Air Quality Impacts of Advance Transit's Fixed Route Bus Service

Final Report

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Introduction

In 2005, the Upper Valley Transportation Management Association (UVTMA) completed research entitled *Operational Impact Study of Advance Transit Fixed-Route Bus Network*. The study, completed at the request of the Lebanon (NH) City Council, examined ridership trends, fuel consumption, air quality impacts, and evaluated the feasibility of instituting a fare structure. The study was based on Fiscal Year (FY) 2004 data, surveys, and analysis.

As part of the *Operational Impact Study of Advance Transit Fixed-Route Bus Network*, the Upper Valley Lake Sunapee Regional Planning Commission (UVLSRPC) developed an analysis of the air quality impacts of Advance Transit's fixed-route bus service. The analysis, also based on FY 2004 data, incorporated a four-part method of quantifying air quality impacts:

1. Calculating the Avoided Vehicle Miles Traveled (VMT) Resulting from "Choice" Riders of Advance Transit's Fixed-Route Services;
2. Calculating the Emissions Correlating to the Avoided Vehicle Miles Traveled;
3. Calculating the Emissions of Buses Operating on Advance Transit's Fixed-Route Services;
4. Reconciling the Passenger Vehicle Emissions Avoided with the Emissions of Buses Operating on Advance Transit's Fixed Route Services to Determine a Net Air Quality Impact.

UVLSRPC staff utilized the U.S. Environmental Protection Agency's (EPA) Mobile 6.2 modeling framework, in consultation with the New Hampshire Department of Environmental Services (NHDES) Air Resources Division to quantify the emissions of three pollutants: Volatile Organic Compounds (VOC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOx).

The following report presents an update to the air quality analysis developed as part of the 2005 *Operational Impact Study of Advance Transit Fixed-Route Bus Network* and is intended to provide comparative figures from FY 2004 and FY 2011.

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Summary of Findings

The following table presents a summary of findings related to the net impact of Advance Transit's fixed-route bus service on the emissions of Volatile Organic Compounds (VOC), Carbon Monoxide (CO), and Oxides of Nitrogen (NOx). For comparative purposes, FY 2004 data is presented alongside FY 2011 data.

ADVANCE TRANSIT Air Quality Impact Analysis 2011		FY2011	FY2004
Row#			
STEP 1: Calculate Passenger Vehicle Miles Avoided through Use of Fixed-Route Bus Service			
1	Total Ridership - Fiscal Year July-June	515,266	278,704
2	Total Operating Days per fiscal year	254	254
3	Average Daily Ridership	2,029	1,097
4	Estimated Number of Passengers per Passenger Vehicle	1.1	1.1
5	Percentage of Passengers with No Car Available	47%	57%
6	Adjusted Average Daily Ridership (Riders with Car Available)	1,075	472
7	Average Trip Length (miles)	4.6	5.4
8	**Passenger Vehicle Miles Traveled (VMT) Avoided per Day**	**4,496**	**2,316**
STEP 2: Calculate Avoided Passenger Vehicle Emissions			
9	Passenger Vehicle Emissions Factors VOC (grams/mile)	0.405	1.063
10	Passenger Vehicle Emissions Factors CO (grams/mile)	13.112	12.600
11	Passenger Vehicle Emissions Factors NOx (grams/mile)	0.365	1.014
12	**Avoided Passenger Vehicle Emissions VOC (grams/day)**	**1,821**	**2,462**
13	**Avoided Passenger Vehicle Emissions CO (grams/day)**	**58,953**	**29,184**
14	**Avoided Passenger Vehicle Emissions NOx (grams/day)**	**1,641**	**2,349**
STEP 3: Calculate Bus Emissions			
15	Total Fixed Route Bus Miles Traveled	432,651	413,733
16	Bus Miles Traveled per day	1,703	1,629
17	Bus Emissions Factors VOC (grams/mile)	0.275	0.594
18	Bus Emissions Factors CO (grams/mile)	2.121	3.882
19	Bus Emissions Factors NOx (grams/mile)	11.232	14.925
20	**Bus Emissions VOC (grams/day)**	**468**	**968**
21	**Bus Emissions CO (grams/day)**	**3,613**	**6,323**
22	**Bus Emissions NOx (grams/day)**	**19,132**	**24,311**
STEP 4: Calculate Net Emissions Reductions from Bus Travel Instead of Passenger Travel			
23	Emissions Avoided VOC (grams/day)	1,353	1,495
24	Emissions Avoided CO (grams/day)	55,340	22,861
25	Emissions Avoided NOx (grams/day)	(17,491)	(21,962)
26	Emissions Avoided VOC (lbs/year)	756	835
27	Emissions Avoided CO (lbs/year)	30,924	12,775
28	Emissions Avoided NOx (lbs/year)	(9,774)	(12,273)
29	**Emissions Avoided VOC (tons/year)**	**0.38**	**0.42**
30	**Emissions Avoided CO (tons/year)**	**15.5**	**6.4**
31	**Emissions Avoided NOx (tons/year)**	**(4.9)**	**(6.1)**
Notes	Volatile Organic Compounds VOC, Carbon Monoxide CO, Nitrogen Oxides NOx		
	Ridership equals passenger boardings		

Technical Summary- Data Sources and Calculations

The following technical summary is intended to serve as a companion to the Summary of Findings spreadsheet provided on Page 3 of this report.

Part 1- Calculating the Avoided Vehicle Miles Traveled (VMT) Resulting from "Choice" Riders of Advance Transit's Fixed-Route Services

Part 1- Step 1: Determine the Total FY 2011 Advance Transit Fixed-Route Ridership

The total FY 2011 ridership on Advance Transit's fixed-route bus network was 515,266. (Source: Advance Transit)

Part 1- Step 2: Determine the Total FY 2011 Fixed-Route Operating Days

Advance Transit's fixed-route bus network operated for 254 days in FY 2011. (Source: Advance Transit)

Part 1- Step 3: Determine the Average Daily Fixed-Route Ridership for FY 2011

Dividing the total ridership of 515,266 by the total operating days of 254, the average daily fixed-route ridership is 2,029 passengers per day.

Part 1- Step 4: Determine the Average Number of Passengers in a Passenger Vehicle

As calculated from the U.S. Census American Community Survey 2006-2008 3-year summary data, average vehicle occupancy in the State of New Hampshire is 1.1 persons. (Source: U.S. Census Transportation Planning Products)

Part 1- Step 5: Determine the Percentage of Advance Transit Riders with No Vehicle Available

According to on-board surveys conducted in 2008, 47% of Advance Transit passengers do not have a vehicle available for their trip. Thus, 53% of Advance Transit riders do have a vehicle available for their trip, and are riding Advance Transit buses by choice. (Source: Tom Crikelair Associates, "Transit Development Plan for Advance Transit", 2008)

Part 1- Step 6: Determine the Average Daily Ridership for "Choice Riders"

Given that the average daily ridership on Advance Transit's fixed-route network is 2,029 (see Part 1-Step 3) and that 53% of riders ride by choice, the average daily ridership for "choice" riders is 1,075.

Part 1- Step 7: Determine the Average Passenger Vehicle Trip Length

According to an analysis of origin-destination pairs provided as part of a 2008 on-board survey, the average trip length of an Advance Transit fixed-route rider is 4.6 miles. (Source: Tom Crikelair Associates, "Transit Development Plan for Advance Transit", 2008)

Part 1- Step 8: Determine Vehicle Miles Traveled Avoided per Day

The avoided vehicle miles traveled per day is computed using the figures calculated in Step 6, Step 4, and Step 7 as follows: (1,075 trips/1.1 passengers per trip) x 4.6 vehicle miles per passenger = 4,496 vehicle miles traveled avoided per day.

Thus, 4,496 passenger vehicle miles traveled per day are avoided due to Advance Transit's fixed-route transit network.

Part 2- Calculating the Emissions Correlating to the Avoided Vehicle Miles Traveled

Part 2- Step 9: Determine Passenger Vehicle Emissions Factor for VOC

The passenger vehicle emissions factor for volatile organic compounds (VOC) was determined by use of an EPA Mobile 6.2 emissions model, modeled for New Hampshire conditions by the New Hampshire Department of Environmental Services Air Resources Division. The light-duty gasoline vehicles (LDGV) classification was used. The passenger vehicle emissions factor for VOC is 0.405 grams/mile. (Source: NHDES)

Part 2- Step 10: Determine Passenger Vehicle Emissions Factor for CO

The passenger vehicle emissions factor for carbon monoxide (CO) was determined by use of an EPA Mobile 6.2 emissions model, modeled for New Hampshire conditions by the New Hampshire Department of Environmental Services Air Resources Division. The light-duty gasoline vehicles (LDGV) classification was used. The passenger vehicle emissions factor for CO is 13.112 grams/mile. (Source: NHDES)

Part 2- Step 11: Determine Passenger Vehicle Emissions Factor for NOx

The passenger vehicle emissions factor for oxides of nitrogen (NOx) was determined by use of an EPA Mobile 6.2 emissions model, modeled for New Hampshire conditions by the New Hampshire Department of Environmental Services Air Resources Division. The light-duty gasoline vehicles (LDGV) classification was used. The passenger vehicle emissions factor for NOx is 0.365 grams/mile. (Source: NHDES)

Part 2- Step 12: Determine Avoided Passenger Vehicle Emissions for VOC

The avoided passenger vehicle emissions for VOC is calculated as vehicle miles traveled avoided per day (4,496 miles/day) multiplied by the passenger vehicle emissions factor for VOC (0.405 grams/mile). As such, the avoided VOC emissions are 1,821 grams/day.

Part 2- Step 13: Determine Avoided Passenger Vehicle Emissions for CO

The avoided passenger vehicle emissions for CO is calculated as vehicle miles traveled avoided per day (4,496 miles/day) multiplied by the passenger vehicle emissions factor for CO (13.112 grams/mile). As such, the avoided CO emissions are 58,953 grams/day.

Part 2- Step 14: Determine Avoided Passenger Vehicle Emissions for NOx

The avoided passenger vehicle emissions for NOx is calculated as vehicle miles traveled avoided per day (4,496 miles/day) multiplied by the passenger vehicle emissions factor for CO (0.365 grams/mile). As such, the avoided NOx emissions are 1,641 grams/day.

Part 3- Calculating the Bus Emissions on Advance Transit's Fixed-Route Services

Part 3- Step 15: Determine Total FY 2011 Fixed-Route Bus Miles Traveled

The total miles traveled in FY 2011 for buses service Advance Transit's fixed-route network was 432,651. (Source: Advance Transit)

Part 3- Step 16: Determine Fixed-Route Bus Miles Traveled per Day in FY 2011

The fixed-route bus miles traveled per day is calculated by dividing the total number of bus miles traveled (432,651) by the total number of operating days (254). As such, the buses serving Advance Transit's fixed-route network traveled an average of 1,703 miles per day.

Part 3- Step 17: Determine Bus Emissions Factor for VOC

The bus emissions factor for volatile organic compounds (VOC) was determined by use of an EPA Mobile 6.2 emissions model, modeled for New Hampshire conditions by the New Hampshire Department of Environmental Services Air Resources Division. The diesel transit and urban bus (HDDBS) classification was used. The bus emissions factor for VOC is 0.275 grams/mile. (Source: NHDES)

Part 3- Step 18: Determine Bus Emissions Factor for CO

The bus emissions factor for carbon monoxide (CO) was determined by use of an EPA Mobile 6.2 emissions model, modeled for New Hampshire conditions by the New Hampshire Department of Environmental Services Air Resources Division. The diesel transit and urban bus (HDDBS) classification was used. The bus emissions factor for CO is 2.121 grams/mile. (Source: NHDES)

Part 3- Step 19: Determine Bus Emissions Factor for NOx

The bus emissions factor for oxides of nitrogen (NOx) was determined by use of an EPA Mobile 6.2 emissions model, modeled for New Hampshire conditions by the New Hampshire Department of Environmental Services Air Resources Division. The diesel transit and urban bus (HDDBS) classification was used. The bus emissions factor for NOx is 11.232 grams/mile. (Source: NHDES)

Part 3- Step 20: Determine Bus Emissions of VOC

The bus emissions of VOC is calculated as bus miles traveled per day (1,703 miles/day) multiplied by the bus emissions factor for VOC (0.275 grams/mile). As such, VOC emissions from Advance Transit fixed-route buses are 468 grams/day.

Part 3- Step 21: Determine Bus Emissions of CO

The bus emissions of CO are calculated as bus miles traveled per day (1,703 miles/day) multiplied by the bus emissions factor for CO (2.121 grams/mile). As such, CO emissions from Advance Transit fixed-route buses are 3,613 grams/day.

Part 3- Step 22: Determine Bus Emissions of NOx

The bus emissions of NOx is calculated as bus miles traveled per day (1,703 miles/day) multiplied by the bus emissions factor for NOx (11.232 grams/mile). As such, NOx emissions from Advance Transit fixed-route buses are 19,132 grams/day.

Part 4- Reconciling Avoided Passenger Vehicle Emissions with Bus Emissions from Advance Transit's Fixed Route Services to Determine a Net Air Quality Impact

Part 4- Step 23: Determine Net VOC Emissions Avoided (grams/day)

Subtracting bus VOC emissions (468 grams/day) from avoided passenger vehicle VOC emissions (1,821 grams/day), Advance Transit's fixed-route service results in net VOC emissions avoided of 1,353 grams/day.

Part 4- Step 24: Determine Net CO Emissions Avoided (grams/day)

Subtracting bus CO emissions (3,613 grams/day) from avoided passenger vehicle CO emissions (58,953 grams/day), Advance Transit's fixed-route service results in net CO emissions avoided of 55,340 grams/day.

Part 4- Step 25: Determine Net NOx Emissions Avoided (grams/day)

Subtracting bus NOx emissions (19,132 grams/day) from avoided passenger vehicle NOx emissions (1,641 grams/day), Advance Transit's fixed-route service results in net NOx emissions *increase* of 17,491 grams/day.

Part 4- Step 26: Determine Net VOC Emissions Avoided (lbs/year)

Using the figure of 1,353 grams/day of net VOC emissions avoided, multiply by 0.0022 lbs/gram and then multiply by 254 total operating days. Thus, 756 pounds per year of VOC emissions are avoided as a result of Advance Transit's fixed-route service.

Part 4- Step 27: Determine Net CO Emissions Avoided (lbs/year)

Using the figure of 55,340 grams/day of net CO emissions avoided, multiply by 0.0022 lbs/gram and then multiply by 254 total operating days. Thus, 30,924 pounds per year of CO emissions are avoided as a result of Advance Transit's fixed-route service.

Part 4- Step 28: Determine Net NOx Emissions Avoided (lbs/year)

Using the figure of 17,491 grams/day of net NOx emissions *increased*, multiply by 0.0022 lbs/gram and then multiply by 254 total operating days. Thus, 9,774 pounds per year of NOx emissions are *increased* as a result of Advance Transit's fixed-route service.

Part 4- Step 29: Determine Net VOC Emissions Avoided (tons/year)

Converting 756 pounds per year of avoided VOC emissions into tons by dividing by 2000 lb/ton, 0.38 tons of VOC emissions were avoided in FY 2011 as a result of Advance Transit's fixed-route bus service.

Part 4- Step 30: Determine Net CO Emissions Avoided (tons/year)

Converting 30,924 pounds per year of avoided CO emissions into tons by dividing by 2000 lb/ton, 15.5 tons of CO emissions were avoided in FY 2011 as a result of Advance Transit's fixed-route bus service.

Part 4- Step 31: Determine Net NOx Emissions Avoided (tons/year)

Converting 9,774 pounds per year of *increased* NOx emissions into tons by dividing by 2000 lb/ton, 4.9 tons of NOx emissions were *increased* in FY 2011 as a result of Advance Transit's fixed-route bus service.

Conclusions

Advance Transit continues to substantially contribute to improving air quality in the Upper Valley region of New Hampshire and Vermont. Advance Transit's fixed-route services resulted in 15.5 tons of avoided CO emissions and 0.38 tons of avoided VOC emissions in FY 2011. Over the past seven years (from FY 2004 to FY 2011), a number of factors have contributed to the positive air quality impacts presented in this report:

- Ridership has increased from under 280,000 to more than 515,000 annually, partially because the service remains fare-free and partially because of expanded service on the popular Red Route;
- The percentage of "choice" riders (i.e. Advance Transit riders that have a vehicle available for their trip) continues to increase- from 43% in FY 2004 to 53% in FY 2011.

The bus emissions factors presented in this report are not specific to Advance Transit's fleet. Rather, they are based on the EPA Mobile 6.2 modeling framework, which reflects a nationwide average of bus fleet characteristics. In 2007, the U.S. Environmental Protection Agency introduced new rules under their Heavy-Duty Highway Diesel Program to reduce 2.6 Million tons of NOx emissions nationwide by incorporating changes to the country's

heavy-duty diesel truck and bus fleets and mandating that refineries produce Ultra Low Sulfur Diesel (ULSD) to power those fleets.

Much of Advance Transit's fleet is comprised of model year 2007 and later buses, which conform to these enhanced NOx emission standards. However, the EPA Mobile 6.2 modeling framework presents bus emissions factors that only partially reflect the nationwide conversion to cleaner burning diesel engines. As such, the model may be systematically overestimating Advance Transit's NOx emissions. It is likely that the EPA's bus emissions factors will soon be revised to better reflect the nationwide transition to cleaner burning heavy-duty diesel engines as the agency continues to develop the EPA Moves (Motor Vehicle Emission Simulator) modeling framework, which will replace the EPA Mobile modeling framework.

Notwithstanding the limitations of the EPA Mobile 6.2 NOx emissions factors, the results are significant. Total NOx emissions from the Advance Transit fleet have decreased by 20% since FY 2004, while simultaneously the number of operating hours for the fleet has increased as a result of expanded service. It is likely that this trend will continue, as the recent acquisition of two hybrid buses will further reduce Advance Transit's emissions and enhance fuel economy in future years.

We recommend that the Advance Transit Air Quality Impact Analysis be updated every five years to track trends and progress, with the next update following FY 2016.