The Environmental Consequences of Traffic Congestion in Providence, RI

By

Jennifer Lee Hogan

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Introduction

Central Question: What are the environmental consequences of traffic congestion in Providence, RI and how can they be reduced?

Automobiles are the dominant mode of transportation in the United States. Since the end of World War II, there has been a tremendous increase in the number of cars on the roads. In 1945, there were 25 million cars registered in the United States; approximately one car for every 5.3 people.[1] By 1994, the United States had 261 million cars registered; one car for every 0.9 people.[2] In addition, there were 56 million light trucks, including vans and sport utility vehicles. Worldwide, the number of cars has increased to 500 million and is expected to reach one billion within the next 25 years. As automobile ownership increased, it became easier to live farther away from urban areas and, conversely, living farther away from urban areas made it necessary to own an automobile. The flexibility of automobile use, which is a great part of its appeal, is being threatened by increasing gridlock on roads and highways and planners predict that the gridlock situation on many roadways is going to get worse within the next 20 years.[3]

When congestion becomes a problem, the traditional response has been to build more roads and sometimes increase funding for public transportation programs. The Rhode Island Public Transit Authority (RIPTA) provides Providence's public transit system. Currently, those without access to cars are the system's primary users. Public transportation systems are not commonly self-sustaining, and many programs are heavily subsidized, as is the case with RIPTA. Currently light-rail is not a component of transportation services in the city. The population of

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[1] Levy, John M. Contemporary Urban Planning. Virginia Polytechnic Institute and State University. New Jersey. Fifth Edition. 2000. p. 183.

[2] Levy, John M. Contemporary Urban Planning. Virginia Polytechnic Institute and State University. New Jersey. Fifth Edition. 2000. p. 183.

[3] Samuel, Peter. "Traffic Congestion, A Solvable Problem." *Issues in Science and Technology.* Spring 1999. p. 49.

Providence is decreasing but the non-urban and suburban areas are growing.[4] Congestion is not going to be solved by an increase in public transportation services since the average car trip is faster than a public transportation trip and costs less.[5]

Although the state is encouraging alternative modes of transportation, motor vehicle use is still increasing. Rhode Islanders currently own more cars, spend more time behind the wheel, and deal with more traffic than ever before. Delay times have increased. By the summer of 1999, the number of automobiles registered in RI reached approximately 961,000; about one vehicle for every state resident (including children).[6] In 1982, drivers in the Providence-Pawtucket urban area each experienced an annual delay of approximately 2 hours. By 1997, that annual delay rose to 17 hours.[7] The increased traffic has been attributed to several causes including:

- More commuters to Providence, Warwick, and Cranston from South County
- Increased border crossing between Rhode Island and Massachusetts
- Providence's new attractions such as Waterfire and the opening of the Providence Place Mall[8]

How do we deal with the rising number of vehicles on Providence's roads and highways? Traditionally, transportation planners have invested in building bigger and wider roadways. Others argue that in order to reduce reliance on cars, letting congestion worsen would persuade people to carpool and switch to alternative modes of transportation. Although some areas have used road construction as their response to congestion, evidence is continually mounting that

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[4] H.C. Planning Consultants, Inc. *Decaying Urban Centers*. Grow Smart. Rhode Island. 1999. p. 10-25.

[5] Samuel, Peter. "Traffic Congestion, A Solvable Problem." *Issues in Science and Technology.* Spring 1999. p. 49.

[6] Sabar, Ariel. "Today's Traffic: No exit – More Cars mean More Congestion." *The Providence Journal.* October 27, 1999. p. A-01.

[7] Schrank, David and Tom Lomax. *1999 Urban Mobility Study*. Texas Transportation Institute. Texas A&M University System. 1999.

[8] Sabar, Ariel. "Today's Traffic: No exit – More Cars mean More Congestion." *The Providence Journal.* October 27, 1999. p. A-01.

demonstrates the ineffectiveness of new roadway construction. The Surface Transportation Policy Project (STPP) released a report in 1999 that examined the effectiveness of road expansion as a congestion mitigation action.[9] They found that metropolitan areas that built roads experienced no more relief from congestion than the areas that did not build, indicating that building is not the answer to alleviating congestion.

Congestion is not defined solely as standstill gridlock, cars not moving on a roadway. Slow moving traffic also is congestion. Beyond a certain number of car-equivalent vehicles per traffic lane per hour on a standard expressway, the entry of additional vehicles causes the capacity of the road to decline sharply. Urban freeways are susceptible to this diminished capacity as a result of recurring congestion. One method used to determine the relationship between capacity and delay is "deterministic queuing analysis" and although, in some cases it underestimates delay magnitude, it is effective in demonstrating the delays imposed on drivers in a congested situation. In the Figure 1, the area between the demand and the capacity curves in a queuing diagram is analytically equivalent to the total vehicle-hours of travel in congestion. It demonstrates that congestion occurs when there are more vehicles on the roadway, congestion delay increases and capacity is compromised.

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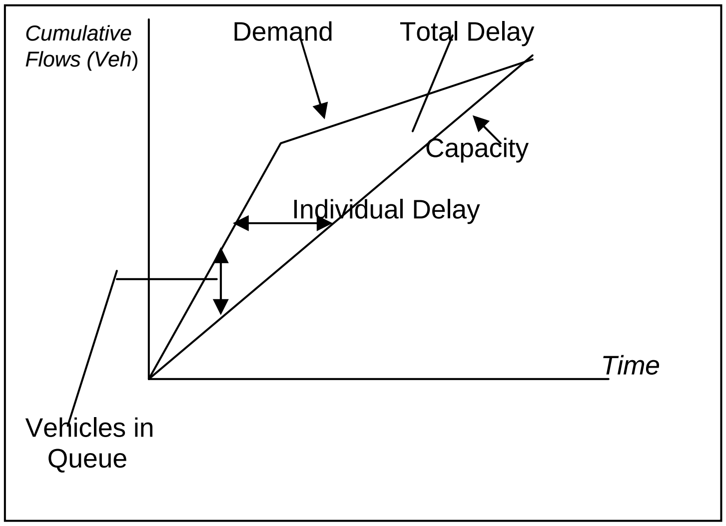
[9] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

Figure 1. Deterministic Queuing Analysis Diagram as function of Time and Vehicle Flow. *Source: Lum, K.M., et al. "Speed Flow Modeling of Arterial Roads in Singapore".* Journal of Transportation Engineering*. ASCE. May/June. 1998. ASCE, ISSN 0733-947X.*



Congestion creates traffic pattern changes. In some cases, "wave phenomenon" develops within the system if drivers are driving safely. Although drivers are comfortable to be a few feet behind the car that is ahead of them when they are traveling at lower speeds, they want progressively more space ahead of them when traffic is going faster. On average, when lane volume reaches 2200-2500 vehicles per lane per hour (depending on weather, driver temperament, and visibility) motorists drive more slowly in an attempt to preserve that comfort space; thereby reducing roadway capacity.[10] The flow becomes unstable. There is also an "induced demand" phenomenon where new road capacity induces additional traffic. Widened roads create additional capacity and drivers switch from their old routes to the newly widened ones. STPP's analysis found that every 10% increase in the size of the highway network is associated with a 5.3% increase in the amount of driving that occurs. In addition, the University

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[10] Samuel, Peter. "Traffic Congestion, A Solvable Problem." *Issues in Science and Technology.* Spring 1999, p. 54.

of California recently found that 10% increases in new lane miles generated 9% increases in traffic.[11] While road construction can decrease congestion in the short term, the extra capacity invites more drivers to the widened road over time.

MOBILE SOURCE AIR POLLUTION

In addition to looking at roadways, policies and technological advances strive towards making fuels and vehicle engines cleaner. Policies and clean air standards have demanded technological innovations such as alternatively fueled vehicles and increased fuel efficiencies. However, sport utility vehicles are gaining more popularity as passenger vehicles, emitting more pollutants, while only subject to truck emissions standards. Although building cleaner cars can reduce mobile source air pollution, manipulating the efficiency of a vehicle and controlling how fast and far it travels, can also reduce vehicle emissions.

The majority of a vehicle's emissions are comprised of water, carbon dioxide (CO_2), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs). Nitrogen oxides, carbon monoxide, and volatile organic compounds are included in the National Ambient Air Quality Standards (NAAQS) and are the focal points of this evaluation. The combustion of a vehicle's fuel also impacts the amount of carbon dioxide (CO_2) released to the atmosphere. Factors including the miles a vehicle travels, the speed at which it travels, the amount of fuel it consumes, and the type and age of the vehicle affect emissions. These factors can be manipulated with different traffic flow controls and each method will yield different emissions results.

TRANSPORTATION PLANNING

Transportation planning is a multi-step process and involves mathematical and computerized modeling. First, planners estimate trip generation, trip distribution, modal split,

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[11] Peirce, Neal R. Washington Post Writers Group. "Do Widened Roads Create their own gridlock?" http:/www.sierraclub.org/sprawl/transportation/gridlock.asp.

and trip assignment.[12] Trip generation is found by looking at the number of people per household, household income, number of vehicles per household, population density and estimates the number of trips per household per day. Trip distribution is an estimate of how the trips will be distributed over the area. Then the division of trips between modes of transportation is determined. It is usually an issue of quality (travel time) and cost of service. Finally, trip assignments are ascertained (who takes which route) through modeling. Results are used for transportation planning.

Creative use of existing roadways can increase capacity and discourage congestion and delay. Traffic control techniques include traffic signals, stop signs, speed limits, and physical road structures such as curves, medians, and speed bumps. Traffic signals timed and linked together along a single roadway prove to be effective in decreasing travel and delay times.[13] Stop signs have primarily been used for safety, and are often installed to slow speeding traffic. Physical structures are quickly becoming abundant in Providence as part of traffic calming programs to discourage cut through traffic on local roads, neighborhood speeding, and can serve as an alternative to stop signs. Communities may have different project goals for utilizing calming techniques. They may also include slowing traffic for safety, maintaining constant speeds to increase flow efficiency, or creating more pedestrian-friendly streets. Individual methods must be evaluated to measure their success for reducing traffic congestion while providing environmental benefits. Changing traffic flow will change the amount of motor vehicle emissions and have an environmental impact.

COMPREHENSIVE PLANNING

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[12] Levy, John M. *Contemporary Urban Planning*. Virginia Polytechnic Institute and State University. New Jersey. Fifth Edition. 2000. p. 183-200.

[13] Rhode Island Department of Transportation. Application form for Candidate Project. Congestion Mitigation and Air Quality (CMAQ) Program. Attached Narrative, "Incremental Benefits of Different Levels of Control." pg. 45. Provided by Paul Silva, Rhode Island Department of Transportation.

Providence is experiencing new development and its growing transportation needs must be included in its comprehensive plan. A comprehensive plan is the basic plan prepared to guide development of the community. This plan contains guidelines for traffic circulation. The plan is long-term and encompasses the entire community. The city is required by state law to create a plan to outline the goals and accomplishments for the city and then update the plan every five years.

Providence's urban development will create more traffic congestion and that will impact the environment including air quality. A comprehensive plan's goals are aimed towards preserving the health, safety and public welfare; traffic congestion alleviation fits into all three categories.[14] A community's ease of traffic circulation is also a central priority for a city plan. Health preservation includes easing the effects of air pollution and securing a community's safety includes safe road building in order to fulfill a community's needs.

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[14] Levy, John M. *Contemporary Urban Planning.* Virginia Polytechnic Institute and State University. New Jersey. Fifth Edition. 2000. p. 100-110.

Chapter 1 - Traffic Congestion

HOW ARE TRAFFIC CONDITIONS MEASURED?

MOBILITY

Besides local and state government, several organizations analyze and evaluate traffic conditions. These organizations are in agreement that the amount of traffic is rising throughout the country, but use different measures of the impacts, such as the effect congestion has on an individual's travel time or on increasing road system delays and backups.

The Texas Transportation Institute (TTI) has used a generally respected method of measuring traffic conditions. Each year, from 1982 to the present, TTI releases an urban mobility study rating traffic conditions in approximately 70 urban areas. This methodological consistency has provided reliable trend information and a comparable database. TTI traffic measures include travel rate index, wasted fuel consumption, hours of driver delay, and congestion cost; they are measures of mobility, travel time and personal movement. Mobility is the key component in TTI's *1999 Urban Mobility Study*[15] and is measured by an individual's increased travel time due to congestion.

The study evaluates urban areas that do not coincide with city and town boundaries. TTI defines an urban area by density and not by town or county boundaries. According to David Schrank of TTI, mobility is measured for each urban area and each area is defined as "only developed land with a density of greater than 1000 persons per square mile" included in the boundary.[16] By this definition, urban areas are generally larger than areas within city limits. The

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[15] Schrank, David and Tom Lomax. *1999 Urban Mobility Study*. Texas Transportation Institute. Texas A&M University System. 1999.

[16] Correspondence with David Schrank, Texas Transportation Institute. Texas A&M University System. March 4, 2000.

TTI study estimates mobility for the entire Providence Metropolitan area and labels the area as "Providence– Pawtucket".

Key components of Mobility:

Travel Rate Index measures the additional delay of trip time, as percent increase or decrease in trip time, with congestion compared to a trip time without congestion. This is a recent addition to TTI's data. It is estimated by converting the average speed in miles per hour to a travel rate in minutes per mile so the rate would be "60" divided by the average speed where 60 is the speed where a road is considered "uncongested".

Daily Vehicle-Miles Traveled (DVMT) is a measure of the average daily traffic of a section of roadway multiplied by the length (in miles) of that section of roadway. In the mobility study, DVMT was calculated both for freeways and arterial streets located in each urban area. The estimates originated from the Highway Performance Monitoring System (HPMS) database and local transportation data sources. The HPMS is a national database that includes data on public roads, arterials, and information on urbanized, small urban and rural areas. Its main purpose is to provide a comprehensive look at the nation's highways.

Annual Excess Fuel Consumption is a measure of the extra fuel used due to congestion, it measures the effect of slower speeds with extra fuel needed each year. This is found by multiplying the hours of delay by the average peak period speed and then dividing that by the average fuel economy.

Hours of Driver Delay is a measure of annual delay (extra travel time) for individual drivers. It is derived from estimates of vehicle traffic per lane and speed and includes both usual and incidental delays.

Congestion Cost – This calculation assigns a value for each hour of travel time and each gallon of fuel. The value of travel time is based on TTI research into the value that people demonstrate by their behavior. Fuel cost is estimated from state averages. These following variables all factor into congestion costs:

1. Vehicle Occupancy estimated as 1.25 persons per vehicle
2. Working Days estimated as 250 days per year
3. Average Cost of Time per person hour
4. Commercial Vehicle Operating Cost
5. Vehicle Mix estimated for 95% passenger and 5% commercial
6. Percent of Daily Travel in Peak Periods
7. Speed was measured as an annual average separately for freeways and arterial streets

Population – Population data are based on urbanized area boundaries and were obtained from the combination of US Census Bureau estimates and 1997 population estimates from the HPMS. The 1997 Providence-Pawtucket urban population is estimated at 899,600 people. Referring back to the previous definition, this population will include any of the surrounding area that has a density of greater than 1000 persons per square miles so may include some of the neighboring suburbs, it is really a measure of the Providence Metropolitan area. The Providence-Pawtucket urban area was categorized as having a medium-sized population meaning that the population was between 500,000 and 1,000,000 people.

Average Peak Period Travel Speed is the average speed during a road's peak period travel time. The mobility study has separate average speeds for freeways and arterial streets.

Measures Defined by Urban Mobility Study: Schrank, David and Tim Lomax. 1999 Urban Mobility Study. Texas Transportation Institute. Texas A&M University System. 1999.

The TTI contends that these measures are appropriate for measuring congestion and highlights the importance of a "travel rate index". The travel rate index answers the question, "How much longer will it take me to get there if I drive during rush hour traffic?" For example, if an area has a travel rate index of 1.3 that means that it takes 30% longer to travel to a destination during the peak traveling time than it would to travel at an off peak or "speed limit" condition. Providence-Pawtucket rated 48 out of 68 for highest travel rate index with a 1997 index of 1.13. Travel rate indices were also influenced by urban area size. The highest travel rate was 1.51 in Los Angeles, CA that was designated as a "very large" city. Providence-Pawtucket was considered a "medium" sized city. Tacoma, WA was also considered a "medium-sized" city and had an index of 1.26 while Colorado Springs, CO, a small city, had an index of 1.10.

TTI's suggests some rather obvious solutions to traffic congestion.

1. Adding Road Space – new or widened roads.
2. Decreasing the number of vehicles on the road or increasing the number of people in each vehicle.
3. Changing the times that vehicles use the roads – having fewer people on the road during conventional peak periods.
4. Achieving more efficiency on the roadways by reducing the buffer space between moving vehicles.

In general, the mobility study concluded that traveling the same distance in large urban areas takes more time than in smaller areas. This is not an extraordinary conclusion, but it does point out the difficulty of managing transportation in growing areas.

BOTTLENECKS

American Highway Users Alliances (AHUA) is a non-profit organization representing a portion of the transportation community interested in safe and congestion-free highways. AHUA evaluates congestion by studying major arteries throughout the United States. They determine if these roads have "bottleneck" tendencies. A bottleneck was defined as "a specific, physical location on the highway that routinely experiences traffic backups".[17] The organization identified "bottlenecks" as a significant cause of congestion and believes that if they were fixed, a significant part of traffic congestion could be resolved.

Their study, "Unclogging America's Arteries: Prescriptions for Healthier Highways," identified and estimated benefits to travelers and the environment by removing these bottlenecks. Bottlenecks create a lot of "stop and go" traffic, which emits more pollutants as well as consumes

[17] American Highway Users Alliance. *Unclogging America's Arteries: Prescriptions for Healthier Highways*. Cambridge Systematics, Inc. Washington, DC. November 1999. p. 6.

more fuel.[18] Removing bottlenecks can prevent accidents, improve air quality, and save time (reducing delays). Bottlenecks can occur in areas where a traffic lane is lost, where there are restrictive side clearances, at signals, before tollbooths, and on merging ramps. The organization gathered information from local transportation planning agencies and state departments of transportation. They identified the 18 "worst bottlenecks" and mentioned additional congested areas.

Rhode Island had two bottlenecks; one in Providence and the other in Kent County, both on Interstate 95 however, the areas were not significant enough to be among the 18 worst. (See Table 1)

TABLE 1. Freeway Bottleneck Locations in Rhode Island.

Urban Area	**County**	**Route**	**Reference Mile point**	**Vehicles/Day**	**1997 Delay (Thous Hrs)**
Providence-Pawtucket	Kent, RI	Interstate 95	24.734	141,500	4,711
Providence-Pawtucket	Providence, RI	Interstate 95	36.878	231,200	3,749

Source: American Highway Users Alliance. Unclogging America's Arteries: Prescriptions for Healthier Highways. Cambridge Systematics, Inc. Washington, DC. November 1999. p. 65.

For the 18 worst bottlenecks, the study suggested traffic flow improvement and quantified the benefits with lives saved, percentage decreases in emissions, and saved time from previous delays. They found that if delay time was reduced and the flow of traffic became smoother at bottlenecks, then tailpipe emissions (CO, VOC, and NOx) would be reduced.

The Surface Transportation Policy Project (STPP) is an organization that has consistently releases a companion study to the Texas Transportation Institute's mobility study. Their report uses TTI's data and tries to give some insight on pressing traffic problems, particularly

[18] American Highway Users Alliance. *Unclogging America's Arteries: Prescriptions for Healthier Highways*. Cambridge Systematics, Inc. Washington, DC. November 1999. p. 3.

congestion. The companion study released in 1999 titled, "Why Are the Roads So Congested?"[19] highlights the Department of Transportation's findings that define causes for congestion.

Although it is common to think that congestion comes from growth, it is important to distinguish which kind of growth is having the effect. STPP found that only 13% of the growth in driving between 1983-1990 was attributed to “new drivers”. This means that most of the driving growth comes from existing drivers. Existing drivers are taking longer trips, carpooling less, and switching from biking, walking, and transit to the automobile.[20] (See Table 2)

TABLE 2. Factors Contributing to Growth in Driving.

% of Contribution to Driving Growth	**Activity Contributing**
18%	Increase in Trips Taken
17%	Decrease in Vehicle Occupancy
17%	Switch Transportation Mode to Driving
13%	Increase in Population
35%	Increase in Trip Lengths

Source: Travel Behavior Issues in the 90's. US DOT, Federal Transit Administration. Washington, DC. July 1992. p. 14.

STPP also explored whether road construction was necessary to keep up with growth. They found that “metro areas” that experienced a decline in the amount of roadway allotted per person actually had slightly lower congestion levels then areas showing an increase of roadway capacity per person.[21] STPP wanted to discover the effect of congestion from road building. This question addresses the previous issue of “induced demand”, did road building alleviate congestion or did actually increase congestion because of the increase in capacity?

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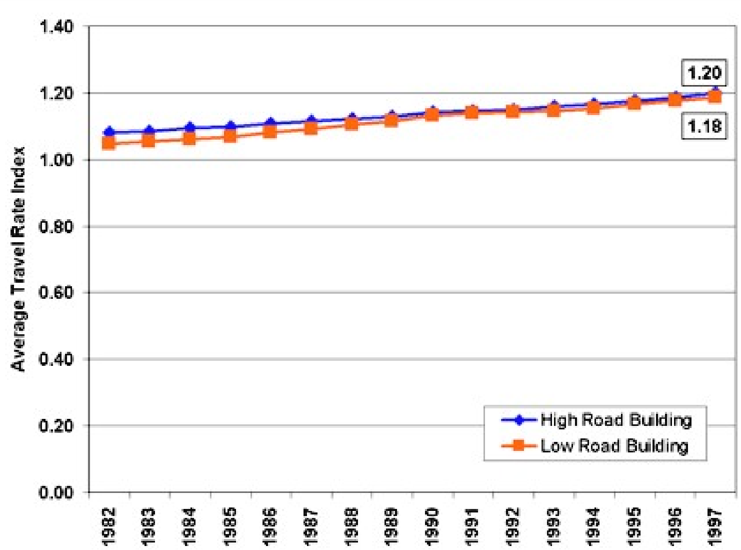
[19] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

[20] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

[21] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

STPP split the 68 urban areas into 3 categories determined by miles of highway built: low, medium, and high levels of road building. The study defined "highway" as lane miles of interstates, freeways, expressways, and principal arterial streets. They discarded the middle group and compared only the high and low categories. Providence was designated as a "high building" area, averaging 28% increase in lane miles per capita. "Low building" was determined to average an 11% decrease in lane miles per capita.[22] Both groups contained 23 urban areas. Metro areas that had built many roads showed slightly higher congestion levels than areas where there was less building, throughout the same time period. (See Figure 2)

Figure 2. STPP High Build vs. Low Build Congestion.



Source: STPP. <u>Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion.</u> Washington, DC. November. 1999. ***<u>http://www.transact.org/constr99</u>***.

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[22] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

While the population in Providence-Pawtucket increased in the urban area by 9%, miles of highway increased by 59%.[23] Their analysis found that the Providence-Pawtucket area's current traffic congestion problems are not an inevitable result of the normal, healthy growth of new drivers and of the metropolitan area – they are more linked to sprawl. Roy Kenitz, Executive Director of STPP says that, "Sprawl is making just about everyone drive farther and more often, and that fills up the roads."[24]

WHAT IS THE MOBILITY IN PROVIDENCE?

The Texas Transportation Institute's data show that while populations in the metropolitan areas studied grew by an average of 22% in the 16 years since 1982, the average traffic delay experienced by individuals has increased by 235%.[25] Population growth is only a minor factor contributing to this congestion; this is also true in the Providence-Pawtucket area. The increase in driving by each resident is making it seem like there are more "new" people on the road. There is a "perceived population" driving. As stated previously, the majority of that population consists of existing drivers using their vehicles more frequently and for longer periods of time. The perceived population was calculated by multiplying each urban area's population by the percentage increase in the area's vehicle miles traveled.

<u>Providence-Pawtucket Area Actual and Perceived Population Growth (1982-1997):</u>

Percent Change in Population:	9.1%
Percent Change in Driving:	62.1%
Actual Population Growth:	75,000
Perceived Population Growth:	512,225

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[23] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

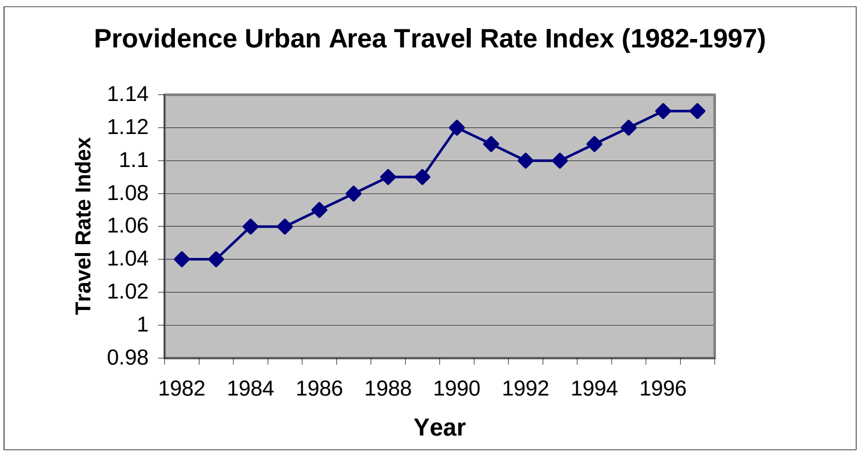
[24] Surface Transportation Policy Project. *Why are the Roads So Congested? An Analysis of the Texas Transportation Institute's Data on Metropolitan Congestion*. Washington, DC. November 1999. http://www.transact.org/constr99.

[25] The Conservation Fund. *Common Ground*. "Small Tracts." Arlington, VA. Vol. 11. No. 2. January/February 2000.

The urban area is experiencing traffic congestion that is almost seven times more than the expected impact from actual population growth and people on the roadways are perceiving that there are seven times more "new drivers".

In the Providence-Pawtucket urban areas, there has also been a steady increase in the travel rate index. (See Figure 3) In 1982, it would only take drivers 4% more time to get to their destinations in a peak period. However, in 1997, it took drivers 13% more time to reach their destinations. Given the perceived population growth, however, it seems like driver's delay is relatively low.

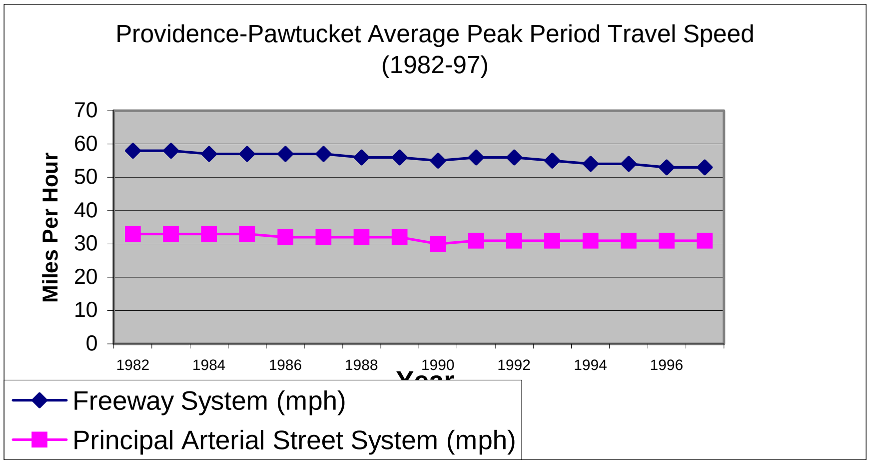
Figure 3. Providence Urban Travel Rate Index (1982-1997).



Source: Texas Transportation Institute. <u>1999 Urban Mobility Study</u>. The Texas A&M University System. College Station, TX. 1999. http://www.mobility.tamu.edu.

A key indicator of congestion is average speed. If speed is decreasing on a road, congestion is likely to be on the rise. In the Providence – Pawtucket urban area, average peak period speeds have been decreasing, although very gradually, from 1982 to 1997. The decrease is seen more in the freeway travel speed and only slightly on principal arterial streets. (See Figure 4) The travel rate index has been increasing so it seems that travel speed should be experiencing a greater decrease due to congestion. Average speed must be affected by the increase in faster top speeds, which has offset rush-hour slow downs keeping the average speed decreasing.

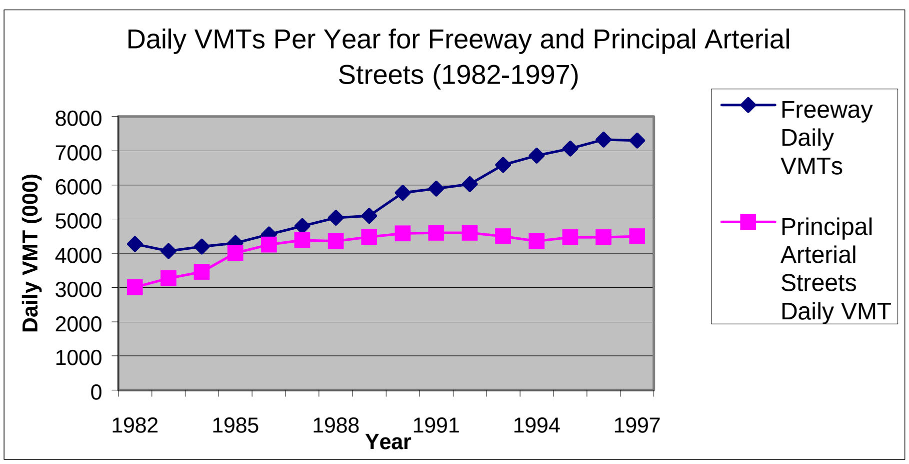
Figure 4. Average Peak Period Travel Speed (mph).



Source: Texas Transportation Institute. 1999 Urban Mobility Study. The Texas A&M University System. College Station, TX. 1999. http://www.mobility.tamu.edu.

The mobility study also distinguishes between "vehicle miles traveled" on freeways and principal arterial streets. (See Figure 5) As shown, freeway miles have significantly increased from 1982 at approximately 3 million daily vehicle miles traveled to over 7 million in 1997. The arterial streets did not experience as much of an increase, only having an additional increase of 1.5 million miles traveled over the 15 years.[26]

Figure 5.   Daily VMTs per Year for Freeway and Principal Arterial Streets.

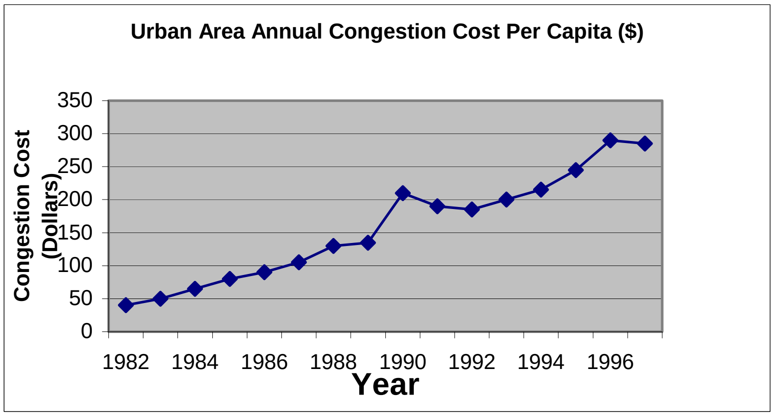


Source: Source: Texas Transportation Institute. 1999 Urban Mobility Study. The Texas A&M University System. College Station, TX. 1999. http://www.mobility.tamu.edu

[26] Schrank, David and Tom Lomax. 1999 Urban Mobility Study. Texas Transportation Institute. Texas A&M University System. 1999. http://mobility.tamu.edu.

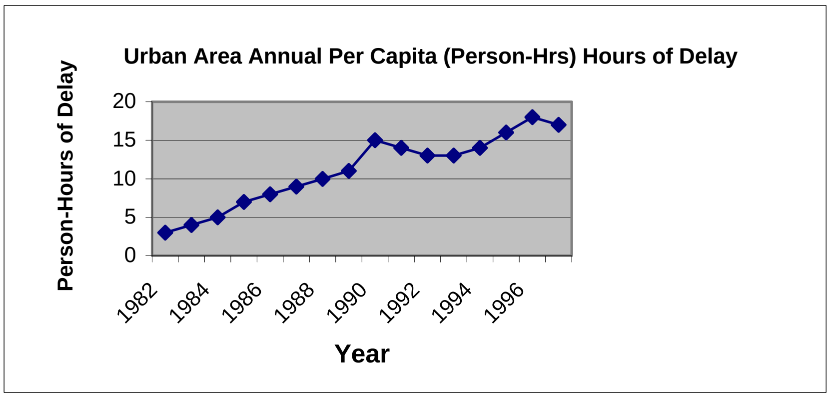
As defined previously, the “urban area” was also evaluated in terms of congestion cost. Over the years, the Providence – Pawtucket area’s annual congestion cost per capita has increased significantly. (See Figure 6) The annual congestion cost (per capita) was under 50 dollars in 1982, but by 1997, individuals were paying over $250 dollars in congestion costs. Although the change in speed was small over the years, the annual hours of delay in 1997 were approximately five times greater than in 1982. Annual hours of delay per capita rose from approximately 3 hours of delay per person to 17 hours per person of delay in 1997. (See Figure 7) There was a corresponding increase in the total amount of fuel wasted by congestion in the area. In 1982, there was an average of 4 million gallons of *excess* fuel consumed. That number increased to 23 million gallons over the 15-year period. (See Figure 8) These increases are significant enough to warrant some concern about congestion. There seems to be some contradictions when looking at these figures. The speed is not changing but the fuel consumption and the vehicle miles traveled are increasing. Also, the percentage of travel that occurs in the peak period is slightly increasing. In 1982, 28% of travel was done during the peak period and in 1997, 33% of traveling was during the peak period. Therefore, some of the factors that the study measured, for example average speed, may not be the best indicator of actual congestion because top speed compared to rush-hour slowdown speeds are being averaged together, not representing a true picture of overall speed conditions.

Figure 6. Urban Area Annual Congestion Cost Per Capita ($)



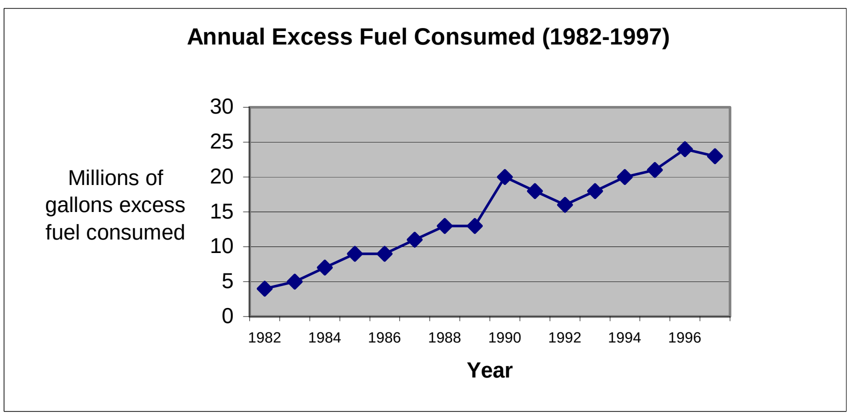
Source: Source: Texas Transportation Institute. 1999 Urban Mobility Study. The Texas A&M University System. College Station, TX. 1999. http://www.mobility.tamu.edu

Figure 7. Urban Area Annual (per Capita) Hours of Delay.



Source: Source: Texas Transportation Institute. 1999 Urban Mobility Study. The Texas A&M University System. College Station, TX. 1999. http://www.mobility.tamu.edu

Figure 8. Annual Excess Fuel Consumed (1982-1997).



Source: Source: Texas Transportation Institute. 1999 Urban Mobility Study. The Texas A&M University System. College Station, TX. 1999. http://www.mobility.tamu.edu

How can the environmental significance of these congestion factors be estimated? The best way currently available is the use of emission estimate models. EPA's MOBILE model estimates emissions from this type of congestion data and is widely used. Rhode Island has used the model for estimating the state's emission's inventory and for quantifying the effects of transportation improvement programs.

WHAT ENVIRONMENTAL IMPACTS RESULT FROM ADDITIONAL TRAFFIC CONGESTION AND CAN THEY BE MEASURED?

There is still no clear choice for a best approach to quantify motor vehicle emissions. There are several tools available, including EPA's MOBILE models. These models are able to estimate criteria pollutant emissions that can be defined as, "pollutants that adversely affect human health and welfare".[27] Carbon monoxide is a criteria pollutant that is a product of incomplete fuel combustion. It interferes with the transportation of oxygen to a body's organs and tissues. Oxides of nitrogen (NOx) is a collective term for a family of nitrogen and oxygen compounds. Ozone is also a criteria pollutant that develops when VOC, NOx, and sunlight interact. Volatile organic compounds (VOC) are photosensitive, carbon based, gaseous compounds. Reactions of SO_2, NOx, and VOC can lead to fine particulate matter formation.

Motor vehicles are the single largest emitter of these pollutants, 60% of the CO, 29% of the VOC, and 31% of the NOx emitted are from on-road vehicles.[28] Carbon dioxide, CO_2, is the primary greenhouse gas that is released from mobile sources. Other pollutants and greenhouse gases such as methane (CH_4) and nitrous oxide (N_20) are also associated with automobile use. The reduction of emissions of all these pollutants by transportation improvement plans would be beneficial.

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[27] Federal Highway Administration. *Transportation Air Quality: Selected Facts and Figures*. Publication No. FHWA-PD-99015. January 1999. p. 1.

[28] Holtzclaw, John, Dr. "Curbing Sprawl to Curb Global Warming." www.sierraclub.org/sprawl/transportation/warming.asp.

Although emissions from individual motor vehicles were decreased with the catalytic converter, the increase in travel has offset much of that emissions reduction.[29] Transportation models look more at the roadways and traffic and less at cars; models are used to determine traffic flow patterns, speeds, and delays. Traffic effects on emissions are hard to measure and there is not a standard method of evaluation. A large part of the problem is estimating changes in emissions as a function of speed. Simple traffic models do not distinguish between traveling a given distance at a constant speed of 25 mph or driving that same distance fluctuating between 0 to 60 mph.[30] Actual road and traffic observation becomes important here. For example, noting that motorists are speeding up between stop signs instead of going a slower, steadier speed is key to transportation planning.

HOW DOES RHODE ISLAND EVALUATE AIR QUALITY AND ARE THESE METHODS USEFUL FOR A CITY'S EVALUATION?

According to the US Department of Transportation, the EPA has classified New England as a serious Ozone Non-attainment Area. This means that the area does not meet National Ambient Air Quality Standards for the Ozone 1-Hour Standard. This designation includes all sources of NOx and VOC, both stationary and mobile sources. This then requires each state in New England to create a state implementation plan (SIP) to address non-attainment. The National Ambient Air Quality Standards, NAAQS, do not include greenhouse gases. The amount of carbon emitted into the atmosphere, however, can easily be calculated if fuel consumption values are available.

Vehicle emissions come from various functions of an automobile. Exhaust (cold start and running exhaust) emissions, and evaporative (running losses, hot soak, emissions while

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[29] Environmental Protection Agency. http://www.epa.gov/otaq. January 29, 2000.

[30] Correspondence with David Hyder. North Carolina Department of Transportation. February 23, 2000.

parked and engine cooled, and refueling) emissions contribute to air pollution. When evaluating the emissions contribution of cars, however, most models assume default values representing operating modes of vehicles.

A model, such as the EPA MOBILE5a, is run at a set temperature after the vehicle is warmed up and does not take into account the emissions that occur after the car is turned off. The model is also based on an average trip speed, which is assumed to be 30 miles per hour.[31] The state can evaluate emissions either on a statewide basis or on a project-specific basis. An emission inventory can be used for SIP Emission Inventories and CMAQ project justification. There has been no attempt in Rhode Island to make any emissions estimations on a city-by-city basis for any type of emissions sources.

MOBILE5a MODEL

In 1994, Rhode Island hired private consultants to conduct an emissions analysis for the entire state as part of a Congestion Mitigation and Air Quality Improvement (CMAQ) project application.[32] CMAQ funding is provided for areas to implement programs that help states meet NAAQS for ozone (VOC and NOx) and CO. Emission estimation updates were conducted in 1994. The consulting firm, Vanasse Hangen Brustlin (VHB), used the EPA model to generate state-specific emissions factors for varying vehicle speed and then conducted an analysis for the year 1999 to demonstrate the emissions benefits of certain traffic flow programming. (See Figures 9,10,11) Since the MOBILE5a model can make emission estimates for a specified year into the future, the consultants and Rhode Island's Department of Transportation chose 1999. This analysis included arterial light synchronization on roads in Providence. They followed a

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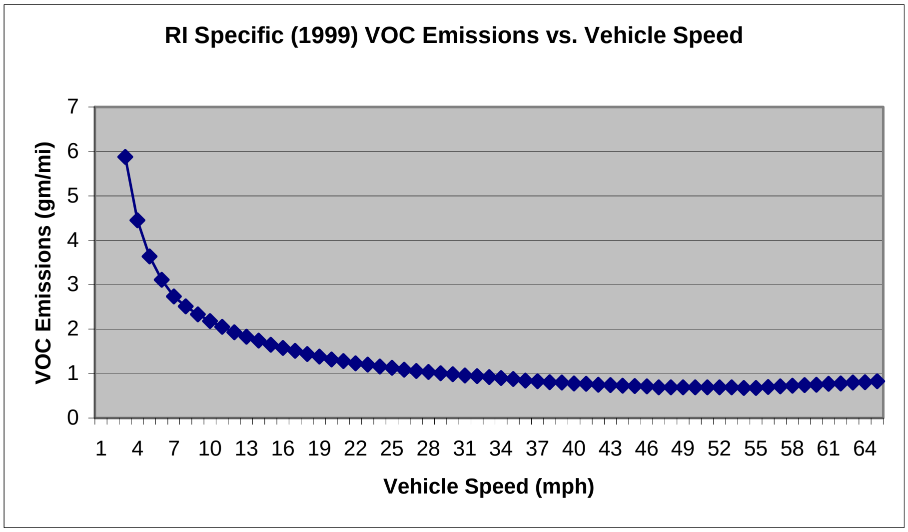
[31] Correspondence with Ron Marcaccio. Rhode Island State Department of Air Resources. March 9, 2000.

[32] Vanasse Hangen Brustlin, Inc. Congestion Mitigation and Air Quality Funding Program - Final Report: Report of the Air Quality/Transportation Subcommittee to the State Planning Council. Rhode Island Department of Transportation. January 1995.

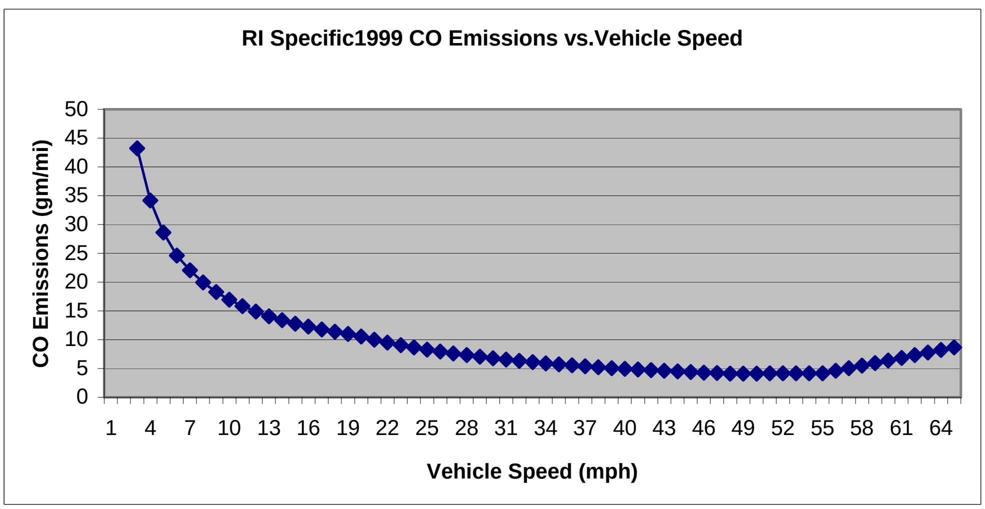
traditional 4-step modeling process that included trip generation, trip distribution (trip purpose and volumes), mode split (transit and auto), and traffic assignment (trips onto highway network). Included in the project were also case studies of the East Providence highway network, the Washington Bridge project, and Route 10. VHB also calculated traffic information such as daily VMT by vehicle type and roadway class.

Figure 9. RI Specific VOC Emissions vs. Vehicle Speed (1999).



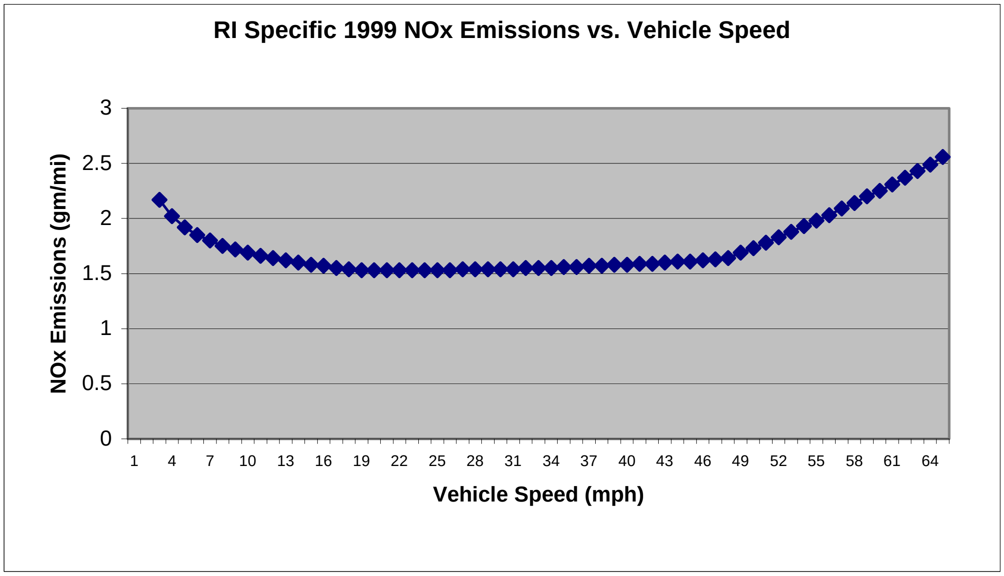
Source: Report of the Air Quality/Transportation Subcommittee to the State Planning Council. Prepared by Vanasse Hangen Brustlin, Inc. Rhode Island Department of Transportation. January 1995.

Figure 10. RI Specific CO Emissions vs. Vehicle Speed (1999).



Source: Report of the Air Quality/Transportation Subcommittee to the State Planning Council. Prepared by Vanasse Hangen Brustlin, Inc. Rhode Island Department of Transportation. January 1995.

Figure 11. RI Specific NOx Emissions vs. Vehicle Speed (1999).



Source: Report of the Air Quality/Transportation Subcommittee to the State Planning Council. Prepared by Vanasse Hangen Brustlin, Inc. Rhode Island Department of Transportation. January 1995.

The MOBILE5a model needs state-specific vehicle classifications and conditions. Each state differs in five categories of the model's input:[33]

1. Inspection Maintenance program and standards (tailpipe testing).
2. Anti-Tampering Components (personal tampering of vehicles).
3. State-Specific Registration Data.
4. State-Specific Vehicle Mix Registration Data.
5. Ambient Temperature - Air quality is usually measured for summertime analysis for an area.

This emissions analysis was conducted in 1994 and at that time the most recent EPA MOBILE model was MOBILE5a. Now, there are more advanced versions including MOBILE6 and MOBILE7 but Rhode Island has not updated their emissions factors. The model simulates an "urban cycle" of travel that includes modal considerations. Acceleration, deceleration, idle, and cruise are incorporated into each speed's emission's estimate. In the MOBILE5a model, however, idle emissions, emissions due to delay and congestion, were incorrectly represented in 1992-released version. The EPA released MOBILE5 without idle/delay emissions rates because

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[33] Phone correspondence with Tom Wholley, Vanasse Hangen Brustlin, Inc. February 9, 2000.

there was not sufficient time to include changes to the rates in MOBILE5a. Thereafter, the EPA put out information sheets instructing the best way to estimate idle/delay emissions.

Idle emission factors can be estimated by using the lowest speed emissions factor; this speed has the greatest amount of idle time incorporated into its emission factor. The delay time can be multiplied by the speed-specific emissions factor of 3 miles per hour, resulting in the calculation of a reasonable daily delay emissions value. Another controversial aspect of MOBILE5a was how the modal emission rates were situated in the model. In MOBILE5a the specific acceleration, deceleration, idle and cruise rates are imbedded in the model and cannot be extracted to use for separate analysis. It does not allow modelers to use the rates separately; they are combined to form the "urban cycle". This will be changed in updated versions so modal emission rates can be extracted from the model separately.

Emissions values were determined for the entire state; they are applicable in each city and can help cities make decisions relating to traffic control measures. Rhode Island, when dealing with those emissions results, must then decide what goals and reductions they want to pursue related to air quality.

WHAT ARE THE ENVIRONMENTAL EFFECTS OF CONGESTION ON THE ENVIRONMENT IN PROVIDENCE? ARE THEY QUANTIFIABLE?

The environmental effects of congestion can be quantified for the Providence-Pawtucket urban area by combining the two data sets previously discussed. By using urban mobility data along with the state-specific emissions factors, I calculated the amount of emissions created by the mobile sector of the Providence-Pawtucket area.

The consultant's emissions factors were calculated for the year 1999. These factors can be used to show the emissions from the mobility in 1999 emission estimates. The vehicle miles traveled can be multiplied by the emissions factor determined for the year 1999 and an emissions rate (grams/day) can be found for all pollutants (CO, VOC, and NOx). The last mobility data measured for the metropolitan area was for 1997. I calculated mobility for the latest year, 1997, using the 1999 emissions factors. (See Table 3)

Mobile Emissions Estimate:

Speed Specific Emissions Factor (kg/mi) {for average speed} * VMTs (mi/day)

TABLE 3. Emissions Estimates for Urban Area's Mobility.

YEAR	VMT	VOC Emissions Rate (kg/day)	CO Emissions Rate (kg/day)	NOx Emissions Rate (kg/day)
1997	11,800,000	18,000	35,000	37,000

Emissions due to congestion can then be added to the estimate by using conversion factors to change driver's delay time into daily emission amounts. The total hours of delay can be converted by the slowest speed's emission factor (3 mph) because that value includes the greatest amount of idle time.

Congestion/Delay Estimate: [34]

Speed Specific Emissions Factor (kg/mi) * 3 (mi/hr) * Delay Time (hr)

This value is not a stopped delay and the delays do not have a predicted speed. Using 3 miles per hour is a conservative calculation to predict emissions due to congestion. A stopped delay would not have a speed and the emissions would be greater. My calculation can still provide a basis for idle emissions of the area. (See Table 4)

Table 4. IDLE EMISSIONS FROM TOTAL HOURS OF DELAY (per day assuming 250 days).

Year	VMT	Daily Congestion VOC Emissions (kg/day)	Daily Congestion CO emissions (kg/day)	Daily Congestion NOx emissions (kg/day)
1997	11,800,000	1,070	7,900	400

As shown in Tables 5, 6, and 7 idling estimates were smaller than mobile estimates. The congestion estimate, however, is a contributing factor to the overall emissions contribution of motor vehicles in the Providence Metropolitan Area.

[34] Environmental Protection Agency. MOBILE5 Information Sheet #2: Estimating Idle Emissions Factors Using MOBILE5. Ann Arbor, MI. July 30, 1993.

Table 5. TOTAL URBAN STUDY VOC EMISSIONS.

Year	VMT	CONGESTION	MOBILE	TOTAL
		VOC emissions kg/day	VOC emissions kg/day	
1997	11,800,000	1,070	18,000	19,070

Table 6. TOTAL URBAN STUDY CO EMISSIONS.

Year	VMT	CONGESTION CO emissions (kg/day)	MOBILE CO Emissions Rate (kg/day)	TOTAL
1997	11,800,000	7,900	34,500	42,400

Table 7. TOTAL URBAN STUDY NOx EMISSIONS.

		Daily CONGESTION NOx emissions (kg/day)	MOBILE NOx Emissions Rate (kg/day)	TOTAL
1997	11,800,000	400	37,000	37,400

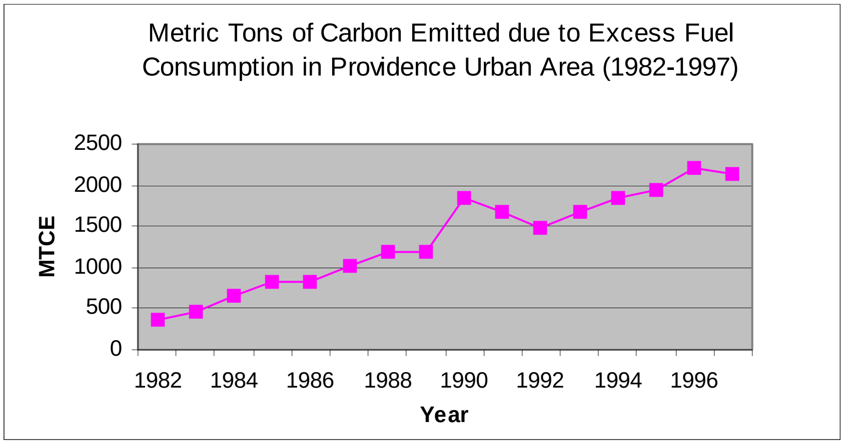
Excess fuel consumption can be used to calculate the amount of carbon emitted into the atmosphere. In 1982, approximately 4 million gallons of excess fuel were consumed due to congestion. That rose to 23 million gallons by 1997. I calculated the amount of carbon by converting barrels of motor gas per million Btu of energy and then converting those Btu's into pounds of carbon emitted into the atmosphere.[35] (See Figure 12) In 1982, the area contributed almost 500 MTCE. The amount of carbon emitted by 1997 increased to over 2000 MTCE.

Carbon Emitted due to Fuel Consumption:

$$\text{Fuel (gals)} * \frac{\text{1 Barrel}}{\text{40 gals}} * \frac{\text{1 million BTU}}{\text{5 barrels}} * \frac{\text{42.8 lbs Carbon}}{\text{1 million BTU}} * \frac{\text{1 ton}}{\text{2000 lbs}} * \frac{\text{0.907 MTCE}}{\text{1 ton}}$$

[35] Environmental Protection Agency. EIIP Document Series, Volume VIII: Estimating Greenhouse Gas Emissions, December 1998. Review Draft. Washington, DC. 1998. Introduction.

Figure 12. Carbon due to Excess Fuel Consumption 1982-1997.



In 1996, the state of Rhode Island emitted 907899 MTCE from motor gasoline use. This is equal to approximately 9.4 billion gallons of fuel.[36] Approximately 0.2% of the total consumption of gasoline in the state resulted from the congestion experienced in the Providence metropolitan area.

While this is not a true baseline, what can be established is the difference between current conditions in certain sections of the city and then evaluate the changes in delay, vehicle miles traveled, and emissions that would occur if traffic control measures were implemented.

[36] Center for Environmental Studies, Brown University. Greenhouse Gas Emissions Inventory for Rhode Island. May 2000. http://www.brown.edu/environmental_studies/GHG. May 8, 2000.

Chapter 2 – Providence's Current Transportation Situation

WHAT IS THE STATE'S TRANSPORTATION SITUATION AND HOW DOES IT IMPACT TRANSPORTATION IN PROVIDENCE?

The state of Rhode Island has a large influence over Providence's transportation system in terms of funding and planning. For example, the Transportation Equity Act for the 21st Century, TEA 21, currently provides states with federal funding for their highway and transit programs. Interstate 195 and Interstate 95 are an integral part of the Providence roadway system, as are other state roads like Routes 1 and 1A. TEA 21 continues the policies of ISTEA. ISTEA, the Intermodal Surface Transportation Efficiency Act, in 1991 declared the interstate highway system finished. It shifted the mission of transportation policy towards ensuring proper allocation of transportation funds by the government for transportation improvement; not to allocate funds solely towards new road construction. Under ISTEA, funding would be put towards decisions that supported local planning and promoted transportation decisions that involved protecting the environment, creating jobs, and presenting communities with more transportation alternatives.[37]

Providence residents are heavy users of the public transportation system run by the Rhode Island Public Transit Authority (RIPTA); it is the city's primary metropolitan bus system. The city is very much a key factor in Rhode Island's transportation activity.

In order to receive federal funding, the state must produce a Transportation Improvement Plan (TIP) every two years that details transportation projects for which Rhode Island would like to receive funding. TIP projects, in general, are evaluated by economic development potential, benefits to mobility, cost-effectiveness, environmental impact, and amount of public support.[38] The plan establishes the state's short and long-term scheduling of transportation projects. The TIP requires the state to provide a forum for public involvement by holding public meetings and

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[37] Surface Transportation Policy Project. http://www.istea.org. January 29, 2000.

[38] State Planning Council. "Transportation Improvement Program for the State of Rhode Island – October 1, 1998 to September 30, 2000." Providence, RI. August 1998. Introduction.

listening to transit program suggestions. The TIP also includes "Main Street" projects that are generally smaller scale activities with specific goals. These projects aim to reduce congestion, create intermodal links in the transportation system, preserve existing infrastructure, encourage tourism, enhance environmental benefits, and retain community and quality of life values. The Transportation Advisory Committee (TAC), the group that approves the TIP, considers urban redevelopment and cost effectiveness as priorities in any improvement project.[39]

Usually a TIP must be prepared for every urbanized area but Rhode Island, because of the small size of its urban areas prepares one for the entire state. In addition, the Rhode Island Department of Administration runs a planning program that outlines the state's goals and direction for transportation action and policy. This plan's main purpose is to set and guide transportation policy.[40]

The Surface Transportation Program (STP) provides a major source of funding for the state. This is a "block-grant program"[41] that may be used by states for any roads that are functionally classified a higher status than "local". Another funding source that the city of Providence often uses is the Congestion Mitigation and Air Quality Program (CMAQ), a program that is part of TEA 21, which distributes funds toward projects classified under the Clean Air Act (CAA). Over the years, the largest contributor of federal funds to the state has been the Federal Highway Administration (FHWA). These funds have primarily been used for highway projects.

The Rhode Island population has been leaving the older cities of the state and moving into suburban and rural areas. Currently, state residents are averaging a trave time of 19 minutes per work trip. Of these commuters, 77.9% people drive alone, 12.1% carpool, and 4.5% bike or

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[39] State Planning Council. "Transportation Improvement Program for the State of Rhode Island – October 1, 1998 to September 30, 2000." Providence, RI. August 1998. p.11.

[40] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program." Providence, RI. November 1998. Part 611-1.

[41] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program." Providence, RI. November 1998. Part 611-1.

walk. A very small percentage takes the bus, 2.1%.[42] "Auto Ownership" and "Vehicle Ownership per Household" have both increased dramatically.[43] The state transportation plan claims the state is in no immediate danger for a large increase in traffic congestion. However, it did identify certain areas within the state that may experience greater congestion problems. The Providence metropolitan area is predicted to have large amounts of congestion during peak hours on interstate highways and arterial roads.[44] The Rhode Island Department of Transportation evaluated the roadway system and identified roadways as having existing peak-hour congestion. Of the twenty-four roadways evaluated, eleven provide direct access to the Providence metropolitan area. In addition, the state found that the majority of "off peak" traffic congestion was also in Providence.[45]

State suggestions made in the transportation plan for future improvements include reevaluating all aspects of parking, establishing satellite parking lots with shuttle service, giving incentives to use alternative modes of transportation, and utilizing traffic calming measures. The state also encourages promoting less-used highways as alternatives to alleviate traffic congestion, establishing more intermodal terminals outside of Providence, improving public transportation in the suburbs, and providing alternative modes of transportation for "short distance high traffic situations".[46] The plan recognizes that additional financing must be provided to RIDOT and RIPTA to achieve some of these goals but the recommendations made will require a lot of action

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[42] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program." Providence, RI. November 1998. Part 611-3.5.

[43] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program". Providence, RI. November 1998. Part 611-3.6.

[44] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program". Providence, RI. November 1998. Part 611-4.

[45] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program." Providence, RI. November 1998. Part 611-4.

[46] Rhode Island Department of Administration. "Transportation 2020 Ground Transportation Plan. Statewide Planning Program." Providence, RI. November 1998. p. 611-4.

to be taken by RIPTA. The plan did not make many suggestions as to how these goals could be accomplished.

WHAT ACTIVITIES AFFECT CONGESTION IN THE CITY?

Providence, because it is quite an old city, was not planned with automobiles in mind, so traffic and parking have always been a problem. The city's location has facilitated its historical development as a New England regional transportation center both because of its location between New York City and Boston and because it is on the edge of the Narragansett Bay. As time passed, suburbanization set in and people moved away from the city. Providence once had a large textile and industrial base, but the jewelry sector is all that currently remains and it is much diminished.

Recently, however, Providence has prospered. This financial good fortune can mean larger markets for housing, consumer goods and services as well as increasing the fiscal resources of the city. City employment is concentrated around jobs in finance, insurance, real estate, and government agencies. With this newfound growth, Providence is very optimistic about the future and would like to regain some of the manufacturing and trade success it once had.[47]

Currently, in Providence, the "primary source of air contaminants is motor vehicle emissions."[48] Vehicles and roadways both have impacts on amount of emissions. The amount, type, idle time and traveling speed of a vehicle will affect the amount of pollutants it emits. Roadway characteristics such as type (highway or local) also affect emissions. The current comprehensive plan's goal for Providence is to promote an "efficient and balanced urban

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[47] "Providence 2000: The Comprehensive Plan." Providence Planning Department. July 1993.

[48] "Providence 2000: The Comprehensive Plan." Providence Planning Department. July 1993.

transportation system to encourage energy conservation, reduce air pollution, and traffic congestion”.[49]

COMPREHENSIVE PLAN

The city’s comprehensive plan addresses the issue of air quality in terms of human health effects but does not include impacts on local and regional ecosystems. Air quality is evaluated by measuring the concentrations five compounds: carbon monoxide, sulfur dioxide, total suspended particle matter, nitrogen dioxide, and ozone.

The comprehensive plan also states that Providence wants to create more convenient intermodal connections. The city wants to improve accessibility into and through downtown, improve the city’s parking efficiency, increase transit use, provide access from remote parking via public transportation (park ’n’ ride), and to reduce traffic congestion and air pollution. The downtown is now experiencing a renaissance and if the area becomes more accessible, people would be more inclined to shop, eat, and spend time in the area. An intermodal transportation system, however, will not work if there is no reason to visit the downtown area. This was an important reason the city recently conducted a downtown circulation study.

Providence is the largest Rhode Island city and the third largest city in New England. Only 15% of Providence’s commuters use mass transit. There are several intermodal hubs surrounding Providence: Kennedy Plaza, Providence Union Station (1500 feet away from Kennedy), and the Greyhound bus station (3 miles away). The T.F. Green Airport, 9 miles south of Providence, could be considered another hub when it is connected to Providence via the rail line.

Downtown’s main bus hub is Kennedy Plaza. It is a poorly maintained open space and is not considered comfortable or aesthetically pleasing to users. There are currently no shelters, however RIPTA is planning to change that with upcoming renovations to the space.

[49] “Providence 2000: The Comprehensive Plan.” Providence Planning Department. July 1993.

If the city wants to become more productive, the downtown will have to become more efficient for vehicles and more attractive to visitors. The Providence Planning Department considers downtown vehicle circulation a priority to visitors.[50] The department believes that once it is easier to travel through the downtown, tourism will increase and help boost the economic vitality of the area. Increased circulation in the downtown can encourage more tourists to explore the city. The Providence Place Mall attracts many out-of-town patrons; an easy circulation system throughout the city can encourage the mall tourists to explore other parts of the city.

WHAT TRANSPORTATION CONDITIONS EXIST AND WHAT IS PREDICTED FOR THE DOWNTOWN AREA? HOW WILL THESE CONDITIONS AFFECT AIR QUALITY?

In the 1940's, suburbs developed on the outer borders of Providence and resulted in increased traffic levels for the downtown area. More people were traveling to the city, causing high levels of downtown congestion. The city planners decided the area's traffic patterns should be changed to help alleviate congestion. One-way street systems were enacted with effective results. In the 1960's, the purpose of downtown streets changed again; the roads reverted to local use, rather than throughway travel.[51] Interstate 95 and 195 were also contributing factors, creating another route for through traffic.

Currently, the city is thinking about bringing back some two-way streets. Attractions such as: the Convention and Civic Centers, the Westin Hotel, the expansion of Johnson and Wales University, new theaters, the newly opened Providence Place Mall, Union Station development, Waterplace Park, and the Fleet Skating Rink have brought a need for downtown access. The city conducted a circulation study to identify strategies to make driving through

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[50] Correspondence with Jon Ozbek. City of Providence Planning and Development Department. December 15, 1999.

[51] Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. p. 1.

downtown easier and more attractive. If driving in downtown is easy, tourists are more likely to access these new facilities. With easier travel, more drivers will then use the road system, filling the road's capacity, exemplifying induced demand. Also, RIPTA is currently planning to renovate Kennedy Plaza and the facility will have new street-use needs.

The circulation reassessment was part of a three-part improvement study from the Providence Planning Department. The first part was the Intermodal Study and the third part will be an evaluation of the lighting and timing of downtown roadway signals. Currently, the city is waiting for additional funding to conduct the third part of the study. These studies were done to plan for traffic flow improvements and were funded by CMAQ money. The goal of the circulation study was to analyze traffic access, circulation, parking, and in some cases, event management associated with the convention and civic centers.

Downtown's evaluation site included the down city area, the Jewelry district, the Convention and Civic Centers, the Capital Center and the financial district.[52] The study looked at "problem intersections and areas" for specific improvements. These areas included Robert Emmet Square, Kennedy Plaza, Washington Street, and Empire Street. Some problems with circulation were associated with the number of roads in intersections. For example, in Robert Emmet Square there are several roads that intersect that complicate the use of effective traffic signal timing. Also, the study examines the new mall's expected impact of added traffic to Memorial Boulevard and Francis Street, an already crowded intersection.

The consultants used circulation models to find the best traffic scenario for the downtown area. First, they created eleven different scenarios and then evaluated their performance with block circulation, parking availability, and transit perspectives. The study used output results

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[52] Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. p. 1.

from the CORSIM simulation model.[53] Scenarios were conducted for existing conditions, a "no-build" scenario, and then scenarios combining 2-way Washington access, decentralized transit operation, transit only roadways, and elimination and inclusion of on-street parking. The consultants concluded that the most appropriate results to look at were street performance, and overall network performance in order to pick the best scenario for traffic circulation.[54] All results were found for evening peak hours. Overall network results included calculations of vehicle hours of travel, vehicle miles of travel, avg. speed, delay per vehicle, number of trips, hours of delay, and transit statistics. Individual traffic operation results measured vehicle hours moving, vehicle hours stopped, and approach trips. This seems a bit inconsistent, especially because the study is trying to evaluate the downtown area and speeds on the arterials, which are the streets with increased speeds, are not really an indication of the circulation since through trips are no longer a major part of the traffic in downtown.[55]

In general, the ideal scenario, the best circulation plan, would have an overall lower "vehicle miles traveled" value than projections based on the existing conditions. Lower VMT's indicate direct routing and less driving. A higher average speed is an indication of lower congestion levels and an increase in downtown "mobility", making downtown travel more attractive.

Although the decentralized transit results were more favorable overall (higher average speed because of less bus congestion at Kennedy and low VMT values because of 2-way street system), these scenarios would make bus transfers difficult and cause great losses in on-street

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[53] Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. p. 11.

[54] Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. p. 33.

[55] Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. p. 35.

parking. It was ultimately removed from consideration as a recommended scenario.[56] The study concluded that the 2-way street system tested in each scenario yields lower values of miles and hours of travel as well as higher values of average speeds. One key finding was that all of the alternative scenarios had a lower VMT than the no-build scenario. The greatest improvements are predicted to result from the decentralized transit scenarios, but after that, the best scenario is a centralized transit zone with Washington Street open to all traffic through Kennedy Plaza, "Scenario 9". This scenario is similar to other centralized scenarios however, Washington, Chestnut, and Empire would be converted to two-way streets, Fulton Street would operate as a one-way westbound, and two-way Dorrance and Exchange streets around the Plaza would allow a clockwise circulation of busses and traffic around the plaza. (See Map 1) It also eliminates left turns in and out of the bus station. (See Map 2) In the study, the proposed hotel located on Broadway and Empire is expected to have little traffic impact on this scenario. The little impact it would have would be in LaSalle Square.

WHAT IS THE RANGE OF PROJECTED CONGESTION?

Table 8. Downtown Circulation Characteristics for Existing, No Build, and Optimal Circulation Scenarios.

<u>Scenario</u>	EVENING PEAK HOUR					
	VMT	*Vehicle Hours Moving*	*Vehicle Hours Stop*	*Vehicle Hours Total*	*Average Speed*	*Total Trips*
Existing Conditions 1998	45,852	1,005	925	1,929	23.8	36,278
Future No-Build 2003	47,334	1,047	1,225	2,272	20.8	37,278
Centralized Transit Washington Open - 2003	46,166	1,028	1,125	2,153	21.4	37,562

Source: Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. Table 2.

[56] Wilbur Smith Associates. "Providence Downtown Circulation Study." Prepared for the City of Providence. Providence Planning Department. February 1999. p. 1.

As shown above, in the evening peak hour model simulations, a no-build scenario will have more troublesome congestion and delay effects than any mitigation scenario. Scenario 9, the plan chosen, will alleviate some future expected congestion but will in no way, make conditions better in downtown than they are today.

WHAT DO THESE SCENARIOS MEAN IN TERMS OF DOWNTOWN'S CONTRIBUTION TO THE AREA'S EMISSIONS?

Emission estimates can be made similar to the calculations performed with the Providence-Pawtucket urban area' data. I calculated estimates for the downtown area network, including "hours stopped" delay time using the Rhode Island specific emission factors for VOC, CO, and NOx. It then is possible to see the difference in emissions between the "no-build" scenario and the improved circulation scenario. As shown, there are significant reductions in emissions with the new circulation scenario. These reductions are attributed to the increase in vehicle speed through the system and the reduced miles traveled throughout the period because of the more direct 2-way street system.

Table 9. VOC, CO, and NOx Emissions for Downtown Scenarios.

Scenario	VOC Emissions		Co Emissions		NOx Emissions		VOC	CO	NOx
	kg/evening peak hr		kg/evening peak hr		kg/evening peak hr		kg/evening peak hr		
	Moving	Congestion	Moving	Congestion	Moving	Congestion	Total	Total	Total
Existing Condition (1998)	53	16	400	120	70	6	69	520	76
Future – No Build (2003)	61	22	480	160	72	8	83	640	80
Chosen Scenario #9 - 2003	60	20	450	150	71	7	80	600	78

Between the two scenarios, an improved circulation system created reductions compared to a “no build”. Residents of the city would not be exposed to an additional kilogram/evening peak hour of VOC, 30 kg/evening peak hour of CO, and one kilogram/evening peak hour of NOx emissions. Savings were also noticed in the decrease in emissions due to congestion. There was no estimation of fuel consumption in the study; therefore I was unable to make estimates for the amount of carbon emitted.

Another significant finding is the difference between moving and idle emissions. A vehicle is most likely going to be traveling most of the time when on the road however when the two scenarios are compared relative to “vehicle hours moving” and “vehicle hours stopped”, the values are not extremely different.

Table 10. Downtown Vehicle Hours Moving/Stopped for No Build and Optimal Circulation.

Scenario	EVENING PEAK HOUR		
	Vehicle Hours Moving	*Vehicle Hours Stopped*	*TOTAL Vehicle Hours*
Future No Build	1,047	1,225	2,272
Centralized Transit, Washington Open	1,028	1,125	2,153

Source: Wilbur Smith Associates. “Providence Downtown Circulation Study.” Prepared for the City of Providence. Providence Planning Department. February 1999. Table 2.

The values found for “moving” and “stopped” vehicle hours are similar to each other so they do not have a significant impact on the emission estimates even though "vehicle hours stopped" with improved circulation decreased about 10%. As stated previously, the reductions are more likely to come from the smaller number of vehicles traveling and faster average vehicle speeds.

The Comprehensive Plan for Providence concludes that the city must accommodate the city’s economic growth and development and the population that comes along with it. The city’s population has parking and improved public transportation needs for employees and customers. RIPTA has conducted its own evaluation of the transit system and states that the public transportation system is doing fairly well in terms of route coverage and providing adequate service. However, transit ridership has decreased over the years and now RIPTA's main riders are considered "transit dependent". RIPTA attributes this to the low variable cost of driving a car and the low cost of parking in the city. What does this all say about transportation and travel within the city?

An overall goal of the entire state is to improve traffic flow and safety through motorist information systems, well-managed highway construction, synchronized signals, left-turn signals, and reconfiguration of intersections. The comprehensive plan for Providence proposes more off-street parking, onsite spaces for businesses, and on-street regulations. The city currently has short term parking facilities. Some of downtown's congestion is due to drivers looking for on-street parking; they rather drive around for 20 minutes to find a free on street parking spot rather than paying for and off-street facility. Free parking should be decreased as well. Adding parking facilities will not solve all of the traffic congestion problems. The plan mentions that public transportation can lend a hand towards reducing traffic congestion, but when the city builds an affordable off-street parking lot, whom will leave their cars home and use public transportation?

Clearly other methods need to be looked at besides bulking up mass transit and hoping people will use it. Light synchronization can help roads maintain steady flows, reduce "stop and go" traffic, and reduce backups. These issues will be addressed in the third part of the downtown evaluation. Traffic calming can slow reckless drivers down or discourage drivers from getting off major freeway or arterial streets. This will decrease the amount of traffic on side streets and local roads, roads that were not built to handle a large quantity of vehicles. Some methods and mitigation techniques are more environmentally beneficial while some, if implemented incorrectly, can have negative impact. Methods, such as side friction and arterial light synchronization or stop signs and parking lanes, can be balanced and combined to produce emissions benefits.

Chapter 3 – Traffic Control Methods

STOP SIGNS

Why are they put up?

Stop signs have been used in the past in conjunction with traffic signals and posted speed limits to calm traffic. The city's traffic engineering office maintains and installs all the stop signs in Providence. (See Map 3) After speaking with several city agencies, I found stop signs are put up mainly for two reasons: 1) political influences, 2) citizen complaints.

A stop sign's true purpose is to stop cars on a thoroughfare; four-ways are put up where dangerous roads intersect.[57] Politically, they are installed to slow cars down. Major Richard Sullivan of the Providence Police Department says that he receives letters everyday from residents asking for the installation of additional stop signs in their neighborhoods.

It is very rare to have residents ask for a removal of a stop sign, but it has happened. For example, Major Sullivan received a letter to take down a stop sign because it was a hazard to the drivers. Everyday, between 3:00 pm and 3:30 pm, youths would hang around a particular intersection and when cars stopped, would harass the drivers. They would throw rocks and shout at the passengers. This became a hazard because, to avoid harassment, everyone was running through the sign. Another complaint was of a four-way stop that was put up in a highly residential area with high traffic volumes. When the stop sign was installed, cars would have to wait for their turn and residents began to complain about cars with loud radios spending more time in the neighborhood than if they could have driven through without stopping.

[57] Phone correspondence with Major Richard Sullivan of Providence Police Department. March 1, 2000.

A sign is not automatically installed in response to complaints. Traffic engineering, if they have had several complaints about a particular intersection, will evaluate the site. For the most part, the engineering department decides the type of control that would solve a certain problem. For example, a stop sign may not be the best control and some areas do not need controls all the time. A school, for example, may only need a crossing guard during school hours instead of a stop sign that is there permanently.[58] This is the usual protocol; however, there are always exceptions. If the traffic engineering office gets a call from a city official who asks for a stop sign installation, the office most likely will install that stop sign, regardless of the actual need.[59]

Some stop signs in the city have been around since the 1930s. According to Major Sullivan, the only reevaluation of these stop signs occurs during sign maintenance. No one has looked at the system, comprehensively, and asked the question, “Does this system make sense and ease traffic flow?” For the most part, the city only considers changes to the current signage situation if complaints or accidents occur.[60] Sullivan admits that there may be signs in the city that have never been reevaluated and that they may no longer be useful traffic controls. However, he states that areas with traffic control devices that are heavily utilized receive routine maintenance and visual inspection.

Do stop signs prevent accidents? When I attempted to correlate traffic accident data with stop sign presence, the Rhode Island Department of Transportation refused to cooperate. Paul Dagostino of RIDOT stated that there is a threat of liability for Rhode Island government, particularly the Department of Transportation, with the release of intersection-specific data. According to Dagostino, the information was not accessible because Title 9 of the US Federal

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[58] Major Richard Sullivan (Phone correspondence). Providence Police Department. March 1, 2000.

[59] Major Richard Sullivan (Phone correspondence). Providence Police Department. March 1, 2000.

[60] Major Richard Sullivan (Phone correspondence). Providence Police Department. March 1, 2000.

Code 23 prohibits any accident data or statistics available to an opposing party in court litigation. This, he stated, governs the state's laws; rules and regulations regarding access to public information, Section 4. Rules and Regulations state that, "any records which would not be available by law or rule of court to an opposing party in litigation," cannot be considered a matter of public record.[61] Therefore, traffic statistics are not public record. The RIDOT refused to release accident information but these regulations do not prohibit the local police department from disclosing accident information. I contacted the Providence Police Department and they said that they would provide me with this information.

Extensive interviews with the Providence Police Department indicates that the traffic data they possess is kept in a "manual system"[62] with thousands of accident records that are not organized by intersection. Captain DeFrances and his administrator would not provide me with intersection-specific accident data. He stated that the organization of these documents does not allow for quick searches relating to specific neighborhoods in the city, that the records are not sorted in that manner. He also said that there are tens of thousands of accidents in a given year in the city and the Providence Police Department did not want to research several years of accident data and then provide me with that information.

However, as part of the Fox Point Traffic Calming Project, private consultants obtained accident data for the neighborhood. Perhaps they talked with a different department or the police department did not want to participate in academic research, but I suspect it was because the consultants wanted information on only a small number of intersections in Fox Point, not data for the entire city. Although it is not citywide data, the area's accidents can be compared with stop sign maintenance and installation records.

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[61] "Access to the public records of the Rhode Island Department of Transportation." Rhode Island Rules and Regulations. Section 4.1.2.5.

Table 11. Fox Point Accident Records (1995-1997).

Street	*Accidents Recorded (#)*	*Incidence Intersection*
Gano	35	Pitman (8) Wickenden (6) Power (6)
Ives	13	Trenton (4)
Governor	8	Power (4)
Hope	28	Power (8) 4 way stops are now in place Wickenden (6) Williams (6)
Brook	29	Wickenden (7) Sheldon (6)
Benefit	27	Wickenden

Source: Paul Murrain Urban Design. Fox Point Neighborhood Traffic Calming Plan. Providence, RI. November 1999. p. 21.

Table 12. Fox Point Traffic Intersections and Accidents.

Intersection	*1995 accidents*	*1996 accidents*	*1997 accidents*	*Total*	*Control Installed*	*Last change*
Gano/Pitman	5	3	0	8	1935	After 1964, it became a light.
Gano/Wickenden	0	2	4	6	1971	1/26/99 last time checked and reinstalled
Gano/Power	4	1	1	6	1971	7/12/91 last time checked
Ives/Trenton	1	0	3	4	1969	Installed Southbound Sign 2/11/00
Governor/Power	1	2	1	4	1955	Installed Westbound Sign in 1997
Hope/Power	1	4	3	8	1932	Installed North and Southbound

[62] Captain DeFrances. (Phone correspondence). Providence Police Department. March 8, 2000.

						signs on Hope 12/21/98
Hope/Wickenden	3	2	1	6	1953	Renewed 5/19/98
Hope/Williams	4	0	2	6	1932	Installed Westbound Sign 1992
Brook/Wickenden	4	1	2	7	1942	1966 removed, 1981 reinstalled
Brook/Sheldon	1	2	3	6	1967	4/7/99 Last maintenance entry
Benefit/Wickenden	7	5	2	14	No info	No information

Source: Beta Engineering. Fox Point Traffic Calming Study. Lincoln, RI. March 10, 2000. Traffic Control data provided by Providence Department of Traffic Engineering. Providence, RI. March 13, 2000.

The above tables show that Gano Street and Hope Street are involved in most of the accidents occurring over the three years cited. Both of these throughways have had accidents at intersections involving Power and Wickenden. These intersections all have stop signs, not signals. According to the traffic engineering data, new action or installations during the same time period as the accident data available did not influence these intersections. In the case of the Hope/Power intersection, north and southbound signs were installed in 1998, perhaps because of the incidents of prior years. Otherwise, accident data does follow a pattern similar to use; the more widely used roads have more accidents because there is a higher probability of being in an accident on a busier road. According to the installation data, none of the stop signs were added within the last few years, although it is quite apparent that signs have been added on Brook Street. This may indicate that there have been no accidents with the new controls in place but there may also be other issues such as the accuracy of record keeping in city government.

Do stop signs have an impact on emissions?

I found one study that estimated the effect of stop signs on speed. Greenville, North Carolina monitored a neighborhood traffic calming pilot project in 1997. The community's concerns were similar to the concerns of Providence's communities; they included excessive speeding and "cut through" traffic.

The Westhaven neighborhood project experimented with traffic calming strategies to reduce roadway speeding behaviors. First, the study established a baseline with traffic counters on Westhaven Road at Amber Lane, Cedarhurst between Westhaven and Boxwood, Cedarhurst between Kempton and Ben Creek, and Kempton Drive between Boxwood and Walnut. (See Map 4) Then, based on the results of the speed study, the community installed all-way stops at 3 intersections. They observed the effectiveness of the stop signs and found that the traffic on Cedarhurst decreased in volume however, the average speed did not change dramatically. The other 2 areas experienced increases in vehicle speeds.

The speed increases are not large, the greatest difference in speed occurred on Westhaven, the road experienced a travelling speed increase of 4 miles per hour. In terms of emissions, Nitrogen oxide emissions increase with the increased speeds while the other two compounds decrease. Westhaven had the second largest value for vehicle miles traveled, as well as the greatest difference between "before and after" speeds. In cases of significant miles traveled, speed is a sensitive factor for CO and VOC, especially in the 30 - 40 miles per hour range. For NOx, however, emissions are not going to have tremendous differences between 19 and 27 miles per hour. In this case, there is a slight change with values above 27 miles per hour. Overall, higher speeds resulted in fewer emissions.

Stop Sign Emissions

Stop signs require drivers to accelerate, decelerate, cruise, and idle. High acceleration rates are significant contributors to emissions rates and that in some cases sharp acceleration can cause as much pollution as a trip.[63] Also, rapid deceleration also results in high emissions.

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[63] Environmental Protection Agency. "Assessing the Emissions and Fuel Consumption Impacts of Intelligent Transportation Systems (ITS). Document 231R98007. http://www.epa.gov/cgi-bin/claritgw. April 5, 2000.

Studies have also indicated that there is a significant difference between the average amounts of gasoline consumed by automobiles as a function of the traffic control implemented. For example, the EPA released figures demonstrating the difference in fuel consumption of a single automobile when the driver stops at a stop sign, yields, or continues to travel without stopping. The most recent figures are from 1974, the EPA has not updated these data; a single automobile requires 0.0068 gallons of fuel to stop at the control, and an automobile uses 0.0062 gallons when the driver yields and 0.0055 gallons at an unsigned intersection and does not stop.[64] The same trend was found in CO, VOC, and NOx emissions.

Although the EPA has not updated its modal emissions there are several traffic modeling programs that have updated emissions and fuel consumption values. One program used to analyze signalized intersections is called TRAF-NETSIM.[65] It evaluates traffic performance in terms of average and maximum queues, average travel speed, fuel consumption (consumed during the peak period), and pollution estimates. These pollution estimates are based upon consumption and emissions rates from the Oak Ridge National Laboratory who measured these rates for the US Federal Highway Administration in the mid to late 1980's. The rates reflect the rate per second and the vehicles used were considered a realistic mix for vehicles used in the United States.[66]

NETSIM CALCULATIONS

Fuel Consumption[67]:

Fuel Consumed in Gallons = Total Travel * k1 + Total Delay * k2 + Stops * k3

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[64] Hall, Dana L., et al. "Comprehensive Evaluation of Nonsignalized Control at Low-Volume Intersections." *Transportation Research Record*. 1978. Number 68. p. 10-12.

[65] Paul J. Bannon, Project Engineer. Beta Engineering, Inc. Personal Correspondence. April 3, 2000.

[66] "HCM/Cinema: The Full Picture." Software Users' Guide provided by Beta Engineering, Inc. Introduction. Received April 12, 2000.

[67] "Synchro User Guide: Traffic Signal Timing Software." Software Users' Guide provided by Beta Engineering, Inc. Introduction. Received April 12, 2000.

Where:

$k1 = 0.075283 – 0.0015892 * Speed + 0.000015066 * Speed^2$
$k2 = 0.7329$
$k3 = 0.0000061411 * Speed^2$
Speed = cruise in mph
Total Travel = vehicle miles traveled
Total Delay = signal delay time (sec)
Stops = total stops (veh/hour)

Control Types and Delay Times[68]:

Control Types	Delay	Stops
No Control	0	0
Stop Sign	5 s/veh	1 stop/veh
Yield Sign	3 s/veh	0.5 stop/veh

Emission Calculations (based on fuel consumption)[69]:

CO = Fuel Consumed in Gallons * 69.9 g/gal = emissions from CO (g)
NOx = Fuel Consumed in Gallons * 13.6 g/gal = emissions from NOx (g)
VOC = Fuel Consumed in Gallons * 16.2 g/gal = emissions from VOC (g)

With specific stop and delay information, a more accurate estimation of emissions can be calculated compared to the crude estimate obtained with average speed data. A comparison can be made between when a road is free of traffic control devices and when controls are implemented. I calculated the fuel consumption and pollutant emissions for the four major roadways in Fox Point, to find the impact of adding stop signs. (See Table 13, 14)

Table 13. Estimations (NETSIM) of Fuel Consumption and Emissions of Roadways without Traffic Controls (Zero Delay).

Road	Daily VMTs	Avg Speed (mph)	Fuel Consumed (gals)	CO Emissions (kg)	VOC Emissions (kg)	NOx Emissions (kg)
Hope St.	1350	23	63	4.4	0.9	1
Governor St.	1591	24	73	5	1	1.2
Gano Street	7100	24	325	23	4.4	5.3
Benefit St.	1891	23	88	6.2	1.2	1.4

[68] "Synchro User Guide: Traffic Signal Timing Software." Software Users' Guide provided by Beta Engineering, Inc. Introduction. Received April 12, 2000.

[69] "Synchro User Guide: Traffic Signal Timing Software." Software Users' Guide provided by Beta Engineering, Inc. Introduction. Received April 12, 2000.

Table 14. Estimations (NETSIM) of Fuel Consumption and Emissions of Roadways with One Traffic Control (Delay of 1).

Road	Daily VMTs	Avg Speed (mph)	Fuel Consumed (gals)	CO Emissions (kg)	VOC Emissions (g)	NOx Emissions (g)
Hope St.	1350	23	67	4.7	.9	1
Governor St.	1591	24	77	5.4	1	1.2
Gano Street	7100	24	329	23	4.5	5.3
Benefit St.	1891	23	92	6.2	1.2	1.4

As shown in the above tables, one stop sign did make a difference in the amount of fuel consumed or the amount of pollutants emitted. It is significant that the control does create differences in the estimates. The control device caused increases for all the streets in each category. As I calculated previously for the entire urban area, the above fuel consumption values can yield carbon emission estimates. No large differences resulted from adding one stop sign however when additional signs were added, pollutant and carbon emissions increased. (See Table 15)

Table 15. Hope Street daily Emissions without a stop sign, with 3 and 5 stop signs.

Hope Street	Fuel Consumed	CO Emissions	VOC Emissions	NOx Emissions	Carbon Emitted
	gals	*kg*	*kg*	*kg*	*MTCE*
Without Stop Sign	63	4.4	0.9	1	0.0061
With 3 Stop Signs	74	5.2	1	1.2	0.0072
With 5 Stop Signs	81	5.7	1.1	1.3	0.0079

AN ALTERNATIVE TO STOP SIGNS: TRAFFIC CALMING

What are the goals of traffic calming and why do/did Elmwood, West Broadway, and Fox Point want/wanted traffic calming measures?

Traffic calming in Providence has been a neighborhood response to increased volumes of motor vehicles traveling quickly on “neighborhood” roads. It attempts to slow traffic, increase pedestrians’ comfort and safety levels, and give vehicles easy entrance into existing traffic flow.

These are the same goals I found that Providence aims to achieve when installing stop signs. Long-term goals for calming commonly include increasing a neighborhood’s quality of life, creating safe and attractive streets, helping reduce the negative effects of motor vehicles on the environment, and promoting the use of non-automobile modes of transportation. Other objectives can include reducing collision frequency and reducing the need for police enforcement.[70] Calming techniques are supposed to discourage drivers from using those neighborhoods as shortcuts to avoid traffic in other heavily utilized areas.[71]

The Conservation Law Foundation (CLF) has evaluated traffic congestion with an "outside of car" approach, from a neighborhood's perspective. Modern standards determine that roads should be wide, straight, and flat, aiming for faster- moving traffic. The CLF supports approaches that make communities "more safe, scenic, and livable" by adopting strategies that reduce traffic speed and design streets and roads to serve a mix of functions. Roads of a city or town are appealing if there a level of street life exists. Making roadways wide and fast will not invite pedestrians to utilize the space. Higher speeds discourage people from walking or biking and as a result, more people drive.[72] CLF endorses a theory that designs roadways to match their uses, not to accommodate only drivers. They suggest that traffic calming can retrofit existing streets and refer to studies throughout Europe to show that traffic calming reduces traffic speeds, accidents, and noise levels. The CLF is a vocal advocate for traffic calming and helped Elmwood and West Broadway start their neighborhood calming pursuits.

Many countries have used calming techniques for the past 20 years on local and arterial streets. The United States does not lead the world in traffic calming, but as time passes, more

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[70] Lockwood, Ian M. and Timothy Stillings. *Traffic Calming on Arterial Streets*. City of West Palm Beach, Florida. Provided by Beta Engineering, Lincoln RI. February 2000. p. 2.

[71] West Broadway Neighborhood Association. “Report to the Rhode Island Foundation on the Traffic Calming Project in the West Broadway Neighborhood.” Providence, RI. August 19, 1998.

[72] Seiderman, Cara B. *Conservation Matters*. Traveling at the Speed of Life. Conservation Law Foundation. Boston, MA. Autumn 1997. p. 20-22.

community street plans are incorporating calming ideas. The urban planner who designed two major calming projects in Providence, Paul Murrain, is from the UK and has brought some European calming ideas to these neighborhood proposals. Although Europe and the United States have very different traffic patterns and standards, many calming structures commonly used in Europe have been incorporated into these proposals. Many ideas from Europe are adaptable to US space standards and work well here.[73]

When a roadway's capacity is evaluated, planners predict future volume and usage goals. If a road's traffic is predicted to increase, planners will expand the road to accommodate predicted levels. Although planners often forecast as far as twenty years ahead, congestion may become a problem on a particular road earlier than anticipated. Although the highways are expanded for future expectations of additional capacity needs, their availability after roadway expansion leads to immediate use. Congestion increases and then the roadway has become a victim of "induced demand". The roadway is now servicing the amount of traffic the engineers had expected 20 years into the future; the maximum capacity, however, can be reached in a few years after construction. After twenty years, the traffic congestion has already overwhelmed the road and levels of congestion are much larger than the original estimates. The goals of traffic calming include narrowing roadways and slowing traffic. Calming methods are intended to bring roads back to an acceptable capacity for the neighborhood, as well as make the road more efficient.

Paul Murrain, an urban designer who worked on both the West Broadway and Fox Point projects, has highlighted the speed of 20 miles per hour as an important speed indication for safety and road capacity. A local roadway can achieve the maximum road capacity if cars are driving safely at twenty miles per hour. In theory, at twenty miles per hour, thirty-four cars may

[73] Paul Murrain Urban Design. Fox Point Neighborhood Traffic Calming Plan. Providence, RI. November 1999.

pass the same spot per minute because the space left between cars by drivers is the minimal.[74] With higher speeds and drivers who are driving carefully, this space length increases, drivers begin to create larger cushions between their cars and fewer cars can pass the same point in a minute.[75] Traffic calming efforts aim for vehicles to stay within 20 to 30 miles per hour. Also, at 20 miles per hour, the injury caused if someone is hit by a motor vehicle is less life threatening than at speeds above 20 miles per hour. On traffic-calmed arterial streets, the expected travel speed is around 30 miles per hour and the expected motor vehicle volumes are 10,000 to 20,000 per day.[76]

Traffic calming can be achieved in two ways. One technique uses physical structures for speed reduction in order to change drivers' behavior. This includes barriers such as speed humps in the roadway. Other physical changes can be lateral road shifts, carriageway constriction, and road markings. The other technique involves changing the environment that surrounds the roadway to create a different ambiance in the neighborhood. Examples of this would include creating "side friction"; restricting a driver's optical width by narrowing the front and side views by using trees or streetlights. Entranceways and gates to the beginning of roads also demonstrate a change in environment; drivers are entering a different type of driving situation and will have to change their behavior accordingly. Islands, sidewalk extensions, and median plantings also change the roadway's character.

PLANS

Elmwood

[74] Fox Point Resident Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. March 1, 2000.

[75] Fox Point Resident Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. March 1, 2000.

[76] Lockwood, Ian M. and Timothy Stillings. *Traffic Calming on Arterial Streets*. City of West Palm Beach, Florida. Provided by Beta Engineering, Lincoln RI. February 2000. p. 3.

The Elmwood neighborhood had some of the above calming techniques installed on streets where the neighborhood was experiencing speeding problems. Elmwood used techniques such as speed humps, medians, and traffic circles. The traffic circles have since proved a hindrance for the police, ambulances, fire trucks, and school buses. The severe speed bumps used in Elmwood are an extreme calming measure and can make for an unpleasant driving experience. While the residents acknowledge considerable traffic reductions occurred, not all are pleased with the type of methods chosen. Also, the streets in the neighborhood without bumps experienced increased levels of traffic; the bumps have just moved the problem, not solved it.[77] The technique was too aggressive; it deterred a large amount of traffic from utilizing the streets and created increased traffic on streets that were not calmed. Other neighborhoods are trying to learn from the negative impacts the Elmwood project had on drivers and the neighborhood residents.[78]

West Broadway

In 1995, the Conservation Law Foundation approached the West Broadway Neighborhood Association. When they introduced the concept of traffic calming to the community, the neighborhood was immediately interested. A few years later, the Elmwood neighborhood pursued ideas for traffic calming. At that time, the Rhode Island Foundation was offering grant money to help fund various projects in the state and thought traffic calming was a worthy endeavor but wanted to provide for more than one neighborhood. West Broadway was interested in the funding and the RIF gave them $6,000 for research and 25 hours of CLF's consulting services.[79] The neighborhood was a good traffic-calming candidate because there had been several severe accidents and a significant amount of cut-through traffic in the West Broadway neighborhood. West Broadway also received funding from donations and grant

[77] Paul Murrain Urban Design. *Fox Point Neighborhood Traffic Calming Plan*. Providence, RI. November 1999. p. 37.

[78] Correspondence with Jon Ozbek. Planner/GIS Coordinator. City of Providence Department of Planning. February 16, 2000.

requests. They received $250,000 as a result of a request by their councilperson from Rhode Island Foundation bond issue money and approximately $350,000 in block grant funds from the Department of Housing and Urban Development (HUD).[80] The neighborhood association then formed a relationship with the city's planning department and has made plans to implement some form of traffic calming.

The West Broadway neighborhood has focused on improving the traffic conditions of 4 major neighborhood streets: Dexter, Parade, Sycamore, and Messer. These streets have significant high-speed travel and are also key routes to important community facilities. The speeding corridors have made it dangerous to access these places. Members of the neighborhood association surveyed the streets for vehicular speeds, obedience to traffic signs, traffic counts and street measurements (however, these data are not included in the traffic calming plan). The community had decided that traffic calming should be implemented and this data collection was to characterize the neighborhood roads to see which were causing dangerous traffic situations. Streets that are not calmed and that will receive the deflected traffic as a result of calming measures are taken into consideration; however, the neighborhood recognized that not every road could be calmed. The neighborhood association plans to continue to watch traffic patterns in the neighborhood and if the deflected traffic is causing problems in other areas, additional calming could be considered. They found that Dexter and Parade had high speeds and high volumes.

- Messer Street – This road is long, wide, and treeless giving drivers unobstructed views down the street. On street parking is legal but rarely occurs. This small amount of side friction creates a convenient situation in which to speed. It is the longest and straightest street in the study, with many four-way intersections. The street is approximately 30 feet wide.

- Sycamore Street – This street also lacks any significant amount of on-street parking and has become a rapid short cut in the neighborhood. On Sycamore, the calming objective is to

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[79] Correspondence with Kari Lang. West Broadway Neighborhood Association. February 2, 2000.

[80] Correspondence with Kari Lang. West Broadway Neighborhood Association. April 4, 2000.

make it more inconvenient to travel than Messer because it is commonly used to dodge traffic.[81]

- Parade Street – This street has several sidewalk trees but wide lanes with underutilized parking on both sides of road. The street is 43 feet wide.
- Dexter Street – Dexter Street is 40 feet wide and reduces to 28 feet wide with parking. This street has experienced several serious accidents in the past and is of particular neighborhood concern.

Tree-lined medians with trees in raised tree pits and street striping adding a different type of paving for the parking lanes were recommended for Parade and Dexter. On Dexter, the plan envisions a gateway into the park and creating a special frontage to the church. The neighborhood also explored options for diagonal parking, and traffic circles. West Broadway's objective was to make drivers realize they are in a highly residential area and that a higher speed will not be tolerated. Other objectives include discouraging through traffic, increasing safety, and bringing activity back onto the streets.

The entire project included many techniques combined in various creative ways, but did not attempt to quantify the calming benefit. West Broadway will begin the project by first adding trees in the parking lanes to decrease overall street width on Messer and Sycamore. Measures for Dexter and Parade will quickly follow. The first building phase will begin in the Spring of 2000.[82] The neighborhood association had to raise their own funds for these projects; the city is not paying for it, but is involved in the process.

After the calming structures are constructed on the first two streets, trees will be put in the parking lanes on Dexter and Parade streets. The overall plan includes narrowing streets and planting trees. Speed cushions, traffic circles, and sidewalk extensions are also planned for more advanced calming. The parking lanes will be a key strategy for narrowing street width. The plan

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[81] West Broadway Neighborhood Association and City of Providence Department of Planning. *West Broadway Neighborhood Pilot Traffic Calming Plan*. Providence, RI. May 1999.

[82] Correspondence with Kari Lang. West Broadway Neighborhood Association. February 2, 2000.

strongly recommends that trees be planted in the parking zone.[83] If that works, West Broadway will not implement any other calming methods. If the trees do not work, they will implement more techniques from the plan such as traffic circles and speed cushions. The neighborhood is planning to plant a total of 600 trees in the parking lanes. The plan stipulates that not all the details need to be implemented; a fixed parking lane, a lane that has been designated for parking by adding tree pits, may be all that is necessary.

<u>Fox Point</u>

The Fox Point area experiences a lot of "through traffic" in route to other areas of the city. Wickenden Street is especially preferred because it follows the route of the adjacent interstate. Fox Point is a mixed-use neighborhood and its uniqueness contributes to its problems. The neighborhood streets form a grid and are easily misused. (See Map 5) A major goal of the community's desire for a traffic calming plan is to preserve the neighborhood quality. The neighborhood agreed with calming goals and wanted to create constant traffic speeds, discourage thru-traffic that could be using principal arterial streets or the surrounding interstates, add public transport to the area, and increase neighborhood safety.[84] Fox Point also listed congestion and weight limit abuse as major concerns.[85]

The community has hosted several public meetings including separate business/resident specific meetings. From these meetings and the traffic calming plan, it became evident that Interstate 195 has had a negative impact on this area. Wickenden has become a "rat run" where cars try to avoid the interstate's traffic congestion. The speed at which cars travel on Wickenden Street is too fast and prevents drivers from taking notice of storefronts. Slower speeds would be

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[83] West Broadway Neighborhood Association and City of Providence Department of Planning. *West Broadway Neighborhood Pilot Traffic Calming Plan*. Providence, RI. May 1999.

[84] Fox Point Business Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. February 16, 2000.

[85] Fox Point Business Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. February 16, 2000.

more beneficial for the businesses. It would also be more beneficial for pedestrians trying to cross the busy roadway. The traffic calming plan is a vehicle for discussion and the purpose is to help decide on some methods that would fit into the Fox Point neighborhood. Business concerns include the loss of storefront parking and servicing space. Residents are concerned with the fast speeds on local roads.

Fox Point junctions are often susceptible to the drivers who want to drive faster on side streets to make up or avoid time lost in the highway congestion of the area. Fox Point is a point of entry and exit to Interstate 195 and is very close to the Interstate 95 and Interstate 195 junction. Gano Street is the perfect example; it is the road where Interstate 195 exit and entrance ramps are located. On this street, some cars travel as fast as 45 miles per hour. Although this speed is only used by a small percentage of the road's user, it is this traffic that causes the problem. Interstate 195 often is "choked up" and results in longer delays because some cars try to save time going through Fox Point and attempt to rejoin the highway at the next junction.[86] Paul Murrain, the urban designer for the project, suggested the neighborhood might be entitled to mitigation cost funding because of the expected relocation of Interstate 195.[87] Funding could be used for the calming construction.

Seekonk River, Benefit Street, India Point Park and Power Street bound the Fox Point neighborhood. Fox Point residents identified several streets that need to be addressed in any calming program. For the selected roads, data for speed and volume of traveling vehicles was collected.[88]

- Hope Street – The average speed on Hope Street was 23 miles per hour. Approximately 5,400 vehicles traveled on the street daily. The maximum speed range was 46-50 mph,

[86] Fox Point Business Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. February 16, 2000.

[87] Fox Point Resident Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. March 1, 2000.

[88] All Fox Point traffic data was found in: Paul Murrain Urban Design. *Fox Point Neighborhood Traffic Calming Plan*. Providence, RI. November 1999.

and the 85th percentile was 28 mph. Hope Street has a mixture of both service and residential uses. The road is 33 feet wide.

- Governor Street – It is a residential street. The average speed traveled on Governor was 24 miles per hour with approximately 4,300 vehicles traveling per day. The 85th percentile was 29 and 95% are going less than 33 miles per hour. On one particular day, ten vehicles were recorded at speeds between 46-50 miles per hour.

- Gano Street – The average speed traveled on Gano was 24 miles per hour with daily traffic volumes equaling 17,750. 85% are going below 28 miles per hour while 95% are going less than 32 miles per hour. This may be of greater concern than the average speed may tend to suggest. It is also the junction of ramp exits to Interstate 195. It is very much a major throughway but Fox Point residents want to include it in traffic calming.

- Benefit Street – Cars traveling on this street averaged 23 miles per hour with an average volume of 6,100 vehicles per day. This average speed can also be deceptive, on one day, 235 vehicles were going 36-40 miles per hour.

- Power Street – This road, only second to Wickenden Street, is the main East/West corridor used in the study area. Surveying occurred in a mid-block between Hope Street and Governor Street. The average speed on Power Street was 23 miles per hour. It is important to note that there are quite a few 4-way stop signs on Power Street.

- Brook Street – This is one of the narrowest North/South streets and includes a children's park and retail facilities. Although Brook has several 4-way stop signs, speeds above acceptable limits (20 miles per hour in this case) were discovered. Brook Street's average speed was 25 miles per hour. There is also a great deal of parking on both sides, leaving less width for cars to utilize. This explains the slower speeds observed on this street.

- Wickenden Street - Speed measurements averaged 24 miles per hour. The study conducted in Fox Point commented that Wickenden is not a pedestrian friendly street, the current median is unsightly, and the exchange at Governor is confusing.

Fox Point's roads are all fairly wide so a main focus of the calming plan is devoted to narrowing these corridors. Fox Point streets are averaging around 30 feet in width; the Institute of Transportation Engineers suggests 24 feet of pavement for safe high-speed streets.[89] The main calming method suggested was tree placement in the parking lanes. This will provide both physical and perceived width limitations, creating "side friction". (See Figure 13) Side friction can also be created with the scale of the buildings, how close they are to the street, the presence

[89] Paul Murrain Urban Design. *Fox Point Neighborhood Traffic Calming Plan.* Providence, RI. November 1999. p. 27.

of trees or parked cars, and the width of the travel lanes. In some cases, as with the proposal for Gano Street at Power, by the park, sidewalks can be widened, putting trees on the new wider walks or, the dominant strategy in the plan, placing all trees in the parking area. The parking lane, even without the presence of cars, will keep the width permanently narrowed. Tree pits are a large part of the Wickenden plan. The urban developer worked with foresters in the state government and, with their help, chose sturdy trees that were best for urban environments. The report, however, did not discuss maintenance or replanting of plants and trees used in the proposal.

Certain details of the plan received negative responses. One particular problem found in Fox Point and West Broadway was the opposition posed from the city's fire department and the city's department of public works. The fire department expressed concern about having trees in the parking lanes, claiming that it may interfere with fire truck ladders in a case of emergency. The department of public works complained about the hassle imposed from parking-lane trees on snow removal and street cleaning. The department of Public Works has also argued that traffic calming requires a lot of maintenance and the city, although it did not implement the calming measures, is financially responsible for its maintenance. Paul Murrain argues that there needs to be a balance.[90] Another retort would be that traffic calming is being implemented in the developed world and in areas where these measures have been implemented, the streets are still being cleaned and the snow is still being removed; it just may be happening in a less-traditional manner than before. Some communities have answered concerns with calming restrictions such as not allowing measures on streets that are determined to be primary emergency or snow

[90] Fox Point Business Information Session on Traffic Calming conducted by Paul Murrain. Fox Point Citizens Association. February 16, 2000.

emergency response routes. Traffic calming measures can still be implemented in other parts of the community.[91]

Does traffic calming conflict with the goal of reducing traffic congestion?

Traffic calming may conflict with other traffic control methods that are aimed at alleviating congestion. Traffic calming on arterials is a contentious issue, “Why would you want to slow down a major throughway?” However, traffic calming on arterial streets and highways as they pass through towns have been successfully done.[92] It all depends on the desired effect on motor vehicle speeds and volumes.

Traffic calming could, on the other hand, unnecessarily slow down a principal arterial that is depended on to move traffic. The wrong calming techniques, such as speed humps or unnecessary stop signs may interfere with the road’s purpose and create congestion. Some roads also just serve for “town functions” and would welcome calming for safety reasons. Traffic calming needs to be evaluated on an area-wide basis, calming every street in a 5-mile radius would not be effective; motor vehicles still need some through streets and major arterials to travel around the calmed area. Calming is not always appropriate on all arterials, but can work on the right ones.

Fox Point is a unique situation because the area includes major highway ramps and requires accessibility for larger vehicles than cars, calming measures will often be wider or less extreme than it would have to be if the area catered only to cars. This might conflict with the community’s desired calming of Gano Street but as a major throughway, congestion must be put higher on the priority list than calming.

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[91] White, Josh. “Manassas to Revisit How to Ease Traffic; Calming Policy a Contentious Issue.” *The Washington Post.* January 24, 1999, Sunday, Final Edition.

[92] Lockwood, Ian M. and Timothy Stillings. *Traffic Calming on Arterial Streets*. City of West Palm Beach, Florida. Provided by Beta Engineering, Lincoln RI. February 2000. p. 1.

Do any traffic calming techniques have environmental benefits?

Calming techniques force vehicles to make vertical and lateral shifts. Techniques like rerouting the driver with slight alterations to street geometry, reducing real or perceived width, and having drivers negotiate curves or objects do not necessarily stop traffic. Assuming stop signs are not a primary calming tool, traffic calming is a type of environmental benefit because the motor vehicles are not traveling in a “stop-start pattern”. Lateral shifts can be planned to maintain constant speeds and keep traffic moving efficiently. Changing pavement surface demands drivers’ attention and reduces the comfortable driving speed while not forcing drivers to stop. Methods that include side friction can also contribute to an efficient traffic system; it doesn’t prevent drivers from maintaining a constant speed.

Speed bumps are not as efficient as other traffic calming measures. They effectively slow traffic down, but force reasonable drivers to behave in a “stop/start” manner. This pattern tends to make the traffic experience unpleasant as well as inefficient.

Effect on Emissions due to Vehicle Speed

Nitrogen oxide emission factors are at a minimum between the speeds 19 miles per hour and 26 miles per hour. Carbon monoxide emissions are minimized at approximately 49 miles an hour. Volatile organic compound emission factors are lowest at 54 miles per hour. There is no common ground between all three. Roadway patterns that allow speeds between 30 and 40 miles per hour would be the reasonable compromise when trying to minimize all three pollutants. However, these speeds are higher than the preferred calming speed of 20 miles per hour. Overall, any traffic calming method that keeps the average speed traveled on a particular road higher rather than lower would create emissions reductions for CO and VOC. Methods that keep traffic moving instead of stopping and starting would also achieve this goal. From an urban standpoint, nitrogen oxides and volatile organic compounds are more of a concern and need to be managed. However, for more local impacts, carbon monoxide should be addressed.

Effects on Emissions due to Traffic Calming Controls

Traffic circles are designed to keep traffic moving and are an alternative to perpendicular intersections. At Michigan State University there is a mix of pedestrians, cars, and bicycles on campus and stop signs (two-way) and traffic signals control most of the campus intersections. Three of these intersections, however, are traffic circles. In 1994, a study compared stop sign intersections and traffic circles in terms of accidents, average speed, average delay, fuel consumption, and fuel emissions.

The study was initiated when the university was experiencing operational problems with one of the two-way stop intersections; there were also two other comparable intersections on campus that carried similar traffic volumes. A suggestion was made to make the intersection a traffic circle and that sparked an evaluation of all six traffic circles and intersections.[93] Two of the three traffic circles, Wilson Street at Bogue Street (Circle 2) and Shaw Lane at Bogue Street (Circle 3) connect two major arterials while the other circle, Red Cedar at Wilson Road (Circle 1), connects a major and a minor arterial.[94] The intersections are all two-way stop signs. Two of the intersections control traffic on major arterial roads; the intersection of Shaw Lane at Chestnut Street (Intersection 1) and the intersection of Wilson Road at Farm Lane (Intersection 2). The third intersection, Shaw Lane at Red Cedar, includes a one-way street section and acts as a "yield intersection," Red Cedars yielding for Shaw Lane traffic.[95]

The study found that the traffic volumes for the three circles were similar to the three two-way stop intersections and that between 1988 and 1991 there were 22.4 accidents for the

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[93] Savage, William F., and Khaled Al-Sahili. "Traffic Circles – A Viable Form of Intersection Control?" ITE Journal. September. 1994. Vol. 64. Iss. 9. p. 40-45.

[94] Savage, William F., and Khaled Al-Sahili. "Traffic Circles – A Viable Form of Intersection Control?" ITE Journal. September. 1994. Vol. 64. Iss. 9. p. 40-45.

[95] Savage, William F., and Khaled Al-Sahili. "Traffic Circles – A Viable Form of Intersection Control?" ITE Journal. September. 1994. Vol. 64. Iss. 9. p. 40-45.

three traffic circles and there were 48.75 accidents for the intersections.[96] These data indicate that traffic circles provide significant safety benefit.

The study also compared fuel consumption and emissions estimates obtained from computer model, NETSIM. This program simulates intersection operation and measures the effectiveness of the controls. Output includes number of stops, average speed, fuel consumption, and fuel emissions. All six intersections were modeled. As shown in Table 16, the traffic circles performed better than the two-way stop signed intersections.

Table 16. Measures of Effectiveness at the Intersections Controlled by Traffic Circles and Stop Signs.

	Intersection Number					
	Circle #1	Circle #2	Circle #3	2-way stop #1	2-way-stop #2	2-way-stop #3
# Stops/Vehicle	0.01	0.02	0.01	0.27	1.33	0.27
Average Speed (mph)	15.36	16.00	14.53	14.47	2.83	10.90
Avg. Delay/Vehicle (sec)	2.25	1.88	1.85	3.91	31.40	6.03
Total Delay (min)	7.20	5.70	9.40	13.40	157.0	24.00
Delay/Veh-Mi (min)	0.80	0.80	1.23	2.03	18.88	2.92
T-Time/Veh-Mi (min)	3.91	3.75	4.13	4.15	21.20	5.50
Fuel Consumption (MPG)	11.61	9.88	8.99	5.81	3.54	7.64
Fuel Emissions* (gm/veh-mi) HC (VOC)	0.183	0.214	0.245	0.364	0.639	0.281
CO	3.080	3.822	4.405	7.306	10.352	5.000
NOx	0.763	1.099	1.207	2.395	2.423	1.413

"*"For composite autos

Source: Savage, William F., and Khaled Al-Sahili. "Traffic Circles – A Viable Form of Intersection Control?" ITE Journal. September. 1994. Vol. 64. Iss. 9. P. 43.

The data shows that although all three traffic circles studied operated better than the intersections with stop signs, the circle with the highest volume (Circle #3), does not operate as well as the other circles. This may be an indication that the effectiveness of a traffic circle

[96] Savage, William F., and Khaled Al-Sahili. "Traffic Circles – A Viable Form of Intersection Control?" ITE Journal. September. 1994. Vol. 64. Iss. 9. p. 40-45.

decreases with an increase in volume. Overall, it seems that traffic circles will be an effective traffic control method. Circles have less of an environmental impact; cars traveling through them emit less volatile organic compounds, carbon monoxide, and nitrogen oxides while maintaining higher fuel efficiencies than cars traveling through two-way stop sign intersections.

LIGHT SYNCHRONIZATION

<u>How do arterials impact congestion?</u>

One of an arterial street's functions is to move large numbers of motor vehicles quickly but another function is to provide and alternative to "side street" and "local road" travel.[97] Increasing the flow of traffic through signalized intersections improves overall traffic flow and reduces congestion. Overall air quality will improve due to efficient movement of traffic and reduction of idling vehicles.

Signal synchronization does not imply that traffic speeds will be increased. For air quality purposes, the intent is to smooth traffic flow and reduce idle time. It is quite likely that the average speed for a corridor will remain about the same, but the flow characteristics will be very different. Assuming that the vehicle "buffer zone theory" still occurs at higher speeds, more traffic can flow past a set point at 30 miles per hour than 45 miles per hour because there is less distance between vehicles.

The Rhode Island Department of Transportation controls and maintains approximately 70 stoplights in the Providence area. The lights are located on major arterial streets within the city. (See Map 6) Of the ten state synchronized arterial systems that RIDOT has installed throughout the state, two of them are in Providence on Route 44, Smith Street. (See Map 7) The city has, in the past, tried timed progression on some streets, but with little effort and only with state assistance. Major Richard Sullivan of the Providence Police Department thinks synchronization

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[97] Lockwood, Ian M. and Timothy Stillings. *Traffic Calming on Arterial Streets*. City of West Palm Beach, Florida. Provided by Beta Engineering, Lincoln RI. February 2000. p. 2.

is a problem within a residential community where, if a “25 miles per hour target” is assumed, traffic delays will occur. He does not believe the sequence will relieve congestion and could create greater gridlock in the downtown and residential areas.[98]

However, delays need not to occur. With a three-phased signal, lights can change signalization time settings according to time of day and traffic demand. A 3-phased light system has three settings: 1) rush, 2) routine, and 3) manual settings. These settings have different signaling times to maximize progression at each setting. These lights are expensive and the city currently does not believe they are a prudent investment. The city wastes money on less sophisticated lights that will eventually have to be replaced. Instead, they should invest in the technologically advanced equipment and rely on the long-term benefits of more sophisticated equipment. According to the city’s traffic engineering office, every time a road is re-lighted or upgraded, the city is required to accept the lowest contractor’s bid. This bid is less expensive because it does not include more advanced lighting equipment; when the needs of the roadways become more complicated and a multi-phased light is required, the city has to buy that light. An initial investment in a multi-phased light would be more cost effective and if the city specified lights that can be synchronized, all bidders would incorporate them.

People, who are constantly stopped at a series of traffic signals or other traffic control devices, as demonstrated in the Greenville, NC study, tend to drive faster between signals to “make up for lost time”.[99] If signs are posted along the signalized system that affirm the road is synchronized and adjusted for a certain speed, “lost time” will no longer be an issue; drivers will attempt to stay at the synchronized time to avoid delay.

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[98] Phone correspondence with Major Richard Sullivan of Providence Police Department. March 1, 2000.

[99] Correspondence with Harrison Marshall. North Carolina Department of Transportation. February 22, 2000.

Does synchronizing and timing lights alleviate traffic congestion or have an impact on emissions?

Synchronized arterials can maximize progression and develop signal-timing plans that ensure continuous movement. They also minimized the "disutility function," timing plans reduce user costs over road network (delays, stops, and fuel consumption).[100] Programs RIDOT use, like TRANSYT – 7F and PASSER (Progressive Analysis and Signal System Evaluation Routine) enable engineers to choose the most suitable solution for their particular signal-timing problem to improve delays and fuel consumption rates. PASSER is a time based optimization model. The Rhode Island Department of Transportation uses this model to estimate arterial timing; in general it is used for analyzing the phasing needs and determining the optimal traffic signal timings at signalized diamond interchanges (developed by Texas Transportation Institute).[101] Signal synchronization does not imply that traffic speeds will be increased. The main goal of synchronization is to have traffic flow more smoothly and result in fewer emissions.

In the Rhode Island CMAQ application, synchronized arterials are projected to provide an emissions benefit. The state applied for funding for a project titled, "Phase I traffic Improvements to 10 arterials, Statewide." This project asked for funding to install state of the art computerized traffic control systems that implement efficient arterial progression. This progression is estimated to result in emission reductions due to the expected higher average speed and reduced vehicle idling. Traffic system controls generate more efficient urban street networks. Results include reductions in travel times and delays that influence vehicle operating emissions and traffic safety.[102]

[100] Khatib, Z. "Arterial Signal Timing Optimization". American Society of Civil Engineers Library Resources. Chicago, IL. June 1997. p. 76-82.

[101] Rhode Island Department of Transportation. Application form for Candidate Project. Congestion Mitigation and Air Quality (CMAQ) Program. Attached Narrative, "Incremental Benefits of Different Levels of Control." p. 57. Provided by Paul Silva, Rhode Island Department of Transportation.

[102] Rhode Island Department of Transportation. Application form for Candidate Project. Congestion Mitigation and Air Quality (CMAQ) Program. Attached Narrative, "Incremental Benefits of Different Levels of Control." p. 45. Provided by Paul Silva, Rhode Island Department of Transportation.

A large part of the state's argument is based on information from a survey entitled, "Energy Impact of Urban Transportation Improvements" prepared by the Institute of Transportation Engineers. The survey includes an evaluation of traffic signal improvements categorized in 5 types representing various actions and base level conditions. Scenario results included[103]:

1) Interconnecting uncoordinated signals, pre-timed signals, and new optimized timing plans with a central master control system resulted in 25% reduction in average travel time,
2) Installing computer control where the base condition was interconnected pre-timed signals operating with old timing plans resulted in 17.5% reduction in average travel time,
3) Implementing computer control where the base condition was non-interconnected controls, traffic actuated control reduced travel time by 16%,
4) Installing computer control where prior there was interconnected multi-dial pretimed control with active signal timing management resulted in 8% reduction in travel time,
5) Optimizing traffic signal timing plans where before there were forms of master control with relatively crude timing plans resulted in 12% reduction of travel time.

The bulk of the state's CMAQ application was aimed to get funding for the computer system. Part of the funding was to improve traffic signal operations, particularly on arterial streets. The application also showed signal timing optimization was responsible for a large portion of reductions in travel time and energy savings.[104] Traffic signal system improvements ranked as one of the most cost-effective urban transportation improvement actions, its annual cost per intersection translated to a few cents per "vehicle hour" reduced.[105]

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[103] Rhode Island Department of Transportation. Application form for Candidate Project. Congestion Mitigation and Air Quality (CMAQ) Program. Attached Narrative, "Incremental Benefits of Different Levels of Control." p. 45. Provided by Paul Silva, Rhode Island Department of Transportation.

[104] Rhode Island Department of Transportation. Application form for Candidate Project. Congestion Mitigation and Air Quality (CMAQ) Program. Attached Narrative, "Incremental Benefits of Different Levels of Control." p. 49. Provided by Paul Silva, Rhode Island Department of Transportation.

[105] Rhode Island Department of Transportation. Application form for Candidate Project. Congestion Mitigation and Air Quality (CMAQ) Program. Attached Narrative, "Incremental Benefits of Different Levels of Control." p. 49. Provided by Paul Silva, Rhode Island Department of Transportation.

Table 17. Expected Improvements of traffic control. Demonstration of travel time reduction and fuel consumption impacts of a hypothetical traffic signal system improvement for an area of one million in population.

Traffic Control Improvement Project	*Reduction in Annual Vehicle Hours (million)*	*VOC Emission Savings (million grams)*	*CO Emission Savings (million grams)*	*NOx Emission Savings (million grams)*
1. Optimize Signal timing at 500 previously coordinated intersections	7.2	127	934	47
2. Interconnect and optimize signal timing at 250 previously uncoordinated intersections	7.5	132	972	49
3. Install advanced computer control system at 500 intersections	4.8	85	622	31
Total Program	19.5	344	2528	127

<u>State Arterial Project</u>

RIDOT traffic flow improvements are an eligible TCM under section of 108 (f) of the Clean Air Act Amendments. They are also eligible for 100% funding by CMAQ. The city should be asking the state's assistance with traffic control funding. Air quality assessment is based on emission reductions associated with the changes in traffic volumes and vehicle trip speeds. The reductions of the 10 arterials were quantified in the report. Arterials were estimated to cost 2.6 million dollars scored a 28 out of 100 points of achieving CMAQ goals in the application. For perspective, only one project scored 100 and the rest scored below 50. Route 44 Smith Street is the affected road that travels through Providence. Expected emission benefits are significant, including expectations of changing vehicle miles traveled:

TABLE 18. Emission Differences if Implementation of Arterials on Route 44, E of Route 15, Route 44, W of Route 15, and Route 15.

	No Build vs. Build Difference in Peak & Off-Peak Total Difference in emissions (kg/day)		
	1996	*1999*	*2010*
VOC TOTALS	-43	-42	-32
NOx TOTALS	0.5	-0.25	-6
CO TOTALS	-433	-422	-0.4

Angell Street Progression

In 1995, the Rhode Island Department of Transportation conducted a study to evaluate the traffic impacts related to the proposed rehabilitation of the Washington Bridge. One part of this evaluation was measuring the expected impact on the surrounding traffic patterns. This included traffic on Angell Street, a major arterial in College Hill continuing onto the downtown area. With this evaluation, the state wanted to try light synchronization on Angell Street to help manage the expected traffic flow increase because of the bridge construction.

South Angell is one-way westbound city roadway connecting the Henderson Bridge with Angell Street. It is considered a principal arterial and the posted limit is 25 mph. Angell Street connects South Angell Street with Memorial Boulevard and Canal Street. It is also classified as a principal arterial and the posted speed limit is 25 miles per hour.[106] The section of Angell Street that was evaluated was approximately 1.3 miles long.

[106] Vanasse Hangen Brustlin, Inc. *Rehabilitation of Washington Bridge North Bridge No. 700*. Rhode Island Department of Transportation. Providence, RI. July 1995.

In 1991, Angell Street had an equipment upgrade and the state treated Angell and Waterman as throughways. The state also tried to implement traffic progression using the TRANSYT modeling program results. Progression didn't work well because the state had included South Angell as part of Angell Street; they stated very different traffic patterns occur on the two sections.[107] Rhode Island Department of Transportation stated that Angell Street actually acts as two different networks; one network includes Waterman and acts as a loop around Thayer Street. Further down Angell, around Wayland Square, Angell Street acts as a throughway. Angell Street, in 1995, was handling approximately 15,994 vehicles per day.[108] Traffic counts were not measured after the attempted progression but that data would have comparable data for before and after congestion estimates.

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[107] Ted Coleman, Traffic Engineer. Rhode Island Department of Transportation. Personal Correspondence. March 8, 2000.

[108] Vanasse Hangen Brustlin, Inc. *Rehabilitation of Washington Bridge North Bridge No. 700*. Rhode Island Department of Transportation. Providence, RI. July 1995.

Chapter 4 – Recommendations

Using traffic controls as a way to reduce VOC, CO, NOx, and carbon emissions is only one option for the city of Providence and the state of Rhode Island. Other methods could include increasing the use of more fuel-efficient vehicles and alternative modes of transportation, tougher emissions restrictions with vehicle inspections, elimination of free parking in the city, or driver incentives to get older cars off the road. However, congestion is increasing in the metropolitan area and different control devices have different impacts on vehicle emissions.

Improved circulation would have a significant impact on congestion because it directly affects delay. Circulation improvements due to synchronization will decrease congestion for the short term. Then, drivers will begin to switch to that road because delays are minimized with synchronization. These drivers will switch from using local roads, reducing congestion in the neighborhoods. In the long term, synchronization may increase traffic volumes on particular roadways because cars are no longer travelling in other parts of the city where faster-moving, high volumes of traffic are not desired. The public transportation system in Providence is currently providing service to people who do not have cars, so almost everyone who can drive and has a car is driving. If you synchronize the lights, you are not inspiring new drivers to start driving, you are moving drivers off the local roads onto the larger, faster moving roadways. Providence could begin to synchronize its current one way roads. In College Hill, Angell Street and Waterman Street could be timed for continual progressions. Synchronizing roads at the correct times of day reduces congestion into and out of the downtown as well as minimizing delay in the neighborhoods surrounding downtown.

Traffic calming deters cars from entering calmed areas; drivers will choose the major arterial and collector roads instead of traveling slowly through the neighborhood. Drivers are not going to be patient with 20 mile speeds if they do not have a purpose in the calmed neighborhood. Slower constant speeds achieved with calming are better for the neighborhood than unnecessary stops signs.

Although, the city has not quantified its attempts with synchronization and traffic calming, these evaluations are important for analyzing congestion and emissions. If the Rhode Island Department of Transportation had conducted traffic counts after its attempt to synchronize the lights on Angell Street, the changes in congestion and emissions could have been evaluated. A more accurate emissions estimate could have been conducted if the RIDOT had updated its emissions factors since 1994. I could have also conducted a better estimate if the city continually estimated traffic flow in all parts of the city, not just downtown. The 1998 downtown circulation study is the only study the city has conducted traffic flow since the 1970's.

STOP SIGNS

Stop signs have a negative impact on traffic flow as well as emissions and fuel consumption. Stop signs penalize motorists who obey speed limits by forcing them to stop unnecessarily every few blocks on main streets. Although increased speeds resulted in reduced emissions from Greenville study, the NETSIM simulation clearly showed the increase in emissions and fuel consumption with adding stop sign. In addition, speeding between signs is not an emission reducing strategy and has a negative impact on the neighborhood.

TRAFFIC CALMING TECHNIQUES

Traffic calming techniques are a favorable alternative to stop signs. Traffic calming can achieve the same results as stop signs without vehicles stop and start, which increases vehicle emissions and fuel consumption. Aggressive techniques such as speed humps on arterials will have negative impact and divert traffic onto local streets that are not designed or intended to carry a large amount of traffic. Techniques that just slow, not stop, traffic include parking lanes with tree pits that narrow the road result in emissions benefits when compared to stop signs. Traffic circles are also shown to be more efficient and environmentally sound than two-way stops. These techniques allow constant flow while slowing vehicles down to safe speed levels for communities.

PROGRESSIONS

Arterial progression, like the system on Smith Street (Rt. 44), has proven to have emissions benefits. Synchronized light systems should be labeled to inform drivers of constant speed expectations ("These lights are timed for drivers to drive 35 miles per hour for continual progression").

NETSIM

The city's planning department, the city's traffic engineering department, as well as the Rhode Island Department of Transportation should use the traffic-modeling program, or a program similar to, NETSIM. It can incorporate and output estimates of capacity and performance characteristics, such as delay, queue length, fuel consumption, and pollutant emissions for all intersection types. It can optimize intersection design, signal phasing and timings and determine signal timings.

This output could be used for environmental implications for traffic calming, quantifying benefits for CMAQ applications, and finding marginal benefits of traffic control devices' used on arterial and local roads.

THIRD SECTION OF DOWNTOWN EVALUATION

The comprehensive plan for Providence sets transportation goals for promoting efficiency and balance in an urban transportation system to reduce air pollution and traffic congestion. The comprehensive plan should also set goals specifically to review and monitor traffic and development data. These data will allow the city to assess the adequacy of the existing system conditions to make recommendations for improvement. For example, the last section of the 3-part study on Providence and downtown activity is meant to deal with managing intersections and light timings. The city should make emission reductions a stated goal in the study and include emissions as a priority to obtain "balance" in the city's urban transportation system.

The third section of the downtown study should also include mobility information, especially looking at stop signs' and signals' impact on the city's travel rate index. The study should attempt to evaluate circulation and impact on individuals' delay. Although comprehensive approaches are useful, individual impact is also very telling.

CONTRACT DECISIONS

The city is required, when contracting projects out to private consulting firms, to accept the lowest bid. This bid is low because of the lower cost of equipment. Low cost equipment, according to Providence Department of Traffic Engineering, usually means less expensive, less advanced, traffic signaling equipment. The city's planning and traffic engineering departments must realize the positive long-term benefits and economical savings of initially investing in more advanced signaling equipment. The city should make high-technology lighting equipment a priority and have all contracts specify this technology. This includes spending more money on advanced 3-phased traffic signals in order to accommodate the more complicated intersections downtown and create synchronized lighting networks that can be changed with changing traffic conditions.

TRAFFIC ENGINEERING

Stop signs are never reevaluated for usefulness once installed. These signs inhibit constant progression on streets. If the traffic patterns of the roadway have changed since the installation, the sign may actually be causing delays or unnecessary accidents. Traffic modeling programs should be used to predict traffic flow and in evaluating stop sign installation.

The city should also conduct ongoing maintenance on all installed stop signs. Maintenance should include an evaluation of current traffic flow patterns, from modeling, and then a decision of whether a stop control is still necessary. This should be done every few years to keep traffic circulation efficient. Although engineering does perform intersection analysis when considering control devices, they do not evaluate requests from high-level city officials. Political requests should be in order to prevent unnecessary traffic control installation.

The city should also consider investing in computer controlled traffic networks, at present the city has not considered this because of funding. Traffic Engineering specifically stated that a computerized system would not seem to be within the department's scope, their main purpose is to maintain existing traffic control equipment, not actual traffic flow. The department's scope perhaps should be reevaluated and broadened to include new responsibilities such as computerized monitoring systems for city traffic controls. Adequate funds should then be allocated to the program.

INTERAGENCY COOPERATION AND COMMUNITY OUTREACH

The three main players in city government that make decisions affecting traffic and transportation are Traffic Engineering, the Planning Department, and the Police Department (specifically Major Richard Sullivan). These groups should work with community groups, listen to neighborhoods' traffic control needs and desires, and begin to address community concerns with traffic congestion. Different communities have different road and street uses. Evaluating specific uses can then make the transportation networks more efficient.

The Comprehensive Plan, under its citywide goals, describes one of its policies to continue improving the arterial street system within the city, in cooperation with the State Transportation Improvement Program. This should be done in cooperation with the Rhode Island Department of Transportation. Conversations and interviews from both sides have shown that this does not seem to be happening. The city traffic engineers do not work with the state engineers or the city's planning department and have expressed no need or desire to. Their relationship with planning is one of information swapping and that doesn't always go smoothly. Every department, state and local, involved in transportation in Providence wants to preserve its jurisdiction. If communication occurs between these departments, a citywide comprehensive look at the transportation problems in Providence can be achieved.

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