Transit Options to Reduce Emissions

by

Jennifer Alexander, Summer Douglas,
Saralyn Hartley and Susan Yang

Natural Science Inquiry

March 9, 2000

Contents

IV. I. Introduction

In the United States, two-thirds of carbon monoxide (CO) emissions come from cars. In urban areas, cars and trucks contribute up to 90% of carbon monoxide pollution (Automobiles). Carbon monoxide is a concern because excessive amounts of it lessen the oxygen levels in our blood. It can cause dizziness, nausea, slow reflexes, and even death.

In Oregon, cars are the number one source of air pollution (Vehicle). As the congestion on roads increase, air pollution will worsen. In 1992, carbon monoxide levels exceeded the Federal air quality standards in 20 U.S. cities, affecting more than 14 million people (Automobiles). Without actions to reduce air pollution, Portland could be the next victim.

Since the majority of carbon monoxide pollution in urban areas is attributed to human activity, there are things that you can do to help reduce air pollution. One solution is to take advantage of public transportation, such as buses and light rail.

Although any alternative to driving helps to reduce CO emissions, this report will show data that support buses as a better alternative than light rail. Also in this report are plans to build High Occupancy Vehicles lanes on highways, retrofit buses, and to expand the current bus system by adding new express routes. These options will benefit everyone not only by reducing CO emissions but will also alleviate traffic congestion. Implementation of these programs will help ensure a more livable environment in the future.

II. Emissions Standards of Current Modes of Transportation

In Portland the most popular mode of transportation are cars, buses and the Metropolitan Area Express. MAX is Portland's very own light rail system. As we find the best way to lower carbon monoxide emissions, our number one priority has to be removing cars from the streets and getting people on the transit system. Cars are the number one pollutant of carbon monoxide emissions and their use seems to only be increasing. Fifty-seven percent of people travel to work in their cars versus twenty-two percent who travel by transit (Cunneen, 3). The obvious way to accomplish this would be to make the transit system more appealing to the drivers to get them out of their cars and into more efficient alternatives. The system needs to be more convenient, safe, and cost effective.

As traffic congestion in Portland continues to increase, the best alternative to driving is using the transit system. But even though drivers are being forced to wait on overcrowded freeways, the convenience of their cars is still more appealing than the inefficient transit system. The only option we have seems to be that we must make the transit system more effective. This can be accomplished by expanding the bus system, making it more accessible and more convenient or by expanding the light rail system. Through our research, we have discovered that the obvious answer is to expand our bus system. We are going to prove how expanding the bus system will get cars off the road and in turn, reduce carbon monoxide emissions which contribute to much of the pollution in the Portland area.

A. Disadvantages of an Expanded Light Rail System

Looking at the growth of Portland, it would not be effective to expand the light rail system any farther. Portland is growing out into several suburban areas surrounding the downtown core. A light rail system would not be able to reach all of these outlying areas. The costs would be far too high if we were to attempt to expand the light rail to reach these areas. It would be much easier for buses to become available to these areas. The routes of buses can be added, changed, or dropped as needed. Express routes can be added to more popular routes and fewer buses can travel to less populated areas. Once a light rail is built, it can’t be moved or changed no matter how ineffective it becomes.

The light rail is extremely expensive compared to other transit options and it doesn’t significantly reduce traffic congestion. The East-West light rail went on-line in 1986. Yet between 1986 and 1992 Portland area traffic congestion grew faster than other Western cities (Buckstein, 1). Tri-Met’s own environmental impact study for West-side MAX said it had virtually no effect on the region’s air quality (Buckstein, 3). This is not surprising since light rail takes so few cars off the road. For the cost of $963 million, a maximum of 416 cars were removed from the roads into Portland during the commute period (MAX Counts, 1). This was figured by counting the number of bi-directional MAX riders and subtracting the number of bus riders on discontinued or altered routes. The new West-side line caused Tri-Met to cancel most of the express routes and replace them with a host of light rail feeders to boost light rail ridership numbers. And more cars had to be driven in order to funnel commuters onto the train because commuters didn't want to suffer. The more transfers people have to make, the less convenient the system becomes, which puts more people back in their cars.

If a North-South light rail was built, it seems the results would be very similar. More than two-thirds of the projected riders of the North Portland light rail line are riders who are being diverted from a bus to a train (Mildner, 2). Rail customers are often former bus customers and rail trips usually involve multiple boarding rides, so the increase in trips is actually much smaller. Tri-Met found that fifty-six percent for the riders on the Eastside MAX line were formally bus riders who moved to the new rail line (Mildner 2).

When the ultimate goal is to get cars off the road, the alternatives must be just as convenient and accessible. People want to spend the smallest amount of time commuting that they have to. Tri-Met insists on increasing rush hour train frequency on the light rail from 11 trains per hour to 19 trains per hour and eventually getting up to 23 trains per hour which will decrease the time to only 2.61 minutes between trains. But Tri-Met has never successfully operated more than 10 trains per hour (Mildner, 4). When Tri-Met tried to operate 12 trains per hour delays occurred in the downtown portion of the MAX line. By expanding the bus system, we will add more buses, more routes, and create more express routes. More routes will make the buses more accessible and the express routes will decrease the commute time spent on the bus.

Much of the problem is that rail tracks are very under-utilized compared to roadway lanes. Tri-Met only runs 115 trains per weekday on each track. So the MAX tracks are unused 99.3 percent of the time. If buses were expanded, busways can be used by more than 700 vehicles per hour and 24 hours a day if necessary (Charles, 2). The costs of a busway are very modest compared to that of an expanded light rail service. In the city of Curitaba, Brazil a thirty seven mile busway was built for less than five percent of the cost of a comparable light rail system. The busway is able to carry 1.3 million passengers a day in a city with a population of 1.6 million.

People often say, “the experience of light rail is better than riding the bus” (Mildner, 23). But that is almost like saying that a new Mercedes is a better ride than the old Ford. If we continue to decrease our bus system while trying to increase the light rail, our entire transit system will decline. The bus system gets faithful riders at a low operating cost, which can only be increased and expanded upon.

B. Total Emissions Reductions

Cars and trucks produce up to ninety percent of urban carbon monoxide emissions (EPA, 1). In order to get people out of their cars we must be able to convince them that there will be a significant difference in the pollutants emitted. If people know they are making a difference, it will serve as an incentive to ride the bus.

The average car emits three times more carbon monoxide per passenger mile than a Tri-Met bus (Environment, 1). When we compare grams per passenger mile of carbon dioxide emitted of a bus compared to a car, the difference becomes even more obvious. The amount of carbon dioxide emitted from a clean diesel engine bus is 2.46 gram per passenger mile with an average of 10 passengers on the bus. A single occupancy vehicle emits 19.3 grams per passenger mile with an average of 1.12 passengers. That is a difference of 16.84 grams of carbon dioxide emitted every passenger mile.

Tri-Met's buses are emitting ninety percent fewer particulates than they did ten years ago and clean diesel fuel is being used which also reduces the amount of pollutants released. Carbon monoxide results from the incomplete combustion of fuel and is emitted directly from vehicle tailpipes. If we could achieve complete combustion we would only have carbon dioxide and water vapor out the exhaust. But complete combustion cannot be achieved due to impurities in the fuel. The diesel engine is the best thermal to mechanical energy conversion device we have to achieve the best trade-off of energy cost, life to overhaul and productivity (Johnson, 4).

C. Costs

With a budget of one billion dollars, the ability to purchase new clean diesel engine buses to add to our fleet and create new routes is very feasible. For a standard clean-diesel engine bus, the cost ranges from $280,000 to $300,000. The operations and maintenance of each bus every year would be approximately $115,000 (Bryant). By purchasing fifty new clean diesel engine buses we can add new routes, expand upon our existing routes, and add more express routes. With the purchase of the new buses and operating and maintaining the buses for over fifteen years, the expansion of the bus system would be less than half the cost of an expanded light rail system.

III. Retrofitting

A. Retrofitting

Our first step in lowering emissions in Portland is to retrofit all diesel buses manufactured before 1993. Retrofitting is the process of rebuilding the bus engine to reduce PM emissions. A retrofitted bus will produce 80% less PM emissions meeting a 0.10g/bhp-hr (grams per brake horsepower-hour) emissions standard (Approval). Previous retrofit kits have only reduced emissions by 25-40% so this retrofit package will decrease emissions another 40-55% (Approval). Certification of the ETX-2002&#129 kit by the EPA was approved on March 24, 1997 to meet these new 0.10g/bhp-hr and all rebuilds after that date were required to meet these standards (Approval). The EPA engine dynamometer test cycle used to test the new retrofit/rebuild package was developed to closely represent the in-use behavior of these engines, so it is assumed that the emissions level produced by the certification test is representative of the average in-use emission level (EPA's Proposal).

A. Health and Environmental Benefits

The effect on our health and environment should be greatly improved through the process of retrofitting buses. The certification will result in lowered

PM emissions, thus helping the air quality in the area. PM is a contributor to air pollution in both urban and rural areas. It has been identified as a probable human carcinogen and high levels of exposure cause increases in bronchitis, Asthma attacks, and respiratory infections. PM emissions also cause reduced visibility. We see an increase in the deterioration of buildings exposed to these emissions (Approval).

C. Costs

In Portland we have 149 buses that have not been retrofitted to meet the standard 0.10g/bhp-hr. The maximum lifetime cost of a retrofit to meet the 0.10 standard is $7,940 per bus (EPA's Proposal). Already we know that buses produce less harmful emissions then cars. By retrofitting all of the buses in our fleets we will be improving the air quality in Portland greatly. So now if people ride the bus and get their cars off of the rode we should have a significant decrease in emissions. We will no longer have the output of emissions from the cars and those put out by the bus will be decreased by up to 80%.

IV. Express Bus Routes

A. Transit Choices for Livability

Between 1996 and 1998, Tri-Met and a citizen advisory committee began a planning process to develop a ten-year transit strategy for our region. The project was called the Transit Choices for Livability (TCL). Citizens in the Portland region were invited to workshops and open houses to discuss ideas on how transit could meet the needs of growing communities. Their suggestions included (Transit):

- 25 new small buses circulating within communities and onto employment sites
- 19 new bus lines
- 9 new express routes to provide faster connection between communities
- 2 new rail lines
- 45 existing Tri-Met routes improved
- Amenities - shelters, customer information, security and pedestrian connections to transit

B. New Express Buses

Based on the citizens' suggestions, five new express routes will be added to the current bus system as part of the one billion-dollar proposal to reduce carbon monoxide (CO) pollution. The express routes will connect Portland to its surrounding cities. The six major cities surrounding Portland are Vancouver, Tigard, Beaverton, Gresham, Lake Oswego, and Milwaukie.

The new routes were determined based on analysis of both employment and population growth within the cities. Table 1 shows that every city except Milwaukie had experienced double digit increases in both employment and population between 1990 and 1996. Milwaukie was ranked the lowest in both categories; therefore, no express route is planned between Portland and Milwaukie. Express buses will run between Portland and each of the 5 remaining cities.

Table 1. Change in employment and population between 1990-1996

Cities	Employment Increase (%)	Rank	Population Increase (%)	Rank
Vancouver	49	1	45	1
Tigard	39	3	22	2
Beaverton	30	4	18	3
Gresham	24	5	16	4
Lake Oswego	45	2	11	5
Milwaukie	12	6	7	6

Express buses will run every 15 minutes during peak time periods (6-9 a.m. and 4-6 p.m.) and every 30 minutes during other times. Buses will have a few stops in each city, but will primarily travel on major highways that connect between the cities. Based on a similar route between Portland and Beaverton, it is estimated that each new route will require 7 new buses. A total of 50 new buses will be purchased to meet the initial demands from the new routes. The extra buses purchased will be reserved to meet increased demand from riders. It is expected that when buses begin running on HOV lanes, demand will increase significantly.

B. Impact on Ridership

In 1999, Tri-Met had 1, 950 average originating daily rides per route (Environment). This number is based on 196,900 average originating daily rides divided by the number of routes (101). With the addition of 5 new express routes, it is estimated that the number of originating daily rides will increase by 9,750. Bus ridership on the express routes is expected to increase dramatically once HOV lanes are complete. According to a report prepared for the Federal Highway Administration, HOV lanes on the Banfield Freeway increased bus ridership by 100 % (Federal). Travel times decreased at the rate of 0.4-0.5 min/mile. Based on Metro’s Congestion Projections, the congested miles on the freeways are expected to be 3 times worst in 2015 than in 1994 (Metro). Evening peak hours of delay will be 3.4 times worst.

The HOV lanes and express buses will help alleviate part of the congestion, and the time savings they offer will be incentive for people to find alternative means of transportation. However, it is important to realize that a transit solution to reduce carbon monoxide is complex and can not be solved with either HOV lanes or express buses alone. The HOV lanes and express buses are two ways to encourage drivers to take public transportation or to find other means of transportation. It is only the beginning of a long-term effort to increase bus ridership and to reduce air pollution. Other improvements to the current bus system are scheduled for the near future. The improvements will focus on the suggestions given by the citizens involved in the Transit Choices for Livability project.

A. Projected Carbon Monoxide Savings

According to Tri-Met, the average car emits three times more carbon monoxide per passenger mile than a Tri-Met bus. Tri-met estimates that 63 pounds of carbon monoxide is saved when one commuter leaves their car at home and takes the bus for one year (Environment). Based on this estimate, the five express routes will remove a total of 511,875 pounds of carbon monoxide per year. The carbon monoxide saving were calculated as follows:

Cars taken off the road by Tri-Met from all routes = 164,083 cars

Total number of routes = 101

Cars taken off the road per route = 164,083/101 = 1,625

Cars taken off the road by 5 new routes = 1,625 x 5 = 8,125 cars

Pound of CO saving per car each year = 63 lbs.

Total CO savings = 8,125 x 63 lbs. = 511,875 lbs. CO

D. Cost

The purchase of 50 buses needed to maintain the 5 new express routes would incur the greatest cost. The new buses will have EPA certified engines and use “clean diesel” fuel, which have been reformulated to reduce sulfur by 90%. Tri-Met buses emit 90% fewer particulates and nitric oxides than 10 years ago (Environment). The total cost of purchasing and operating cost per year are summarized below:

Cost per bus = $280,000

Cost of 50 new buses = $280,000 x 50 = $14 million

Operating cost per year = 5,705,000

Total Cost = $19,985,000

V. High Occupancy Vehicle Lanes

As was noted earlier, building high occupancy vehicle (HOV) lanes will be an important component to the success of this proposed project. Combining HOV lanes with an increase in express bus routes, lowering emission levels on current buses and building future buses with clean burning diesel engines should have a profound effect on total emission levels for our state. I will outline the pros and cons of HOV lanes, propose where they should be located in the Portland-Metro area and what will help make the HOV lanes be successful. Then I will look at how much they cost and make an estimate of how much they should reduce carbon monoxide (CO) emissions. Based on these facts, I should be able to convince others that HOV lanes would be beneficial to the environment.

A. Examples of High Occupancy Vehicle Lane Projects

There are many examples of cities implementing HOV lanes to reduce emissions and to help solve congestion problems in their area. As of 1990, the US Department of Transportation reported about 340 miles of HOV lanes in the United States (Christiansen). Some have been more successful then others but generally, the cities using HOV lanes have seen some level of improvement as a result of this strategy. To help make this report succinct, I will use two specific examples of HOV lanes. One is the San Bernardino Freeway in Los Angeles, California and the other is the I-84 (Banfield Freeway) that used to be right here in Portland before MAX was built in its place.

The San Bernardino HOV lane was, and still is, a highly successful project. It is an 11.2 mile segment of freeway running from downtown Los Angeles to the El Monte Park and Ride terminal. It started out as a lane for buses only (in 1973) and then 1977 extended it extended to carpools during peak traffic periods (Rothenberg). Since its inclusion of carpools, the city has observed some phenomenal benefits to congestion, emissions and fuel consumption. One positive result is the amount of travel time saving, which increased 5 to 9 minutes for peak periods without effecting the travel time of the bus service along the freeway. Los Angeles also saw an increase of 1000% in bus ridership, due in part to an increase in express bus routes as well as the HOV lane (Rothenberg). Surveys have shown that approximately 75% of the people riding the bus previously traveled by car (Andrle). They also saw an increase of 300% in carpooling, which were shown to be new carpools rather then diverted ones (Rothenberg).

As far as the environment is concerned, the San Bernardino Freeway was also successful. Emissions were estimated to drop 20% during peak hours and fuel consumption dropped 10% as well. These estimates, however, are not based on a comparison to the absence of the "Busway", so different conditions may exist if all the lanes were open to all vehicles (Andrle).

The I-84 (Banfield Freeway) HOV lane was not as successful as the San Bernardino Freeway. It could be considered a good example of what not to do when constructing a HOV lane. The reasons for its lack of success lay strictly in the planning and construction because, as I will point out later, the environment did benefit from its presence. Some problems were that it only ran two miles in the eastbound direction and only one mile in the westbound direction. Obviously, the longer the HOV lane, the more beneficial it is to the commuter. Other drawbacks were the lack of a separate entrance or exit, no separation from the general lanes, and no shoulders on the freeway to allow room for policing (HOV lane). As I mentioned earlier, despite its poor construction, it was still effective for the Portland area before it was removed, in 1983, for the construction of MAX.

There were several reasons the I-84 HOV lane was considered effective even though it was not built well. One is the increase in Tri-Met ridership. Tri-Met increased the amount of peak hour express buses on that route and also established some park and ride lots to feed the HOV lanes. This, coupled with the HOV lane, helped the percent of rider's go up 111% in just one year, from 300 riders a day to 633 riders a day. Another benefit was the average person per car going up 3%, from 1.22 to 1.26 (Andrle). In fact, during the six years it was operational, traffic counts in that area only grew from 101,424 per day to 103,301 cars per day. Since MAX was built we have gone from 117,928 cars per day to 172,721 per day (HOV Lane). Obviously some of this increase is due to population growth but it seems logical that changes in the bus system and carpool system also contributed.

The most important statistic to look at is the emission levels as a result of the HOV lane. Interestingly, the analysis of the specific site (I-84) showed an increase in CO and HC emissions of 2% over what would have been anticipated without HOV lanes. However, a survey of the whole region indicated 3% reduction in congestion and pollutants on arterial streets because cars were using the carpool lane instead (Andrle). When you take all those components into consideration, you find the decrease in the entire area outweighs the increase in pollutants registered specifically on the Banfield. One particular analysis of the whole area showed a reduction in emissions, "by about 14% while carrying 20% more people than the same facility in 1975 without HOV lanes" (Andrle). Comparing these two projects, one can see that even a poorly designed HOV lane can be effective in certain circumstances. On the other hand, there are great possibilities if you design and maintain a good system.

B. Limitations of High Occupancy Vehicle Lanes

If HOV lanes are so beneficial, why don't we put all our money into them? Well, there are many parts to answering that question. One is the "image" factor. Rail projects tend to be flashy and make a city look attractive (and modernized) versus HOV lanes being not as valued. Another piece is the impact of land development. With rail transit, people have incentives to develop right on the rail line allowing them greater access to a high concentration of people. Obviously, HOV lanes do not accomplish this. Public opinion has been another drawback to HOV lanes. People generally support carpool lanes but then tend to question their effectiveness if the HOV lane takes away from general lanes. Also, if they are sitting in standstill traffic and the HOV lane has hardly anyone in it, they often question if the lanes are used enough to warrant their presence. The length of the trip served by the HOV lane is another point of contention. In order for them to be effective, the trips should be relatively long and during peak hours. Rail can be more effective if the trip is short or if it is during off peak hours. The cost of maintenance and enforcement can be a concern for HOV lanes and a poorly designed collection and distribution system (to and from the HOV lanes) can cause disruption to the flow of traffic in the area (Christiansen). Clearly HOV lanes are not a perfect system but I don't think there is a system without flaws.

In order to combat these issues, Portland would have to do some careful planning when adding HOV lanes. One possibility for success would be only adding a carpool lane if the freeway could be expanded. In other words, we would commit to not taking away an existing lane and turning it into a HOV lane. Another would be to look at the whole HOV system and make it efficient and convenient for commuters. To do this we would want to have park and ride lots and HOV bypass ramps so those carpool or bus riders wouldn't have to wait on metered on-ramps. Some incentives might be free parking for carpoolers or state-funded vanpool programs. We would also have to make creating a carpool fast and easy so that the commuter doesn't have to do too much work to organize it.

C. Proposed Areas for High Occupancy Vehicle Lanes in Portland

If we decide to add carpool lanes, the next step would be to decide where to put them. All of the main freeways in the Portland-Metro area would benefit from a HOV lane but I think adding lanes to four specific areas could make a difference. The US-26 (Sunset Hwy.) desperately needs help. Hwy. 26 has constant problems and adding West-Side Light Rail did not solve them. To build a HOV lane in this area will be a tricky project.   Much of the highway, west of Hwy. 217, has a grassy median so there may be less of a cost if this area were simply filled in and paved. It is the rest of the corridor that would probably be the most costly. One thing to consider is how the carpool lanes would feed the vehicles onto their next freeway without causing a disruption to the flow of general lane commuters. I think I will leave this to experts to figure out but I hope, in general, a HOV lane would really help this area.

Highway 217 is similar to US-26 in that it is a highly congested route and the population growth is soaring in those areas connected to the highway. A HOV lane running the whole length of Hwy. 217 would be a wonderful addition for commuters going that way. If we really thought big, the carpool lane off of

Hwy. 26 could connect to the carpool lane on 217 and those commuters wouldn't have to do any merging with the general traffic. For those living in the Aloha or Hillsboro area, the convenience and speed of this lane could be plenty of incentive to form a carpool.

Another good place for a carpool lane would be to get one back on I-84. It worked before and is a highly traveled area so based on congestion alone, this freeway could benefit from getting the HOV lane back. Although this time, the designers should make it run the length of the freeway and should consider how they can more easily feed the carpool lane to and from the ramps.

We have already built a HOV lane on the north part of the I-5 corridor because of the Interstate Bridge painting project. I am not clear on whether or not ODOT plans to keep the HOV lane after the painting project is done, but my vote would be to maintain the existing HOV lane and extend it south so that it extends to the interchange at Hwy. 217. It would take some creative engineering to have a HOV lane over the Marquam Bridge but if they could do it, I could see carpooling becoming very popular for the I-5 commuters.

A. Projected Carbon Monoxide Reduction

By adding all these lanes we could possibly see a reduction in emission levels by as much as 4,671,513 pounds of CO each year. In order to project this number, I used statistics from the I-84 HOV lane project. When that HOV lane was operational, there was a 3% decrease in the amount of vehicles on the road so based on a traffic count of 112,000 cars, we can estimate 3,465 fewer cars were on the road in that area (Andrle). The I-84 HOV lane was 3 miles so we can calculate approximately 1,155 cars are off the road for every mile of HOV lane. We know we are adding 64.2 miles of HOV lane so this brings the total amount of cars off the road to 74,151. Tri-met estimates a savings of 63 pounds of CO each year when you take one car off the road, so if you multiply the total amount of cars off the road by the 63 pounds, you will get a total of 4,671,513 pounds per year (Environment). If my formula is correct, it is possible that the amount of CO saved each year could be even more than this. We can only make a judgement based on how the I-84 HOV lane did and that was over 10 years ago. With population growth and congestion being at an all time high, it doesn't take much more than this to convince me that carpool lanes are going to be a help.

E. Projected Cost

So what does this all cost? It was hard to pin down an exact figure because these types of projects are site specific, but based on some general information you can get a reasonable figure. We are setting a budget of $6,525,000 per mile of HOV lane. To get this amount, I took an average from several different sources including ODOT's budget from 1999 (ODOT Lists), the San Bernardino HOV lane project (Andrle) and from two other HOV lane projects in Oregon and Washington (Christiansen)

In order to build in all the areas I discussed earlier, we will be adding a total of 64.2 miles of freeway. For the Banfield we have 6.2 miles each way, for

Hwy. 217 there are about 8 miles each direction, I-5 is a 9.4 mile stretch and Hwy. 26 is 8.5 miles each way. That would bring the total cost to approximately $418,905,000 for the whole project. In comparison to the East-side light rail project at a cost of $14 million a mile, HOV lanes seem pretty cheap and are really doing more for the environment (Christiansen).

Based on the success of previous HOV lanes lowering emission levels, lowering fuel consumption, relieving congestion and increasing travel time, one can conclude that HOV lanes are an important component to the overall pollution problem. They are one part to the vision of making the Portland Metropolitan area a clean place to live and breathe.

VI. Conclusion

Our proposal clearly favors alternatives other than light rail. By retrofitting our current flee of buses and committing to the future purchases of only clean diesel buses, we will save 16.84 grams of CO emissions for every mile a single passenger rides a bus. As our bus system expands and new buses are purchased, we will be able to add enough express routes to save 511,874 pounds of CO every year not to mention the savings that are already happening from existing bus routes. Carpools will save us another 4,671,513 pounds of CO each year. Although MAX has virtually no emissions, the amount of people carried on the train’s pale in comparison to HOV lanes and expanded bus systems.

With our budget of $1,000,000,000 we will need to spend $1,192,000 to retrofit our current fleet of buses. The express bus system will cost us $14,000,000 and the HOV lanes will be $418,905,000. If we leave ourselves a leeway of $50,000,000 for any other cost that might arise, we will have just under half a billion dollars that we are planning to invest. We will use a low risk mutual fund with a minimum 12% annual return. This will give us a minimum of approximately $57,000,000 dollars each year, without ever touching the principle, to cover maintenance and operations for the years to come. We are not looking for the quick fix, we want to be able to run this program indefinitely and have the money to make improvements as new technology arises. As science moves forward, we want to be able to move with it. This is why we feel setting aside a portion of our funds is important in helping the air quality of Portland. Considering the low cost of such high savings in carbon monoxide emissions, we owe it to our city to consider options other than light rail.

Works Cited

Andrle, Steven, Frank Spielberg, Michu Tcheng and Carl Zellner, Evaluation ***of Freeway High Occupancy Vehicle Lanes and Ramp Metering***. U.S. Department of Transportation, Washington D.C.; August 1980.

Carpools, Tri-Met Bikes, Carpools & Vanpools Home Page, available at http://www.tri-met.org/carpool.htm.

Christiansen, Dennis L. ***High-Occupancy Vehicle System Development In The United States***. A White Paper, U.S. Department of Transportation for Texas Transportation Institute, Texas A&M University, College Station, Texas; December, 1990.

Definitions of Performance Measures, Oregon Department of Transportation carpool information home page, available at http://www.hov.odot.state.or.us/evaluation.htm.

HOV Lane/Light Rail Comparison-High Occupancy Vehicle Lanes, available on http://www.hevanet.com/oti/webdoc4.htm, pg. #2.

ODOT Lists Construction Spending for 1999, Oregon Department of Transportation News Media Home Page, available at http://www.odot.state.or.us/news/2000021701.htm, pg. #3-5.

Rothenberg, Morris J. & Samdahl, Donald R. ***Evaluation of Priority Treatments for High Occupancy Vehicles***. U.S. Department of Transportation for Federal Highway Administration, Office of Research and Development, Washington D.C.; January 1981.

ODOT Lists Construction Spending for 1999, Oregon Department of Transportation News Media Home Page, available at http://www.odot.state.or.us/news/2000021701.htm, pg. #3-5.

Buckstein, Steve. ***Top Ten Light Rail Myths***. January 30, 1999. http://www.cascadepolicy.org/transit/topten.htm

Cunneen, Michael J. ***Trip Behavior after Eastside MAX in Portland, Oregon***. May 1999. http://www.cascadepolicy.org/transit/cunneen.htm

Environmental Protection Agency. Automobiles and Carbon Monoxide. http://www.epa.gov/orcdizux/03-co.htm

Hevanet. ***Light Rail Counts (Or Does It).*** http://www.hevanet.com/oti/maxcounts98.htm

Johnson, Andy, Cummins Northwest, Inc. Diesel Emission Information. http://www.tri-met.org/cummins/htm

Mildner, Gerard C.S. An Analysis of the Airport Light Rail Proposal in Portland, Oregon. http://www.cascadepolicy.org/transit/airport.htm

Mildner, Gerard C.S***. Punishing North Portland, commuters & taxpayers***. Policy Insight December 1999.

Tri-Met. ***Environment and Clean Air***. http://www.tri-met.org/envfacts.htm