, and Benefits. Science, New Series, Vol. 268, No. 5213, pp. 991-993.

Clark County Department of Air Quality and Environmental Management. (2004). Nevada Air Quality Designations Boundary Recommendations for the 8-hour Ozone NAAQS for Clark County, Nevada. pp. 1-69.

Ford, Andrew (1999). Modeling the Environment: An introduction to System Dynamics Modeling of Environmental Systems. Island Press, Washington, DC, pp. 3-13.

J.G. Calvert, J.B. Heywood, F.F. Sawyer, et al. (1993). Achieving Acceptable Quality: Some Reflections on Controlling Vehicle Emissions. Science, News Series, Vol. 261, No. 5117., pp. 37-45.

Levy II., H., Kasibhatla, P.S., Moxim, W. J., et al. (1997). The Global Impact of Human Activity on Tropospheric Ozone. Geophysical Research Letters, Vol. 24, No. 7, pp. 791-794.

Land Use, Transportation and Air Quality (LUTAQ) Working Group. (2005a). LUTAQ Draft, April 17, 2005. Southern Nevada Regional Planning Coalition Working Group, Clark County, NV.

Land Use, Transportation and Air Quality (LUTAQ) Working Group. (2005b). Guide to Input Decisions and Output Graphs SNRPC Planning Directors, April 4, 2005. Southern Nevada Regional Planning Coalition Working Group, Clark County, NV.

Rogers, Keith. (2004, April 16). Clark County flunks air quality standards :[Final Edition]. Las Vegas Review - Journal, p. 1a.

Rogers, Keith. (2004, July 30). County Issues Ozone Advisory:[Final Edition]. Las Vegas Review – Journal, p. 12b.

Rogers, Keith. (2003, May 1). Ozone Pollution Report Card: Group gives Clark County:[Final Edition]. Las Vegas Review – Journal, p. 3b.

Schlink Uwe, Volta Marialuisa. (2000) Grey Box and Component Models to Forecast Ozone Episodes: A Comparison Study, Environmental Monitoring and Assessment, Volume 65, Issue 1-2, Pages 313 – 321.

Sillman S., (1999). The relation between ozone, NO(x) and hydrocarbons in urban and polluted rural environments,Atmospheric Environment, Volume 33, Issue 12, pp. 1821-1845.

Stave A. Krysyna, (2003). A System Dynamics Model to Facilitate Public Understanding of Water Management Options in Las Vegas, NV. Journal of Environmental Management 67, pp. 303-313.

Valente R.J., Imhoff R.E., Tanner R.L., et al. (1998). Ozone Production During an Urban Air Stagnation Episode Over Nashville, Tennessee. Journal of Geophysical Research, Vol. 103, No. D17, pp. 22,555-22,568.

Clark County Air Quality, (2004). Monitoring Stations, OZONE.
http://www.ccairquality.org/station_list.htm#station_ozone

Clark County Air Quality & Environmental Management, (2004).Ozone Q & A.
http://www.co.clark.nv.us/air_quality/Ozone_QA.htm

System Dynamics Society, 2004. MIT System Dynamics Group Literature Collection.
http://www.albany.edu/cpr/sds/

U.S. Environmental Protection Agency (USEPA), 1993a. The Plain English Guide to the Clean Air Act.
http://www.epa.gov/air/oaqps/peg_caa/pegcaain.html

U.S. Environmental Protection Agency (USEPA) Office of Mobile Sources, (1993b). Automobiles and Ozone.
http://www.epa.gov/otaq/consumer/04-ozone.pdf

U.S. Environmental Protection Agency (USEPA), 2003. Proposed Rule to Implement the 8-Hour Ozone National Ambient Air Quality Standard
http://www.epa.gov/ttn/naaqs/ozone/o3imp8hr

U.S. Environmental Protection Agency (USEPA), 2004a.Good Up High Bad Nearby.
http://www.epa.gov/oar/oaqps/gooduphigh/ozone.html#good

U.S. Environmental Protection Agency (USEPA), 2004b. Las Vegas, NV 8-hour Ozone Designation.
http://www.epa.gov/region09/air/nvozone/clark.html

Washington University in St. Louis Chemistry 152, 2004. How does Ozone Form?
http://www.chemistry.wustl.edu/~courses/genchem/Tutorials/AirQuality/origin.htm

Appendix 1

LUTAQ Model
Guide to Input Decisions and Output Graphs
SNRPC Planning Directors
April 4, 2005

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.

Model Structure

The model divides developed land in the Las Vegas Valley into two areas: an urban core and a non-core area. The urban core roughly represents Downtown Las Vegas and the Strip -- an elongated transportation corridor along which development might have relatively densities. The non-core area would be the existing suburban areas surrounding the core plus any new development laying beyond.

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. Then the model plays out the effect of those policy changes over the next 30 years.

You can design a different policy package for each area and you can specify how much of each area the policy will apply to.

Input Decisions

Figure 1 shows the policy input screen. Each column represents a different policy package or set of decisions. The first column is the Policy for Redone land in the Urban Core. The second column is the Policy for New Development in the Non-core area.

You set values for any decision variables in a policy by either moving the slider bar until the value you want appears in the center box or by typing the value directly into the box. If you do not change a value, it remains at the current value.

For each area, you can set values for each of the following 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.

2. housing density

   Density is measured in dwelling units per acre. 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 day

   The number of trips per day is also 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. ratio of travel time by bus versus personal vehicle

   The ratio of travel time is considered a factor in whether people will choose to take mass transportation or not. If it takes much longer to make a given trip by bus than by personal vehicle, the attractiveness of bus transportation decreases, and bus ridership decreases. Decreasing the ratio of travel time by bus versus personal vehicle would make bus transportation more attractive and increase ridership.

6. ratio of travel time by rail versus personal vehicle

   Similarly, the ratio of travel time by rail versus personal vehicle affects the use of rail transportation. Decreasing the ratio of travel time by rail versus personal vehicle would make rail transportation more attractive and increase ridership.

7. average cost per round trip by bus

   The cost of travel by mass transportation relative to cost by personal vehicle also affects ridership. As the average cost by bus decreases, bus transportation is more attractive.

8. average cost of round trip by rail

   As the average cost of travel by rail relative to personal vehicle travel decreases, rail transportation is more attractive.

9. average cost of parking per trip

   The cost of parking is included explicitly in the model because it is a potential policy variable in Las Vegas. Changes in the cost of parking affect the overall cost of travel by personal vehicle, which affect the relative cost of travel by mass transit.

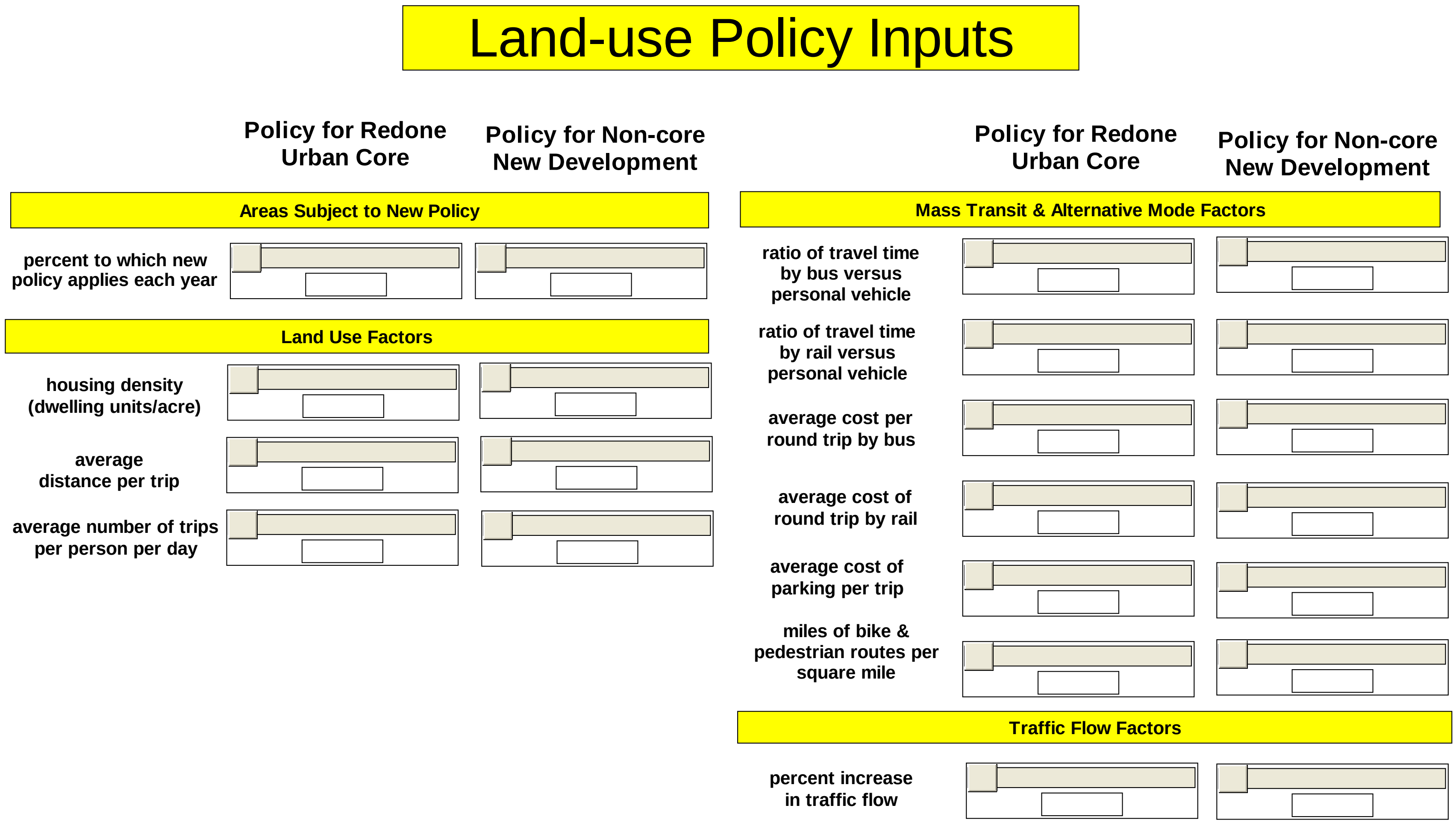
10. miles of bike and pedestrian routes per square mile

    The model assumes that a major factor in the use of alternative modes of transportation, specifically bicycles and walking, is the availability of bike and pedestrian routes. As the miles of such routes increase, use of these alternatives modes increases.

11. percent increase in traffic flow

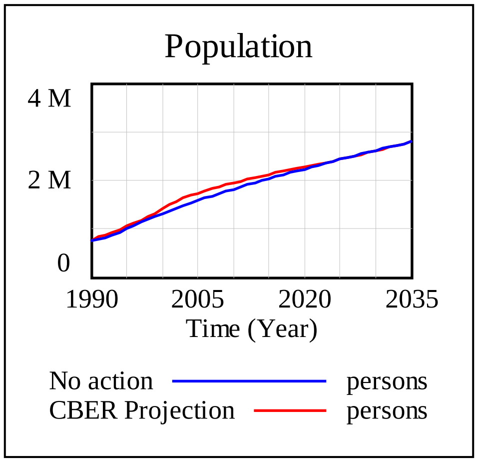
    Traffic flow can be affected by a number of land use and transportation design considerations. These include the number of curb cuts on major streets, turnout lanes, and other factors.

Figure 1. Policy Input Screen



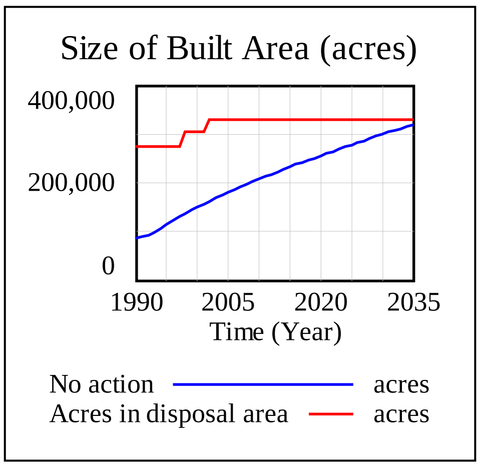
Output Graphs

1. Population



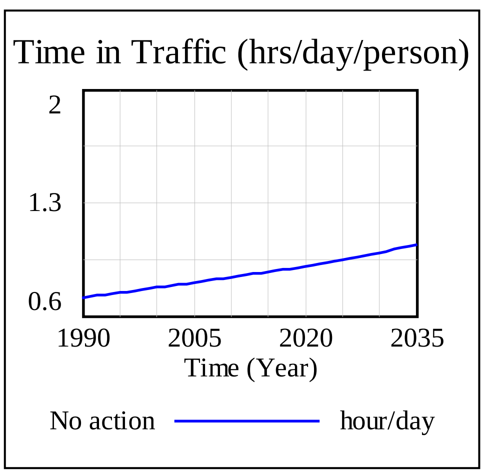
The Population graph shows the projected population that results from the proposed policy changes. The gray or dashed line represents the Center for Business and Economic Research (CBER) projected population for the valley. Population is affected by the inmigration and outmigration rates as well as births and deaths. Inmigration and outmigration is affected by the desirability of living in Las Vegas, which is affected in part by the traffic and air quality conditions in the valley.

2. Size of Built Area



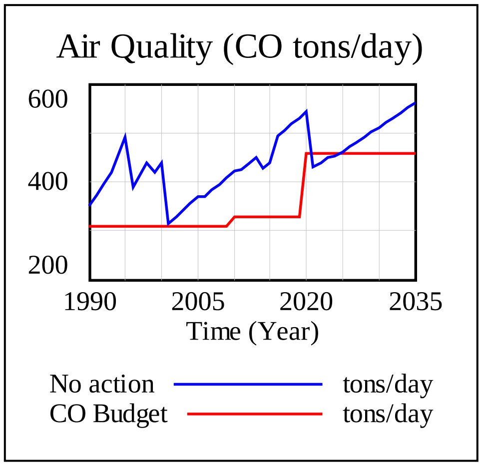
The Built Area graph shows the number of acres of developed land in the Las Vegas Valley. The gray or dashed line is a reference line that shows the number of acres within the BLM disposal boundary. The acres of built area increase to accommodate population that cannot be absorbed by existing developed land.

3. Time in Traffic



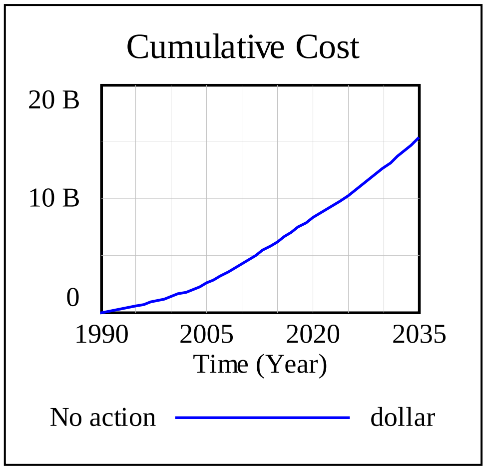
The Time in Traffic graph shows the average number of hours spent in traffic per person per day. This is a measure both of the average speed of traffic (which is a function of traffic congestion) and of the number of miles traveled per person.

4. Air Quality



The Air Quality graph shows the amount of carbon monoxide produced in the valley per day as a result of automobile traffic. The gray or dashed line is a reference line that shows the CO budget specified by the EPA. For any year actual CO is above the CO budget, the Las Vegas valley is in danger of losing $80 million in federal transportation subsidies. CO is increased by the number of vehicle miles traveled in the valley and is influenced by the average speed of traffic. Slower traffic produces more CO per mile than faster traffic.

5. Cumulative Cost



The Cost graph shows the total cost of the policy package between 2005 and 2035. Costs include any federal transportation subsidy lost plus the cost of transportation infrastructure on any newly developed land.

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EDUCATION

University of Nevada – Las Vegas May 2005

1. BA, Environmental Science
2. Thesis: Using a System Dynamics Approach to Minimizing Ozone in Las Vegas NV

WORK EXPERIENCE

Office Assistant, Student Enrollment & Financial Services, University of Nevada – Las Vegas
08/03-Present & 8/02-5/03 & 9/01-5/02

- Perform office duties & adhere to confidentiality policies
- Answer phones, take phone messages and faxes, and assist with filing
- Input data into & query information from campus wide database
- Monitor front desk and answer general student questions

Ski Instructor, Las Vegas Ski and Snowboard Resort, Lee Canyon, NV
1/04 –Present & 1/03-3/03

- Instruct students from diverse backgrounds in skiing techniques
- Assist students of all levels on how to improve their abilities
- Instruct children in a beginner ski program

Wrangler, South Fork Mountain Lodge & Outfitters, Buffalo, WY
Summer 2003

- Guided guests on horseback rides and overnight pack trips
- Provided horse care including administering preventive medicines, feeding, etc.
- Waited tables, took reservations, and cleaned cabins
- Completed training in CPR and first aid

Forestry Recreation Aid, U.S. Forest Service, Harlowton, MT
Summer 2002

- Monitored & maintained campgrounds in Lewis & Clark Forest of Musselshell District
- Enforced campground rules and regulations
- Completed re-certification to fight wild land fires
- Completed training in CPR, first aid, and HAZMAT

Forestry Trail Aid, U.S. Forest Service, Harlowton, MT
Summer 2001

- Dug trails on a crew in Lewis & Clark Forest of Musselshell District
- Completed certification to fight wild land fires
- Completed training in CPR, first aid, HAZMAT, and chainsaw use

AWARDS & ACTIVITIES

- Leave No Trace Instructor, Friends of Nevada Wilderness (2004)
- Mojave Max Project – Volunteer Educator, Clark County Desert Conservation Program (2004)
- Students Conscious of Protecting the Environment, University of Nevada – Las Vegas (2004)
- Panhellenic Delegate, Sigma Kappa, University of Nevada – Las Vegas (2002)
- Intramural Sports, University of Nevada – Las Vegas (2001-2002)

REFERENCES

Available upon request.