# APPENDIX

## Meetings

## Summits

## NIA Compliance

## FHWA: Off-Model Air Quality Analysis – A Compendium of Practice – August 1999

# *ITS Strategic Deployment Plan*

*Rural Piedmont Region*
*Planning Meeting*
*November 19, 1999, 10:30 AM*
***MEETING SUMMARY***

Attending:

| Name | Agency | Phone | Fax | Email |
|---|---|---|---|---|
| Joe Stanley | City of Eden | 336-623-2110 | 336-623-4041 | Joe.stanley@ci.eden.nc.us |
| Kelly Stultz | City of Eden | 336-623-2110 | 336-623-4057 | Kelly.stultz@ci.eden.nc.us |
| Danny Johnson | Granville County | 919-603-1331 | | Planning@granvillecounty.org |
| James Dunlop | NCDOT - -Cong. Mgmt. | 919-250-4151 | 919-250-4195 | Jdunlop@dot.state.nc.us |
| JoAnn Oerter | NCDOT – Cong. Mgmt. | 919-250-4195 | 919-250-4195 | joerter@dot.state.nc.us |
| Terry Hopkins | NCDOT – Cong. Mgmt. | 919-250-4151 | 919-250-4195 | Thopkins@dot.state.nc.us |
| Wayne Atkins | NCDOT – Division Eleven | 336-667-9111 | 336-667-4549 | Watkins@dot.state.nc.us |
| Joey Hopkins | NCDOT – Division Five | 919-560-6851 | 919-560-3371 | Jhopkins@mail.dot.state.nc.us |
| David Spainhour | NCDOT – Division Nine | 336-637-1340 | 336-761-2347 | Dspainhour@dot.state.nc.us |
| Douglas Waters | NCDOT – Division Nine | 336-761-2200 | 336-761-2347 | dwaters@dot.state.nc.us |
| John Davenport | NCDOT – Division Nine | 336-761-2257 | 919-715-2656 | jdavenport@dot.state.nc.us |
| Mike Mills | NCDOT – Division Seven | 336-334-3192 | 336-334-3637 | Mmills@dot.state.nc.us |
| Pat Ivey | NCDOT – Division Seven | 336-334-3192 | 336-334-3637 | Pivey@dot.state.nc.us |
| Patty Eason | NCDOT – Division Seven | 336-334-3192 | 336-334-3637 | peason@dot.state.nc.us |
| Jon Nance | NCODT – Division Five | 919-560-6851 | 919-560-3371 | Jnance@mail.dot.state.nc.us |
| Faye Scearce | Rockingham County | 336-342-8134 | 336-342-8362 | Fscearer@co.rockingham.nc.us |
| Kenn Fink | Kimley-Horn & Associates | 919-677-2237 | 919-677-2050 | kfink@kimley-horn.com |

The ITS Strategic Deployment Plan planning meeting for the Rural Piedmont Region was commenced at approximately 10:30 AM in the Penn House in Reidsville, North Carolina. Following is a summary of the proceedings of this meeting.

Kenn Fink began the meeting by asking the participants to introduce themselves, and reviewing the agenda for the meeting. Mr. Fink stated that the purpose of the meeting was to have a working session to identify the process for developing a strategic deployment plan for the Rural Piedmont Region. Mr. Fink then presented an overview of ITS, and the process that the Department was undertaking in developing the statewide plan. Mr. Fink then began a discussion with those in attendance about the development of the plan in the region.

**What is the perception of ITS in the Region?**

In general the region is not aware of ITS or how ITS can benefit the region.

**What are some of the major concerns in the Region?**

- Safety, specifically at unsignalized intersections and on narrow 2-lane roads.
- Convenience of use of the transportation system.
- The beginning of growth in the area. As more people move into the rural area, the commuting routes into the major employment areas are becoming clogged.

- Short term congestion due to large developments.
- Poor planning of developments and their impacts to the roads.
- Schools, location, better planning, efficient routing of buses.
- Safety at railroad grade crossings.
- Specific Areas
  - Highway 700 and 770
  - Highway 14
  - The intersection of Highway 14 and Kings Highway
  - Signal coordination on Washington Street and Highway 14

**What needs to be accomplished to help implement ITS in the Rural Piedmont Region?**

- Need to educate local planning agencies, government agencies, and others about ITS and its benefits.
- Provide applicable example projects.
- A formal process has to be establish for local agencies to communicate their needs to the Department
- There needs to be an understanding of the changes in demographics that growth is bringing.
- Needs to involve Smart Growth planning.

**Who needs to be involved?**

- All local (City and County) groups
- The School Boards
- The State of Virginia
- Subgroups should be formed based on needs and how they commute.

Mr. Fink then thanked the participants for their participation, and asked for their continued support.

**ACTION ITEM(S):**

- If you have any comments about these minutes, or the meeting/process in general, please contact Kenn Fink at *ITS-RURALPIEDMONT@KIMLEY-HORN.COM*, or by phone at (919)-677-2237.

The next meeting for the Rural Piedmont Region is not yet scheduled. The next meeting will likely occur in January.

# National ITS Architecture Compliance

The Statewide ITS Architecture and Strategic ITS Deployment Plan development process are both intended to be planning tools. The Strategic ITS Deployment Plan is a planning document which draws inputs from potential ITS customers throughout the State and Region. These inputs are logged and documented, then ranked to provide a snapshot of the perceived ITS needs for the next 20 years. Based on this documentation, the benefits of each project or improvement can be identified and, in turn, added to regional Transportation Improvement Plans (TIP) and the North Carolina Statewide Transportation Improvement Plan (STIP).

The development of the Statewide ITS Architecture is intended to guide the implementation process by providing a structure around which to design. ITS elements and concepts are generically named to permit a wide variety of design options, changes in technology, or institutional changes that occur over time. The intent is to provide freedom to designers and implementers by providing a stable structure for interconnection while providing flexibility to meet the unique needs of specific users.

The National ITS Architecture is divided into three levels: logical, physical and technical. The logical architecture provides a functional view of a system that assists in organizing complex entities and relationships by identifying system functions and information flows. The logical architecture guides development and deployment through functional requirements that are independent of institutions and technology. The logical architecture does not identify how each ITS function is to be implemented.

The physical architecture is the physical representation of how a system should provide the desired functionality. The physical architecture defines the information and data flows between elements and the communication requirements needed to make the system function. The data flow definitions within the physical architecture require standards to provide functionality between systems, which is the basis of the ITS standards development process.

The technical architecture is the formal design and implementation process. The technical architecture defines the implementation of the physical architecture. The technical architecture is the formal design and implementation that defines system hardware and software functionality, their interaction, and the deployment of a system that processes and distributes the gathered data.

The three levels of the National ITS Architecture work together to refine the ITS needs from the planning stage down to a specific hardware deployment. For example, the logical and physical architecture may identify the need for shared traffic information. The physical architecture would define traffic information as traffic data from detectors and video from CCTV cameras.

The purpose of this document is to develop a logical architecture for ITS deployments in the State of North Carolina. The physical architecture is part of this document, but only in describing the interaction between elements, centers, etc. The appendices document the physical architecture through the data flow diagrams and other visual methods.

This document provides the logical and physical architectures as required by FHWA and used in the long-term ITS deployment throughout the state. The details in the development of the technical architecture are left up to each entity and their designers and implementers. The logical and physical architecture layers are a tool that is to be used by the designers and implementers to ensure that data and information is shared between systems. By approaching the ITS Architecture deployment from the logical and physical levels, this document will serve as a roadmap for ITS deployments throughout the State of North Carolina for years to come without locking the State into specific technologies that may change over time.

# Off-Model Air Quality Analysis: A Compendium of Practice

**Federal Highway Administration**
**Southern Resource Center**
**August 1999**

# Introduction

Air Quality analysis methodologies have become more refined over the years to fill the need in the transportation community to satisfy various requirements including Transportation Conformity and Congestion Mitigation and Air Quality Program project justification. Off-Model methods continue to be developed and refined to allow for analysis of innovative, as well as some common, projects to account for reductions in vehicular emissions. The most typical analysis is associated with Vehicle Miles of Travel (VMT) reductions, but reductions in emissions can also occur due to decreases in vehicular delay.

This is an observation in techniques which have been used in the South to provide for the evaluation of possible emission reductions. For the purpose of this compendium, Off-Model methodologies are analyses performed without the specific use of a Travel Demand Model. As previously stated, these analyses can be used for either of two primary purposes. These two purposes are Transportation Conformity Analyses and Congestion Mitigation and Air Quality (CMAQ) Improvement Program project justifications. The later of these two is probably the most crucial given the need for project justification as a funding mechanism; however, with the increasing difficulties in showing an offset of VMT growth in most areas, any reduction will only provide a benefit to the Conformity Process.

This compendium offers a look into several methodologies utilized in Federal Highway Administration's Southern Resource Center geographic area and may be duplicated and disseminated at will. These methodologies are not all encompassing but should offer valuable insight into Off-Model practice. Updates of this compendium will occur and include any needed changes in the reference section.

If you have any questions or comments please address them to:

Andrew Edwards, Air Quality Specialist
Federal Highway Administration
Southern Resource Center
61 Forsyth St., Suite 17T26
Atlanta, GA 30303-3104
(404) 562-3673

# Table of Contents


## Intersection Improvements

General Analysis 4
Traffic Signal Computer Upgrade 5

## High Occupancy Vehicle (HOV) Lanes

General Analysis 6

## Transit Improvements

General Analysis 7
Express Bus Service for Broward County, Florida 8
Transit Centers 9
Park and Ride Lots 10

Alternative Fuel Buses 11
Tampa Historic Electric Streetcar 12
Bus Bays on Oakland Park Boulevard 14

## Vanpool Programs

General Analysis 16
Dade County, Florida Vanpool Program 17

## Other Off-Model Methodologies

Incident Management 18
Pedestrian/Bikeway - General 19
Bikeways - General 20
Sidewalks Near Schools in Farragut, Tennessee 21

I/M Compliance Changes, Texas 22
TDM Public Education Campaign, Pinellas County, Florida 23
Ramp Metering 24
University North Commuter Center 27
Qualitative Analysis - Intermodal Transit Links 28

## References

# Intersection Improvements

1. General Analysis

This analysis incorporates a conservative approach to intersection improvements. It can be used for grade separation and signal timing. The conservative approach is only analyzing Volatile Organic Compound (VOC) reductions; however, $NO_x$ may be analyzed in a similar fashion.

The analysis is as follows:

a) Calculate the existing VOC emissions.
$VOC_B = EF_B * VOL_{APP} * DIST_{APP}$

where,
$VOC_B$ = Emissions before improvement, grams
$EF_B$ = Emission factor (grams per mile) based on assumed speed before improvement
$VOL_{APP}$ = Peak period approach volume
$DIST_{APP}$ = Approach distance in miles

b) Determine the average speed after the improvement.

c) Calculate the VOC emissions after the improvement.
$VOC_A = EF_A * VOL_{APP} * DIST_{APP}$

where,
$VOC_A$ = Emissions after improvement, grams
$EF_A$ = Emission factor (grams per mile) based on average speed after improvement

d) Calculate daily VOC emission reductions.
$VOC_R = (VOC_B - VOC_A)$

where,
$VOC_R$ = VOC emission reductions, grams/day

2. Traffic Signal Computer Upgrade[2]

The analysis of this project was for the upgrade of computer equipment and software, cabinets and controllers, and replacement of the Communications Plant. The justification was based on an increase in the reliability of the traffic control device synchronization in the metropolitan area. This would decrease delays and reduce vehicle idle emissions. The analysis for this project was performed as follows:

a) 3-4 minutes per vehicle per direction on a major arterial with an average vehicle rate of 38,000 vehicles or 2533 hours per day was assumed to be the savings by having the more reliable system. These are the savings for a single computer section.

b) There were 60 computer sections amounting to a savings in idle time of 152,000 hours of vehicle delay per day.

c) Emission rates were established by Hillsborough County using Mobile 5a. The rates were as follows:
CO = 0.32018 kg/vehicle hour
VOC = 0.0227 kg/vehicle hour
$NO_x$ = 0.00988 kg/vehicle hour

d) To be conservative, especially with the negative benefits which would occur for NOx with an increase in speed, emission benefits were assumed to occur only during the AM and PM peak periods (4 hours total).

e) The benefits were then calculated.
CO = (0.32018 kg/vehicle hour)(152,000 veh hrs/day)(4 pk hrs/24 hrs) = 8,111 kg/day (8.922 tons/day)

VOC = (0.0227 kg/vehicle hour)(152,000 veh hrs/day)(4 pk hrs/24 hrs) = 575 kg/day (0.632 tons/day)

$NO_x$ = (0.00988 kg/vehicle hour)(152,000 veh hrs/day)(4 pk hrs/24 hrs) = 250 kg/day (0.275 tons/day)

Note: Delay reductions can be obtained through most intersection analysis software.

# High Occupancy Vehicle (HOV) Lanes

1. General Analysis

Similar to the general intersection analysis, the HOV lane analysis is again conservative with only VOC reductions accounted; however, $NO_x$ may be analyzed in a similar fashion. This analysis also assumes that emission reductions are for the HOV lane only.

The analysis is performed as follows:

a) Calculate the existing VOC emissions.
$VOC_B = EF_B * VOL_B * DIST$

where,
$VOC_B$ = Emissions before improvement, grams
$EF_B$ = Emission factor (grams per mile) based on assumed speed before improvement
$VOL_B$ = HOV Volume * Auto Occupancy of HOV / AO of Mixed Flow
DIST = HOV lane distance in miles

b) Determine the average speed after the improvement.

c) Calculate the VOC emissions after the improvement.
$VOC_A = EF_A * VOL_A * DIST$

where,
$VOC_A$ = Emissions after improvement, grams
$EF_A$ = Emission factor (grams per mile) based on average speed after improvement
$VOL_A$ = HOV Volume after improvement

d) Calculate daily VOC emission reductions.
$VOC_R = (VOC_B - VOC_A)$

where,
$VOC_R$ = VOC emission reductions, grams/day

# Transit Improvements

1. General Analysis

The key to Transit Improvements is increased ridership. If transit ridership goes up then Vehicle Miles of Travel (VMT) should be reduced proportionately. The approach to this analysis is trend, that is, the analysis should call on previous expansions and their effect on ridership as input into the analysis. Since this increased ridership actually decreases VMT, reductions are found for both VOCs and $NO_x$.

The analysis is as follows:

a) Calculate the daily VMT reduction.
VMT = (Avg. Daily Ridership After - Avg. Daily Ridership Before) / Avg. Auto Occupancy * Avg. Trip Length

b) Calculate the reduction in daily emissions.
$E_D = EF_x * VMT$

where,
$E_D$ = Daily Emissions, grams/day
$EF_x$ = Emission factor for pollutant x, grams/mile
VMT = vehicle mile/day

2. Express Bus Service for Broward County, Florida[3]

The analysis of this project was done to add new Express Bus Service in Broward County Florida. The basis for the project was to provide a needed service to the general public and reduce Vehicle Miles of Travel (VMT). The new transit service will operate during the morning (AM) and afternoon (PM) peaks. The AM peak will consist of three one-way trips from southwest Broward County to Downtown Fort Lauderdale with one return trip. The PM peak will consist of the reversal of the AM peak. Each peak is considered for exactly two hours (6:00AM to 8:00AM and 4:00PM to 6:00PM). The analysis for the project is as follows:

a) The Peak Hour Ridership was determined by running the FSUTMS model (Florida's Travel Demand Model). Both the AM and PM peak ridership were calculated by multiplying the peak hour ridership by 2.0 hours to yield Person Trips.
Peak Hour Ridership (from FSUTMS) = 54 Person Trips
AM Peak = 2.0 Hours * 54 = 108 Person Trips
PM Peak = 2.0 Hours * 54 = 108 Person Trips
Daily Person Trips = 108 + 108 = 216 Person Trips

b) An estimate of auto trips is found by dividing the person trips by the average auto occupancy for Home Based Work (HBW) trips.

216 Person Trips / 1.12 = 193 Auto Trips

c) An estimate of VMT is then calculated by assuming the auto trips would have taken the same trip length as the new service or 31.0 miles.
193 Auto Trips * 31.0 Miles/Trips = 5983 Daily VMT

d) The daily reduction in $NO_x$ and VOC is found from MOBILE 5.0a using Light Duty Gas Vehicle (LDGV) emission rates. The average speed is derived from the average auto travel speed along the proposed transit route, which is 37.9 mph.
$NO_x$ emission reduction = 5983 VMT * 1.63 g/mile * kg / 1000 g = 9.75 kg/day

VOC emission reduction = 5983 VMT * 1.25 g/mile * kg / 1000 g = 7.48 kg/day

e) The increase in VMT due to the express service is then found with the knowledge that there are four trips per peak period, again, with a distance of 31.0 miles.
Daily Transit VMT Increase = 31.0 * 8 trips/day = 248 Daily VMT

f) The daily increase in $NO_x$ and VOC is found from MOBILE 5.0a using Heavy Duty Diesel Vehicles (HDDV) emission rates. The average speed is derived from the average bus speed along the proposed route, which is 28.7 mph.
$NO_x$ emission increase = 248 VMT * 1.8 g/mile * kg/1000g = 0.45. kg/day
VOC emission increase = 248 VMT * 11.68 g/mile * kg/1000g = 2.90 kg/day

g) The net reduction is then found.
$NO_x$ emission reduction = [9.75 - 2.90] kg/day = 6.85 kg/day
VOC emission reduction = [7.48 - 0.45] kg/day = 7.03 kg/day

3. Transit Centers[1]

Transit centers combine frequent bus service with park and ride (P&R) lots. The main benefit of these facilities is to reduce VMT, thus allowing for a reduction in both ozone precursors. The analysis for these facilities/projects is as follows:

a) The first step in the analysis is to estimate the number of autos removed by the new facility.
Autos Removed = Historical P&R Lot Utilization * Parking Spaces in Lot

b) Next, knowing the average peak hour speed and the average driving distance for the area emission reductions can be found. Note: Distance is multiplied by 2 to account for round trip.
Auto Emission Reduction = Autos Removed * (Avg. Driving Distance * 2) *Peak Hour Speed Emission Rate for LDGVs

c) Calculate the emissions from the increase in transit vehicles, utilizing known Avg. Driving Distance and Avg. Peak Hour Speed.
Bus Emission Increase = # of Bus Increase * (Avg. Driving Distance * 2) *Peak Hour Speed Emission Rate for HDDVs

d) The final calculation yields emission reductions in kg/day.
Daily Emission Reductions = (Auto Reductions - Bus Increase) * kg/1000g

4. Park and Ride Lots[1]

The P&R lot analysis is similar to the analysis of the transit center with the exception that increased bus service is not added. The analysis is as follows:

a) The first step in the analysis is to estimate the number of autos removed by the new facility.
Autos Removed = Historical P&R Lot Utilization * Parking Spaces in Lot

b) Next, knowing the average peak hour speed and the average driving distance for the area the total emission reductions can be found in, kg/day.
Auto Emission Reduction = Autos Removed * (Avg. Driving Distance * 2) *Peak Hour Speed Emission Rate for LDGVs * kg/1000g

Note: Distance is multiplied by 2 to account for round trip.

5. Alternative Fuel Buses[14]

Broward County, FL proposed to buy 4 alternative fuel (electric) transit buses to operate as circulators in Downtown Ft. Lauderdale. The purpose of this analysis is to demonstrate that using electric buses instead of the heavy-duty diesel buses will improve air quality.

*Assumptions*

- Buses will operate weekdays between 7:30 am and 5:30 pm (10 hours)
- 30 minute (0.5 hour) headway between buses per route
- Number of Daily Trips = Operation/Headway = 10 hours/0.5 hours = 20 Trips
- Average bus running speed is 14.4 mph
- Electric buses were assumed to produce zero emissions
- MOBILE model was used to obtain HDDV emission rates
- Round Trip distance is approximately 4.8 miles.

*Analysis*

a) Estimate emissions due to operating 4 diesel buses.

Emissions = Number of Buses * Round Trip Length * Number of Daily Trips * Emission Factor

VOCs = 4 buses * 4.8 round trip miles * 20 trips/day * 0.0030 kg/mile = 1.15 kg/day
CO = 4 buses * 4.8 round trip miles * 20 trips/day * 0.0163 kg/mile = 6.26 kg/day
NOx = 4 buses * 4.8 round trip miles * 20 trips/day * 0.0149 kg/mile = 5.72 kg/day

b) The above values reflect the emissions that would be reduced by replacement of the diesel buses with alternatively fueled buses thus showing an improvement in air quality.

6. Tampa Historic Electric Streetcar[15]

The proposed historic street car, when completed, provides intermodel connections for persons who arrive at the Convention Center or one of the hotels from Tampa International Airport and who have taken a taxi to downtown. To calculate emission benefits the following methodology was used.

a) Ridership projections were obtained from annual attendance figures estimated by the City of Tampa, Ybor City, the Port Authority, the Tampa Bay Lightning, the Florida Aquarium, and the Tampa Convention Center. Ridership figures were also based on the Memphis, TN streetcar project. The Memphis project is given reference since the attractions along the system are more relative to that of the Tampa/Ybor area. Based on the Memphis project a conservative 5% ridership at each of these venues was used for calculations. To estimate the miles saved an assumption was made that half of the estimated 5% ridership would ride the streetcar the 4.5 mile round trip between Ybor City and the Garrison Seaport District and the other half would ride shorter 2 mile trips.

| | Yearly Projected Attendance | 5% Ridership Assumption |
|---|---|---|
| Arena (Tampa Bay Lightning) | 800,000 | 40,000 |
| Aquarium | 1,000,000 | 50,000 |
| Crosstown-Ybor | 1,320,000 | 66,000 |
| Cruise Ships | 300,000 | 15,000 |
| Hogan Burke Theater | 1,000,000 | 50,000 |
| Hotels-Convention Center | | |
| Convention Center | 112,000 | 5,600 |
| Special Events | 305,000 | 15,250 |
| Hyatt Regency | 201,000 | 10,050 |
| Local Events | | |
| Guavaween | 75,000 | 3,750 |
| St. Patricks/Jose Riley | 4,000 | 200 |
| Gasparilla | 100,000 | 5,000 |
| Special Weekend | 75,000 | 3,750 |
| | | |
| Total | | 264,600 |

b) Calculate VMT reductions.
132,300 passengers travel 2.0 miles round trip = 264,600
132,300 passengers travel 4.5 miles round trip = 595,350

Total = 859,950 miles/year = 2356 miles/day

c) Calculate emission reductions achieved from the program.

Emission Reductions = VMT * Emission Factor

VOCs = 0.0014 kg/mile * 2356 mile/day = 3.3 kg/day
CO = 0.0114 kg/mile * 2356 mile/day = 27 kg/day
NOx = 0.002 kg/mile * 2356 mile/day = 5 kg/day

7. Bus Bays on Oakland Park Boulevard[16]

Broward County proposed to build 5 transit bus-bays along Oakland Park Boulevard between Andrews Avenue and Inverrary Boulevard. Currently there are three transit routes that provide service and make frequent stops along that segment of Oakland Park Blvd. The purpose of this analysis is to demonstrate that building bus bays will improve air quality by estimating the reduction in time loss due to buses stopping to load and unload passengers. The concept is based on the reductive effects of local transit buses on the traffic carrying capacity of an arterial street. The concept in Chapter 12 of the 1994 Highway Capacity Manual (HCM) was used to estimate that reduction. For comparison purposes, traffic carrying capacity of Oakland Park Blvd. was evaluated under two conditions: one with bus bays and the other without.

In the first case, (with bus bays), buses stop in a lane that is not used by moving traffic (curb parking lane), thereby reducing the impeding effects to other traffic. The time loss to other vehicles due to bus stopping at a bus bay is estimated at 4 seconds per bus which counts for bus acceleration and deceleration time in the traffic stream.

In the second case, buses stop in the normal traffic lane impeding traffic flow and causing queuing of vehicles behind the stopped bus. The time loss in this case includes the dwell time to load and unload passengers and time loss for stopping and starting. The time loss for the lane in which the bus operates can be estimated using equation 12-3 of the HCM.

TL = (g/c)*N*(D+L) where,

TL = time loss, in seconds per hour
g/c = intersection green time/cycle time ratio
N = number of buses that stop per hour
D = average dwell time, in seconds
L = additional time loss due to stopping, starting and queuing in seconds (6 to 8 seconds on average).

The analysis covers the impact of constructing five bus bays and to simplify the calculations, the reduction was estimated for one bus bay and then multiplied by five.

*Assumptions*

- Three bus routes operate along the subject segment of roadway
- 30 minute headway per route
- Number of buses (3*60/30) = 6 buses per hour
- Buses operate 16 hours/day average weekday
- The average speed along Oakland Park Blvd is 24.5 mph

*Calculation of Loss Time with Bus Bays*

The time loss is due to buses maneuvering in and out of bus bays.

Timeloss/hour = 4 seconds/bus * 6 buses/hour = 24 sec/hr

Where,

Time lost due to bus decel and accel out of bus bay, TL = 4
Number of buses per hour, N = 6
Average g/c = 0.4
Capacity of through lane = 1800 pcphpg (passenger cars per hour per green)
Capacity of one lane per hour at 0.4 g/c ratio = 1,800 * 0.4 = 720 pcphpg
Total green time available to through lanes is 0.4 * 3,600 sec/hour = 1,440 sec/hour

The percent loss in lane capacity may be expressed as:

(24 sec/hr / 1,440 sec/hour) * 100 = 1.7%

This results in a capacity loss in the right lane of 720 pcph * 0.017 = 12 pcph

*Calculation of Loss Time without Bus Bays*

The average dwell time using results from a field survey is 18 seconds per stop.

with,
g/c = 0.4
N = 6 buses/hr
D = 19 sec/bu
L = 6 sec/bus
TL = 0.4*6*(18+6) = 58 sec/hour

The percent loss in lane capacity is; (58/1,440)*100 = 4.03%

This results in a capacity loss in the right lane of 720 pcph * 0.0403 = 29 pcph

*Emission Reduction Estimate*

Net Capacity gain due to building Bus Bays = 29 - 12 = 17 pcph

The distance of the highway impacted by each bus bay is 500 feet

Net VMT gained by installing Bus Bays = (500 ft/ 5280 ft/mile) * (17 pcph * 16 hours/day)
= 26 mile/day

The average travel speed is 24.5 mph

VOCs = 26 mile/day * 2.31 g/mile * kg/1000g * 5 locations = 0.30 kg/day
CO = 26 mile/day * 20.31 g/mile * kg/1000g * 5 locations = 2.64 kg/day
NOx = 26 mile/day * 2.48 g/mile * kg/1000g * 5 locations = 0.32 kg/day

# Vanpool Programs

1. General Analysis

Vanpools achieve emission benefits by reducing vehicle trips. Average commute distance is doubled to simulate a round trip. Average ridership should be based on historical vanpool size data obtained from the Metropolitan Planning Organization (MPO). The analysis is performed as follows:

a) Calculate vehicles removed by the vanpool.
VMT removed = Historical Vanpool Size / Avg. Vehicle Occupancy

b) Calculate the Daily Emission Reduction achieved by the reduced VMT, kg/day.
ER = VMT removed * Avg. Commute Length * 2 * Peak Hour Speed Emission Rate (LDGV) for Pollutant * kg/1000g

2. Dade County, Florida Vanpool Program[4]

The Dade County Vanpool Program provided 30 vans to qualified participants. Air quality benefits are achieved through the reduction in VMT associated with the reduction of individual commuters. The increase in vehicles due to the vans provides a somewhat negative offset of these benefits. The analysis consists of five steps.

1) Estimate the number of autos removed from the roadway by the vanpool program.
2) Calculate the Daily VMT eliminated.
3) Calculate the emission reductions due to the decrease in VMT.
4) Calculate the addition emissions generated by the new service.
5) Derive the Net Benefits from the Program.

The following provides an example.

a) Reduction in Automobile use is calculated by knowing the amount of seating and the average area auto occupancy. The total seating provided by the vanpool is 345 seats, divided into vans with capacities of 15 and 8 passengers. The average auto occupancy of Dade County is 1.22 persons per automobile. The calculation is as follows:
Autos Eliminated = Vanpool Seats / Auto Occupancy = 345 Seats / 1.22 Persons / Auto = 283 Autos

b) VMT reduction is calculated through the knowledge of average round trip commuter distance for Dade County.
VMT Reduction = Autos Eliminated * Average Commute Distance = 283 Autos * 21.8 Miles / Auto = 6169 Miles

c) Emission Reductions are found by using the appropriate emission rate for LDGVs.
The Average operating speed for Dade County is 27 mph.
Emission Reduction = Emission Rate * VMT * kg/1000g
Emission Reduction = 81.49 kg/day CO; = 10.49 kg/day VOC; = 10.12 kg/day $NO_x$

d) Emission increases, due to the implementation of the new vehicles, are calculated knowing the emission rate for Light Duty Gas Trucks (LDGTs) and the VMT for the fleet. The VMT is derived from the fleet size and the average Dade commute distance, previously noted, or 654 VMT.
Emission Reduction = Emission Rate * VMT * kg/1000g
Emission Reduction = 10.63 kg/day CO; = 1.33 kg/day VOC; = 1.22 kg/day $NO_x$

e) The Net Air Quality difference is thus a product of the Reductions calculated in step c) subtracted by the Increases in emissions calculated in step d).
CO = 70.86 kg/day
VOC = 9.16 kg/day
$NO_x$ = 8.90 kg/day

# Other Off-Model Methodologies

1. Incident Management[1]

The main goal of an Incident Management Program is to reduce congestion by removing vehicles which are debilitated, injured or just broke. Nonrecurring Congestion is the effect these vehicles have on the main line flow. Excess freeway emission are caused by this type of congestion. This analysis provides the basis for calculation of reduction of VOCs due to these programs; however, $NO_x$ can be analyzed in a similar fashion.

a) Determine Regional Freeway VOC Emissions, $E_B$.

b) Determine Freeway Emissions due to Nonrecurring Congestion, $E_C$.
$E_C = E_B * 0.049$

Note: 4.9 Percent of Freeway Emissions are Caused by Nonrecurring Congestion.[5]

c) Next the Daily VOC reductions, $E_D$, are calculated. These assume, since freeway emissions are directly related to VMT, that the VMT in the program area is used to calculate emission reductions.
$E_D = L * VOL_i * E_C / VOL_T * EFF$

where,
L = Length of Freeway
$VOL_i$ = Volume of Freeway i
$VOL_T$ = Regional Freeway VMT
EFF = Project Effectiveness, 50% for Incident Detection and Response, 25% for Motorist Assistance, and 15% for Surveillance.

2. Pedestrian / Bikeway - General[1]

The main goal of bicycle and pedestrian facilities is to provide other transportation options for a community. The air quality benefits, as with most projects, come with a reduction in VMT. The general calculation for these projects is shown below.

a) First, calculate the Daily VMT reduction.
VMT Reduction = PD * Area * L * BMS

where,
PD = Population density of location, persons/mile$^2$
Area = Project length * 1 mile radius, mile$^2$
L = Round trip length, one-half of the project length times 2 daily trips, miles
BMS = Bike mode share, %

b) Last, calculate the Daily Emission reductions for a pollutant.
$E_D = EF_x$ * VMT Reduction

where,
$E_D$ = Daily Emissions, grams/day
$EF_x$ = Emission factor for pollutant x, grams/mile
VMT = vehicle mile/day

3. Bikeways - General

Little data is available on the utilization of bikeways; however, if such data is available it can prove invaluable in providing mode shift data to predict VMT reduction. The following is an analysis which shows how to calculate emission reductions if a history of mode shift percentage is known.

a) First Calculate daily VMT reduction provided by mode shift in the corridor.
VMT Reduction = AADT in the corridor * PMS

where,
PMS = historical percentage of mode shift for area

b) Last, calculate the Daily Emission reductions for a pollutant.
$E_D = EF_x$ * VMT Reduction

where,
$E_D$ = Daily Emissions, grams/day
$EF_x$ = Emission factor for pollutant x, grams/mile
VMT = vehicle mile/day

4. Sidewalks Near Schools in Farragut, Tennessee[6]

This project connected and extended previously constructed sidewalks along the parental responsibility zone of the Farragut schools. This analysis assumes a minimum usage increase of 10%, with a VMT reduction of 2 miles on arterials and 5 miles on local roads. There are 5,602 students in Farragut schools. It should be noted that students walking remove 4 vehicle trips. The analysis is as follows:

a) Since VMT is reduced on both arterials and local roads, there are two VMT reduction calculations.
Students with Travel Mode Change = 5602 *.10 = 560
VMT Reduction (Arterials) = 560 Persons * 2 Miles / Person = 1120
VMT Reduction (Local) = 560 Persons * 5 Miles / Person = 2800

b) Knowing the Average Speed for the given roadway classification emission factors are generated for both VOC and $NO_x$ by roadway classification.
VOC Reduction = (1120 VMT * .00194 kg/mile) + (2800 VMT * .00227 kg/mile) = 8.6 kg/day

$NO_x$ Reduction = (1120 VMT * .0022 kg/mile) + (2800 VMT * .0019 kg/mile) = 7.8 kg/day

5. I/M Compliance Changes, Texas[1]

Procedures leading to a higher compliance rate for a I/M program benefit air quality by detecting then repairing faulty emission control systems. The Texas Air Control Board was asked to supply projected compliance rates for changes to our current I/M system. Current compliance rates for each county are available from TACB. Emission benefits are calculated with the following equations:

a) The first step is to calculate the emission rates before and after a change in compliance rates, g/day.
Improved Emissions = Projected I/M compliance * AADT * 24hr Avg. Speed Emissions
Previous Emissions = Current I/M compliance * AADT * 24hr Avg. Speed Emissions

b) The final step is to calculate the Daily Emission benefit due to the increased compliance rate, kg/day.
Daily Reductions = (Improved Emissions - Previous Emissions) * kg/1000g

6. Travel Demand Management (TDM), Public Education Campaign, Pinellas County, Florida

The purpose of this project was to provide intermodal transportation information via several programs within a public education campaign to promote a shift from the use of single occupant vehicles (SOV) to alternatives such as bicycle, public transportation, and ridesharing. By educating the public to these transportation options and their cost effectiveness, a substantial number of vehicles could be eliminated from the roadway, thus reducing VMT.

a) The first step in the analysis is to combine the knowledge of Work Trips for the area with the Trip Rate. Pinellas County has an estimated employment of 377,312. Knowing the Home Based Work Trip Rate is 1.8, provided by the FSUTMS model, Daily work trips can be calculated.

Daily Work Trips = Total Employment * Trip Rate = 377,312 * 1.8 = 679,162 Trips

b) The 1991 Tampa Bay Regional Survey conducted by Florida Department of Transportation provided Trip Length Distribution information. This survey showed the Mean Trip Length was 26.6 minutes, reflecting travel time and terminal times. Using an average area speed of 19.6 mph the Average Trip Length can be calculated.

Average Trip Length = Average Travel Speed * Mean Trip Length * hr / 60min = 19.6 miles/hr * 26.6 min * hr / 60min = 8.68 miles

c) Next the VMT reduction can be found with the knowledge of the Daily Work Trips and Average Trip Length.

Work VMT Reduced = 679,162 * 8.68 miles = 5,895,123

d) Based on a study conducted by STAPPA/ALAPCO an estimated percent reduction in work travel VMT was found to be 0.5 %.[8] Therefore, the VMT Reduction due to the implementation of the Public Education Campaign is:

VMT Reduction = 5,895,123 * 0.5 = 29,476

e) The final step is to calculate the emission reductions using MOBILE emission factors for the known Average Speed of 19.6 mph.

Emission Reduction = VMT * Emission Factor (g/mile) * kg/1000g
VOC Reduction = 29,476 * 2.36 g/mile * kg/1000g = 69.6 kg/day
$NO_x$ Reduction = 29,476 * 2.46 g/mile * kg/1000g = 72.5 kg/day
CO Reduction = 29,476 * 20.38 g/mile * kg/1000g = 600.7 kg/day

7. Ramp Metering[9]

*Project/Policy Description*

Ramp metering is a common form of urban traffic control. It aims to reduce or eliminate operational problems resulting from freeway congestion by restricting flow to the freeway mainline. With mainline demand restricted to less than the available capacity, ramp metering tends to maintain uninterrupted, non-congested flow on the freeway. By smoothing vehicle flow, ramp metering aids in utilizing the existing freeway capacity and also reduces the probability of accidents at merge locations.

The total change in vehicle emissions due to ramp metering can be broken down into 3 elements: travel changes on the mainline, travel changes on the arterial street system, and changes in operating conditions on the ramp. All three elements are affected by the changes in traffic volumes resulting from ramp metering, including increased traffic volumes on the arterial street system. Emissions on the ramp change because of the changes in the way the ramp is operating. Ramp metering results in greater vehicle idling and greater acceleration on the ramp then is experienced without ramp metering. The travel demand forecasting model accounts for emissions resulting before the implementation of ramp metering. Therefore, the change in emissions before and after ramp metering is calculated in this analysis so that the difference can be applied to the total regional emissions from the travel demand forecasting model.

*Assumptions*

1) Vehicles entering at on-ramps are not experiencing delay before the implementation of ramp metering.
2) Emissions associated with the change in acceleration/deceleration on the ramps are negligible compared to emissions resulting from the increases in travel speeds on the freeway mainline.
3) Ramps are only metered until the maximum storage capacity of the ramp is met. After that time, ramp metering is turned off.
4) Queuing emissions on the ramp include that emission of the vehicle traveling on the ramp at low speeds.
5) No consideration was given to concurrent use of HOV facilities in the ramp metering corridor.

*Emissions Analysis*

a) Determine the freeway limits and time period for the ramp metering. Considerations for the implementing ramp metering are discussed in the*Manual on Uniform Traffic Control Devices* and the NCHRP Report 232, *Guidelines for Selection of Ramp Control Systems,* Page 52. The Florida DOT used freeway volume after the merge point and speed to determine if ramp metering was warranted as documented in the *Southeast Florida Intelligent Corridor System Ramp Metering Analysis.*

b) Obtain volumes (HPMS adjusted), capacities, and speeds of travel demand network links for all freeways, ramps, arterial cross streets and parallel cross streets which will be affected by ramp metering.

c) Calculate total emissions before ramp metering for the time period when ramp metering will be implemented (such as the peak period):

Total Emissions = 3 ($LENGTH_i$ x #$VEHICLES_i$ x EMISSIONS $RATE_i$ )

where,
i = 1 to n, and n is the number of links

d) Determine ramps to be metered and their associated storage capacity and metering rates. Ramp metering rates can be determined by first calculating the reduction in demand required to result in the desired mainline operating condition. After the mainline difference is calculated, the difference is distributed between the upstream ramps. The metering rate will be dependent on the required reduction, the demand at the particular on-ramp and the storage capacity of the ramp.
The recommended minimum metering rate is 300 vehicle per hour (for a one-lane ramp), and the recommended maximum is 900 vehicles per hour (for a one lane ramp).[10]

e) Calculate total ramp delay and the maximum individual waiting time due to the implementation of ramp metering. These can be calculated using basic queuing diagrams of number of vehicle accumulated over time (see example in Figure 1).

f) Estimate the diversion of vehicles to the parallel arterial. The number of vehicles diverting will be a function of trip length, queue length, ramp delay, and the availability and efficiency of alternate routes.[11]

g)Adjust volume/capacity ratios for all links as needed to account for ramp metering (queuing on the ramp) and diversion.

h) Calculate new freeway, cross street arterial and parallel arterial speeds using the travel demand model volume/delay curves.

i) Calculate after metering emissions based on new link volumes, capacities and speeds. Freeway and arterial link emissions can be calculated as described in step 3.

j) For the on-ramps, calculate queuing emissions as follows:
Total Emissions = Total Delay x Emissions $Rate_{Idling}$

k) Calculate the difference between before metering and after metering emissions.

l) Calculate emission differences for all peak periods which are metered.

m) Apply the total difference in emissions for all peak periods to the total emissions calculated from the travel demand model output (total emissions before metering).

*Caveats*

1) The congestion mitigation benefits of ramp metering are conservative since the methodology is based on average annual daily traffic and no incident delay is incorporated into the analysis. Ramp metering will reduce incidents at the freeway merge and the associated vehicle delay.

2) The emissions estimate assumes that there will be no change in demand as a result of the ramp metering. The same number of vehicle trips will be made although they may be diverted to the arterial street systems. The methodology does not take into consideration latent demand that may be generated with better operations on the freeway; in the forecast years, this will be less critical due to the fact that demand will probably greatly exceed capacity.

8. University North Commuter Center[13]

The University North Commuter Center will offer information and related services to promote greater use of a range of commuter alternatives to SOV travel, including public transit, ridesharing, bicycling, walking, telecommuting and others. Services include a staffed information center, located at the University Mall, a transportable kiosk for special events within University North, a "Virtual Commuter Center" web page, and covered bicycle storage units available to participating employment sites. The analysis is as follows:

a) Estimate the number of users/participants, users. 400 new users.

b) Estimate gross vehicle trip reduction (VTR) based on mode shifts. Gross one-way vehicle trips reduced = users * mode Trip Reduction Factor (TRF).

| | Users | TRF | Daily Trips | Gross Trips Reduced |
|---|---|---|---|---|
| New Carpooler | 210 | 0.5 | 2 | 210 |
| New Vanpooler | 10 | 0.9 | 2 | 18 |
| New Transit User | 100 | 1 | 2 | 200 |
| New Bicyclist | 50 | 1 | 2 | 100 |
| New Walker | 20 | 1 | 2 | 40 |
| New Telecommuter | 10 | 1 | 2 | 20 |
| New Compressed Work Week | 0 | 1 | 2 | 0 |
| New Satellite Work Center User | 0 | 0 | 2 | 0 |

Total Gross Trips Reduced = 588

c) Fraction of users or participants using prior HOV and/or SOV access, in percent.

HOV% = 10.0

d) Determine net VTR. Net Vehicle One-way trips reduced = Gross VTR * (1 - HOV%/100)

Net VTR = 588 * (1 - 10/100) = 529.2

e) Determine vehicle miles of travel reducted (VMT). Average one way trip length = 11 miles/trip.

Reduced VMT = Net VTR * Average Trip Length = 529.2 * 11 = 5821.2

f) Determine daily emissions reduced. Daily Emissions Reduced = Emission Factor * Reduced VMT
CO Reduced = 5821.2 mile/day * 0.0114 kg/mile = 66.4 kg/day
NOx Reduced = 5821.2 mile/day * 0.0020 kg/mile = 11.6 kg/day
VOC Reduced = 5821.2 mile/day * 0.0014 kg/mile = 8.1 kg/day

9. Qualitative Analysis - Intermodal Transit Links[12]

*Project Description*

The study will examine transit system connections withing the Downtown and a Historic Area that will coordinate with other transportation components such as parking and bicycle / pedestrian facilities.

*Purpose*

The proposed CMAQ grant will fund a study which examines opportunities to improve the efficiency of transportation services in the Downtown and a Historic area. This project will examine optimal transfer of locations for intermodal connections between all modes of transportation including an electric streetcar, future rail transit, buses, bicyclists, pedestrians, and automobiles. Parking availability and opportunities will also be analyzed.

*Project Justification*

Effective intermodal connections are essential to an efficient transportation system. This study will identify optimum locations for intermodal transfers to reduce vehicular congestion, idle times in buses and automobiles, and overlapping transit service. In addition this analysis will identify ways to improve service and public use for through trips and intermodal connections by improving or streamlining routes and improving and adjusting headways. The air quality benefits derived from this project are difficult to quantify. However, for the purposes of this analysis, it is assumed that efficient intermodal connections will achieve a substantial reduction in the overall mobile source emissions in the study area for several reasons.

- Increased transit ridership attributed to better connectivity
- Amenities for pedestrians and cyclists (information kiosks, bike racks, shelters)
- Increased use of non-motorized travel
- Less vehicle idle times waiting for connections
- Reduced, shorter internal trips, less cold starts

# References


1. *Texas Department of Transportation: CMAQ Analysis Procedures*, date unknown.

2. City of Tampa, Hillsborough County MPO, *CMAQ Project Summary Tampa Traffic Signal Computer Upgrade II and III*, July, 1996.

3. Broward County MPO, *Southwest Broward Express Bus System CMAQ Justification*, December, 1994.

4. Florida Department of Transportation (FDOT) District 7, *Dade County Vanpool Project CMAQ Justification*, June, 1995.

5. "Urban Freeway Congestion: Quantification of the Problem and Effectiveness of Potential Solutions", Jeffrey A. Lindley, 1987.

6. State of Tennessee Annual Report on CMAQ, *Sidewalks Near Schools in Farragut*, 1995.

7. Pinellas County MPO, *CMAQ Justification Analysis: Public Education Campaign for New Transportation Ethics, Five Projects*, February, 1995.

8. STAPPA/ALAPCO, "Meeting the 15-Percent Rate-of-Progress Requirement Under the Clean Air Act: A Menu of Options", September, 1993.

9. *Regional Ramp Metering System Analysis*, Jean Mazur and Andy Edwards, FHWA, 1997.

10. *Traffic Control Systems Handbook*, FHWA, February, 1996.

11. "Guidelines for the Selection of Ramp Control Systems", NCHRP Report 232, May, 1981.

12. CMAQ Project Review and Concurrence - Planning - FDOT District 7, *Intermodal Transit Links Analysis*, Hillsborough County Metropolitan Planning Organization, 1997.

13. CMAQ Project Summary, *University North Transportation Initiative*, University of South Florida, 1998.

14. *Broward County CMAQ Justification Report Alternative Fuel Buses*, April, 1997.

15. CMAQ Project Review and Concurrence - Planning - FDOT District 7, *Tampa Historic Electric Streetcar*, Hillsborough County Metropolitan Planning Organization, 1996.

16. *Broward County CMAQ Justification Report for Bus Bays on Oakland Park Boulevard*, April, 1997.