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Sharon Feigon, Manager of the Research and Development Division at the Center for Neighborhood Technology, was the principal investigator. The other authors of this report are Jen McGraw, Coordinator, Community Energy Division, CNT; Lisa McNally, Research Analyst, CNT. Information Technology and additional Data Analysis were conducted by Peter Haas, Technical Information Manager, CNT; Timothy Lang, Website Developer, CNT; and Paul Smith, Information Technology and Systems Administrator, CNT.

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EXECUTIVE SUMMARY

The Center for Neighborhood Technology (CNT), with TransManagement, under the Transit Cooperative Research Program (TCRP) Project H-21, "Combating Global Warming with Sustainable Surface Transportation Policy," created a research report and website with information for individuals and transit agencies on the greenhouse gas reduction potential of the public transportation sector. Greenhouse gas reductions must be considered in the context of the Clean Air Act regulations on the "criteria pollutant" emissions of transit agencies. These regulations are aimed at reducing the direct criteria pollutant emissions of transit vehicles themselves and at encouraging transit ridership in place of personal automobiles. Both of these emissions reduction strategies are directly applicable to greenhouse gases. Because greenhouse gases are currently unregulated, they do not often factor into transit agency decisions designed to comply with the Clean Air Act.

TCRP Project H-21A, an extension to Project H-21, encourages better decision-making by enabling transit professionals and the public to consider both the greenhouse gas and criteria air pollutant impacts of transit planning decisions. Project H-21A, for which the product, www.TravelMatters.org, can be viewed on-line, is composed of three tasks: 1) a Criteria Pollutant Emissions Calculator for transit fleets; 2) an Emissions Avoided Module for trip planning websites; and 3) a Learning Center for youth and educators.

1) Criteria Pollutant Emissions Calculator for Transit Fleets
   The *TravelMatters* Transit Planning calculator, a website created under Project H-21, was expanded under H-21A by adding criteria pollutants to information on transit fleet emissions and the emissions benefits of alternative fuels, advanced transit technologies and increased transit ridership. CNT adapted the U.S. Environmental Protection Agency's (USEPA) mobile source emissions modeling tool, Mobile 6.2, to generate emissions estimates for volatile organic compounds (VOC), nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter (PM2.5).

   The resulting Transit Planning calculator is a quick and easy tool that can be used to estimate criteria pollutant emissions. The user does not need to input any data to receive useful emissions estimates; CNT has provided default factors to the Mobile 6.2 model for each transit agency's profile based on its regional climate, elevation, and fuel characteristics. In addition, because so many transit agencies provide train service, CNT has incorporated calculations for diesel locomotive criteria pollutant emissions; locomotives are excluded from USEPA's model. While CNT's adaptations to Mobile 6.2 make it easy to use, the modifications mean that the Transit Planning calculator generates estimates only and is not intended for use for regulatory purposes. Please see Appendix A for a screenshot of the *TravelMatters* homepage.

2) Emissions Avoided Module for Trip Planning Websites
   To help transit agencies make use of data that demonstrates the emissions benefits of transit, CNT developed the *TravelMatters* Emissions Avoided Module (EAM), which is an Internet-based computer program that can be added to transit trip planning websites and gives individuals an estimate of the emissions avoided by taking transit instead of driving a personal vehicle. The EAM receives data on the length of a transit trip and the type of transit vehicle used and calculates the emissions avoided as compared to a similar personal automobile trip. This program and instructions on how to set it up are available to any interested party at the *TravelMatters* website.

3) Learning Center for Youth and Educators
   The Learning Center on the *TravelMatters* website contains activities and resources for junior high and high school students and educators on the connections between driving, climate change, and local air quality. There are two sections of the Learning Center: "Activities for Students" and "Tools for Teachers." The resources in the Learning Center are a Travel Log for youth to record their transportation activities and relevant comprehension questions; interactive quizzes on the content in the *TravelMatters* site; a resource list for further learning; a list of suggested classroom activities to augment the website tools; and a downloadable presentation of the *TravelMatters* material.

CNT concludes this report by identifying a number of additional research opportunities that could help transit agencies as they strive to achieve the goal of sustainable surface transportation. For example, a set of in-depth analyses of the data developed for Projects H-21 and H-21A could provide a better understanding of the emissions trends among transit agencies and could deepen the understanding of the link between transit emissions and successful mitigation methods. Also, study of land use and transit emissions on a national scale, specifically in terms of Transit Oriented Development (TOD), could help further quantify the emissions benefits of transit and identify the best land use configurations for transit to become a vital transportation solution to climate change in every community.

CHAPTER 1

INTRODUCTION AND RESEARCH APPROACH

This report begins with a review of TCRP Project H-21 and a summary of the extension project, H-21A, including its three tasks to:

- Create a criteria pollutant emissions calculator for transit fleets;
- Develop an "Emissions Avoided Module" for trip planning websites; and
- Create a learning center for youth and educators.

The three tasks have been incorporated as a complete on-line product; this product is available for interactive use at www.TravelMatters.org. The approach and methodology related to each task is fully described. The report concludes with research recommendations to further assist transit agencies seeking to reduce climate change emissions. The appendices at the end of the report provide additional information on each task, including screenshots of various components of the *TravelMatters* website.

TRANSIT COOPERATIVE RESEARCH PROGRAM PROJECT H-21

The United States (U.S.) produces one-quarter of the world's global greenhouse gas emissions.[i] One way to mitigate these emissions is through more sustainable surface transportation, which can be implemented locally and regionally with the support of citizens, transit agencies, and metropolitan planning organizations. Although there are few initiatives that specifically address climate change with respect to local emissions reduction, decreasing greenhouse gas emissions is often a collateral benefit of sustainability and smart growth projects. Actions ranging from an individual choosing to bike instead of drive to work, to the construction of commuter rail in a region, to building affordable housing near transit and employment can all reduce emissions by decreasing personal vehicle travel.

Engaging key decision-makers to implement a set of actions that explicitly reduce transportation-related greenhouse gas emissions is critical to slowing global warming. By educating people about the threat of climate change, their contribution to it, and the ways in which they can reduce their emissions, individuals, public sector agencies, and government officials can be encouraged to change their transportation patterns to reduce their carbon production. To that end, the Transit Cooperative Research Program's (TCRP) Project H-21 developed three products: 1) a paper on the science behind climate change and the U.S. surface transportation sector's contribution to it;[ii] 2) a review of sustainability initiatives that impact greenhouse gas emissions, including an analysis of available and potential alternative technologies and fuels for transit vehicles and the opportunities for and challenges of implementing them within transit agencies; and 3) a web-based resource tool, www.TravelMatters.org that helps individuals, transit agencies, planning entities, and municipalities understand their production of greenhouse gases and what they can do to set and meet a carbon budget. The interactive tool consists of two emissions calculators; the emissions calculator for individuals measures how much greenhouse gas an individual generates as a result of daily transportation activity. The calcultor for transit agencies provides transit agency professionals and decision-makers

emissions data for carbon dioxide generated by a revenue fleet, and allows them to determine emissions saved if changes were made to tranit fuel types and passenger load.

TRANSIT COOPERATIVE RESEARCH PROGRAM PRJECT H-21A

Project H-21 focuses on the importance of transit-based greenhouse gas emissions reductions, but recognizes that transportation decisions cannot be made on greenhouse gas considerations alone. In TCRP Report 93, *TravelMatters: Mitigating Climate Change with Sustainable Surface Transportation,* CNT examined the costs and feasibility of alternative transportation technologies, policies, and fuels in addition to their greenhouse gas emissions impacts. Project H-21A continues to promote sustainable transportation by incorporating emissions data for "criteria" air pollutants regulated by the Clean Air Act into the *TravelMatters* emissions calculator. By enabling transit professionals to examine regulated criteria pollutants together with presently unregulated greenhouse gas emissions, CNT hopes to foster comprehensive emissions reduction strategies.

While greenhouse gas pollutants are currently unregulated, the Clean Air Act as amended in 1990 imposes a number of direct and indirect requirements on transit agencies regarding other emissions. The USEPA set National Ambient Air Quality Standards (NAAQS) for six principal pollutants considered harmful to the environment and public health. These six "criteria pollutants" are nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter (PM), lead (Pb), and ozone (O_3).[iii] Each of these pollutants is discussed in detail in Appendix B.

Transit agencies play a dual role in air emissions regulations—transit vehicle fleets generate pollution, which must be regulated, but transit agencies also contribute to clean air through the avoided emissions of transit riders not driving personal vehicles. The latter role is increasingly important—while aggregate criteria pollutant emissions in the U.S. decreased by 48 percent between 1970 and 2002, vehicle miles traveled (VMT) increased 155 percent,[iv] and transportation sector carbon dioxide emissions increased by 725 million metric tons during that same time period.[v] Increased transit use is one of the primary ways to decrease VMT, curb greenhouses gases, and further reduce air pollution.

As a result of the dual role the transit agency plays in relation to emissions, criteria pollutant emissions are taken into consideration in a wide range of transit decisions, including scheduling and operations, vehicle purchasing, maintenance, and transit pass programs. Each of these decisions can affect greenhouse gas emissions as well. Appendix C provides a summary of the major Clean Air Act regulations affecting transit, which may be useful in understanding the ways in which transit professionals are already implementing criteria pollutant emissions reductions and may be able to incorporate or quantify greenhouse gas emissions reductions concurrently. Some criteria pollutant emissions reduction strategies, such as increased transit ridership, have greater greenhouse gas reduction benefits than others, such as conversion to compressed natural gas vehicles. Transit agencies are encouraged to use the data provided through this

project to pursue transit strategies that engender the maximum emissions reduction of all types of air pollutants.

Projects H-21 and H-21A created and enhanced the *TravelMatters* Transit Planning calculator as an easy-to-use tool to help transit agencies take a first cut at assessing impacts of potential decisions about alternative fuels, transit technologies, and increased ridership on both greenhouse gas and criteria pollutant emissions. The emissions calculator is not intended to be used for Clean Air Act regulatory compliance, but provides transit agencies and other interested parties with quick, simple estimates of transit emissions. With this fleet planning tool, transit agencies are better equipped to make decisions about fleet management and operations.

H-21A Summary and Research Approach

In May 2003, the research team began working on the extension phase of Project H-21. This one-year extension project, H-21A, consisted of three tasks. Task One resulted in the development of a replicable web-based module that can be integrated into a transit trip planning website. The module, accessible via the Transit Planning calculator, determines the amount of carbon dioxide emissions avoided by any auto trip replaced by a specific transit trip. Task Two resulted in expanding the capacity of the Transit Planning calculator to compute criteria pollutants in addition to carbon dioxide. Task Three resulted in the Learning Center—an on-line instructional resource for educators and repository of interactive materials for students. The educational resources and materials directly correspond to the youth-friendly, online Individual Emissions calculator that was developed as a primary component of the *TravelMatters* Project H-21.

Task One: Create a Criteria Pollutant Emissions Calculator for Transit Fleets

The expanded capacity of the *TravelMatters* website to calculate criteria pollutants provides a useful instrument to urban and transit planners seeking a quick and reliable resource for estimating the amount of emissions generated by local transit vehicles. The calculator's expanded capacity is particularly relevant, as the Clean Air Act mandates that many regions report on these specific emissions. In addition to providing a benchmark of carbon dioxide emissions for a transit agency's fleet, the extended version of the calculator now also provides estimates for oxides of nitrogen (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter ($PM_{2.5}$). The Transit Planning calculator allows users to make hypothetical fleet and ridership changes resulting in altered emissions outputs. The enhanced site provides a relevant tool for supporting local and state decision-making about roadway development, fleet purchases, and community design as one means for increasing transit ridership. Although the Transit Planning calculator interfaces with the USEPA Mobile 6.2, it is not a regulatory mechanism.

Task Two: Develop an "Emissions Avoided Module" for Trip Planning Websites

The Emissions Avoided Module (EAM) allows individuals who visit a trip planning website for transit itinerary information to also receive an estimate of the emissions avoided by taking the suggested transit trip instead of driving to the same destination by car or sports utility vehicle. While providing trip planning information to the public, transit agencies expand the utility of widely-used trip planning tools by relaying additional information about the users' impact on environmental quality. The EAM reinforces the importance of taking mass transportation over driving by quantifying emissions saved. At the same time, the scorecard of emissions avoided by taking transit helps to educate the public about how their travel decisions impact climate change and local air quality.

Task Three: Create a Learning Center for Youth and Educators

Task Three focused on increasing consumer and social awareness of greenhouse gas emissions resulting from individual transportation activities among a younger population. The *TravelMatters'* Learning Center provides interactive activities and relevant resources for youth and educators that help illuminate the connections between driving, climate change, and local ambient air quality. Educational material was added to the site that directly relates to the use of the Individual Emissions calculator, emissions maps, and research material in the *TravelMatters* site. When used together, the educational resources help underscore how individual transportation choices impact the local environment.

The Learning Center addendum speaks specifically to youth, since they may have a greater propensity to explore alternative options for mobility, especially if they are not yet driving personal vehicles. An effective place for using this tool is in the classroom. Included in the Learning Center is an Activity Guide for teachers to implement projects, and an extensive PowerPoint lecture that includes instructional notes for a teacher who may be new to the topics of ambient emissions and climate change. Through usage of the Individual Emissions calculator as a hands-on activity in the classroom, the *TravelMatters* site becomes a useful and timely resource tool in science and social science curricula.

SUMMARY

By providing alternative, on-line tools that facilitate decision-making about transit operations (by transportation planners) and daily transportation choices (by individuals), *TravelMatters* Project H-21 and its extension project, H-21A, illuminate strategies to reduce greenhouse gas and criteria pollutant emissions from the transportation sector. The calculator also calculates the impact of using non-transit modes including carpooling, biking, and walking. The *TravelMatters* website allows users to simply and easily identify the relationships between annual usage of an array of transit modes and fuel use, and how annual fluctuations in transit ridership directly alter greenhouse gas and criteria pollutant emissions. It also allows individuals to visualize the comparative emissions, on a monthly basis, resulting from the choice to use a personal vehicle or alternative transit mode.

[i] U.S. Department of Transportation, *Energy Data Book*, ed. 22. Online version at www.cta.ornl.gov/data/Index.html.

[ii] Transit Cooperative Research Program, *TCRP Report 93, Travel Matters: Mitigating Climate Change with Sustainable Surface Transportation*. Washington, DC, 2003.

[iii] U.S. Environmental Protection Agency, Technology Transfer Network, National Ambient Air Quality Standards, Online version at www.epa.gov/ttn/naaqs.

[iv] U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division. *Latest Findings on National Air Quality, 2002 Status and Trends.* Online version at www.epa.gov/airtrends/2002_airtrends_final.pdf.

[v] U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2002*. Online version at www.eia.doe.gov/oiaf/1605/ggrpt/pdf/appendixb.pdf

CHAPTER TWO

TASK ONE: CRITERIA POLLUTANTS AND TRANSIT

INTRODUCTION

One of the primary tasks for this TCRP project was to expand the transit emissions calculation tool at www.TravelMatters.org to include criteria air pollutant emissions. As was discussed in the introduction, this expansion of the Transit Planning calculator is intended to encourage integrated decision-making for criteria pollutant and greenhouse gas reduction strategies. This chapter provides background on criteria pollutant modeling and details the methodologies CNT used to calculate transit criteria air pollutants. It concludes with a discussion of the results of the criteria pollutant emissions calculations.

CRITERIA POLLUTANT EMISSIONS MODELING

In the regulation of transportation criteria pollutant emissions, USEPA developed a set of modeling tools to help state agencies estimate the emissions from mobile sources. These models are used to create State Implementation Plans (SIPs) for Clean Air Act compliance and for transportation planning. As they are the most widely used criteria pollutant emissions models, and are familiar to transportation professionals, CNT chose to adapt the USEPA models for the *TravelMatters* website. Currently, the USEPA has two approved tools:

- Mobile 6.2 is the latest version of modeling software for on-road mobile sources such as automobiles, trucks, and buses.
- NONROAD is a modeling tool for off-road mobile sources such as lawnmowers, construction equipment, and recreational marine vehicles. NONROAD does not, however, model the two major off-road transit vehicles: ferries and trains.

The USEPA is developing a new mobile emissions modeling system, the Motor Vehicle Emissions Simulator (MOVES), which will eventually replace Mobile 6.2 and NONROAD. MOVES will be able to model emissions of all major mobile sources, both on-road and off-road, including commercial marine vehicles and locomotives. MOVES is planned to add functionality by modeling greenhouse gas emissions and emissions at finer geographic scales. In addition, MOVES may overcome some of the software limitations in the Mobile 6.2 software. The final version of MOVES for on-road sources and the draft version for off-road sources are scheduled for release in 2007.[i]

USEPA's Mobile 6.2 Emissions Model

The USEPA provides Mobile 6.2 to help regional planners estimate the road-based emissions produced across a geographic area. The latest version of Mobile 6.2 was recently updated, in part to better estimate particulate matter emissions according to the latest Clean Air Act regulations. The USEPA originally designed the Mobile Emissions Model as a PC-based application. Users specify a variety of parameters to localize

Mobile 6.2 estimates to their particular geographic area and transportation practices. Through this model, regional planners can determine how to make strategic changes to transportation operations and fleet management to attain air quality compliance.

The USEPA designed Mobile 6.2 to function as a generic application. It accepts a variety of user inputs, including, but not limited to: environmental conditions such as temperature and humidity; fuel characteristics such as sulfur content and Reid Vapor Pressure (RVP); elevation; roadway type and the speed of vehicles on different types of roadways; and composition and age of vehicle fleets.

CNT identified a number of challenges when trying to adapt Mobile 6.2 for use with *TravelMatters.* Some of these—the fairly high level of expertise needed for use and interpretation of results, the lack of a web interface (it must be downloaded and run on the user's computer)—were relatively easy to fix. Other challenges—the exclusion of diesel locomotives or other non-road transit vehicles, the inability to localize results without specific information, and the inaccuracy of calculations when the model does not receive parameters in a specific format or in its expected sequence—required more programming expertise.

CNT first transferred the original code into a less technical, user-friendly system (as described in the methodology section below), where web users can generate easily understandable pollutant emissions estimates. The *TravelMatters* Transit Planning calculator estimates emissions using the Mobile 6.2 model's processing core, but it does not replicate the full model. The calculator provides the following enhancements to the base Mobile 6.2 model:

- The user interface is practical and customizable.
- Users do not need to understand Mobile 6.2's parameters and constraints in order to acquire pollutant emissions for a given transit fleet.
- Transit agencies can create unique emissions benchmarks, using profiles determined by the FTA's National Transit Database (FTA NTD), the National Oceanic and Atmospheric Administration (NOAA) Weather Service Database, and other regional characteristics. Agencies can quickly determine how their fuel and vehicle choices affect regional air quality.
- Emissions estimates include non-road transit vehicles (primarily diesel-pulled commuter rail).
- Planners can compare hypothetical changes to their fleet structure with the emissions fleet, technology, and capacity of their 2002 fleet profile.
- Users can examine the impact of alternative fuels and transit technologies on currently unregulated greenhouse gas emissions as well as criteria pollutant emissions.

In addition to the road-based vehicles profiled by Mobile 6.2, *TravelMatters* uses a separate model, designed by CNT, to estimate commuter rail emissions. The model uses the 2002 FTA NTD to define an agency's commuter rail emissions benchmarks. As a result, transit operators can use the same *TravelMatters* interface to evaluate how

commuter rail changes affect the overall emissions for their fleets. The model is based on several USEPA and FTA sources, which are described in the methodology section below.

Criteria Pollutant Calculator Methodology

The expanded *TravelMatters* website uses Mobile 6.2 to calculate criteria pollutants for road-based vehicles. To obtain these results, *TravelMatters* determines the regional and transit agency values that apply to a representative subset of Mobile 6.2's input parameters. For values that *TravelMatters* does not explicitly provide, Mobile 6.2 will use its default parameters. *TravelMatters* localizes its input parameters using the FTA NTD 2002 and an average of weather data inputs from the NOAA's National Weather Service Database 2000-2002. The methodology used to derive the weather inputs is explained in Appendix D.

Since *TravelMatters* results are not designed to fulfill regulatory requirements, the results reflect only a subset of Mobile 6.2's functionality. The results will not consider every factor that Mobile 6.2 can incorporate. As a result, *TravelMatters* may report different values than a full Mobile 6.2 model run. Transit officials should only use *TravelMatters* to determine current emissions benchmarks and to plan future emission reduction and purchasing strategies.

Significant Factors: Sensitivity Analysis

Mobile 6.2 uses many inputs mostly related to compliance issues regarding transportation plans and the Clean Air Act. As stated above, *TravelMatters* is not designed to fulfill regulatory requirements. It is meant to demonstrate how a transit agency could vary, rather than operate, its fleet to affect criteria pollutants. As a result, not all of the parameters included in Mobile 6.2 were needed for *TravelMatters*. The following Mobile 6.2 parameters are included in *TravelMatters*:

- **Temperature.** The average high and low temperatures for July 1 from 2000 to 2002 were used (please see Appendix D).
- **Humidity.** The average absolute humidity for July 1 from 2000 to 2002 was calculated (please see Appendix D).
- **Elevation.** The average elevation for the city in which the transit agency is located was used. If the elevation was more than 5,000 feet, it was considered a high elevation.
- **Roadway usage.** The Mobile 6.2 default usage was used because it was impossible to know the distribution of vehicles on the four different roadway types identified in Mobile 6.2 (arterials, local roads, freeways, and freeway ramps). To incorporate each roadway type would have meant running Mobile 6.2 many times for each vehicle type within an agency, significantly affecting the website's usability.
- **Speeds** on different roadway types. See above.

In order to make the Transit Planning calculator as usable as possible, CNT created greater functionality in three areas, allowing users to customize the calculations to their own fleets:

- Reid Vapor Pressure (RVP) of gasoline. This is a standard measure of the volatility of gasoline. Regions that are in non-attainment must decrease the RVP for their fuel supply. The USEPA specifies the RVP value by county for the entire country. Although this value is used as the default for each transit agency, users can vary it to understand the benefit of buying lower RVP gasoline.[ii]
- Sulfur content of diesel fuel. Currently most diesel fuel is sold with 500 ppm of sulfur, however "ultra low sulfur" diesel fuel is available in several regions in the country. The sulfur content of diesel fuel affects the amount of particulates generated by diesel engines.
- Year of run. Since both the age of fleet vehicles and the rules regarding fuels affect the amount of pollution generated, users can use the present year (which is the default on the application) or choose another year.

While the age of the vehicles and the composition of the roadway types were determined to be significant factors in calculating criteria pollutant emissions, CNT did not include these variables in the Transit Planning calculator for two reasons. It would have increased the complexity of the user interface and CNT could not be confident of the meaning of the results. The inclusion of the criteria pollutant emissions from Mobile 6.2 was meant as an estimate for planners to aid in decision-making, not a substitute for running the Mobile 6.2 to its fullest extent. CNT focused on sulfur content of diesel and RVP as two variables that could be modified by transit planners and could conceivably be changed more readily than, for example, the routes and speeds by which the fleet traveled.

Assumptions

Because the *TravelMatters* criteria pollutant calculations are based on the Mobile 6.2 model, they are limited by many of the same constraints. Some of the constraints of the criteria pollutant portion of the Transit Planning calculator follow:

- It recognizes only two days out of the year (January 1 and July 1); all other days are beyond the model's scope.
- It consolidates vehicles into very large and general categories. As a result, all buses above 15 seats are placed in the same vehicle category.[iii]
- It recognizes only two elevation options (high or low).
- It uses a humidity measurement that is not widely reported (absolute humidity rather than the more common relative humidity).
- It recognizes a temperature range of only $0\text{-}120^0$F.
- It applies to only one alternative energy source (compressed natural gas).
- It constrains some route profiles to a default speed.
- It uses nationwide averages that may not apply to individual locations.

Modifications

Mobile 6.2 was written in the Fortran programming language and is meant for DOS PCs. CNT acquired the source code to the application from the USEPA website and recompiled it to run on the Linux and FreeBSD operating systems. CNT identified seven Mobile 6.2 input parameters to base calculating criteria pollutant emissions on: year, elevation, minimum and maximum temperature, absolute humidity, sulfur content and RVP. CNT then developed a "wrapper," a common programming technique to provide a translation layer between two application layers that may not be directly compatible, or to make one application fit into an environment in which it would not normally function well. This was necessary to address the original design of the Mobile 6.2, which was meant to run on a single desktop PC and not in a server environment with multiple requests coming in simultaneously. In this case, CNT created a script in the Python programming language that receives the condensed input, converts it to the file format expected by Mobile 6.2 under normal conditions, executes Mobile 6.2 automatically with this generated input file, intercepts the native output file format from Mobile 6.2, converts this output into a form that is easy to work with in the CNT web server programming language (PHP), and then passes it on to the web server. The diagram in Appendix E illustrates the relationship between the *TravelMatters* website, the Mobile 6.2 processing core and external databases.

Regional Definitions. Although *TravelMatters* uses the NTD and the NWS databases to characterize local conditions, the Mobile 6.2 constraints affect how closely *TravelMatters* can define a region and a transit agency. *TravelMatters* mostly specifies local conditions determined by the USEPA to have a "major" or "intermediate" effect on emissions levels, as presented in a systematic study of the relative importance of various Mobile 6 input parameters.[iv] If *TravelMatters* cannot determine local conditions from its sources, it uses the model's default of national average conditions.

Humidity. *TravelMatters* uses the NWS Database to determine a three-year average (2000-2003) of a region's temperature range, average barometric pressure, and absolute humidity. Like most conventional weather reports, the NWS Database provides relative rather than absolute humidity values. The value of absolute humidity is critical in order for Mobile 6.2 to model the amount of pollution generated in running an engine, since this is a measure of grains of water in a pound of air, and it is that water that determines the amount of pollutants generated. To convert the relative humidity to absolute humidity, *TravelMatters* follows the formulas provided by the USEPA's Office of Transportation and Air Quality.[v]

Table 2.1: Mobile 6.2 Weather Constraints Implemented by *TravelMatters*

	LOW TEMP (^{0}F)	HIGH TEMP (^{0}F)	AVERAGE TEMP (^{0}F)	ABSOLUTE HUMIDITY (grains/lb)	PRESSURE (inHg)*
LOWER LIMIT	0	10	0	20.0	24.5
UPPER LIMIT	100	120	120	528.0	31.5
DEFAULT VALUE			Average of High and Low Temp	75.0	29.92 (Mobile 6.2 default)

*The pressure range conforms to average NWS Database 2000-2002 range rather than to Mobile 6.2 constraints. The Mobile 6.2 range is 13.0-33.0inHg.

Elevation Data Settings and Regional Fuel Characteristics. TravelMatters also makes an important modification to Mobile 6.2 to address evaluation data settings and regional fuel characteristics. Mobile 6.2 uses the evaluation year to determine how to apply air quality regulations and how to calculate emissions factors. It accepts years between 1952 and 2050. TravelMatters resets evaluation years to the nearest value within this range. By default, TravelMatters will use the current year for evaluation. The calculator provides an interface for manually changing the year of evaluation. A transit agency planner can choose to see what the criteria pollutant emissions might look like in the future after clean air regulations have gone into effect and have changed the kinds of fuels available for purchase.

As described earlier, Mobile 6.2 only accepts two date entries out of the year—January 1 and July 1. The date selected affects how Mobile 6.2 calculates fleet age and seasonal fuel changes. To accommodate this limitation, *TravelMatter*s uses the July 1 date, since this is in the ozone season for most areas.

Mobile 6.2 distinguishes between evaluations at high altitude, defined as greater than 5,500 feet above sea level, and low altitude. CNT used a Geographic Information System (GIS) to assign each transit agency with either a high or low altitude value by examining the average elevation in the city where the transit agency is located. This value is automatically included as part of the simplified input to Mobile 6.2 on the Transit Planning calculator.

When defining a region's pollution profile, Mobile 6.2 could also consider the transit agency's fleet characteristics—the age of the vehicles and the mileage each vehicle accumulates. The FTA NTD 2002 provides each agency's vehicle counts and the mileage accumulated per vehicle category. To incorporate this data into its emissions calculations, *TravelMatters* uses the NTD to determine an agency's fleet profile. This profile is created according to Mobile 6.2's requirements and is limited by its capabilities—profiles are created according to relative age and average mileage per vehicle. Relative ages are listed according to a percentage of model year counts against the vehicles in the total fleet. Vehicles newer than the profile year are not counted. The fleet profiles do not currently accept any other model characteristics other than age. Although the NTD reports make and model, seating capacity, fuel types, maintenance schedules, and route usage, Mobile 6.2 only considers model year and mileage. CNT found that the fleet profile is important

to fully evaluate emissions, the complexities of doing so in a web-based tool were considered prohibitive.

Route Structure. Mobile 6.2 includes parameters to characterize an agency's route structure—how many miles are traveled on what types of roads and at what speed. An improved version of the calculator might provide a user interface for changing the composition of the roadway types, the percent of vehicle miles traveled on each, and the average speed. Average speed, however, is further constrained by fixed speeds for local streets (12.9 mph) and expressway ramps (36.6 mph). This default loading of the road network is used for all calculations in *TravelMatters.* CNT explored adding the ability to adjust route speed and miles traveled on different roadways to the Transit Planning calculator, but did not do so because it would take a different run of Mobile 6.2 for each vehicle class and significantly slow down the calculator. Please see Appendix F for an example of how the route calculation could look on the *TravelMatters* website.

In order to make it as useful and useable as possible to the transit agency planner, a development process of an improved calculator should include a usability study of planners. Mobile 6.2 defines the following default route mix for all vehicles:

Table 2.2: Mobile 6.2 Default Route Mix for All Vehicles

ROADWAY TYPE	VEHICLE MILES TRAVELED (%)	AVERAGE SPEED (mph)
Expressways	34.2%	36.5 mph
Arterial Roads	49.8%	31.2 mph
Local Streets	13.0%	12.9 mph (FIXED)
Ramps Leading to Expressways	3.0%	36.6 mph (FIXED)
OVERALL	100.0%	27.6 mph

*Defaults are derived from the national average provided by the USEPA document, "User's Guide to Mobile 6.1 and Mobile 6.2," EPA420-R-03-010, August 2003, p. 228 and 229, and explained by USEPA document "Development of Methodology for Estimating VMT Weighting by Facility Type," EPA420-R-01-009, April 2001.

Commuter Rail Emissions Implementation

Methodology

Mobile 6.2 is a pollution model for road-based mobile sources. It does not apply to rail-based transit. To estimate diesel commuter rail emissions, the *TravelMatters* website designers developed a separate Commuter Rail Emissions model. This model is based on estimates and regulations explained by four EPA papers dated between 1997 and 1999[vi] and data points from the FTA's NTD 2001. The USEPA provides the regulatory standards for current diesel locomotives and a protocol to estimate locomotive emissions per gallon of fuel. Using the NTD, CNT estimated the miles per gallon efficiency of each agency fleets and its overall age and propulsion characteristics. The model uses USEPA's

estimates to calculate the average emissions per locomotive model year. USEPA also defines default passenger rail emissions per calendar year. When combined with the miles per gallon efficiency calculation, these estimates provide an agency's current diesel commuter rail criteria emissions in gram pollutant per mile. Since these measurements are roughly equivalent to Mobile 6.2, they allow users to estimate rail- and road-based emissions using similar metrics.

Assumptions

Although the NTD 2001 includes many different pieces of information and several different sources for similar data, it also has several limitations addressed by CNT's Commuter Rail Emissions (CRM) model. The limitations are related to self-propelled rail cars and dual-powered trains (trains powered by both electric and diesel propulsion). Unlike buses and other types of transportation, trains often have only one propulsion source leading several un-powered vehicles—a single locomotive is typically used to lead a train of passenger cars. The cars following the locomotive provide passenger seating and facilities but do not significantly contribute to the train's motive power or its pollution emissions. Some trains, however, have several engines assigned to each car. The combined power of the individual engines moves the train forward. When trains operate under both electric and diesel power, the CRM model calculates emission values for the different propulsion methods. To accommodate these different types of trains, this model reports pollution emissions according to train mileage rather than individual car mileage. In addition to the pollution estimates, the CRM model also returns the train mileage and average train lengths used to calculate the estimates.

The NTD provides data to characterize an agency's commuter rail fleet—the seating, the number of cars, the makes and models, and the mileage across the particular category. The database uses consolidated values to report train and route mileage, gallons of fuel used, and kilowatt-hours used. These consolidated values do not distinguish between train and route miles accumulated by electric and diesel vehicles or between self-powered railcars and locomotive-pulled trains. The database only distinguishes these values by the Directly Operated (DO) and Purchased Transportation (PT) service codes. The CRM model uses the database values "Annual Passenger Car Mileage" and "Annual Train Mileage" to calculate average train length. Since several self-propelled cars are often used in place of a locomotive-pulled train of similar length, the model uses average train length to rescale self-propelled car mileage to self-propelled train mileage. Locomotive mileage is considered equivalent to locomotive-pulled train mileage. This change allows the model to provide equivalent results for self-propelled and locomotive-pulled trains. Default train length values correspond to the national average.

The train mileage counts and power consumption reports allow the model to determine train mileage per gallon of diesel fuel and train mileage per kilowatt hour of electricity. The model divides dual-powered locomotive mileage and dual-powered self-propelled car mileage (these are modeled as DP units) between diesel- and electric-powered miles. The current modeling assumptions count one-half of the dual-powered mileage as electric

mileage and one-half of the dual-powered mileage as diesel mileage. If an agency does not report its fuel consumption, the model uses the national commuter rail average.

The USEPA's emissions regulations define the criteria pollutant limits for passenger locomotives. These regulations define the grams of pollutant emissions per unit of fuel (for diesel emissions, they are defined as grams pollutants per gallons of diesel). The regulations are based on a locomotive's original assembly date and evaluation year. The USEPA also estimates the emissions produced by locomotives produced during a range of model years. A transit agency's current fleet and the evaluation year determine the fleet emissions estimates used by the CRM model. For emissions purposes, a locomotive is not counted if its assembly date is after the modeled calendar year. However, it is still counted to estimate the diesel/electric route miles and the agency's fuel efficiency. If a transit agency does not provide a locomotive inventory, the CRM model uses USEPA's passenger locomotive emissions estimates, which are proportionate to the number of locomotives operating from a given model year.[vii]

By dividing estimated grams pollutants per gallons diesel by the miles per gallon diesel, the CRM model calculates the grams pollutants per miles. The USEPA only provides emissions limits for CO, HC, NOx, and PM.[viii] It does not state the size standard used for PM. Since electric vehicles are considered Zero Emission Vehicles, the model does not report criteria pollutants for electric trains. Dual-fueled locomotives are considered to produce one-half the emissions per operating mile of equivalent diesel-powered locomotives—the remaining one-half of the dual-fueled locomotives' operating miles are considered electric-powered miles and are, therefore, modeled as Zero Emission Vehicles.

Electric Vehicles Emissions Implementation

Electric vehicles that use electricity generated from fossil fuels produce both criteria pollutant and greenhouse gas emissions. These emissions, however, are produced at the electricity generating plant, not at the tailpipe. The USEPA regulates the criteria pollutant emissions from electric vehicles as "point source" rather than "mobile" emissions. As a result, Mobile 6.2 has electric vehicles producing no criteria pollutant emissions. Since the *TravelMatters* Transit Planning calculator uses a modified version of Mobile 6.2, electric vehicles show zero criteria pollutant emissions. This shows a discrepancy between the *TravelMatters* modeling of greenhouse gas emissions and criteria pollutants. Since the USEPA does not regulate greenhouse gas emissions, CNT created a model for the greenhouse gas emissions of transit agencies. CNT calculated the greenhouse gas emissions of electric vehicles resulting from the generation of electricity (this calculation was detailed in TCRP Report 93). A similar calculation can be done for criteria pollutants by using the emissions factors for the electricity generating facility, or an average for the facilities in an area, and multiplying those emissions factors by the amount of electricity a transit agency uses. CNT considered adding such criteria pollutant emissions calculations for electric transit vehicles to the *TravelMatters* site, but decided against this option so that it would be most relevant and useful to transit agencies and be aligned with current transit emissions regulations for criteria air pollutants. Nevertheless, it is illustrative to

look at estimated criteria emissions per mile of electric vehicles, as shown in Appendix G.

TRANSIT PLANNING CALCULATOR RESULTS

The addition of criteria pollutant calculations to the Transit Planning calculator allows transit professionals to explore the interplay between transit technologies and operational changes that lower criteria pollutant reduction and their resultant effect on greenhouse gas emissions. Below are the results for three areas: Chattanooga, Tennessee; Washington D.C.; and Los Angles, California.

Chattanooga, Tennessee

The Chattanooga Area Regional Transit Authority (CARTA) has a diverse fleet of nearly 90 transit vehicles that operate on diesel fuel, gasoline, and electricity. The majority of the vehicles in CARTA's fleet are buses, and most of these are diesel-fueled buses, which travel over a million miles each year. CARTA's buses compose the bulk of the agency's total emissions for all pollutants except for VOC, which is produced in greater amount by its demand response vans. As part of its effort to improve air quality, CARTA owns 18 vehicles that run on electricity and are thus considered to have zero emissions by Clean Air Act regulations. CARTA's zero emissions electric buses are also the agency's most efficient vehicles for greenhouse gas emissions—emitting just 3.5 pounds of CO_2 per mile, which demonstrates how greenhouse gas emissions and criteria pollutant emissions can be addressed together through alternative fuel and fleet technology improvements.

Table 2.3: Chattanooga Area Regional Transit Authority 2002

	Pounds of Pollutant Emitted per Year				
Mode	**CO_2**	**VOC**	**NO_X**	**CO**	**$PM_{2.5}$**
Bus	12,047,847	2,755	70,265	18,190	5,579
Demand Response	1,651,537	3,565	3,373	6,839	574
Inclined Plane	178,394	--	--	--	--
Totals	**13,877,778**	**6,320**	**73,638**	**25,029**	**6,153**

Washington, D.C.

Washington DC's rail system is one of the most extensive in the country; Washington Area Metropolitan Transit Authority trains traveled over 51 million miles in 2002. The Metrorail system runs entirely on electricity, which gives it a very clean profile according to Clean Air Act regulations. But as discussed earlier in this report, electric vehicles result in indirect emissions at the electric generating facility, and depending on the fuel mix and efficiency of the electric generation, the indirect emissions impacts of electric vehicles can be quite substantial. As the electricity in the D.C. area is largely fossil fuel generated, Metrorail's CO_2 emissions per mile are more than 60 percent higher than the emissions per mile of the agency's diesel buses. This discrepancy is somewhat mitigated on a per rider basis by the larger passenger capacity of rail. Metrorail's ridership

provides a net greenhouse gas and criteria air pollutant benefit to the area through the large amount of avoided personal vehicle travel.

Table 2.4: Washington Area Metropolitan Transit Authority 2002

	Pounds of Pollutant Emitted per Year				
Mode	**CO_2**	**VOC**	**NO_X**	**CO**	**$PM_{2.5}$**
Bus	380,173,693	54,066	1,621,094	405,378	127,851
Heavy Rail	797,292,227	--	--	--	--
Totals	**1,177,465,920**	**54,066**	**1,621,094**	**405,378**	**127,851**

Los Angeles and Santa Monica, California

The backbone of Los Angeles' transit system is its buses: the Los Angeles County Metropolitan Transit Authority (LACMTA) has a fleet of more than 2,400 buses that travel over 90 million miles per year. The ongoing ambient air pollution problems in Los Angeles, combined with strict state emissions standards, spurred the LACMTA to upgrade nearly half of its bus fleet to Compressed Natural Gas (CNG). The CNG buses have a much better emissions profile than diesel buses for NO_x— a primary contributor to smog—emitting an estimated 12.1 grams per mile as compared to diesel's 18.6 grams per mile. The CNG buses perform significantly better for PM 2.5 as well, at 0.9 grams per mile vs. 1.5 grams per mile for diesel. For greenhouse gases, Los Angeles' CNG buses also offer a less dramatic, though important, emissions benefit per mile of 16 percent over the diesel portion of its fleet.

Table 2.5: Los Angeles County Metropolitan Transit Authority 2002

	Pounds of Pollutant Emitted per Year				
Mode	**CO_2**	**VOC**	**NO_X**	**CO**	**$PM_{2.5}$**
Bus	835,282,236	160,089	3,276,117	1,005,816	254,695
Light Rail	9,787,135	--	--	--	--
Heavy Rail	22,586,060	--	--	--	--
Totals	**867,655,431**	**160,089**	**3,276,117**	**1,005,816**	**254,695**

[i] Beardsley, M., U.S. Environmental Protection Agency, Office of Transportation and Air Quality. *MOVES Update.* Online version at www.epa.gov/otaq/models/ngm/may04/crc0304u.pdf.

[ii] U.S. Environmental Protection Agency, *Guide on Federal and State Summer RVP Standards for Conventional Gasoline Only.* Online version available at http://www.epa.gov/otaq/regs/fuels/b03002.pdf.

[iii] U.S. Environmental Protection Agency. Office of Mobile Sources. *Update of Fleet Characterization Data for Use in Mobile 6, Final Report*, June 1998. Online version at www.epa.gov/otaq/models/mobile6/m6flt002.pdf.

[iv] U.S. Environmental Protection Agency. *Sensitivity Analysis of Mobile 6.0*, December 2002. Online version at www.epa.gov/otaq/models/mobile6/m6tech.htm.

[v] U.S. Environmental Protection Agency. *Sensitivity Analysis of Mobile 6.0*, December 2002. Online version at www.epa.gov/otaq/models/mobile6/rel-hum1.xls.

[vi] U.S. Environmental Protection Agency. Office of Mobile Sources. *Emissions Factors for Locomotives,* December 1997; *Final Emissions Standards for Locomotives*, December 1997; *Applicability of Locomotive Emissions Standards,* September 1999; and *Locomotive Emissions Standards/Regulatory Support Document*, April 1998. Online versions at yosemite.epa.gov/ncepihom/nsCatalog.nsf/0/e664225640c976af85256ea20064b069?OpenDocument; yosemite.epa.gov/ncepihom/nsCatalog.nsf/0/c6acad113d8b2ef585256ea20064be2e?OpenDocument; and www.epa.gov/otaq/regs/nonroad/locomotv/frm/locorsd.pdf.

[vii] U.S. Environmental Protection Agency. Office of Mobile Sources. *Locomotive Emissions Standards/Regulatory Support Document*, April 1998. Online version at www.epa.gov/otaq/regs/nonroad/locomotv/frm/locorsd.pdf.

[viii] U.S. Environmental Protection Agency. Office of Mobile Sources. Emissions Factors for Locomotives, December 1997; Final Emissions Standards for Locomotives, December 1997; Applicability of Locomotive Emissions Standards, September 1999; and Locomotive Emissions Standards/Regulatory Support Document, April 1998. Online versions at yosemite.epa.gov/ncepihom/nsCatalog.nsf/0/e664225640c976af85256ea20064b069?OpenDocument; yosemite.epa.gov/ncepihom/nsCatalog.nsf/0/c6acad113d8b2ef585256ea20064be2e?

CHAPTER THREE

TASK TWO: EMISSIONS AVOIDED MODULE

INTRODUCTION

As was discussed earlier in this report, replacing personal vehicle use with transit trips provides an immediate and significant strategy for reducing transportation greenhouse gas and criteria air pollutant emissions. To quantify the benefit of transit, the *TravelMatters* Transit Planning calculator reports the emissions avoided by transit riders and allows transit professionals to estimate the net emissions benefit of increasing transit ridership.

Transit agencies may be able to use the estimates of the emissions avoided by transit ridership provided by the Transit Planning calculator in promotional campaigns to influence environmental and public health conscious consumers to use transit. While most travelers may know that a personal vehicle produces more pollution per person than a bus or train, the extent of these emissions benefits may not be well understood. Transit agencies are encouraged to use the emissions data compiled for TCRP H-21 and H-21A in literature, transit vehicle ads, as part of ozone action day promotions, and to augment other forms of public outreach, such as to outreach to gain support for transit expansion plans in neighborhoods which stand to benefit from the reduced emissions and improved air quality.

To help transit agencies make use of avoided emissions data, CNT developed an application, the Emissions Avoided Module (EAM), which can be used on transit trip planning websites. The EAM allows individuals and transit agencies to determine the amount of carbon dioxide (CO_2) avoided by taking transit instead of driving a personal vehicle. The module allows travelers to consider consequent emissions resulting from personal travel decisions, while allowing transit agencies to demonstrate how a given transit trip decreases emissions compared to the personal automobile.

EAM TECHNICAL DESCRIPTION

The EAM is provided as a web service to allow transit agencies to integrate EAM results directly into itinerary planning web pages without hosting the application on their own servers. Web services allow developers to share data over the Internet in a controlled and predictable way. For instance, it obviates the need to expose an internal database which may be protected by a firewall or other protective mechanism. The EAM web service uses the XML-RPC protocol, one of the two most common formats for providing web services through the Hyper Text Transfer Protocol (HTTP), the underlying protocol used by the World Wide Web. XML-RPC—and web services in general—allow developers to present a platform-neutral interface to their applications over the Internet. Another developer can then access that application and the data it provides without using the same

programming language in the original application. This can be easily achieved, as XML-RPC interfaces are now available for most common programming languages.

The EAM resides on the CNT web servers, and web developers for transit agencies interact with it over the Internet via XML-RPC. From the transit agency, the EAM receives the length in miles of a transit trip itinerary as input data. Specifically, EAM receives an array of data for which input elements are the individual legs of the total trip, if applicable. For instance, a total trip of 12 miles may include a leg of nine miles on a subway and three miles on a bus. The EAM identifies the transit agency by its National Transit Database ID (NTDID), passed to the EAM as part of the input. The NTDID is used to query the *TravelMatters* database for the emissions profiles of the vehicles that comprise the transit agency's fleet. By knowing the emissions profiles of the different modes and the trip length, the EAM is able to calculate the amount of CO_2 generated in pounds for the length of that transit trip. This calculation uses the same methodology as the *TravelMatters'* Transit Planning calculator to determine greenhouse gas emissions. *TravelMatters* currently computes emission averages using data from the FTA NTD, and national statistics data culled from the American Public Transportation Association for average occupancy rates.

For comparison, the EAM also calculates the CO_2 generated by an equivalent length trip if taken by an average car and sport utility vehicle (SUV). These three emissions amounts —transit, car, SUV—are packaged for output as an array of values and returned to the transit agency website that initiated the calculation. The values are then available directly as native variables in the transit agency's application, and can easily be passed on for formatting and output on the trip itinerary web page to be viewed by the end user.

The benefit of the EAM as a web service is that it is replicable; CNT can provide this service to any transit agency that offers a trip itinerary planner. A transit agency need only know their NTDID (CNT provides a link for those agencies that do not know), the Universal Resource Locater (URL) for the web service and the trip lengths and modes from the trip itinerary service. A step-by-step "How To" web page on the *Travel Matters* site details the process for transit agency developers, both novice and experienced, for connecting to the EAM service.

Please see Appendices H and I to view an example of the EAM and a script explaining how a transit agency could add the module to a trip planning site.

CHAPTER FOUR

TASK THREE: LEARNING CENTER

INTRODUCTION

Most people are unaware of the amount of carbon dioxide ($CO_{2)}$ they cause to be emitted into the atmosphere as a result of their transportation choices. The *TravelMatters* calculators are intended to fill this gap in awareness by educating people about the greenhouse gases generated in the course of their daily travel, and encouraging them to shift to lower-emissions modes. The Individual Emissions calculator delves more deeply into transportation emissions—and the consequent effects of those emissions, such as on climate change— than other CO_2 calculators that are currently available on the web.

The Individual Emissions calculator is a standalone tool that can be used by anyone. The *TravelMatters'* Learning Center, however, is designed specifically for teachers and students. It makes the content and interactive features of the individual calculator more accessible to a younger audience and provides activities for teachers with which to engage their students. Also available on the *TravelMatters* site is easily-accessible research content on alternative fuels, the science of climate change, and the significance of pollutants and the affect on air quality. Embedded in the research text are hyperlinks to other relevant topics. Students can follow the links to learn more about the science and social issues surrounding the operation and use of the public transportation sector. Within the context of the Learning Center, the Individual Emissions calculator promotes critical thinking and helps young people recognize how their local actions affect climate change. In doing so, it underscores how every effort is significant in reducing climate change. Together with the supporting on-line educational and teacher resource content, *TravelMatters* encourages the re-thinking of individual travel choices. By informing youth's decisions concerning transit system choices, the overall greenhouse gas contribution of the transportation sector can be reduced.

By registering with the website, students create trackable emissions profiles which can be saved on a monthly basis and then reviewed and compared over time. Such a feature encourages students—or an entire class—to set goals and track their progress towards reducing emissions. Thus, the components of the website inform individuals on an on-going basis about climate change and the importance of reducing greenhouse gases. In addition, the results allow students to learn about personal emissions generated by daily travel and provide practical solutions for reducing emissions.

ON-LINE ACTIVITIES AND RESOURCES FOR STUDENTS AND TEACHERS

The Learning Center is intended to support students' engagement with the calculator and experimentation with the amount of emissions released when taking different modes of transportation. It is also meant to supplement teachers' curriculums on climate change by providing interactive comprehension questions, a travel log, classroom activities, a presentation on transportation and climate change, and additional web and literature resources.

There are two sections of the Learning Center: "Activities for Students" and "Tools for Teachers." The former section guides students through the *TravelMatters* site and reinforces knowledge gained from using the Individual Emissions calculator, interacting with the emissions maps, and reviewing the climate change research. The latter provides teachers with additional tools to supplement their lessons on environmental quality and climate change. The resources and activities are meant to engage junior high and high school students in the classroom, and after school programs. At the same time, the activities available on the site have been designed to be used for individual learning. That is, using the Individual Emissions calculator in tandem with the Learning Center can be done without the necessary guidance of teacher instruction. The research material on the site is an important resource for research projects, and it is written in a language that is comprehensible to youth.

All of the on-line components of the student and teacher materials can be downloaded and printed if computer access is unavailable. However, the educational activities of the Learning Center are meant to be used in tandem with the on-line emissions calculator, emissions maps and climate change text. Learning Center content assumes that students have accessed the *TravelMatters* site and used the Individual Emissions calculator. Divided into two sections, the *Learning Center* offers activities that can be accessed via the Student or Teacher page, with several of the same activities linked to both pages for quick and easy access. Educational components consist of the following activities:

- Interactive Travel Log
- Interactive Comprehension Questions
- Interactive Quizzes (three quizzes consisting each of various levels of difficulty)
- Resource List
- Classroom Activities
- PowerPoint on Transportation and Climate Change

The first three activities above are interactive, allowing students to complete their answers on-line, print, and save their work in their individual profiles.

Travel Log and Comprehension Questions

In the Learning Center, a Travel Log section and a Comprehension Questions section were developed as components of the youth site, written primarily for an audience between the ages of twelve and eighteen. The Travel Log is a student exercise meant to be completed before the Individual Emissions calculator is used. The Log helps students think more critically about their daily travel decisions and also serves as a place to collect and aggregate travel data so that it can be entered into the Individual Emissions calculator with greater ease.

The objective of the Comprehension Questions section is to help students better understand the connection between climate change and everyday travel decisions. The questions guide the student through the *TravelMatter's* Individual Emissions calculator. Please see Appendices J and K for screenshots of the Travel Log and Comprehension Questions sections.

Interactive Quizzes

The *Learning Center* provides four interactive quizzes of various difficulties:

- The "True/False" quizzes are interactive in that the correct answer pops up each time the user answers a question, and each answer is accompanied by an explanation or follow-up to the question.
- The "Primer" quiz introduces students to the basic link between transportation and climate change, preparing students for the more specific discussions and educational content included in the *TravelMatters* site. The Primer Quiz can be taken as an introduction to the Individual Emissions calculator.
- The "Intermediate" and "Advanced" level quizzes allow students to test their new climate change and transportation knowledge.

Please see Appendix L for a screenshot of the online Beginner Quiz.

Resource List

The Resource List is relevant to both students and teachers. For students, the resources provide additional information that can supplement reasearch projects, especially those covering topics such as transportation's impact on climate change, alternative fuels, and smart growth. For teachers, the Resource List provides teaching aids for integrating climate change into classroom curricula; links are available to websites that offer background information, additional lesson plans, and relevant video and book resources.

Classroom Activities

The Classroom Activities section provides a list of independent and group projects that encourage and integrate the use of the emissions calculator. It supplements the calculator

activity, encouraging students to reflect on its design and methodology; expands the concepts in the science discussion on climate change; and encourages group responses and problem solving. For example, in one activity, Planning for Public Transportation, students use role-playing to develop strategies for sustainable growth and development that reduce emissions, create more efficient and friendly transportation, and minimize the costs associated with driving.

PowerPoint

The PowerPoint introduces students to the connections between transportation and climate change, and is meant to supplement a multi-day lesson on climate change and ambient pollution and help explain the impacts that transportation choices have on climate. The PowerPoint includes information on new vehicle technologies and alternative fuels. The PowerPoint is also replete with educator speaking and discussion notes that can augment classroom lesson plans. Suggestions help teachers integrate the PowerPoint lecture into any educational climate change module. Individuals other than teachers can also use the presentation as an education resource tool.

OBJECTIVES OF ON-LINE LEARNING CENTER

Ultimately, *TravelMatters,* with the Learning Center as a component of it, provides a framework for bringing transportation issues into the forefront of youth consciousness and underscoring how every effort is significant in mitigating climate change. It challenges students to think critically about their family's travel decisions and their own travel decisions, and how different decisions could curb the process of climate change. It does this by helping youth analyze the connections between fuels, technologies, and transportation, and the different levels of environmental consequences associated with each factor.

Specifically, the Learning Center was designed to meet the following objectives:

1. Focus students' attention as they make their way through the site and create the conditions by which they can *experiment* with the amount of CO_2 emissions generated from taking different modes of transportation.
2. Invite students to test their knowledge about basic elements of climate change. This is done through the exploration of the cause and effect of students' actions on greenhouse gas emissions gained from information included in the site. For example, students can learn about alternative energy, a discussion meant to encourage thinking outside the "conventional fuel" box, while also teaching about feasible alternatives to everyday travel choices.
3. Catalyze guided interaction amongst students to share their learning about climate change and about how their own decisions can have a direct impact on their local environment and beyond.

CLIMATE CHANGE WORKSHOP AND FOCUS GROUP

In the fall of 2003, a Climate Change workshop for Chicago teachers was co-facilitated by CNT in collaboration with the Peggy Notebaert Nature Museum. By using the *TravelMatters* site and individual emissions calculator as an activity and resource tool during the workshop, CNT introduced *TravelMatters* to Chicago educators and highlighted additional features and objectives of the *Learning Center*.

During the workshop, teachers were asked to evaluate the Comprehension Questions section, an essential component of the Learning Center that students would use to make their way through the *TravelMatters* site. Workshop attendees were given additional "evaluation questions" to help them assess the language and relevancy of the Comprehension Questions for student use. Teachers completed evaluation forms that elicited suggestions for how the Comprehension Questions could be altered or improved given current learning standards and student needs.

Because there were two weeks separating the two days of the workshop, teachers were given homework assignments at the end of the first day in the form of the Travel Log. Using the Travel Log, teachers were asked to record their travel behavior for one week. After recording the total mileage and modes used in the Log, teachers were able to more easily enter their travel data into the calculator on the second day of the workshop. A revised version of the Travel Log is now an on-line component of the Learning Center.

In addition to learning about the linkages between climate and transportation, teachers who attended the workshop acted as a focus group that tested the comprehensiveness and relevancy of the *TravelMatters* site. Through group exercises and general discussion about climate change and the use of *TravelMatters* as a tool to teach climate change, teachers provided feedback on how the student exercises then under development could be enhanced and made relevant to current topics being taught in the classroom.

Throughout the two-day workshop, a working dialogue produced feedback and input on best practices for presenting on-line activity materials, from the perspectives of the educators. The Learning Center was developed to meet the current goals of educators wanting to teach climate change while making connections to everyday, local activities that contribute to its occurrence.

PARTNERSHIPS AND FEEDBACK

In addition to holding the workshop in the early design phase of the educational materials, CNT sought collaboration with both other professionals who have experience in working with educational curricula and with actual teachers and their students. One of our collaborators was Leanne Jablonski, PhD., director of the Marianist Environmental Education Center and ecologist specializing in climate change. The Environmental Center is located in Dayton, Ohio and is affiliated with the University of Dayton. Ms.

Jablonski has written a curriculum guide to supplement the Union of Concerned Scientists' (UCS) *Climate Change in the Great Lakes Region*, due out in fall 2004. Discussions centered on how the youth portion of the *TravelMatters* site and associated activities could be incorporated into the UCS curriculum guide. This partnership helped shape the approach to and content for the design and creation of the youth site. Meetings with Ms. Jablonski also helped to identify many relevant on-line research resources that are used in current curriculum development on climate change.[i]

The process of completing the content of the youth site was aided by continued outreach and feedback from high school students and educators in both Chicago and Hayward, California. A student volunteer from Evanston Township High School spent a day at CNT testing and using the site, and responding to the educational materials that had just been completed. After testing the site, she interviewed five high school students using a standard questionnaire similar in form to the one used for educators at the teacher's Climate Change Workshop. Some of the students' responses were used to make helpful additions and alterations to the on-line materials.

After completing a draft of the educational materials, CNT engaged math and science teachers in the peer-editing review process during a winter conference hosted by the Chicago Teacher's Federation. Using information packets that introduced *TravelMatters* and the first phase of the nascent Learning Center, teachers were invited to use *TravelMatters* as a resource tool in their classrooms.

In the spring, when the Learning Center component of the site was near completion, activity packets consisting of its on-line content were provided as a print-form supplement to the *Sustainable Transportation Workbook* created by the Mineta Institute for the "National Garrett Morgan Sustainable Transportation for the 21st Century Program" that commenced in mid-March. Some of the teachers participating in that program requested additional information and *TravelMatters* workbooks were sent to Meadows Elementary in San Jose, California; Leonardtown High in Leonardtown, Maryland; and Argyle Middle School in Silver Spring, Maryland. In preparation for the symposium and videoconference on March 23, 2004, sponsoring organizations including the American Public Transportation Association, American Association of State Highway and Transportation Officials, and the Mineta Institute worked with participating classes on project development. After the videoconference took place, the Mineta Institute did not engage in specific follow up on the curriculum or the use of the *TravelMatters* educational supplements. However, now that the completed version of the *TravelMatters'* Learning Center is on-line, it can be incorporated into the workbooks for next year's symposium and videoconference.

[i] Jablonski, L., Director, Marianist Environmental Education Center, personal communication, September 18 and 23, 2003.

CHAPTER FIVE

CONCLUSIONS AND SUGGESTED RESEARCH

Transit agencies play an important role in criteria pollutant emissions reduction strategies as regulated by the Clean Air Act. Transit is unique in that it is not only a regulated pollution source, but it is also used as an air pollution solution in communities around the country. As shown in TCRP Project H-21 and H-21A, wise transit operation, purchasing, and planning decisions can allow transit to serve as a climate change solution as well.

Future emissions regulations are likely to require greater emissions reductions by all sectors in the U.S. Transit agencies should see this trend as an opportunity to increase the profile of transit and its importance as a part of a healthy community. By seizing the potential—today—for emissions reductions through clean transit fleets and increased transit ridership as an alternative to personal vehicle travel, transit can benefit as the leading provider of sustainable transportation solutions tomorrow. During the course of this project, CNT has identified additional research opportunities that could help transit agencies achieve this goal.

DATA MINING

In developing the outreach for H-21 and H-21A, CNT discovered that much more analysis could be done of the data already assembled for both these projects to build further knowledge related to climate change and transportation. CNT's report, *Travel Matters: Mitigating Climate Change with Sustainable Surface Transportation*, provides an overview of existing climate change science and key strategies for reducing transportation emissions. Aside from the three case studies analyzed in Chapter Three of TCRP Report 93, however, CNT did not use the data to perform significant comparative analysis between transit agencies or trends analysis of the field. Analyzing the existing data and assessing the emissions trends among transit agencies could deepen the understanding of the link between transit emissions and successful mitigation methods. Examples of the topics that could be further studied using the existing data from project H-21 include:

- Variations in U.S. transit agency fleet emissions by regions.
- Correlations between transit agency fleet emissions per mile, fleet size and metropolitan area size.
- A thorough comparison of transit agency fleet greenhouse gas and criteria air pollutant emissions.

LAND USE AND EMISSIONS

Continued research is needed to further examine the links between transit emissions and land use. While studies have examined the emissions implications of land use and Transit Oriented Development (TOD) in a few localities, none have addressed this issue at stations nationwide.

Replacing vehicle trips with transit trips is an emissions reduction strategy with community benefits as well as revenue benefits for transit agencies. One way to increase ridership is through better land use around stations, as TOD practitioners and researchers are increasingly confirming. Transit agencies are beginning to understand the ridership benefits of TOD: "Transit agencies often take the lead on TOD projects because they own the land adjacent to their stations and view joint development as a way to increase ridership and generate revenue from ground leases."[i] Therefore, a logical next step is to link increases in ridership from TOD to decreases in emissions.

Some communities and transit agencies are already recognizing this important link between transit accessibility, ridership, and emissions reduction. For example, the City of Portland's "Local Action Plan on Global Warming" promotes increased access to transit to decrease local greenhouse gas emissions. As a result of service expansion and a concerted effort to increase transit access, local transit ridership increased 60 percent between 1990-2000.[ii]

DATA COLLECTION

Project H-21 and H-21A created the *TravelMatters* emissions calculator using many publicly available data sources, such as the NTD. Increased data collection would allow further analysis and lead to a deeper understanding of the factors affecting transit emissions. An expanded National Household Travel survey with a sample size that allows analysis on the local level, data on the transportation mode used to access transit stations by area, and a better understanding of trip chaining (where a traveler makes multiple stops on a single trip) are all examples of data that would improve the analysis of the emissions saved through increased transit ridership.

FUTURE STEPS

Much work remains to be done to realize the full range of sustainable benefits from transportation planning. As emissions modeling and other GIS tools grow more sophisticated, it is becoming possible to improve transit efficiency route by route to reduce emissions and improve travel times. Sophisticated mapping tools are already being used at companies to help employees plan their commutes, take advantage of transit alternatives, and reduce commuting emissions. *TravelMatters* adds to this growing toolkit of information systems with fleet-specific emissions data and modeling tools. CNT plans to continue to seek resources to enable their refinement and expansion.

[i] Dittmar, H. and G. Ohland, eds. The Transit-Oriented Development Drama and Its Actors. *The New Transit Town: Best Practices in Transit-Oriented Development.* Island Press. Washington, 2004, pp. 41-56.

[ii] City of Portland and Multnomah County, Office of Sustainable Development. *Local Action Plan on Global Warming*, April 2001. Online version at www.sustainableportland.org/Portland%20Global%20Warming%20Plan.pdf.

Appendix A: *TravelMatters.org* Homepage

Appendix B: Criteria Pollutants Descriptions

Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, odorless gas that is poisonous in high concentrations. CO is created from incomplete combustion of fossil fuels. When there is not enough oxygen present during combustion to form carbon dioxide (CO_2), CO is the result. Mobile sources account for 77 percent of CO emissions in the U.S. To help control CO emissions, regulators have begun requiring oxygenated fuels in the winter, when CO is more of a problem. The *TravelMatters* Transit Planning calculator reports the estimated CO emissions of transit agency vehicles.

Lead (Pb)

Lead (Pb) is a heavy, soft metal with a metallic blue hue. When inhaled or ingested, lead particles are toxic. Lead is a cumulative poison to the central nervous system and is particularly damaging to the mental development of young children. Lead emissions in the U.S. fell 93 percent from 1982 to 2002. Transportation was once the primary source of atmospheric lead pollution, but since leaded gasoline was banned, transportation lead emissions from on-road vehicles have been nearly eliminated. Therefore, lead emissions are not reported in the *TravelMatters* Transit Planning calculator.

Nitrogen Oxides (NO_x)

Nitrogen oxides comprise a family of highly reactive gases that includes nitrogen dioxide (NO_2), nitric oxide (NO), and nitrous oxide (N_2O). NO_2 is a lung irritant, a cause of acid rain, and a precursor to ground level ozone. The burning of fossil fuels, such as in motor vehicles or power plants, produces both NO and NO_2. Once in the atmosphere, NO reacts to form NO_2. While the NAAQS regulate NO_2 concentrations in the air, emissions regulations focus on controlling emissions of the entire NO_x family. CNT reports NO_x emissions in the *TravelMatters* Transit Planning calculator. The USEPA issued new limits on NO_x emissions for manufacturers of heavy-duty diesel engines, such as those used in many transit buses, beginning in 2007.

Ozone (O_3)

Ground level ozone is a key component of smog and can cause respiratory damage. The USEPA regulates ground level ozone pollution, which is formed through a set of chemical reactions in the air that can be generally described by the following equation:

$$VOC + NO_x + heat + sunlight = \text{ground level ozone } (O_3)^{i}$$

To control ozone pollution, the chemicals known as "Precursor Pollutants," which react in the air to create it, must be controlled. Therefore, the *TravelMatters* Transit Planning calculator reports volatile organic compound (VOC) and nitrogen oxide (NO_x) emissions. Ozone is not reported in *TravelMatters* because it is not directly emitted by transit vehicles

Particulate Matter (PM)
Particulate Matter (PM) can be either solid particles or liquid droplets. PM is measured in micrometers, with matter less than 10 micrometers in diameter posing the greatest health risk. Particles less then 2.5 micrometers in diameter are described as being "fine" particles. These particles are easily inhaled and can become lodged in the lungs and produce respiratory illness. PM greater then 2.5 micrometers in diameter is usually the result of smoke and dust from industry and agricultural production, while particles less then 2.5 generally come from combustion of fossil fuels, such as in vehicles. The *TravelMatters* Transit Planning calculator reports PM 2.5 emissions because these are the main components of vehicle particulate emissions.

The USEPA recently started regulating PM 2.5 in the atmosphere and is expected to designate those communities that are meeting the air quality standard for this pollutant in December 2004. Communities that do not meet the standard will be "out of attainment." This may impact transit agencies with diesel-fueled vehicles. In addition, the USEPA has issued new limits on PM 2.5 emissions for manufacturers of heavy-duty diesel engines, such as those used in many transit buses, beginning in 2007.

Sulfur Dioxide (SO_2)
Sulfur Dioxide (SO_2) belongs to a family of gases called sulfur oxides (SOx). SO_2 can cause respiratory and pulmonary difficulties. The gas can react with NO_x and other chemicals in the air to form acid rain. The USEPA's Mobile 6.2 emissions model does not calculate SO_2 emissions because SO_2 emanating from mobile sources are nominal. Roughly one-third of atmospheric sulfur compounds come from human-made sources.[ii] Of this one-third, only 5 percent of annual anthropogenic SO_2 emissions come from mobile sources.[iii] The USEPA mandated that the sulfur content of diesel fuel be reduced beginning in 2006.[iv] The *TravelMatters* Transit Planning calculator does not compute estimates for SO_2.

Volatile Organic Compounds (VOCs)
Volatile organic compounds, which are sometimes referred to as hydrocarbons (HC), are organic chemicals that, when released into the atmosphere, participate in photochemical reactions such as the reaction to create ground level ozone. VOCs can be emitted when unburned or partially burned fossil fuels are released as exhaust. They can also be emitted when fuel evaporates, including during refueling. Mobile sources account for about a quarter of VOC emissions in the US.[v] The *TravelMatters* Transit Planning calculator reports on VOC emissions from transit agency vehicles.

Appendix C: Summary of Clean Air Act Regulations Affecting Transit Agencies

Transit agencies are required to coordinate with state agencies for criteria pollutant emissions inventories and state transportation planning. Agencies also face emissions regulations on new transit vehicles, bus retrofits and fleet upgrades. Transit is an important part of many transportation control measures that encourage transit ridership and expand transit to improve air quality. This section briefly describes some of these air quality policies that impact transit agencies.

State Implementation Plans and Transit Agencies

The USEPA measures criteria pollutants at monitoring stations around the country, and if a metropolitan area has more pollution than regulations allow, the area is determined to be "out of attainment" for a given pollutant. Communities may also become out of attainment due to procedural violations of Clean Air Act regulations. States with communities that are out of attainment are required to create a State Implementation Plan (SIP), a federally enforceable plan detailing how a state's communities will meet the attainment level for the regulated pollutants. The USEPA has the power to impose penalties -- such as withholding federal transportation funds -- on states that do not meet the pollution regulations.

Depending on the severity of the community's pollution, the state is required to include specific measures in its SIP that can affect transit agencies. These measures can include an emissions inventory, for which a transit agency must report its fleet emissions; or a clean fuel program for fleets, which may require a transit agency to retrofit or replace vehicles.

SIPs can benefit transit agencies through Transportation Control Measures, which may include transit system or service expansion, operational improvements, or inducements to increase ridership. Encouraging transit ridership in place of driving through what the USEPA calls "Commuter Choice" programs can have a direct financial benefit for transit agencies. Commuter Choice programs are flexible employer commute benefit programs and include employer transit subsidies, pre-tax transit checks, and payment to employees for not using workplace parking.[vi]

The Clean Air Act requires that federally funded transportation projects "conform" to the SIPs. Therefore, the state must demonstrate that its Transportation Improvement Program (TIP) conforms to the SIP and will not adversely impact the attainment of regulated emissions levels in the area. [vii] This mandate to demonstrate conformity puts low emissions transit projects at a competitive advantage for acquiring funding over highway projects and other federally funded projects that are likely to increase VMT. However, a 1999 report to the USEPA and Federal Highway Administration (FHA) suggests that transportation and air quality conformity requirements have a greater impact on expanding existing transit service than on new large-scale transit investments in areas without robust transit systems.[viii]

Heavy Duty Diesel Regulations

Other aspects of the Clean Air Act regulations affecting transit agencies are restrictions on the amount of emissions emanating from on-road heavy-duty diesel engines. The newest regulations for on-road diesel engine emissions set limits on Particulate Matter (PM) and Nitrous Oxides (NOx) emissions and are to be phased in from 2007-2010. The USEPA recently announced off-road heavy duty diesel engine regulations that will affect new diesel trains and ferries beginning in 2008. These regulations are directed at the manufacturers of heavy duty diesel engines, but the stricter standards may influence the purchasing decisions of transit operators with diesel fleets, and are likely to increase the cost of new engines. In addition, because sulfur damages the new pollution control technology required on heavy duty diesel engines, the USEPA requires a reduction in the sulfur content of diesel fuel beginning in 2006. This may result in a fuel cost increase for transit agencies, but may also decrease maintenance costs. [ix]

Fleet Requirements

The Clean Air Act also requires owners of centrally-fueled fleets in metropolitan areas that are out of attainment and have populations over 250,000 to buy clean fuel vehicles as a percentage of the fleet.[x] Purchases of clean fuel vehicles in excess of the requirements or before the required date can generate credits, which can be included in the SIP to offset other emissions sources.

Urban Bus Retrofit Program

While urban buses emit a small percentage of overall transportation emissions, their emissions are specially regulated partly because their operation is concentrated in areas of high population density where the health impacts of pollutants can affect large numbers of people. Transit agencies in large metropolitan areas must meet emissions guidelines for buses made in 1993 or earlier. Since urban bus engines are rebuilt several times over the lifetime of the vehicle, upon rebuilding the pre-1993 models, the transit agency must either retrofit the bus to reduce its Particulate Matter (PM) emissions, or offset the PM emissions of the older buses with clean buses in its fleet through an averaging program. The transit agency may be fined for failing to meet these urban bus retrofit requirements.[xi]

Funding Opportunities

A number of funding sources have been created to help transit agencies meet air emissions regulations and take proactive steps to improve air quality. The Congestion Mitigation and Air Quality Improvement Program (CMAQ) was created under the Intermodal Surface Transportation Efficiency Act (ISTEA) and continued under the Transportation Equity Act for the 21st Century (TEA-21). It provides communities with funding for transportation projects that help meet the requirements of the Clean Air Act. Transit agencies may benefit from this program as it funds Transportation Control Measures that are directed at increasing ridership. CMAQ funds may be used by transit agencies to purchase alternative-fuel vehicles.[xii] The Federal Transit Agency also runs a Bus and Bus Facilities Capital Grant program to help transit agencies adopt alternative

fuels, purchase advanced bus technologies, and build the maintenance facilities needed to support them. These funding sources may provide transit agencies with the means to reduce greenhouse gas emissions while reducing criteria pollutant emissions.

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[i] U.S. Environmental Protection Agency. *Ground Level Ozone: What is it? Where does it come from?* May 2004. Online version at www.epa.gov/air/urbanair/ozone/what.html

[ii] Encyclopedia of the Atmospheric Environment. *Air Pollution Chemistry.* May 2004. Online version at www.ace.mmu.ac.uk/eae/Air_Quality/Older/Air_Pollution_Chemistry.html.

[iii] U.S. Environmental Protection Agency. *AirTrends*. May 2004. Online version at www.epa.gov/airtrends/sulfur2.html

[iv] U.S. Environmental Protection Agency. May 2004. Online version at www.epa.gov/otaq/regs/fuels/diesel/diesel.html.

[v] U.S. Environmental Protection Agency. Online version at www.epa.gov/otaq/invntory/overview/pollutants/hydrocarbons.htm.

[vi] U.S. Environmental Protection Agency, Office of Mobile Sources. *State Implementation Plan Development Guidance: Using Emission Reductions from Commuter Choice Programs to Meet Clean Air Act Requirements.* Online version at www.epa.gov/otaq/transp/comchoic/sipguide.pdf.

[vii] Mayer, S., *Implementing the Clean Air Act Amendments of 1990: Where Are We Now?* National Council for Science and the Environment, Environment and Natural Resources Policy Division. 1995. Online version at www.ncseonline.org/NLE/CRSreports/Air/air-9.cfm?&CFID=13870342&CFTOKEN=52089017

[viii] Howitt, A. and E. Moore, *Linking Transportation and Air Quality Planning: Implementation of the Transformation Conformity Regulations in 15 Non-Attainment Areas.* Harvard University, John F. Kennedy School of Government, Taubman Center for State and Local Government, 1999. Online version at www.epa.gov/otaq/transp/conform/fullrpt.pdf.

[ix] U.S. Environmental Protection Agency, Office of Mobile Sources. *Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements.* Online version at www.epa.gov/otaq/regs/hd2007/frm/f00057.pdf.

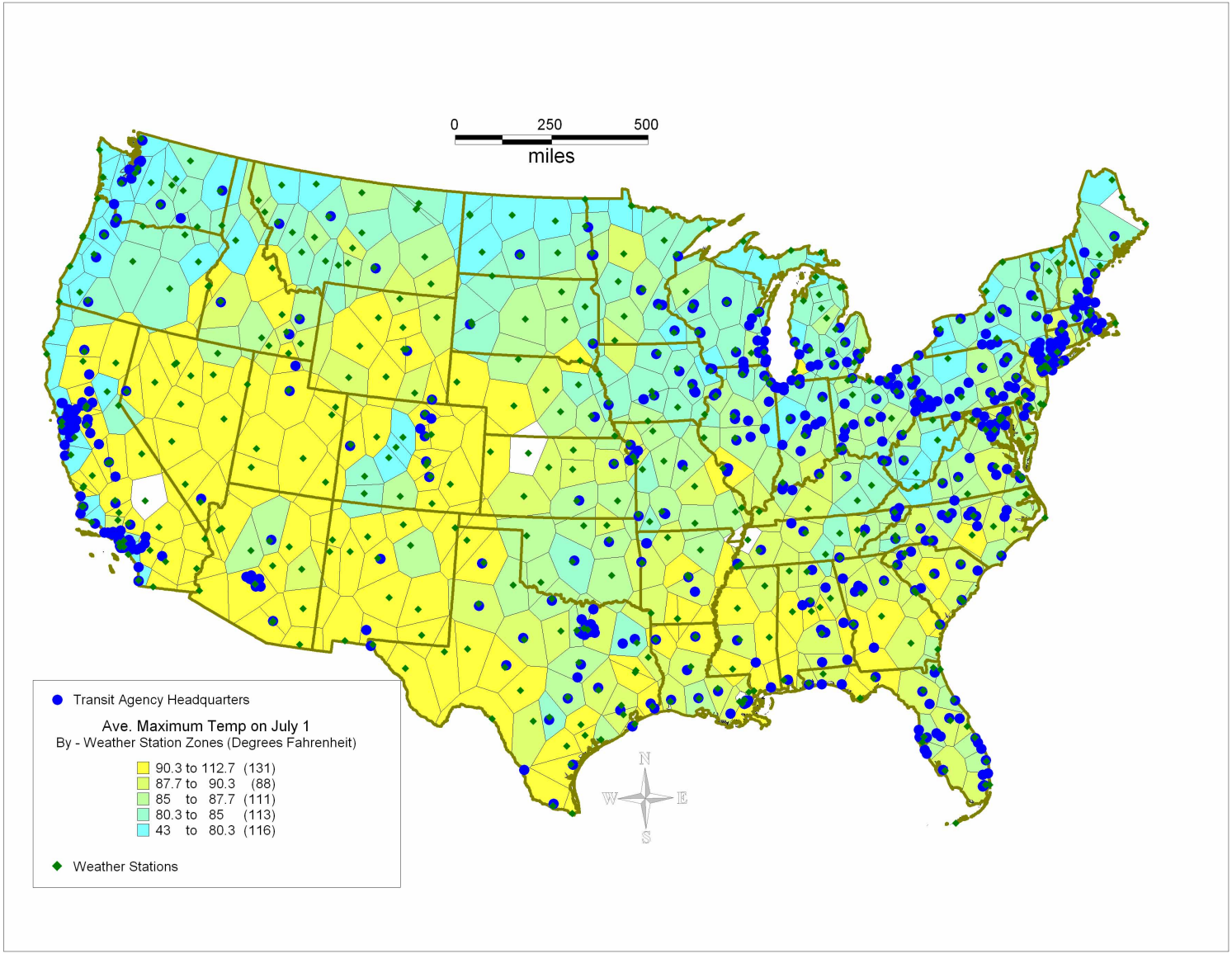
[x] U.S. Department of Energy. *Comparative Alternative Clean Fuel Provisions of the Clean Air Act and the Energy Policy Act.* On-line version at www.ott.doe.gov/pdfs/provisns.pdf.

Appendix D: Weather and Humidity Data

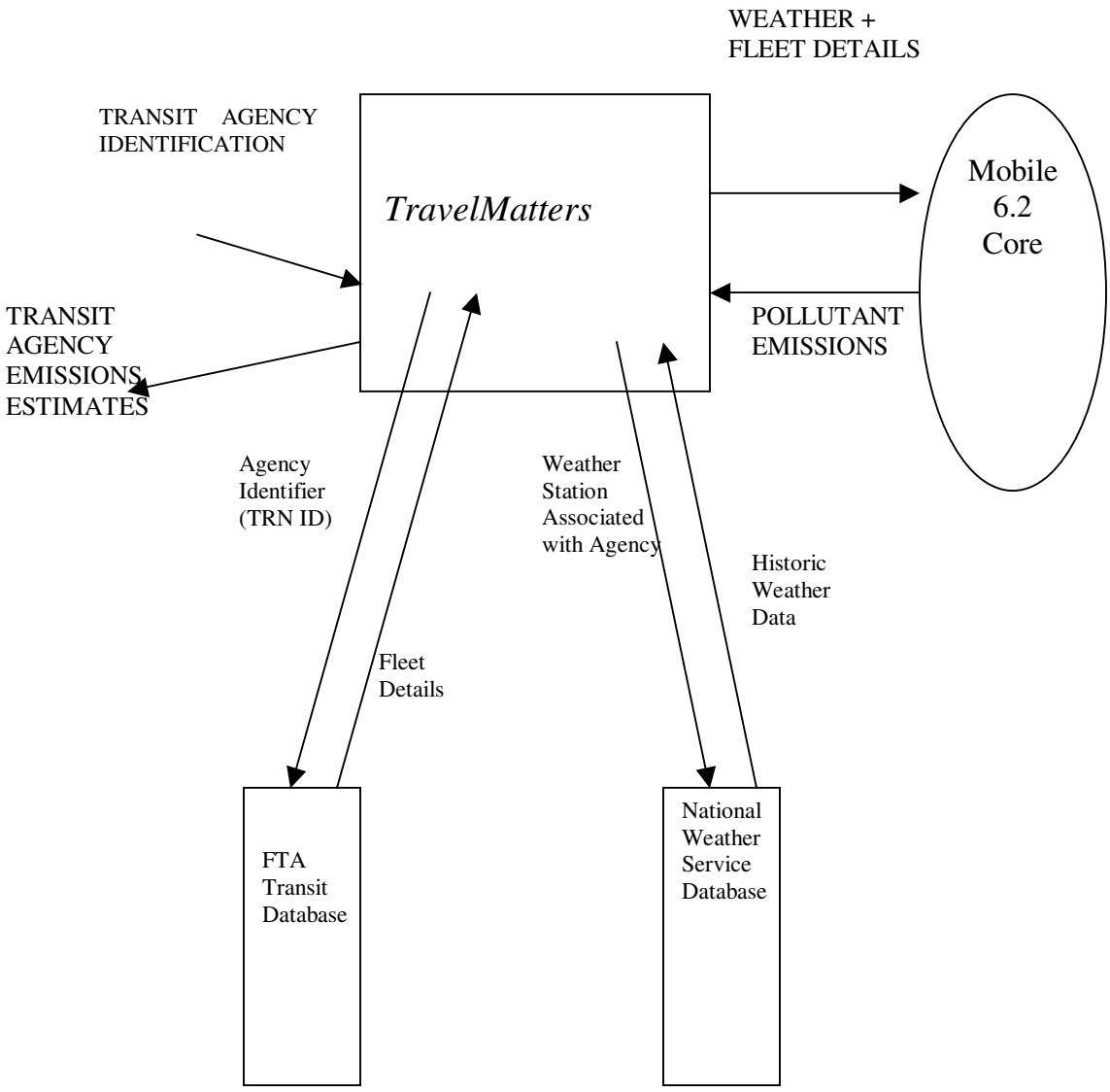
The USEPA's Mobile 6.2 emissions model requires input data for temperature and humidity. These parameters affect the operation of a fleet, which in turn affects the criteria outputs emitted. In order to assign a high temperature, low temperature and an absolute humidity to every transit agency, CNT obtained annual weather data from the National Oceanic and Atmospheric Administration (NOAA) for the years 2000 through 2002. NOAA measures weather variables per hour at weather stations across the U.S., including the latitude and the longitude of the weather stations. From this database, CNT averaged the relevant weather data (temperature and humidity) for July 1st from the three years worth of readings.

Using Geographic Information Systems (GIS), CNT's researchers assigned the weather data to each transit agency. Initially, a "Voronoi" polygon was created around each weather station (a "Voronoi" polygon is a partition of space into cells such that each cell is an area in which the contained points are closer to the enclosed site than to any others – MapInfo Help File Description.) CNT then took the transit agency's office zip code and assigned the center of the zip code as the agency's location. If a zip code was not listed, researchers used the city center instead. The researchers then determined which Voronoi polygons contained each agency location and assigned that weather station to the agency. In other words, CNT used a standard GIS technique to assign weather stations to transit agencies by finding the pair that is the closest together. This spatial analysis allowed the researchers to assign the highest and lowest temperature, relative humidity and barometric pressure to each agency. In cases where any of weather station variables were missing, researchers used variables from the next nearest weather station.

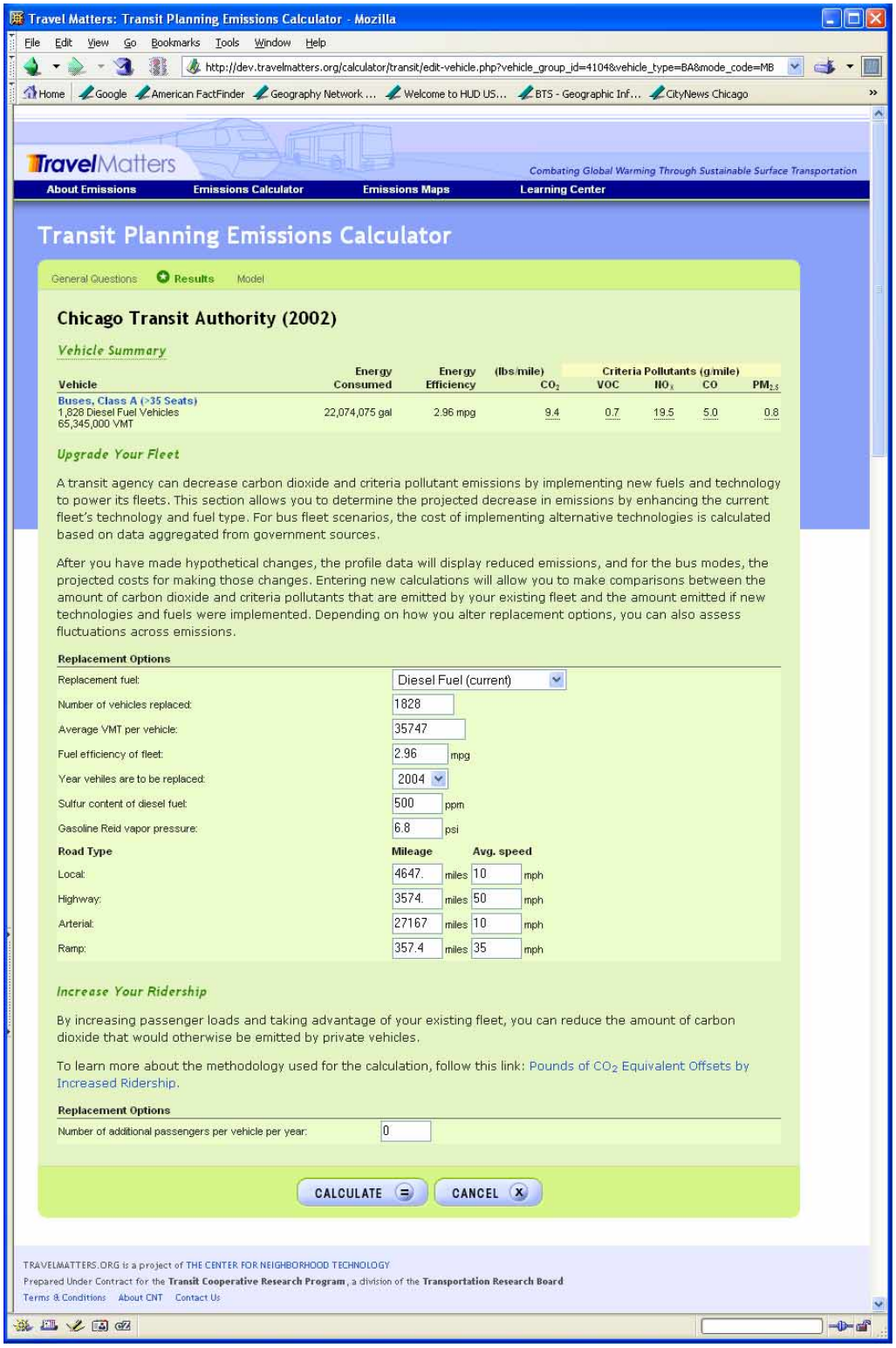
In order to calculate the absolute humidity from the relative humidity, CNT used an USEPA spreadsheet developed for this purpose. The temperature, barometric pressure and relative humidity variables for each station as described above were inputted into this spreadsheet. CNT then assigned an absolute humidity and high and low temperature for July 1 to each transit agency from these calculations.


0
250
500
miles
Transit Agency Headquarters
Ave. Maximum Temp on July 1
By - Weather Station Zones (Degrees Fahrenheit)
90.3 to 112.7 (131)
87.7 to 90.3 (88)
85 to 87.7 (111)
80.3 to 85 (113)
43 to 80.3 (116)
Weather Stations
N
W
E
S

Appendix E: Relationship between TravelMatters Emission Calculator, Mobile 6.2 Processing Core and External Databases



Appendix F: Improvement Example for Transit Planning Calculator: Input Parameters for Roadway Types



Appendix G: Electric Propulsion Transit Vehicle Indirect Emissions

Location	Vehicle Type	Fuel Type	CO2 lbs/mile	VOC g/mile	NOX g/mile	CO g/mile	PM2.5 g/mile	SO2 g/mile	Hg g/mile	PM 10 g/mile
Illinois	Heavy Rail	Electric	6.2	0.08	7.6	0.6	0.14	13.9	1.1E-04	0.24
New York	Heavy Rail	Electric	5.1	0.08	3.5	0.5	0.05	9.9	1.9E-05	0.09
California	Heavy Rail	Electric	3.5	0.06	1.3	0.4	0.02	0.4	9.4E-08	0.02
California	Light Rail	Electric	11.6	0.19	4.3	1.3	0.06	1.3	3.1E-07	0.07
California	Trolleybus	Electric	6.8	0.11	2.5	0.8	0.04	0.8	1.8E-07	0.04
California	Class A Bus	Diesel	11.5	0.60	18.6	4.7	1.50	NE	NE	NE
New York	Class A Bus	CNG	8.1	0.90	12.1	3.4	0.90	NE	NE	NE

Notes:

Electric vehicle indirect CO_2 emissions are calculated using statewide electric generation fuel mixes from USEPA's E-Grid Database and CO_2 emissions factors by fuel. Criteria pollutant calculations use state level emissions factors calculated for the Multiple Pollutant Emission Reduction Reporting System (MPERRS) from E-Grid and USEPA's National Emissions Trends database (see http://www.cleanerandgreener.org/download/efactors.pdf).

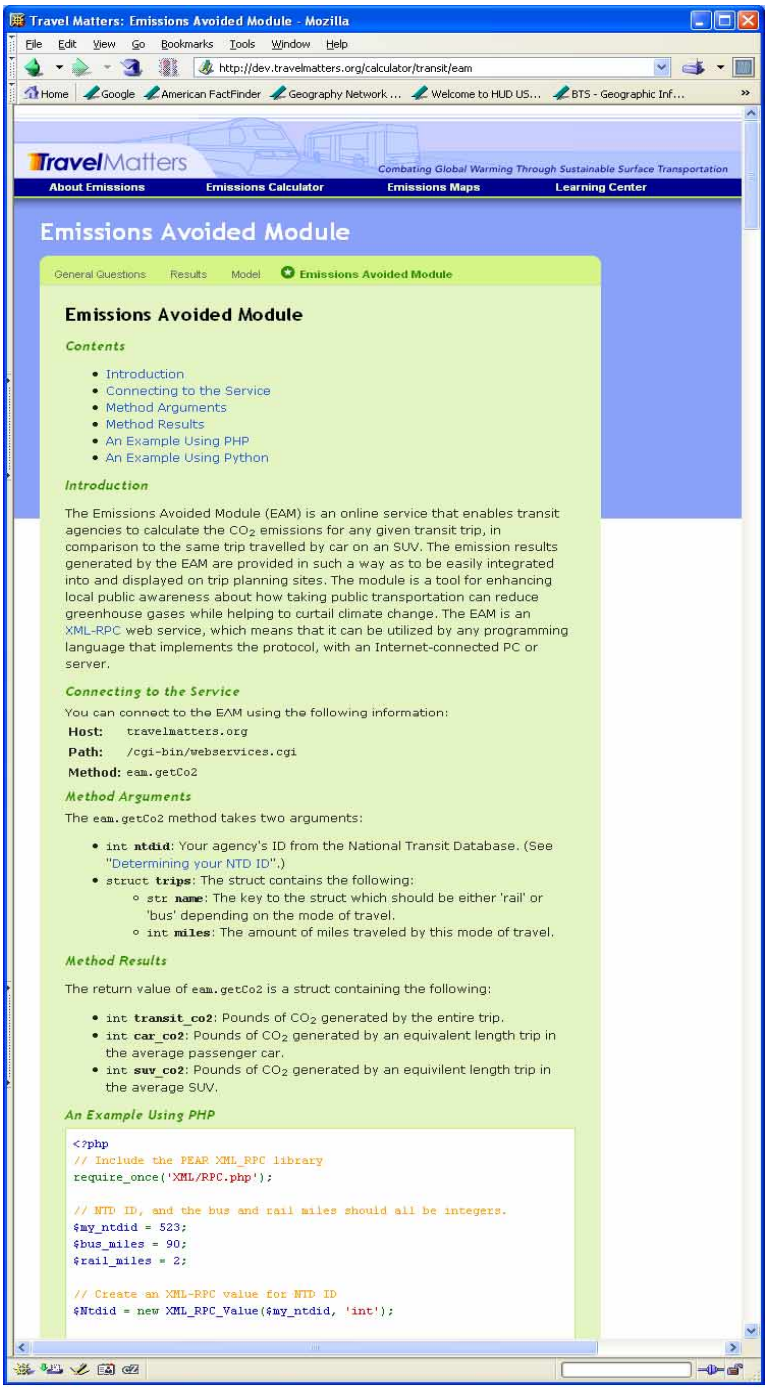
NE -- Not Estimated

CNG -- Compressed Natural Gas

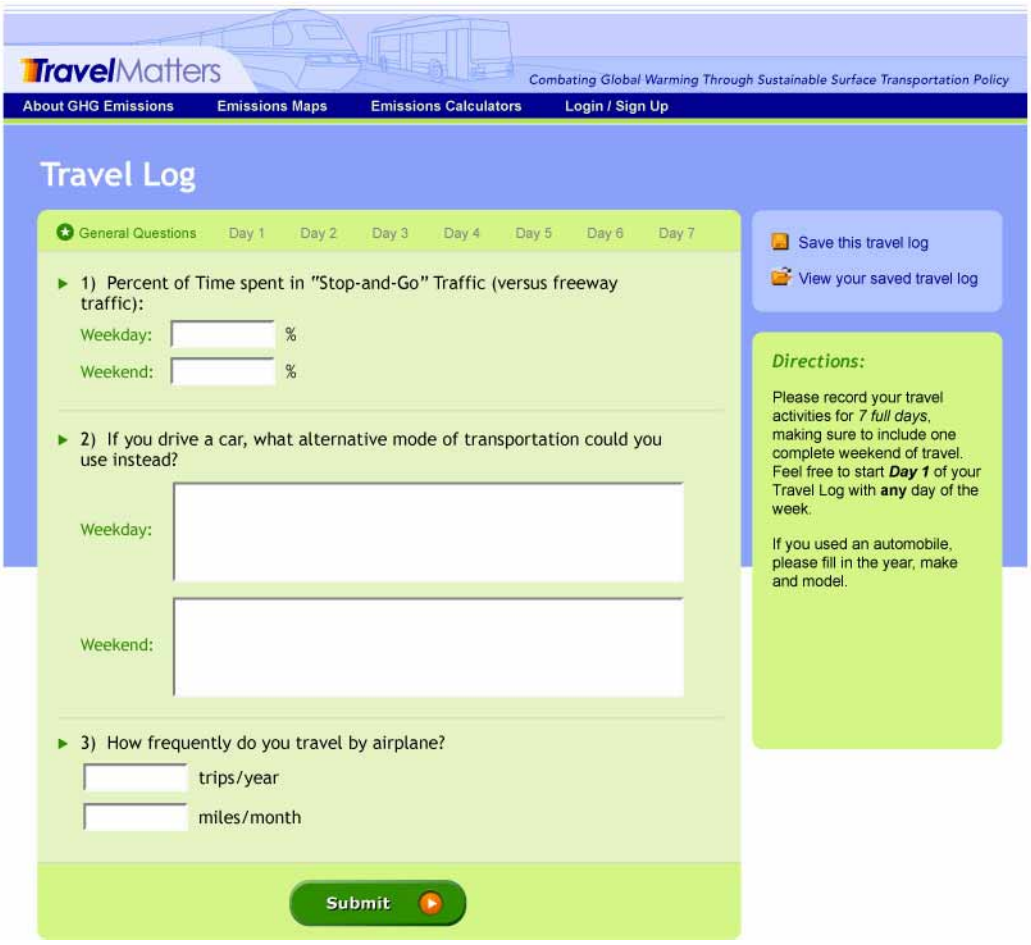
Appendix H: Example of How Result of Emissions Avoided Module Could be Displayed on a Trip Planning Site

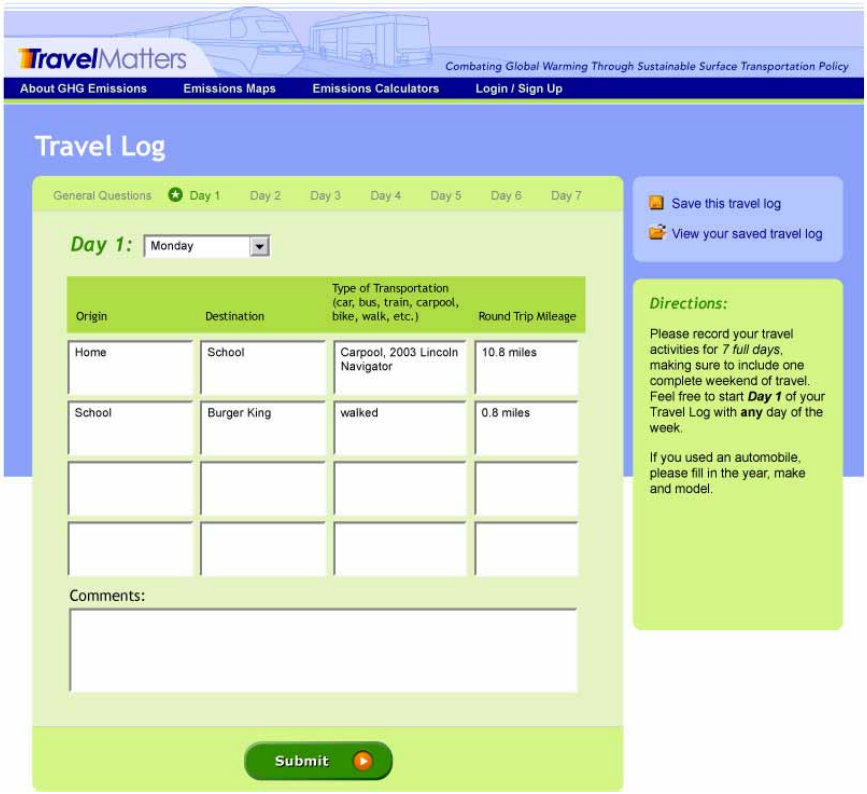
	Walk 0.1 mile E from 2125 W NORTH AVE to DAMEN CTA (BLUE – O'HARE)		
	Take CTA BLUE LINE TRAIN (TO FOREST PARK)		
	DEPART:	DAMEN: CTA	At 01:43 PM
	ARRIVE:	JACKSON/DEARBORN CTA	At 01:56 PM
	Walk 0.2 mile W to 175 W JACKSON BLVD		
	By taking this transit route, you save **3.6 pounds** of CO_2 emissions		

Appendix I: "How To" Language for Emissions Avoided Module

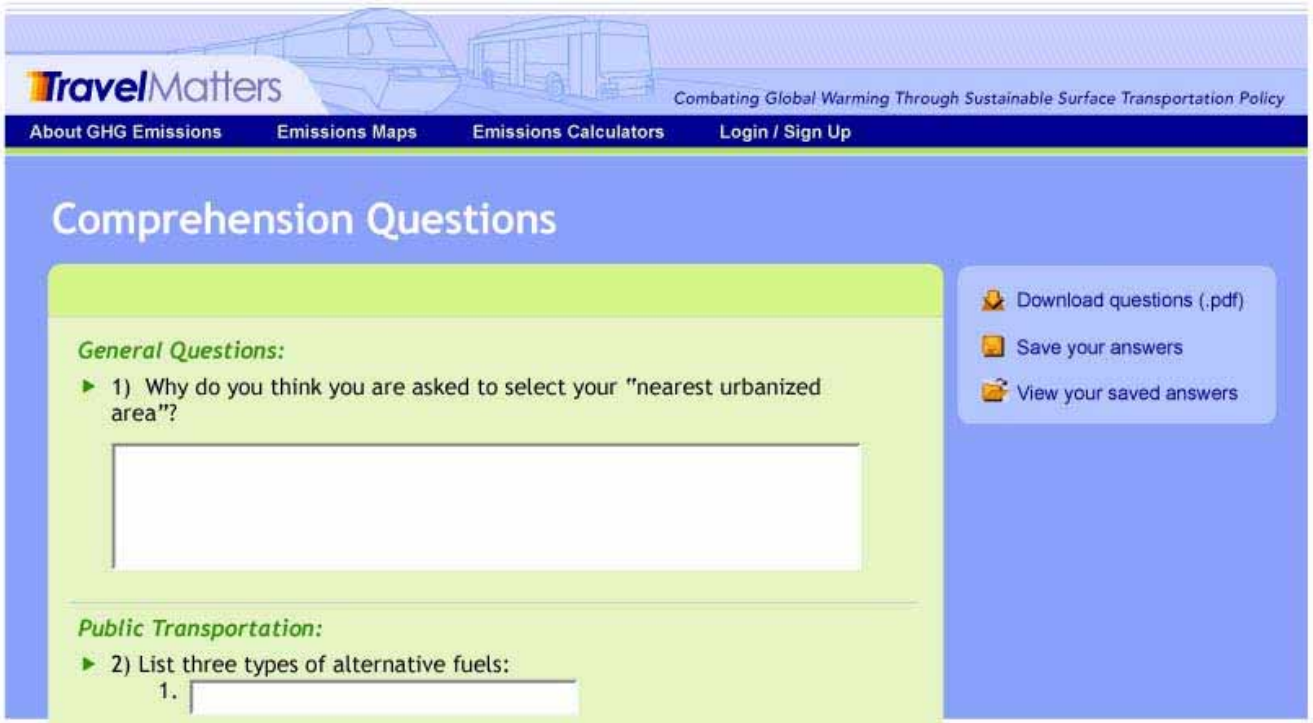


Appendix J: *TravelMatters* Learning Center, Travel Log





Appendix K: *TravelMatters* Learning Center, Comprehension Questions



Appendix L: *TravelMatters* Learning Center, Interactive *Beginner* Quiz