Software User's Guide: URBEMIS2002 for Windows with Enhanced Construction Module

Version 8.7
Emissions Estimation for
Land Use Development Projects

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The primary URBEMIS2002 (version 8.7) improvement is a major upgrade to the operational on-road mitigation measures. Adam Millard-Ball and Patrick Seigman of Nelson\Nygaard Consulting Associates developed the revised mitigation measures. A peer review process was used to evaluate and provide comment on Nelson\Nygaard's proposed approach. The peer reviewers of Nelson\Nygaard's on-road mitigation measures included the individuals listed in the previous paragraph along with:

- Ron Milam and Richard W. Lee, Ph.D., AICP – Fehr and Peers Associates,
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Based on comments received from the peer reviewers during several meetings, Nelson\Nygaard prepared a revised methodology that has been incorporated into URBEMIS2002, version 8.7, and that is described in Appendix D of this User's Guide.

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I. INTRODUCTION

URBEMIS2002 for Windows version 8.7, like its predecessors, is designed to estimate air emissions from land use development projects. The earliest versions of URBEMIS (URBEMIS versions 1 through 5) were designed to estimate only motor vehicle emissions from trips generated by land use development. URBEMIS2002 for DOS was enhanced to enable users to estimate construction and area-source emissions and to select mitigation measures for construction emissions, area sources, and motor vehicle trips. URBEMIS 2002 for Windows 5.1.0, which followed version URBEMIS2002 for DOS, was written to run in the Windows 95/98 environment. URBEMIS2001 for Windows 6.2.2, released in early 2001, allowed users to estimate motor vehicle emissions using the California Air Resources Board's EMFAC2001 emissions model (version 2.08).

The two major differences between URBEMIS2001 version 6.2.2. and URBEMIS2002, version 7.5, were that version 7.5 had an enhanced construction emissions module and used EMFAC2002, version 2.2 emission rates. The major enhancements of EMFAC2002 version 8.7 as compared to previous versions of EMFAC2002 include improvements to the area source emissions module, and to the area and operational mitigation measures.

The flowchart shown on the following page (Figure 1) provides a conceptual overview of URBEMIS2002. Once the URBEMIS2002 program has been initiated, the user must first either select an existing project or start a new one. For new projects, the air district in which the project is located must be selected. Then, the user typically goes to the land uses module to enter land use information relevant to his project. Once land use information has been entered, the user must select the relevant construction, area, and operational assumptions that apply to the project. Mitigation measures can also be selected as applicable. Once all information has been selected for a project, the user clicks the results button to obtain the emission estimates. After reviewing the results, the user can either save the project or go back and edit the land use or construction/area/operational module assumptions for the project.

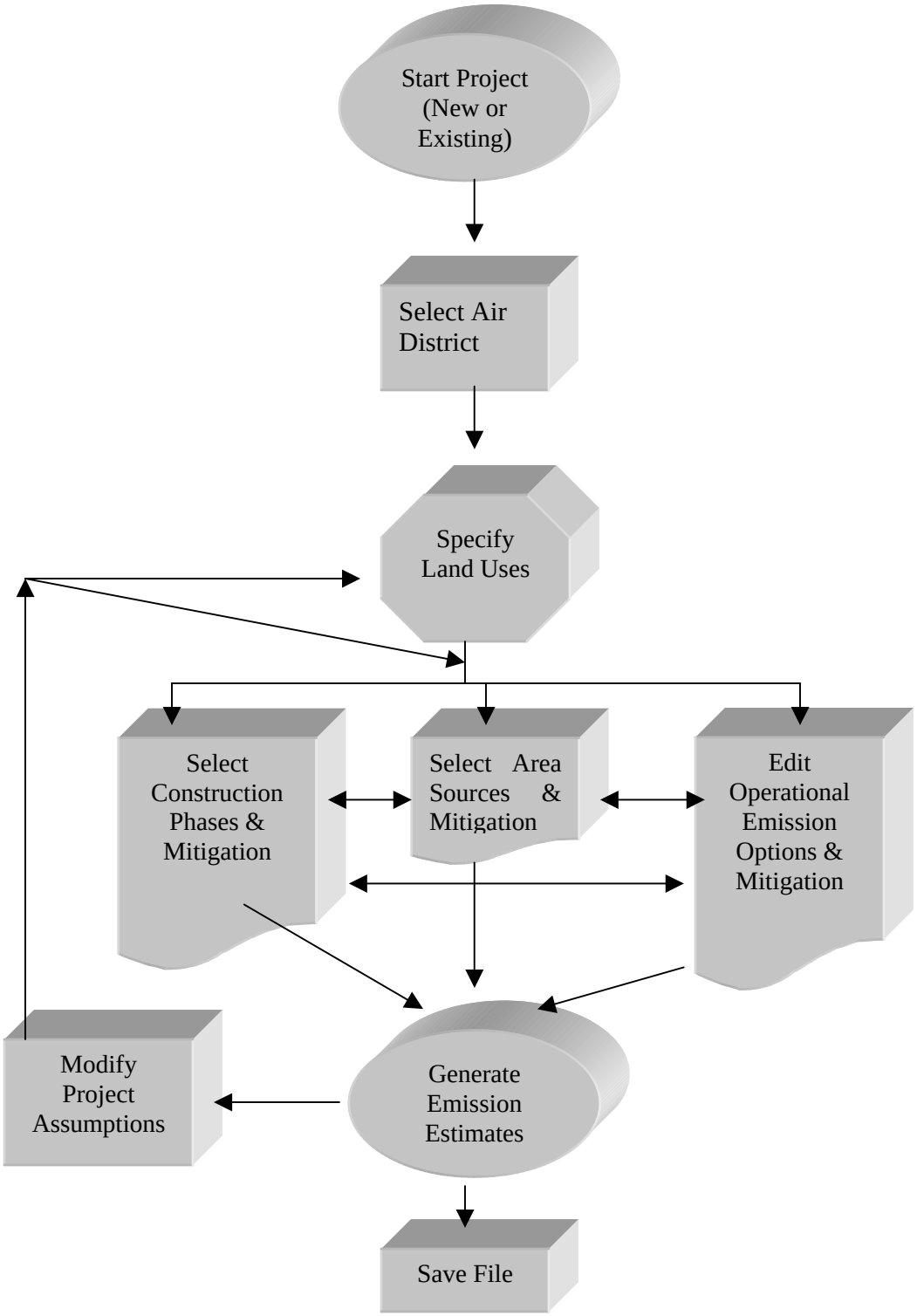

Figure 1. URBEMIS2002 Conceptual Flow Chart

II. GETTING STARTED

II.1 Memory Requirements

URBEMIS2002 is written in Microsoft Visual Basic for Windows, version 6.0. Unlike previous versions of URBEMIS, URBEMIS2002 for Windows does not have a memory limit when operating within the Windows 95/98/2000 environment except for the limits imposed by the computer on which it is installed.

II.2 Disk Limits

URBEMIS2002 requires substantial amounts of hard disk space, primarily to store EMFAC2002 files. The EMFAC2002 files require 61.6 megabytes of storage space. The remaining files, which include air district default files, the executable file, help file, and other miscellaneous supporting files, require less than 4 megabytes of hard disk space. In addition to these storage requirements, you should have at least one megabyte of additional hard disk space to store project files.

II.3 Installation

This description assumes that the required URBEMIS2002 files are first downloaded from the South Coast Air Quality Management District, California Air Resources Board, or URBEMIS.com website, then installed on a computer. A similar approach can be used if URBEMIS is being installed from a compact disk (CD).

- Step one involves downloading the installation files: Install_Urebemis_8_7.msi and Insta1.cab to the same location on your hard drive.
- Step two requires that you click on the .msi file downloaded in step one and follow the directions for installation.

When installation is complete, you will see a cloud icon on your desktop with the URBEMIS 8.7 caption. To run the software, double click on the cloud icon. To save disk space, the installation file (InstallUrbemis7_8.exe) can be deleted.

II.4 Starting URBEMIS2002

Once URBEMIS2002 has been successfully installed, it can be started by selecting the URBEMIS2002 icon from the desktop or by clicking on the Windows Start button, selecting Programs from the list, then selecting URBEMIS2002 from the list of programs.

One problem that frequently arises when starting URBEMIS2002 is that the program does not fit entirely within the computer screen. The optimal screen settings for running URBEMIS2002 are 1024 x 768 pixels, with the small fonts advanced setting option. These are Windows settings that can be changed by selecting the Start/Settings/Control Panel/Display from within the Windows operating system.

III. USING URBEMIS2002

III.1 Differences from Previous Versions

III.1.1 Additions

Several versions of URBEMIS have been released by the California Air Resources Board (ARB) since the early 1980s: Urbemis1, Urbemis2, Urbemis3, and Urbemis5, URBEMIS7G for DOS, URBEMIS7G for Windows, URBEMIS2001 version 6.2.2, URBEMIS2002 version 7.4, URBEMIS2002 version 7.5, and URBEMIS2002 version 8.7. (Urbemis4 was not released for use by the public.) Previous versions of URBEMIS allowed the user to estimate motor vehicle emissions associated with vehicle trips generated by land use development projects. Generally, each new release of URBEMIS has been associated with ARB's update of its motor vehicle emission factors.

URBEMIS7G represented the successor to URBEMIS5. URBEMIS7G differed from URBEMIS5 in several ways. First, URBEMIS7G was an updated version of URBEMIS5 because it included EMFAC7G, ARB's California motor vehicle emission factors model.

Another difference is that, for the first time, URBEMIS7G provided users with the ability to estimate construction and area source emissions. In addition, URBEMIS7G gave the user the ability to select mitigation measures for construction, area source, and motor vehicle emissions, another option not available in previous versions. And, URBEMIS7G provided estimates of the emissions benefits of those mitigation measures.

URBEMIS7G also included a series of enhanced land use selection screens. The enhancements included additional land uses, updated trip generation rates, trip generation rates for certain land uses based on equations included in the ITE Trip Generation Manual Version 6.0 (Institute of Transportation Engineers 1996), and the option of specifying whether the project is located is an urban versus a rural environment.

Previous versions of URBEMIS did not allow for estimation of reentrained road dust. URBEMIS7G estimated road dust emissions for both paved and unpaved roads.

URBEMIS7G also allowed the user to select a new “double-counting” option. This option was designed to minimize double counting of internal vehicle trips between residential and nonresidential land uses. Finally, URBEMIS7G allowed users to select a new “pass-by trips” option. With this option selected, URBEMIS7G could be used to estimate vehicle trip emissions based on the percentage of primary trips, diverted linked trips, and pass-by trips assumed for specific land use types.

URBEMIS7G was superceded by URBEMIS7G for Windows. The primary advantage of this enhancement is that it allowed the user to estimate emissions from within the Windows operating system environment. Several other minor improvements were made to fix previously identified bugs. URBEMIS2001 was released in early 2002, following by URBEMIS2002 in March 2003. URBEMIS2001 incorporated EMFAC2001 emissions factors, while URBEMIS2002 version 7.5 incorporated EMFAC2002 emissions factors and ITE Trip Generation, 7th edition emission factors. Additionally, EMFAC2002 included several additional land uses, contained a major enhancement to the construction emissions and mitigation measures module, and included a screening analysis option. URBEMIS2002 version 8.7 includes enhancements to the area source emission factors, and to the area source and operational mitigation measures.

III.1.2 Appearance

The appearance of URBEMIS2002 is similar to URBEMIS2001 and URBEMIS7G for Windows.

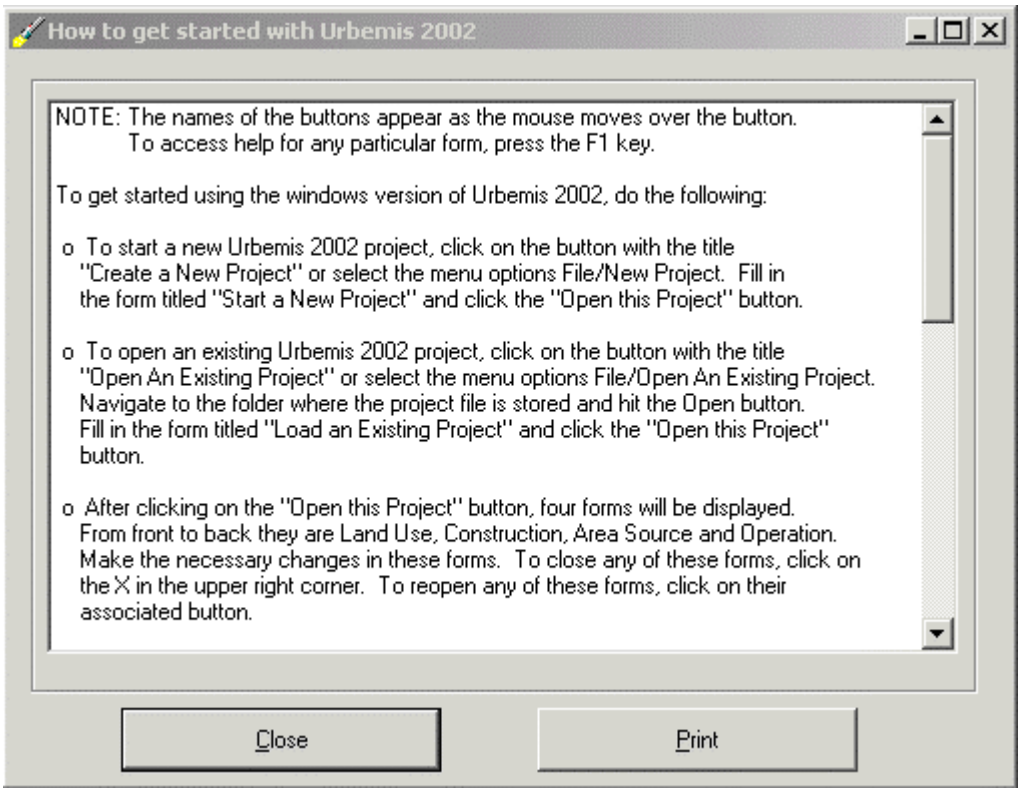

Figure 2. Introductory URBEMIS2002 for Windows Screen

When URBEMIS2002 is started, an introductory screen is presented that describes “How to Get Started with URBEMIS2002” (see Figure 2). That screen includes the basic information needed to

start URBEMIS202. Once that introductory screen is closed, URBEMIS2002 shows the user the initial screen shown in Figure 3.

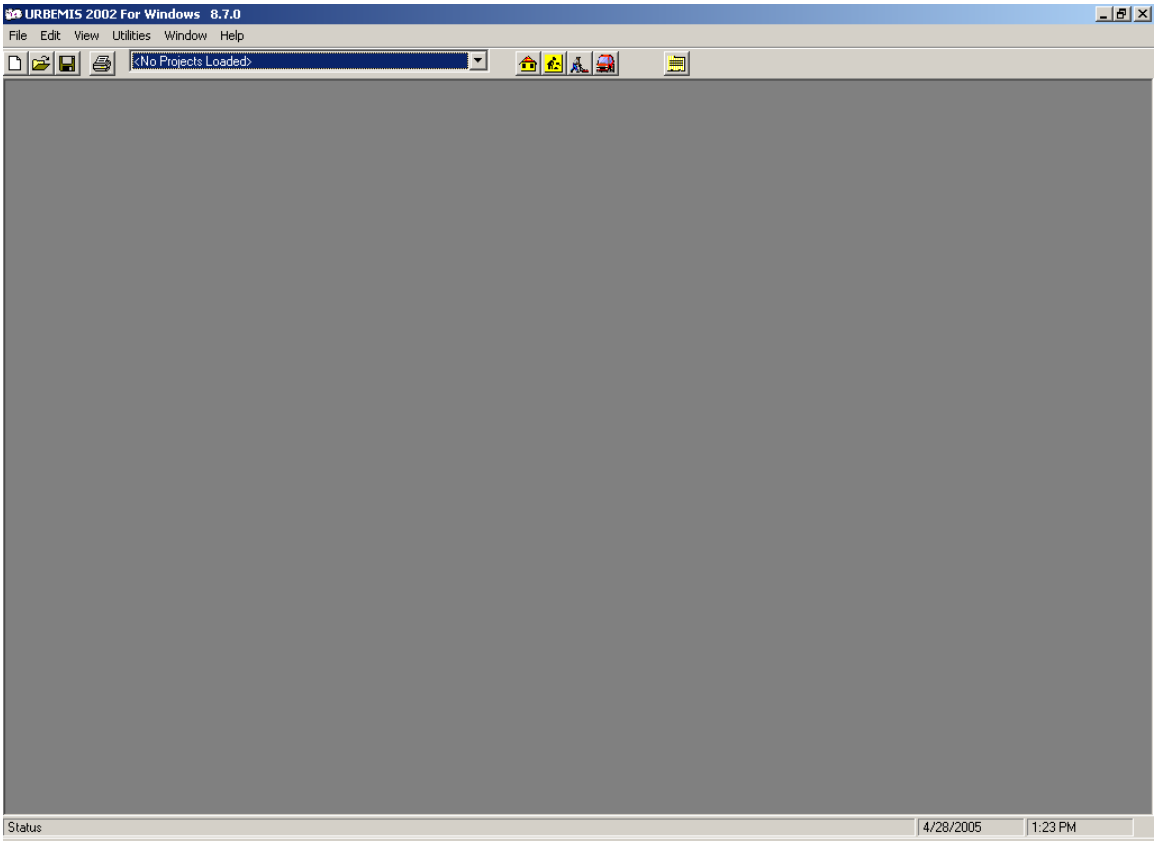

Figure 3. URBEMIS2002 Initial Screen

The screen is essentially blank except for a row of icons, referred to as the Icon Bar, and a row of words referred to as the Menu. On the icon bar, four icons are located to the left of the display showing which project is loaded. Those four icons, listed from left to right are the "Create a New Project" icon, "Open an Existing Project" icon, "Save Project Settings to File from Memory" icon, and the "Print Selected Results" icon. Five icons are located to the right of the display showing which project is loaded. The first four of these from left to right are the land uses icon, the construction emissions icon, the area source icon, and the operational (or motor vehicle icon). The icon is the view results icon, which allows the user to send the emission results to a file, a printer, or the screen.

III.1.4 File Structure

Due to several enhancements, URBEMIS2002 version 8.7 uses a different file structure than previous versions of URBEMIS, including URBEMIS2001 and previous versions of URBEMIS2002. Consequently, project files generated by previous versions of URBEMIS are not readable by URBEMIS2002. Attempting to read files from previous versions will generate an error message.

III.2 Program Overview

Upon starting URBEMIS2002, you are taken to the “How to Get Started with URBEMIS2002 screen. This screen contains instructions for quickly starting the URBEMIS2002 program (see Figure 2 above).

III.2B Setting Directories

Upon starting URBEMIS2002, you are shown the URBEMIS2002 main menu. You should ensure that the directories are set correctly (see Section III.10, “Setting Default Drives and Directories”) before proceeding. The directories specify where URBEMIS2002 reads files from and writes them to.

III.3 Beginning a New Project

From the initial screen, you begin a new project by either selecting "File" from the Menu, then selecting "New Project” from the drop down menu. Alternatively, you may select from the Menu the left most icon (white sheet of paper icon) for New Project. Once you have selected the "New Project" option, URBEMIS2002 loads a screen entitled: "Start a New Project" (See Figure 4). That screen requires the user to enter a project description and to select the air basin or air district in which the project will be located (one of up to ten air basins or air districts). By selecting the air basin location, the associated default information for that basin is loaded into the project emissions source categories (construction, area, and operational) for which emissions will be calculated. The information included in the default file has been supplied by the respective air district(s). The project setting and the project emission source categories can be modified by the user by clicking the “edit these project settings” button.

Two buttons are included on this screen that allows the user to “Open Project Without Forms Showing” or “Open Project with Forms Showing”. One of these two buttons must be selected in order to proceed to the next screen. If the user opts for the “Open Project With Forms Showing” button, then URBEMIS2002 loads the land use screens and the project emission source screens (construction, area, and/or operational). If the “Open Project Without Forms” button is clicked, then URBEMIS2002 presents the user with the icon bar and an empty screen (see Figure 3). The user must then click on the land use screen (house) icon to continue entering information on the new project.

One addition to the new project screen is the “screening analysis mode” checkbox located just to the right of the project description. (Please note: the “screening analysis mode” can not be selected if your project is located within the South Coast Air Basin.) If the user clicks on the screening analysis mode checkbox, then to proceed to subsequent screens, the user must click on the “Open this Screen Analysis” button that appears. By selecting screening analysis, the user will not be able to edit the default values for construction, area sources, or operational emissions. In addition, because the construction module depends on several key assumptions that must be reviewed by the user, the screening analysis mode only allows emissions to be estimated for the area and operational source categories.

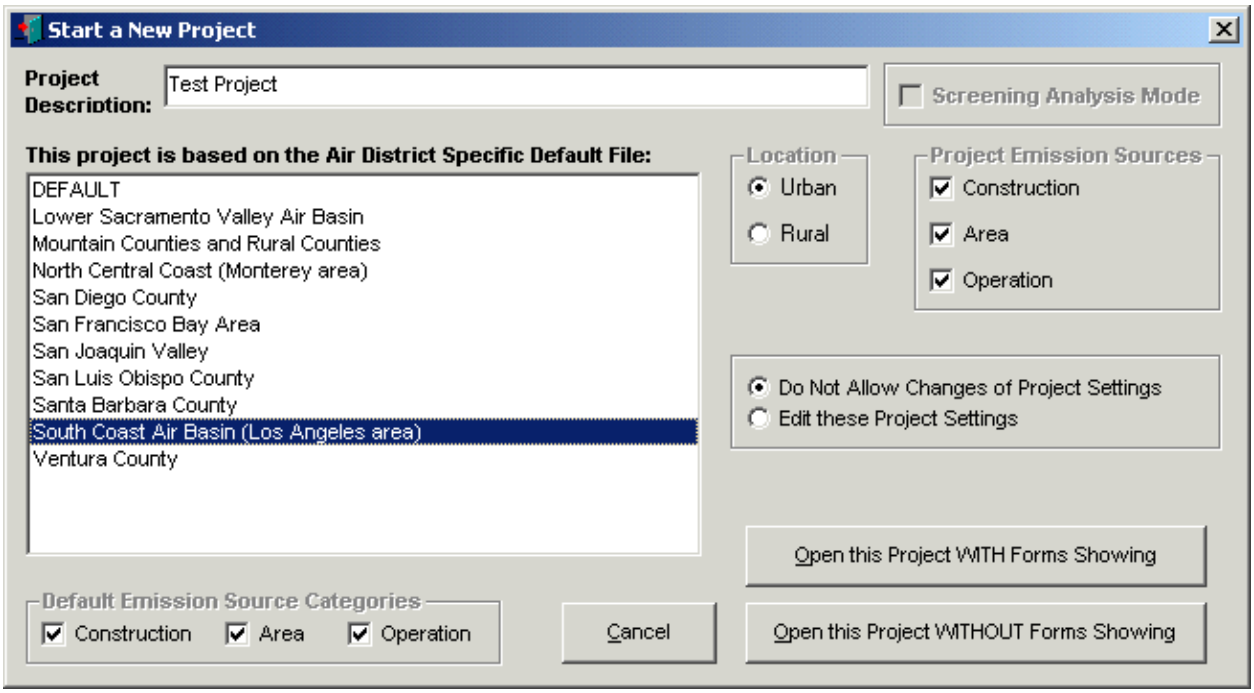

Figure 4. New Project Screen

III.4 Open an Existing Project

From the default menu, you open an existing project by selecting "File" from the Menu, , then selecting "Open an Existing Project" from the drop down menu. Or, alternatively, from the Icon Bar select the icon located on the second from the left (looks like a manila folder). If you select the "Open an Existing Project" option, URBEMIS2002 loads a screen entitled: "Select a Project File". At this point you must either double-click on the name of one of the files listed, enter the name of the file, or change the directory from which you want to select a file. If you enter a file name that does not exist in the selected directory, URBEMIS2002 flashes a message telling you that the selected file does not exist. **Please note: URBEMIS2002 version 8.7 uses a different file structure than previous versions of URBEMIS, including URBEMIS2001 and previous versions of URBEMIS2002. If you attempt to load a file created with an earlier version of URBEMIS, you will get an error message.**

Once the user has opted to open an existing project, URBEMIS shows a screen (Figure 5) that allows the user to edit the project description, air district default file, project setting (rural versus urban), and project emissions source categories (construction, area, operational).

By selecting the air basin location, the associated default information for that basin is loaded into the project setting, and project emissions source categories (construction, area, and operational) for which emissions will be calculated. The information included in the default file has been supplied by the respective air district(s). The project environment and the project emission source categories can be modified by clicking the “edit these project settings” button.

Two buttons are included on this screen that allows the user to “Open Project Without Forms Showing” or “Open Project with Forms Showing”. One of these two buttons must be selected in order to proceed to the next screen. If the user opts for the “Open Project With Forms Showing” button, then URBEMIS2002 loads the land use screens and the project emission source screens (construction, area, and/or operational). If the “Open Project Without Forms” button is clicked, then URBEMIS2002 presents the user with the icon bar and an empty screen (see Figure 3). The user must then click on the land use screen (yellow house) icon to continue editing the existing information on the project. Alternatively, the user can select the construction (construction worker with shovel icon), area (lawn mower operator icon), or the operational (red car icon) buttons to review or edit the default assumptions.

One addition to the new project screen is the “screening analysis mode” checkbox located just to the right of the project description. If the user clicks on that checkbox, then to proceed to subsequent screens, the user must click on the “Open Screening Analysis” button that appears. By selecting screening analysis, the user will not be able to edit the default values for construction, area sources, and operational emissions. In addition, because the construction module depends on several key assumptions that must be reviewed by the user, the screening analysis mode only allows emissions to be estimated for the area and operational source categories.

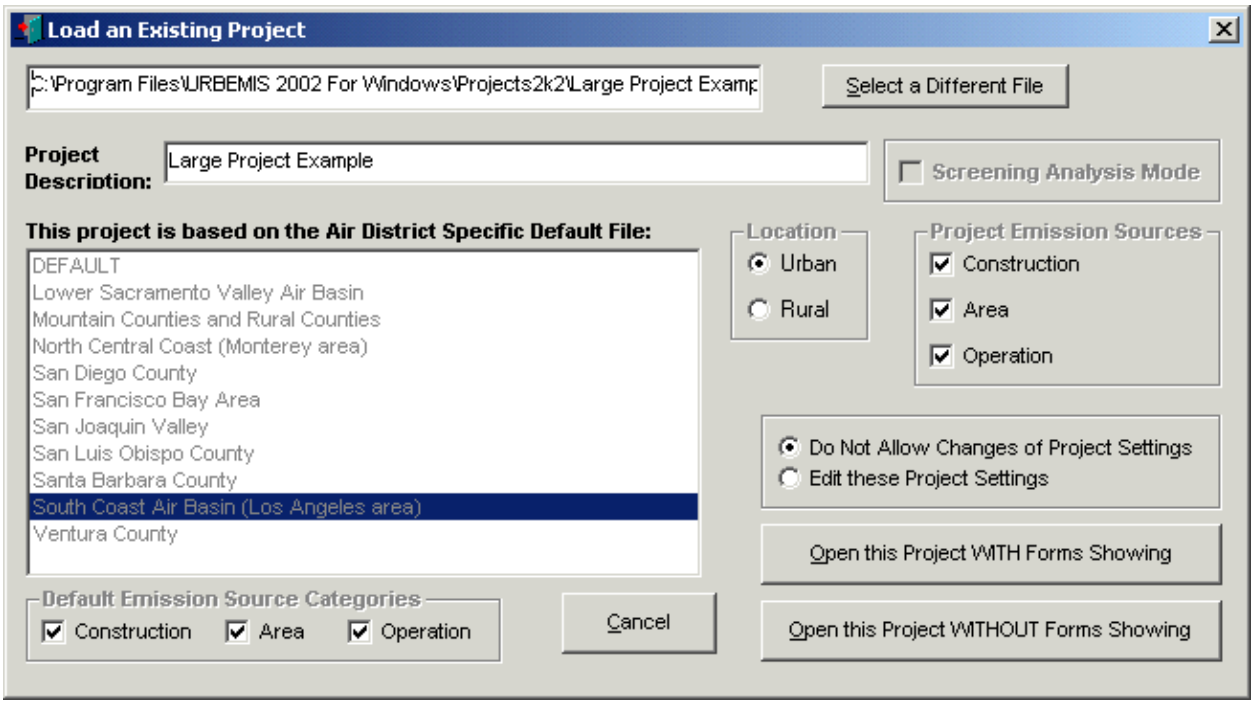

Figure 5. Load an Existing Project Screen

III.5 Specifying Land Uses

If you opt to open a project with all forms open, then URBEMIS presents the form shown in Figure 6. The land uses screen is shown in front of construction, area sources, and operational emissions

screens. The first land use screen displays the first of seven possible land use screens, which are organized as follows:

- residential;
- educational;
- recreational;
- large retail;
- retail
- commercial and;
- industrial.

You may access the land uses associated with either of the seven land use screens by clicking on the appropriate tab.

If you have opted to open a project without having the forms automatically opened, then you will have to manually open the land use screens by clicking on the land use (yellow house) icon on the Icon Bar.

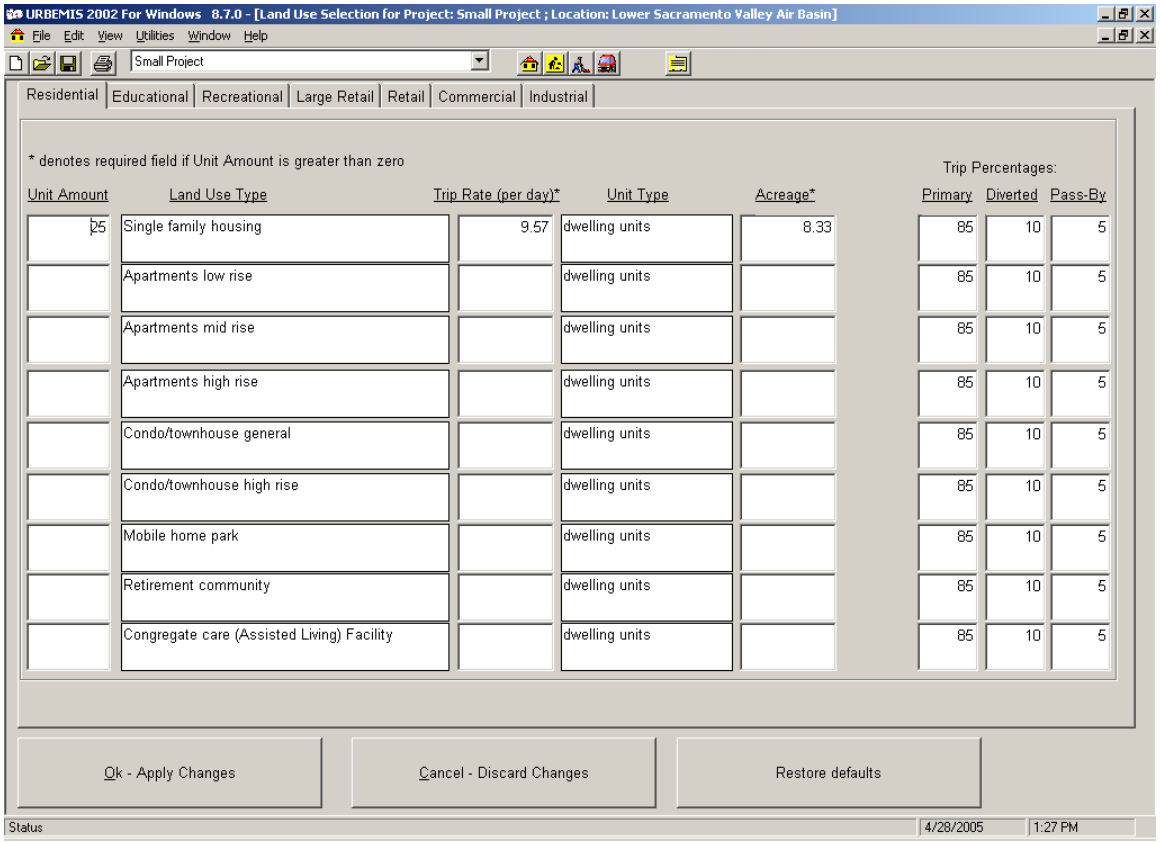

Figure 6. Land Uses Screen

Table 1 lists each of the URBEMIS2002 land uses, provides a definition of each land use, and shows the percentage of worker commute trips associated with each land use. Those percentages are called Percent Worker Commute in Table 1.

For each land use type, you are given the option of entering the project size or unit amount. For residential land uses, URBEMIS2002 automatically calculates the acreage associated with that land use type and the trip rate based on the unit amount. The user can and should modify the acreage for a project if it differs from the default values used by URBEMIS. Changing the project acreage will, however, also change the trip rate using a procedure developed by Nelson\Nygaard (see Appendix D of this manual).

The equation or value used to estimate trip generation is shown in Table 2. You can override the trip rate by typing in a different rate. For certain land uses, you also can select a different unit type by clicking on the "Unit Type" arrow (if it is shown for that particular land use). If a land use's unit type does not have an arrow, then you can simply edit the name of the unit type. You can also edit the name of the land use type.

For all non-residential land uses, you also have the option of modifying the default "% Worker Commute" value. This value represents the percentage of worker commute trips attracted to that land use as a percentage of all trips generated by that land use.

Once you have finished entering land uses, you must click the OK-Apply Changes button to save those changes to memory. Please note that by clicking on OK-Apply Changes button will not save those changes to a file. Saving changes to a file is described in Section III-11.

Table 1. Land Use Definitions and Percent Worker Commute

	Land Use Definition	Percent Worker Commute
First Land Use Screen: Residential		
Single Family Housing	Detached homes on individual lots	N/A
Apartments, Low Rise	Buildings with one to three floors	N/A
Apartments, Medium Rise	Buildings with four to ten floors	
Apartments, High Rise	Buildings with more than ten floors	N/A
Condo/Townhouse General	Condos and townhomes in buildings with one or two levels.	N/A
Condo/Townhouse High Rise	Condos and townhomes in buildings with 3 or more levels.	N/A
Mobile Home Park	Trailers sited and installed on permanent foundations.	N/A
Retirement Community	Self-contained villages restricted to adults or senior citizens	N/A
Congregate Care (Assisted Living) Facility	One or more multiunit buildings designed for elderly living and may contain dining rooms, medical, and recreational facilities.	N/A
Second Land Use Screen: Educational		
Day-Care Center	Facilities that care for pre-school children, normally during daytime hours. May also include after-school care for older children.	5
Elementary School	Generally includes Kindergarten through either 6th or 8th grades.	20
Junior High School	Includes 7th, 8th, and often 9th grades.	20
High School	Includes 10th, 11th, and 12th grades and oftentimes 9th grade.	10
Junior College (2 years)	Most have facilities separate from other land uses and exclusive access points and parking facilities.	5
University/College (4 years)	Four year and graduate educational institutions.	5

Library	Public or private facility, which houses books, and includes reading rooms and possibly meeting rooms.	5
Place of Worship	Building(s) providing public worship services.	3
Blank (Edit all 5 columns)	Blank commercial land use that can be entered by the URBEMIS2002 user.	2
Third Land Use Screen: Recreational		
City Park	Owned and operated by a city, these facilities can vary widely as to location, type, and number of facilities. May including boating, swimming, ball fields, camp sites, and picnic facilities.	
Racquet Club	Privately owned facilities with tennis, racquetball, and/or handball courts, exercise rooms, and/or swimming pools and/or weightrooms	5
Racquet/Health Club	Privately owned facilities with tennis, racquetball, and/or handball courts.	5
Quality Restaurant	Typically with customer turnover rates of at least one hour.	8
High Turnover (sit-down Restaurant)	Typically with high customer turnover rates of less than one hour.	5
Fast Food Restaurant with Drive Through	Includes fast food restaurants with drive through windows, such as McDonald's, Burger King, and Taco Bell.	5
Fast Food Restaurant without Drive Through	Includes fast food restaurants without drive through windows, such as McDonald's, Burger King, and Taco Bell.	5
Hotel	Place of lodging providing sleeping accommodations, restaurants, and meeting or convention facilities.	5
Motel	Place of lodging providing accommodations and often, a restaurant.	5
Fourth Land Use Screen: Large Retail		
Free-Standing Discount Store	Free-standing store with off-street parking, can be part of neighborhood shopping centers.	2

Free-Standing Discount Superstore	Same as free-standing discount store but also include full service grocery department under the same roof.	2
Discount Club	Discount/warehouse store whose shoppers pay a membership fee to take advantage of discounted prices.	2
Regional Shopping Center	Integrated group of commercial establishments that are planned, developed, owned, and managed as a unit.	2
Electronics Superstore	Free-standing warehouse type facilities specializing in the sale of home and vehicle electronic merchandise, as well as TVs, compact disc and cassette tape players, cameras, radios, videos, and general electronic accessories.	2
Home Improvement Superstore	Free-standing warehouse type facilities specializing in lumber, tools, paint, lighting, wallpaper and paneling, kitchen and bathroom fixtures, lawn equipment, and garden plants and accessories.	2

Fifth Land Use Screen: Retail

Strip Mall	Neighborhood store complexes with a variety of retail outlets.	2
Hardware/Paint Store	Stores selling general hardware items and/or paints and supplies.	2
Supermarket	Free-standing stores selling a complete assortment of food, food preparation and wrapping materials, and household cleaning and servicing items. May also contain money machines, photo centers, pharmacies, and video rental areas.	2
Convenience market (24 hour)	These markets sell convenience foods, newspapers, etc. and do not have gasoline pumps. (Trip generation rates with gas pumps is approximately 12% higher than without.	2
Convenience market with gas pumps	These markets sell convenience foods, newspapers, etc. and do have gasoline pumps.	2
Gasoline/Service Station	Excludes gasoline stations with convenience	2

	stores or car washes.	

Sixth Land Use Screen: Commercial

Bank (with drive-through)	Banks with one or more drive-up windows.	2
General Office Building	Houses multiple tenants in a location where affairs of businesses, commercial or industrial organizations or professional persons or firms are conducted.	35
Office Park	Contain general office buildings and related support services, arranged in a park- or campus-like setting.	48
Government Office Building	Individual building containing the entire function or simply one agency of a city, county, state, or federal government.	10
Government (Civic Center)	Group of government buildings connected with pedestrian walkways	10
Pharmacy/Drugstore with Drive Through	Retail facilities selling prescription and non-prescription drugs. Also typically sell cosmetics, toiletries, medications, stationary, personal care products, limited food products, and general merchandise. These facilities include a drive-through window.	2
Pharmacy/Drugstore without Drive Through	Retail facilities selling prescription and non-prescription drugs. Also typically sell cosmetics, toiletries, medications, stationary, personal care products, limited food products, and general merchandise. These facilities do not contain a drive-through window.	2
Medical Office Building	Includes both medical and dental office buildings that provide diagnoses and outpatient care. Generally operated by one ore more private physicians or dentists.	7
Hospital	Any institution where medical or surgical care is give to non-ambulatory and ambulatory patients and overnight accommodations are provide.	25

Seventh Land Use Screen: Industrial

Warehouse	Buildings devoted to the storage of materials, also include office and maintenance areas.	2
General Light Industry	Typical light industrial activities include:	50

	print plants, material testing labs, and assemblers of data processing equipment. They employ fewer than 500 persons and tend to be free-standing.	
General Heavy Industry	Could also be categorized as manufacturing facilities. However, heavy industrial uses are limited to the production of large items.	90
Industrial Park	Contain a number of industrial or related facilities and are characterized by a mix of manufacturing, service, and warehouse facilities. May contain highly diversified facilities, a number of small businesses, or one or two dominant industries.	41.5
Manufacturing	Sites where the primary activity is the conversion of raw materials or parts into finished products. May also included associated office, warehouse, research, and other functions.	48

Percent worker commute represents the percentage of total trips that are work-related commute trips.

Table 2. URBEMIS2002 Trip Generation Rates

Land Use	Trip Generation Rate	Units *	Source
Single Family Housing	9.57	Dwelling Unit	ITE (210)
Apartment, Low Rise	6.9	Dwelling Unit	ITE (221)
Apartment, Mid Rise	5.76	Dwelling Unit	ITE (223)
Apartment, High Rise	5.29	Dwelling Unit	ITE (222)
Condominium/Townhouse, General	6.9	Dwelling Unit	ITE (230)
Condominium/Townhouse, High Rise	5.26	Dwelling Unit	ITE (232)
Mobil Home Park	4.99	Dwelling Unit	ITE (240)
Retirement Community	3.71	Dwelling Unit	ITE (251)
Congregate Care (Assisted Living) Facility	2.02	Dwelling Unit	ITE (253)
Day-Care Center	79.3	1000 sq. ft.	ITE (565)
Elementary School	14.49	1000 sq. ft.	ITE (520)
Elementary School	1.29	Student	ITE (520)
Junior High School	13.78	1000 sq. ft.	ITE (522)
Junior High School	1.62	Student	ITE (522)
High School	12.89	1000 sq. ft.	ITE (530)
High School	1.71	Student	ITE (530)
Junior College (2 Years)	27.49	1000 sq. ft	ITE (540)
Junior College (2 Years)	1.2	Student	ITE (540)
University/College (4 Years)	2.38	Student	ITE (550)
Library	54	1000 sq. ft.	ITE (590)
Place of Worship	9.11	1000 sq. ft.	ITE (560)
City Park	1.59	Acre	ITE (411)
Racquet Club	14.03	1000 sq. ft.	ITE (491)
Racquetball/Health Club	32.93	1000 sq. ft.	ITE (492)
Quality Restaurant	89.95	1000 sq. ft.	ITE (931)
High-Turnover (Sit-Down) Restaurant	127.15	1000 sq. ft.	ITE (932)
Fast-Food Restaurant w/o Drive-Through Window	496.12	1000 sq. ft.	ITE (933)
Fast-Food Restaurant with Drive-Through Window	716	1000 sq. ft.	ITE (934)
Hotel	8.17	Rooms	ITE (310)
Motel	5.63	Rooms	ITE (320)
Free-Standing Discount Store	56.02	1000 sq. ft.	ITE (815)
Free-Standing Discount Superstore	49.21	1000 sq. ft.	ITE (813)
Discount Club	41.8	1000 sq. ft.	ITE (861)
Regional Shopping Center	42.94	1000 sq. ft.	ITE (820)
Electronics Superstore	45.04	1000 sq. ft.	ITE(863)
Home Improvement Superstore	29.8	1000 sq. ft.	ITE(862)
Strip Mall	42.94	1000 sq. ft.	ITE (820)
Hardware/Paint Store	51.29	1000 sq. ft	ITE(816)

Supermarket	102.24	1000 sq. ft.	ITE(850)
Convenience Market (24 hr.)	737.99	1000 sq. ft.	ITE (851)
Convenience Market with Gasoline Pumps	845.6	1000 sq. ft.	ITE (853)
Gasoline /Service Station	162.78	Fueling Positions	ITE (945)
Bank (with Drive-Through)	246.49	1000 sq. ft.	ITE (912)
General Office Building	3.32	1000 sq. ft.	ITE (710)
Office Park	11.42	1000 sq. ft.	ITE (750)
Government Office Building	68.93	1000 sq. ft.	ITE (730)
Government (Civic Center)	27.92	1000 sq. ft.	ITE (733)
Pharmacy/Drugstore without Drive Through	88.16	1000 sq. ft	ITE(880)
Pharmacy/Drugstore with Drive Through	90.06	1000 sq. ft	ITE(881)
Medical/Dental Office Building	36.13	1000 sq. ft.	ITE (720)
Hospital	17.57	1000 sq. ft.	ITE (610)
Hospital	11.81	Beds	ITE (610)
Warehouse	4.96	1000 sq. ft.	ITE(150)
General Light Industry	6.97	1000 sq. ft.	ITE (110)
General Light Industry	51.8	Acre	ITE (110)
General Light Industry	3.02	Employee	ITE (110)
General Heavy Industry	1.5	1000 sq. ft.	ITE (120)
General Heavy Industry	6.75	Acre	ITE (120)
Industrial Park	6.96	1000 sq. ft.	ITE (130)
Industrial Park	63.11	Acre	ITE (130)
Industrial Park	3.34	Employee	ITE (130)
Manufacturing	3.82	1000 sq. ft.	ITE (140)

Notes
sq. ft. = Square Feet
All trip generation rates from ITE Trip Generation Rate Manual, 7th Edition.
* "Dwelling unit" is a residential housing unit (including 'single room occupancy' units and 'granny flats'). "Square feet" refers to the total floor area (on all levels) of buildings, but does not include parking structures even if they are within a building (also known as 'gross leasable area'). "Acres" refers to the gross surface of the entire site, including any structures, streets, sidewalks, parking, and landscaping (but not including building or parking lot floor areas above the first level).

Pass-by Trips

URBEMIS2002 allows users to select a pass-by trip option, which results in lower operational emissions. If the default pass-by trip information is changed, the URBEMIS report ("changes to default" option) shows that the default values have been changed.

The pass-by trip option splits trips into percentages of primary, pass-by, and diverted-linked trips. Primary trips are trips made for the specific purpose of visiting the designated land use. The stop at that trip generator is the primary reason for the trip. Pass-by trips are trips made as intermediate stops on the way from an origin to a primary trip destination. Pass-by trips are attracted from traffic passing the site on an adjacent street that contains direct access to the generator. Diverted-linked trips are trips attracted from the traffic volume on roadways in the vicinity of the generator but which require a diversion from that roadway to another roadway to gain access to the site.

When the pass-by option is turned off, URBEMIS assumes all trips are primary trips. When pass-by is turned on, lower emissions result because a percentage of trips associated with each land use is assumed to be pass-by and diverted linked trips (see Table 3). Pass-by and diverted-linked trips have a lower trip distance than primary trips. URBEMIS assumes that pass-by trips result in virtually no

extra travel, with an assumed trip length of 0.01 miles. Diverted-linked trip lengths are assumed to equal 25% of the primary trip length.

As shown in Table 3, the "fast-food restaurant without drive-through window" land use consists of 50% primary trips, 40% diverted linked trips, and 10% pass-by trips. Assuming a trip length of 10 miles, emissions calculated using the pass-by trip option would be calculated by assuming that 50% of the trips would be 10 miles, 40% of the trips would be 2.5 miles, and 10% of the trips would be 0.01 miles.

Unlike URBEMIS2002, previous versions of URBEMIS did not present the primary/pass-by/diverted-linked trip percentages on screen. The individual air districts have the option of determining whether the URBEMIS end-user can modify those percentages for projects within their jurisdiction.

Table 3. URBEMIS Land Uses Sorted by Category with Trip Percentages

Land Use	Land Use Category	Primary Trip (%)	Diverted Linked Trip (%)	Pass-By Trip (%)	Source
Single-Family Housing	Residential	85	10	5	Sandag 1996
Apartment, Low Rise	Residential	85	10	5	Sandag 1996
Apartment, High Rise	Residential	85	10	5	Sandag 1996
Condominium/Townhouse, General	Residential	85	10	5	Sandag 1996
Condominium/Townhouse, High Rise	Residential	85	10	5	Sandag 1996
Mobile Home Park	Residential	85	10	5	Sandag 1996
Retirement Community	Residential	85	10	5	Sandag 1996
Residential Planned Unit Development (PUD)	Residential	85	10	5	Sandag 1996
Congregate Care (Assisted Living) Facility	Residential	85	10	5	Sandag 1996
Day-Care Center	Educational	25	60	15	Sandag 1996
Elementary School	Educational	60	25	15	Sandag 1996
High School	Educational	75	20	5	Sandag 1996
Junior High School	Educational	65	25	10	Sandag 1996
Junior College (2 Years)	Educational	95	5	0	Sandag 1996
University/College (4 Years)	Educational	90	10	0	Sandag 1996
Library	Educational	45	45	10	Sandag 1996
Church	Educational	65	25	10	Sandag, 1996
City Park	Recreational	70	25	5	Sandag 1996
Racquet Club	Recreational	50	40	10	Sandag 1996
Racquetball/Health Club	Recreational	50	40	10	Sandag 1996
Quality Restaurant	Recreational	50	40	10	Sandag 1996

Land Use	Land Use Category	Primary Trip (%)	Diverted Linked Trip (%)	Pass-By Trip (%)	Source
High-Turnover (Sit-Down) Restaurant	Recreational	30	40	30	ITE 1997
Fast-Food Restaurant without Drive-Through Window	Recreational	50	40	10	Sandag 1996
Fast-Food Restaurant with Drive-Through Window	Recreational	30	30	40	ITE 1997
Hotel	Recreational	60	35	5	Sandag 1996
Motel	Recreational	60	35	5	Sandag 1996
Free-Standing Discount Store	Large Retail	45	45	10	Sandag 1996
Free-Standing Discount Superstore	Large Retail	55	40	5	ITE 1997
Discount Club	Large Retail	55	40	5	Sandag 1996
Regional Shopping Center	Large Retail	55	35	10	Sandag 1996
Electronics Superstore	Large Retail	45	40	15	Sandag 1996
Home Improvement Superstore	Large Retail	45	40	15	Sandag 1996
Strip Mall	Retail	45	40	15	Sandag 1996
Hardware/Paint Store	Retail	45	40	15	Sandag 1996
Supermarket	Retail	45	40	15	Sandag 1996
Convenience Market (24 hr.)	Retail	25	30	45	ITE 1997
Convenience Market (w/gas pumps)	Retail	25	30	45	ITE 1997
Gasoline/Service Station	Retail	20	40	40	ITE 1997
Bank (with Drive-Through)	Commercial	35	45	20	Sandag 1996
General Office Building	Commercial	75	20	5	Sandag 1996
Office Park	Commercial	80	15	5	Sandag 1996
Government Office Building	Commercial	50	35	15	Sandag 1996
Government (Civic Center)	Commercial	50	35	15	Sandag 1996
Pharmacy/Drugstore with Drive Through	Commercial	45	40	15	Sandag 1996
Pharmacy/Drugstore without Drive Through	Commercial	45	40	15	Sandag 1996
Medical Office Building	Commercial	60	30	10	Sandag 1996
Hospital	Commercial	75	25	0	Sandag 1996
Warehouse	Industrial	90	5	5	Sandag 1996
General Light Industry	Industrial	80	20	0	Sandag 1996
General Heavy Industry	Industrial	90	5	5	Sandag 1996
Industrial Park	Industrial	80	20	0	Sandag 1996
Manufacturing	Industrial	90	5	5	Sandag 1996

III.6 Construction Emissions

III.6.1 Specifying Construction Emissions

Main Construction Screen: Overall Construction Settings. Figure 7 shows the introductory or main construction emissions screen. Please note that the screen or window is divided into two panes, the left pane and the right pane. A splitter bar separates the left and right panes. By placing the cursor on the splitter bar and dragging right or left with the mouse, the relative size of each pane can be changed. This allows the user to see text that may be partially hidden. The cursor can also be placed on the edges of the window and dragged to make the entire window larger or smaller. The left pane contains a list, with each item on that list called a node.

The construction emissions portion of URBEMIS2002 has been substantially modified from previous versions. URBEMIS2002 allows the user to specify information for three construction phases that are typical for most projects. Those phases include demolition, site grading, and building construction. URBEMIS assumes that these three phases cannot overlap and that demolition occurs first, followed by site grading, then finishing with building construction.

For the construction screen, each of the nodes in the left pane represents one of the three construction phase categories or construction types. The three subphases associated with Phase 3 are also shown, along with the mitigation measure button. When the cursor is placed on one of the categories or nodes in the left pane and clicked, information associated with that category is shown in the right pane.

The main construction screen requires that the user specify the project start year, the start month, the construction period (in months), and the number of construction days per month (see Figure 7). (In this version of URBEMIS2002, the user cannot edit the number of construction days per month.) URBEMIS2002 calculates default phase lengths (months) for each of the three phases. Those calculations assume that Phase 1 consists of 5 percent of the total construction period, Phase 2 consists of 10 percent, and Phase 3 consists of 85 percent. The user can either agree to use the URBEMIS default phase lengths or can enter project specific phase lengths. The user also has the option of turning off a phase if it is not applicable to the project. For example, many land use development projects do not include demolition; consequently, Phase 1 would need to be turned off for those projects. Whenever a phase is turned off by the user, URBEMIS recalculates the default phase lengths for those phases that remain turned on.

Phase 3, building construction, consists of up to three subphases: building construction, application of architectural coatings, and asphalt laying. Either of these three subphases of Phase 3 can be turned off by the user. Unlike the three phases, the subphases can occur either sequentially or with partial or complete overlap. URBEMIS automatically calculates the start month and duration of each subphase, which also can be overridden by the user. As a worst case, URBEMIS assumes that the three subphases will overlap. Unless overridden, URBEMIS2002 automatically assumes that the building construction subphase will begin immediately after Phase 2 has ended and will continue until the end of Phase 3. URBEMIS2002 also assumes that paint application and asphalt laying will overlap with building construction. Since the paint and asphalt subphases generally do not last as long as building construction, they are assumed to overlap at the back end of Phase 3 (see Figure7) unless overridden by the user.

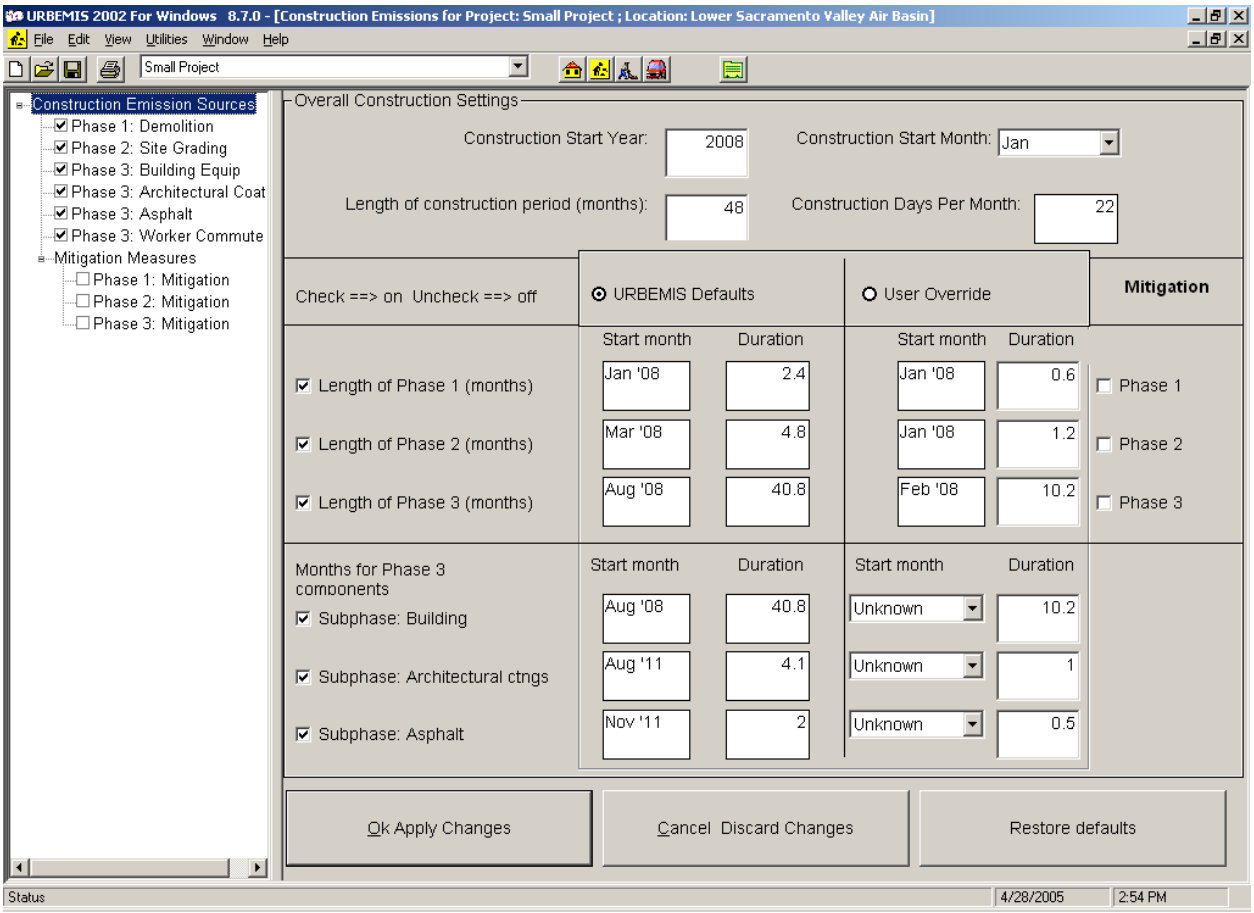

Figure 7. Construction Emissions Main Screen

Phase 1 - Demolition

From the construction emissions main screen (see Figure 7), demolition emissions can be specified by clicking on the Length of Phase 1 checkbox in the right pane. Clicking the OK-Apply Changes button saves that information. Then to enter specific demolition information, you must click on the Phase 1 – Demolition node found in the left pane. By doing so, you are taken to the first of four demolition screens (Figure 8). Those four screens are as follows:

Phase 1 – Demolition Dust and On-Road Emissions Settings
Phase 1 – Demolition Equipment Exhaust 1
Phase 1 – Demolition Equipment Exhaust 2
Phase 1 – Demolition Equipment Exhaust 3

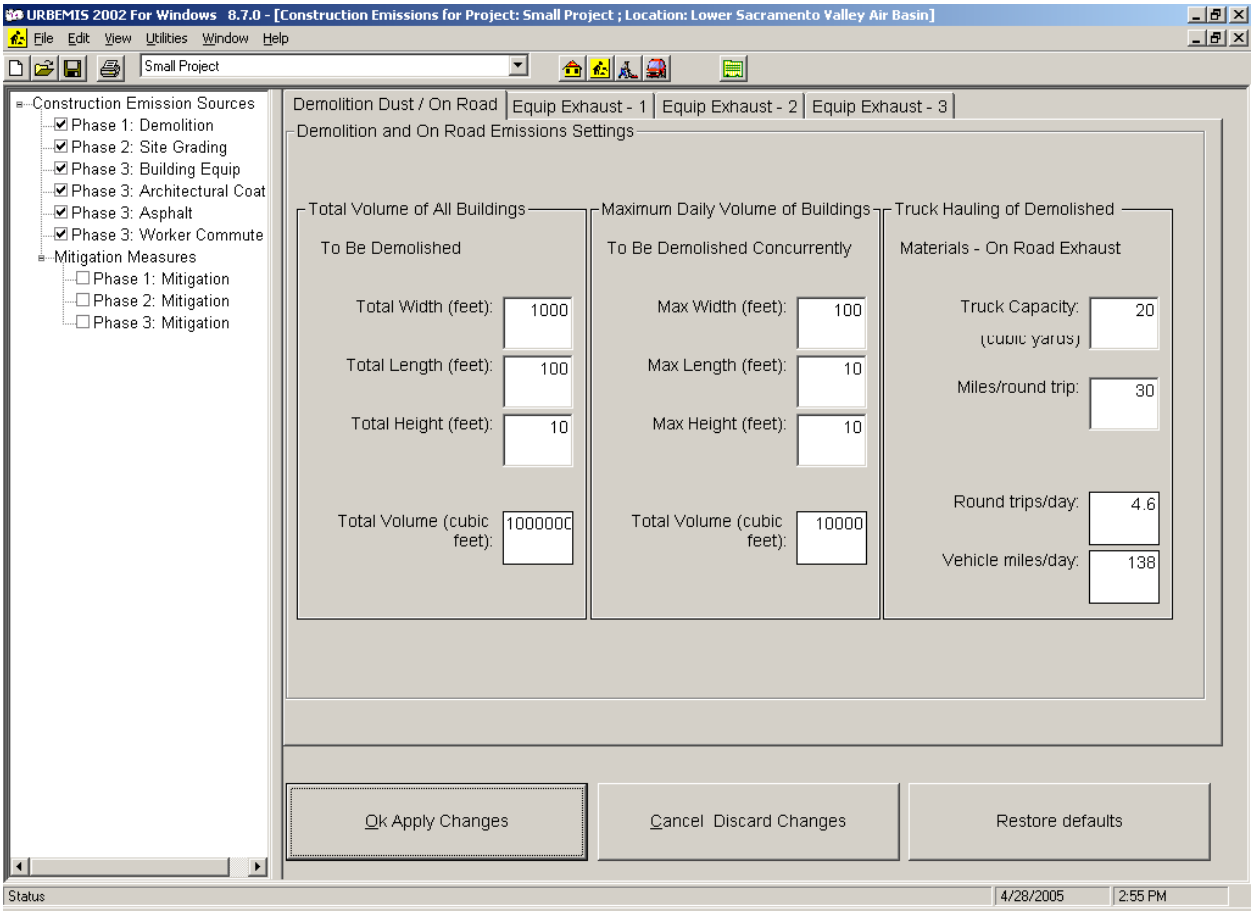

Figure 8. Phase 1 – Demolition Dust and On-Road Emissions Settings

You can switch between these four screens by clicking on the tabs found at the top of the right pane. The first of these four screens – Demolition Dust and On-Road Emissions Settings – allows the user to enter the total volume of material to be demolished and the maximum daily volume of material slated for demolition. URBEMIS uses the maximum daily building volume of material to estimate the on-road vehicle miles traveled per day needed to haul the demolished material to its ultimate destination. The amount hauled per day is assumed to equal 25% of the total building volume demolished per day. The program assumes a default truck capacity of 20 cubic yards (of demolished material) and a round trip haul distance of 30 miles. Both of these values can be overridden by the user. Changing default truck capacity and round trip haul distance also changes the total on-road VMT per day estimates.

The three remaining demolition screens are used to specify the number and type of off-road equipment that will be used during the demolition activities. The user must enter the number of each type of equipment that will be used for demolition and, if necessary, modify the horsepower, load factor, and hours per day that the equipment would operate.

Phase 2 – Site Grading

By clicking on Phase 2 – Site Grading in the left pane of the construction screen, URBEMIS displays the first of six screens (Daily Acreage) in the right pane (Figure 9). The user can go back and forth between these six screens by clicking on the tabs at the top of the right pane. Those six screens include:

1) Daily Acreage
2) Fugitive Dust
3) Soil Hauling
4) Equipment Exhaust – 1
5) Equipment Exhaust –2
6) Equipment Exhaust – 3

The Daily Acreage screen contains an important summary of the land use information for the project, including the number of single family and multi-family units and the total square footage of the non-residential projects (see Figure 9). Each time land uses are modified, URBEMIS will not modify the number of single and multi-family units and total square footage until the user hits the Recalc with Land Uses button. By hitting that button, URBEMIS recalculates the values in the Daily Acreage screen so that the residential units, building square footage, and acreage values are consistent with the land use values. The total acreage and maximum acreage disturbed per day values at the bottom of this screen are estimates generated by URBEMIS that can be overridden by the user. These total values are important because URBEMIS will, if requested, use them to calculate values in other parts of URBEMIS, including the number of construction vehicles used in site grading and in building equipment.

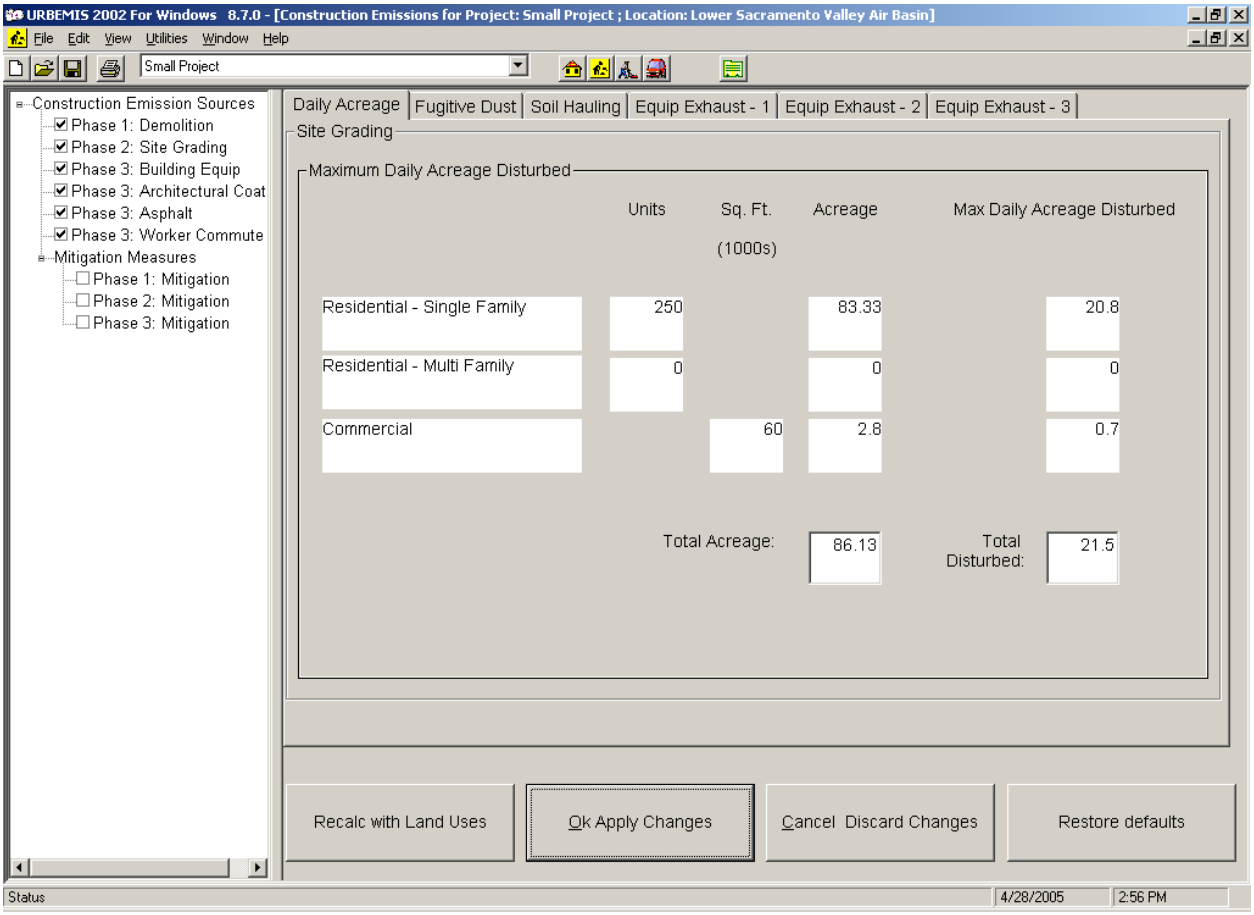

Figure 9. Daily Acreage

Clicking on the second tab – Fugitive Dust – takes the user to the next screen (Figure 10). The user is provided with the option of selecting one of four fugitive dust emission levels with the Default Level requiring the least information and the High Level requiring the most detailed information. Each level requires increasingly more detailed information about project construction. If the Low, Medium, or High levels are selected, additional information must be entered by the user. If the Default Level is selected, no additional information need be entered, though the user has the option of modifying the default fugitive dust emission rate. The Default Level represents the approach used to estimate fugitive dust in URBEMIS2001. To estimate fugitive dust emissions, URBEMIS estimates emissions in the Default Level by multiplying the default emission rate by the maximum acreage disturbed per day (from the previous acreage screen).

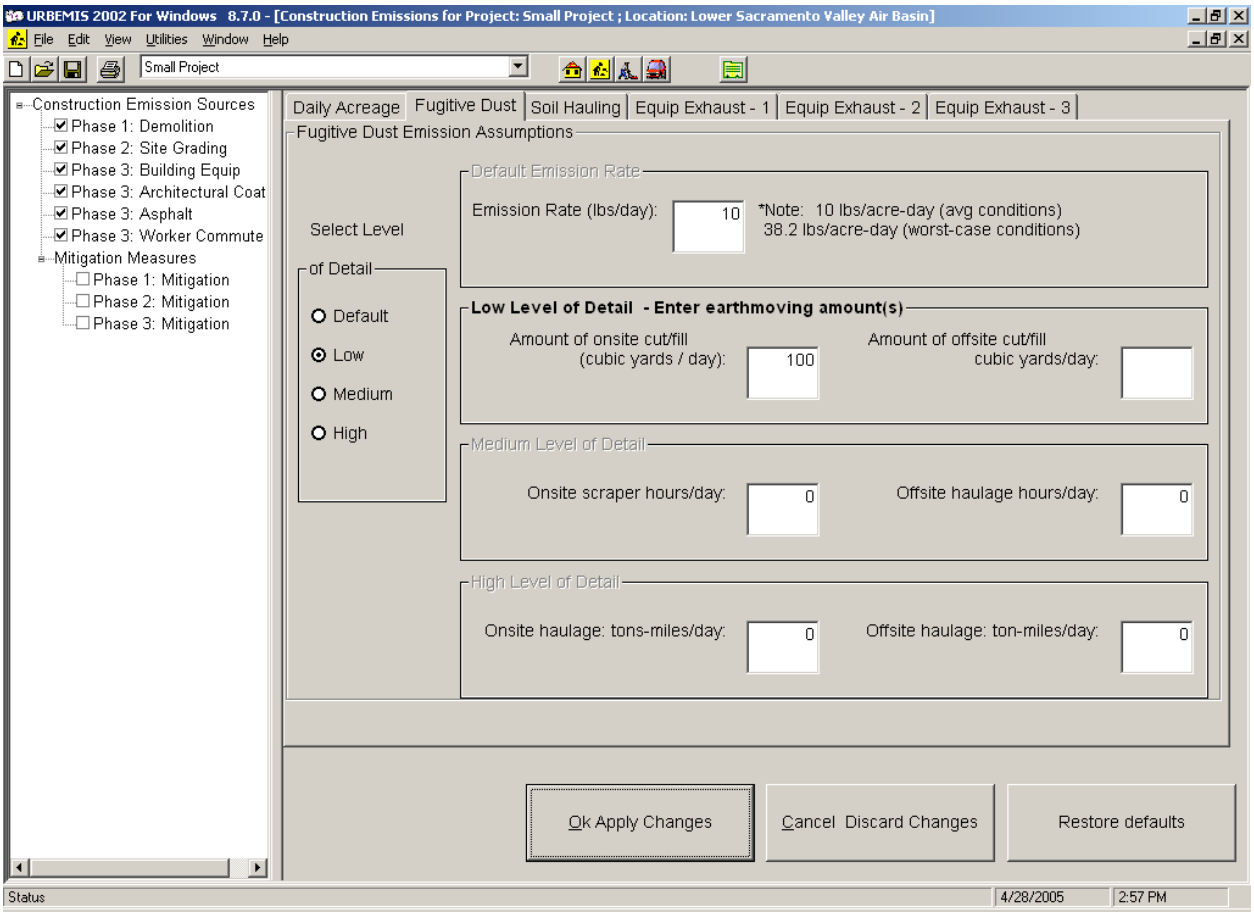

Figure 10. Phase 2 – Fugitive Dust

The third tab – soil hauling – is used to estimate on-road vehicle emissions associated with site grading (see Figure 11). The user must enter the amount of soil to be imported to and/or exported from the site. The user can also modify the average truck hauling capacity (20 cubic yards) and the truck haul round trip distance (20 miles).

The fourth, fifth, and sixth tabs represent the off-road construction vehicles that can be selected for the site grading phase. The user has the option of selecting the type and number of vehicles applicable to the project, and can modify the vehicle horsepower, load factor, and hours per day for either of the vehicle types. Also, the user can tell URBEMIS to estimate the number and type of vehicles appropriate for a project of the size specified by the user. To do that, you must hit the

Recalc with Land Uses button. URBEMIS will replace any information entered by the user with the values it calculates.

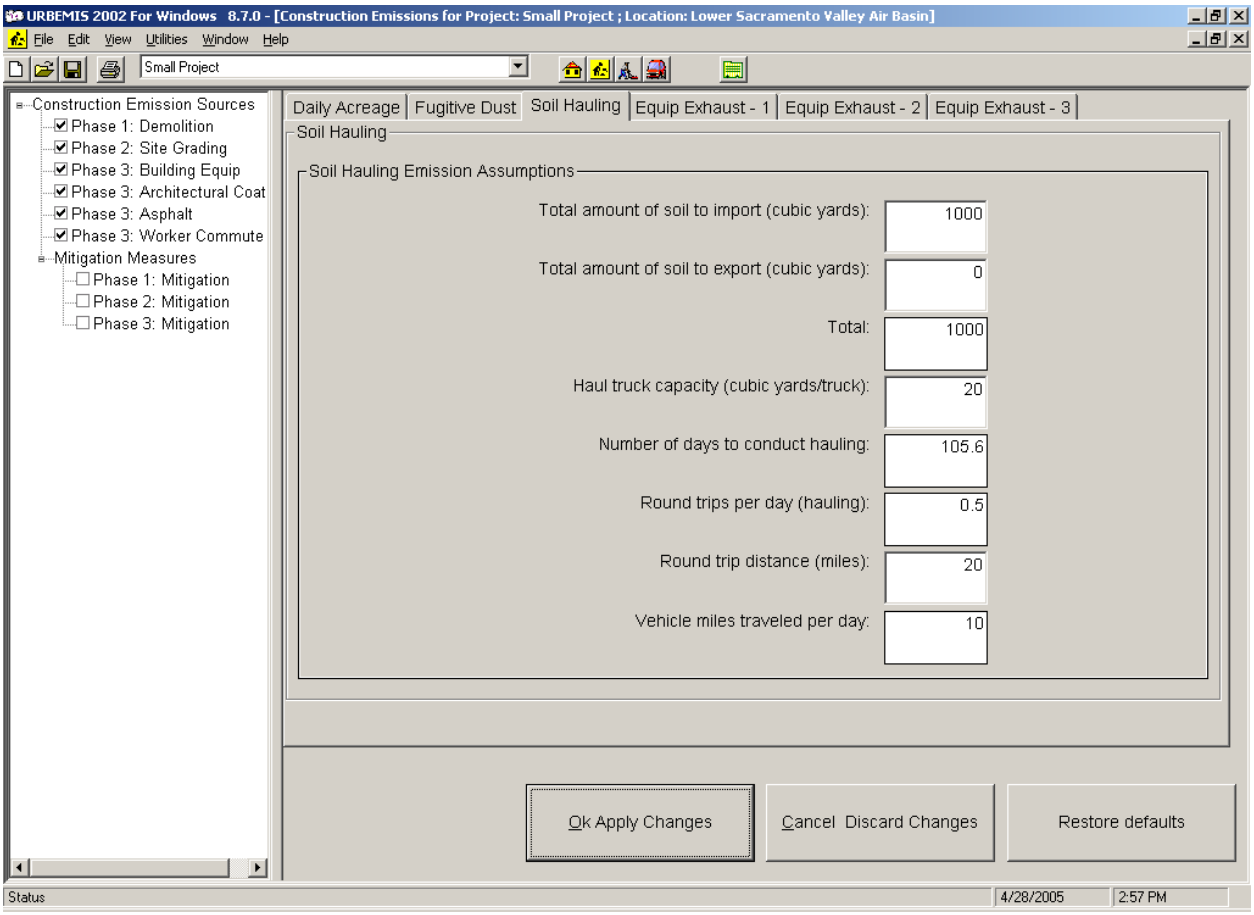

Figure 11. Phase 2 – Soil Hauling

Phase 3 – Building Construction

Phase 3 is treated slightly differently than Phases 1 and 2. When you are working in the URBEMIS2002 construction module, the left pane of that module includes one node for Phase 1, one node for Phase 2, but four nodes for Phase 3 (see Figure 7 above). By clicking on the first of these four nodes – Building Equipment – URBEMIS displays the first of three equipment exhaust screens in the right pane. You can go back and forth between the three equipment exhaust screens by clicking on the tabs at the top of the right pane. Within these three screens, you should enter the number of each type of off-road construction equipment that will be used during the Phase 3 building construction subphase of the project. You should also edit the horsepower, load factor, and hours per day if that level of detail is available for the project. If construction equipment numbers are unavailable, then you can hit the Recalc with Land Uses button, which will prompt URBEMIS to enter its estimate of the default number of vehicles based on the land uses that have been entered.

The second of the four Phase 3 nodes in the left pane is Architectural Coatings. By clicking on that node, URBEMIS displays in the right pane the residential and nonresidential assumptions used to estimate architectural coatings. All of the displayed assumptions can be modified by the user.

The third of the four Phase 3 nodes in the left pane is Asphalt. By clicking on that node, URBEMIS displays the first of four screens in the right pane. Those four screens include: Off-Gas Emissions and Equipment Exhaust 1, 2, and 3. The user can navigate between the four screens by clicking on the tabs found at the top of the right pane. The Off-Gas Emissions screen shows the acres to be paved and the ROG off-gas emission rate in pounds per acre. The information in this screen is used to estimate total off-gas emissions from asphalt used in paving the site. The user should enter the total acres to be paved, if known. If that value is unknown, then URBEMIS will calculate a value based on entered land uses when the user clicks on the Recalc with Land Uses button.

In addition to the Off-Gas Emissions screen are the three equipment exhaust screens. You can go back and forth between the three equipment exhaust screens by clicking on the tabs at the top of the right pane. Within these three screens, you should enter the number of each type of asphalt construction equipment that will be used during the Phase 3 asphalt paving subphase of the project. You should also edit the horsepower, load factor, and hours per day if that level of detail is available for the project. If asphalt construction equipment numbers are unavailable, then you can hit the Recalc with Land Uses button, which will prompt URBEMIS to generate its own estimate of the type and number of vehicles based on the land uses that have been entered.

The fourth of the four Phase 3 nodes in the left pane is Worker (Commute Trips). By clicking on the Worker node in the left pane, URBEMIS displays the construction worker trip generation rates that it uses to calculate worker trips and associated emissions. URBEMIS displays those trip generate rates in the right pane. Those trip rates can be edited by the user.

III.6.2 Specifying Construction-Related Mitigation Measures

To specify construction mitigation, you must first check one, two, or all three construction mitigation boxes found on the right side of the construction main screen (see Figure 7). You should be aware that you cannot turn on a construction mitigation phase unless you have also turned on that phase by checking the phase box. For example, you cannot turn on the demolition mitigation box unless you have already turned on Phase 1 demolition. And, once you have turned on one or more of the three mitigation phases, they will not be saved until you hit the OK-Apply Changes button at the bottom of the screen. Once you have hit the OK-Apply Changes button, however, the boxes in the left pane of the screen are made consistent with those on the right pane of the construction start screen. Then, to specify mitigation measures applicable to a project, you must first click on one of the boxes in the left pane of the construction screen.

By clicking on the Phase 1- Mitigation node in the left pane, you are taken to the first of four screens from which demolition related mitigation measures can be selected (see Figure 12).

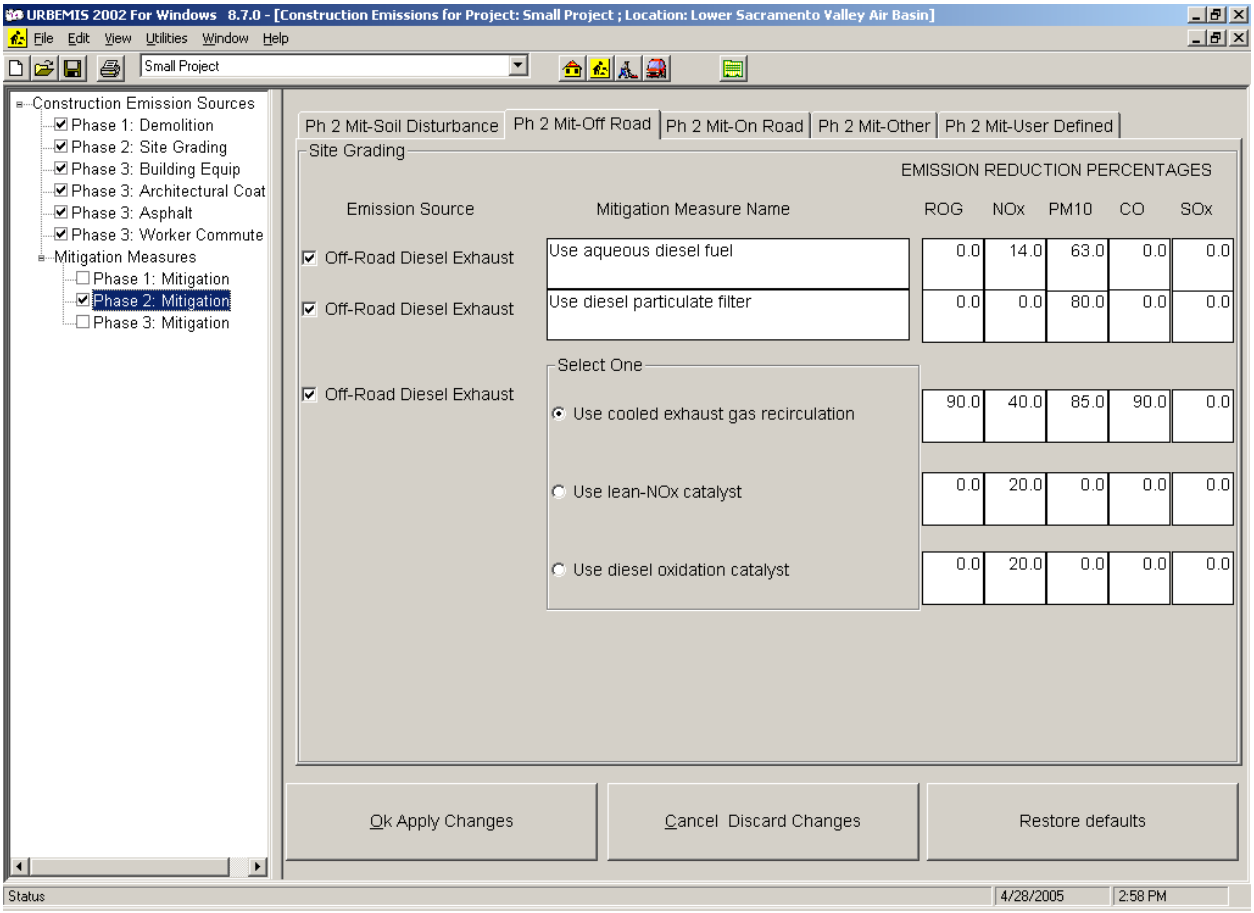

Figure 12. Phase 1 - Mitigation for Off-Road Diesel Exhaust

Those four screens, which can be selected by clicking on the tabs, include the following:

Phase 1 Mitigation for Off Road Diesel Exhaust
Phase 1 Mitigation for On Road Diesel Exhaust
Phase 1 Mitigation for Worker Commute Trip Emissions
Phase 1 Mitigation – User Defined Options

From the first three of these four screens, the user can select pre-defined mitigation measures that are applicable to the project being analyzed. Each of these pre-defined measures includes specific emission reduction efficiencies. The fourth screen allows the user to specify additional mitigation measures and control efficiencies.

Construction mitigation measures for Phase 2 – Site Grading works similarly to the Phase 1 mitigation measure. By clicking on Phase 2- Mitigation (left part of construction screen), you are taken to the first of five screens from which site grading related mitigation measures can be selected. Those five screens, each of which can be selected by clicking on the tabs, include the following:

Phase 2 Mitigation for Soil Disturbance
Phase 2 Mitigation for Off Road Diesel Exhaust
Phase 2 Mitigation for On Road Diesel Exhaust
Phase 2 Mitigation for Other Emission Sources
Phase 2 Mitigation – User Defined Options

For the first four of these five screens, the user can select pre-defined mitigation measures that are applicable to the project being analyzed. Each of these pre-defined measures includes specific emission reduction efficiencies. The fifth screen allows the user to specify additional mitigation measures and control efficiencies.

Construction mitigation measures for Phase 3 – Building Construction works similarly to the Phase 1 and 2 mitigation measures. By clicking on Phase 3- Mitigation (left pane of construction screen), you are taken to the first of five screens from which building construction related mitigation measures can be selected. Those five screens, each of which can be selected by clicking on the tabs, include:

Phase 3 Mitigation for Off Road Diesel Exhaust from Building Construction
Phase 3 Mitigation for Off Road Diesel Exhaust from Asphalt Paving
Phase 3 Mitigation for On Road Diesel Exhaust
Phase 3 Mitigation for Worker Commute Trips
Phase 3 Mitigation – User Defined Options

For the first four of these five screens, the user can select pre-defined mitigation measures that are applicable to the project being analyzed. Each of these pre-defined measures includes specific emission reduction efficiencies. The fifth screen allows the user to specify additional mitigation measures and control efficiencies.

III.7 Area Source Emissions

III.7.1 Specifying Area Emissions

The "Area-Source Emission" screen allows you to estimate area-source emissions for up to five categories of emission sources. Four of these five categories are fuel combustion related: natural gas, wood stoves, fireplaces, and landscape maintenance. The fifth, consumer products, includes only reactive organic compound emissions released through the use of products such as hair sprays and deodorants. The emission factors used by URBEMIS2002 to estimate area-source emissions are described in detail in Appendix B.

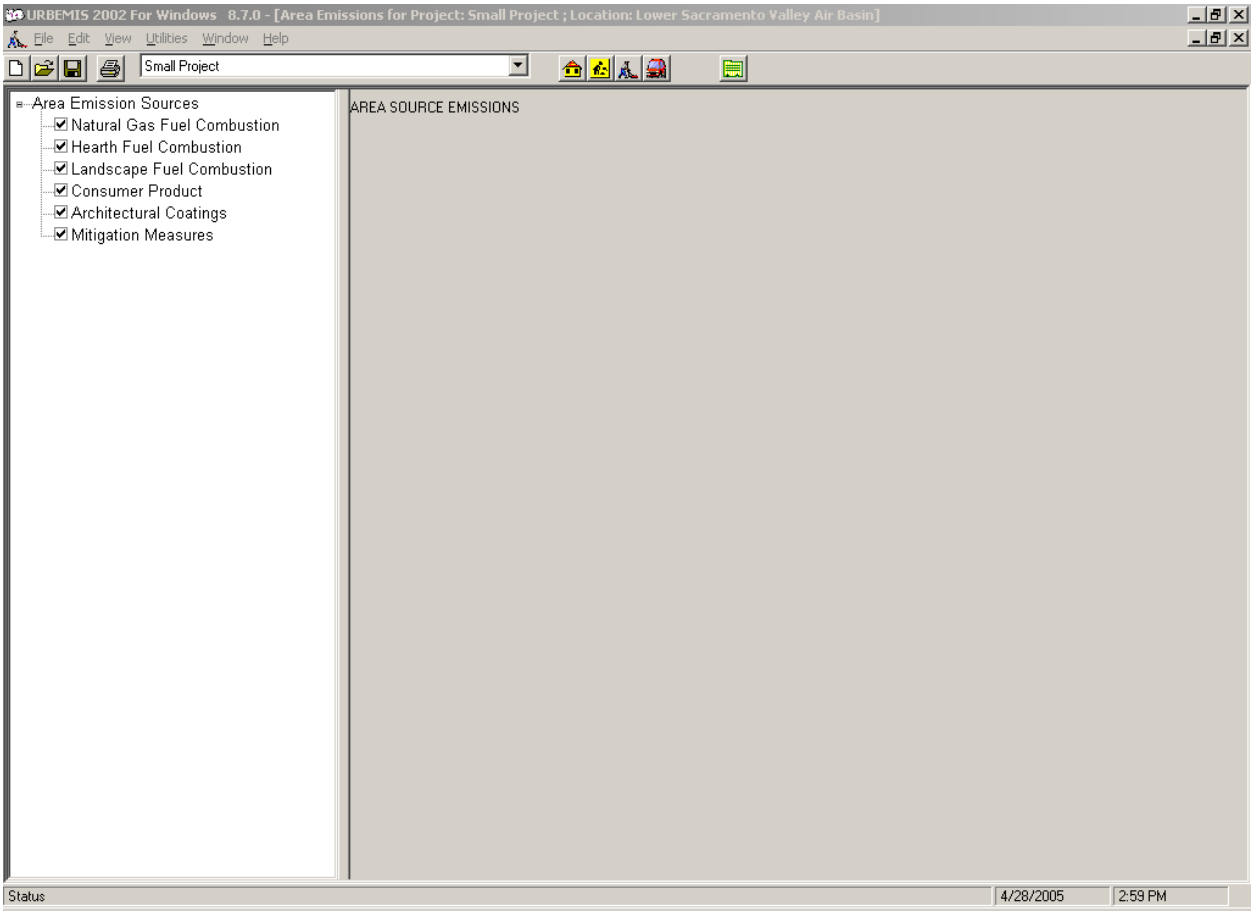

Figure 13. Area Source Entry Screen

Figure 13 shows the introductory area source emissions screen. Please note that the screen or window is divided into two panes, the left pane and the right pane. A splitter bar separates the left and right panes. By placing the cursor on the splitter bar and dragging right or left with the mouse, the relative size of each pane can be changed. This allows the user to see text that may be partially hidden. The cursor can also be placed on the edges of the window and dragged to make the entire window larger or smaller. The left pane contains a list, with each item on that list called a node.

Each of these five area source categories is shown in the list of the left pane. Information associated with each category is shown in the right pane. To examine the information associated with an item in the list, move the cursor to the item in the list shown in the left pane and click on that item. Information associated with that item is then displayed in the right pane. Although you can use this procedure to examine information in the right pane, the user must check the box associated with each of the categories for which emission estimates are desired.

When you click on the “Natural Gas Fuel Combustion” settings button in the left pane list, the right pane changes to show you the “Natural Gas Combustion Settings” default information. You may then modify any of the settings, which will be saved by clicking on the “OK-Apply Changes” button. A similar procedure can be used to review or modify the settings for each of the area emission sources. The user should note, however, that clicking the “OK-Apply Changes” button save the information to memory, but not to a file. To save information to a file, see section III.11.

Note that the setting for fuel combustion-landscape maintenance requires you to enter the year being analyzed. This year does not have to match the year entered for construction or motor vehicle emissions.

III.7.2 Specifying Area-Source Mitigation Measures

From the "Area Source" main menu, you may select area-source mitigation measures by clicking the "Mitigation Measures" checkbox in the left pane list. This action forces URBEMIS2002 to display the area source mitigation measures in the right pane. The user can select up to five area-source mitigation measures for residential, commercial, and industrial sources (see Figure 14). These mitigation measures are described in more detail in Appendix B.

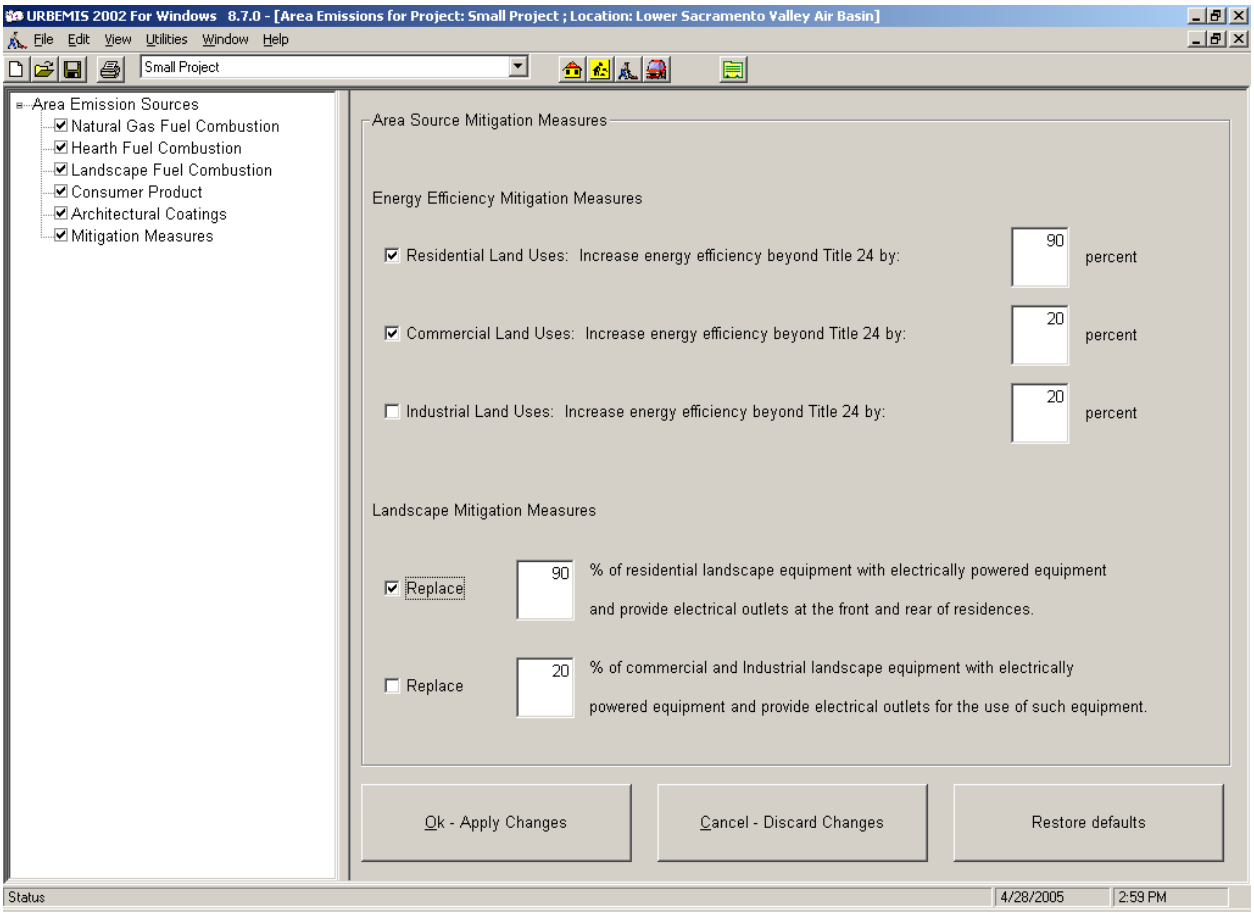

Figure 14. Area Source Mitigation Measures

III.8 Vehicle or Operational Emissions

III.8.1 Specifying Vehicle Emissions

The "Settings for Operational-Related Emissions" entry screen in shown in Figure15. Please note that the screen or window is divided into two panes, the left pane and the right pane. A splitter bar separates the left and right panes. By placing the cursor on the splitter bar and dragging right or left with the mouse, the relative size of each pane can be changed. This allows the user to see text that may be partially hidden. The cursor can also be placed on the edges of the window and dragged to

make the entire window larger or smaller. The left pane contains a list, with each item on that list called a node.

The left pane of Figure 15 shows eight separate nodes in the list (excluding the mitigation check boxes). Each node represents information needed to estimate motor vehicle emissions. The first five of these nodes (vehicle fleet percentages, target year, trip characteristics, temperature data, variable starts, and road dust) must be checked (they cannot be unchecked) to obtain motor vehicle emissions. The remaining three nodes (road dust, pass-by trips, and double counting) are optional and do not have to be checked to obtain motor vehicle emission estimates. The double counting node does not appear unless the user has indicated a mixed use project by entering both a residential and a non-residential land use in the land use selection screens.

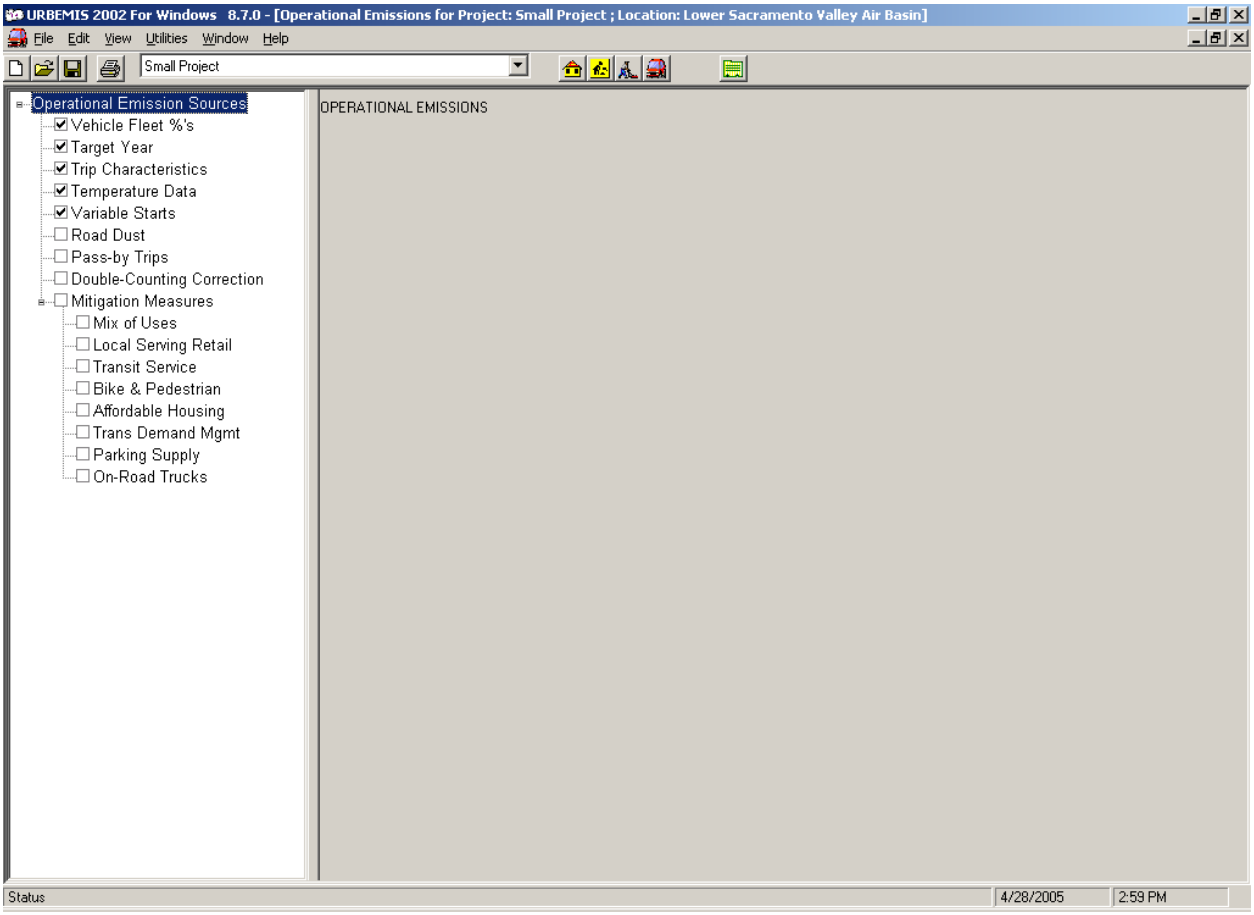

Figure 15. Operational Emissions Entry Screen

Each of the operational vehicle categories is shown as a node in the left pane list. Information corresponding to each node can be accessed by placing the cursor on the node and clicking. This forces URBEMIS2002 to display the associated information in the right pane

Note that neither the "Settings for Operational-Related Emissions" screen nor any of its supporting screens allow you to specify the season (winter or summer) for which you want to estimate emissions. URBEMIS2002 automatically estimates motor vehicle emissions for both winter and summer of the target year using the temperature data specified in the temperature data screen. You

are given the option of viewing or printing either summer or winter emission estimates in the output screens (see discussion under Section III.9).

Vehicle Fleet Percentages. The vehicle fleet percentages can be selected by clicking on the vehicle fleet percentages node in the left pane. This action displays "Vehicle Fleet Characteristics -1" in the right pane. This right pane also includes a second tab, "Vehicle Fleet Characteristics – 2". URBEMIS2002 includes 13 vehicle types. And for each vehicle type, there are three fuel/technology classes: non-catalyst (gasoline), catalyst (gasoline), and diesel. Within the right pane, you can modify any of the fleet percentages or fuel/technology classes. The total fleet percentage must total to 100. Also, for each vehicle type, the three fuel/technology classes must subtotal to 100 percent. Once you are satisfied with the information, you can save it to memory by hitting the "OK Apply Changes" button.

Target Year. The target year can be modified by clicking on the "Target Year Settings" box in the left pane list, which then shows you the "Target Year" screen in the right pane. You should click on the year for which you would like to estimate emissions. Once you have selected the correct year, you can save it to memory by hitting the "OK Apply Changes" button.

Trip Characteristics. The "Trip Characteristics" screen can be modified by clicking on the "Trip Characteristics Settings" node in the left pane. This action displays the trip characteristics in the right pane. Several pieces of information are contained in the "Trip Characteristics" screen: average trip speeds, trip percentages, and trip lengths for five different trip types (home-based work trips, home-based shopping trips, home-based other trips, work trips, and commercial-based non-work trips).

Note that the "Trip Characteristics" screen allows you to enter the trip percentages for home-based trips, which must total 100 percent. However, this same screen does not permit you to enter trip percentages for commercial-based trips. Instead, commercial-based percentages are calculated separately by URBEMIS2002 for each nonresidential land use selected in the "Land Use" screens (see Section III.5).

The "% Worker Commute" information from the land use screens corresponds to the commercial-based commute work trip value. The commercial-based commute trip percentage is then used to estimate commercial-based non commute work trip and customer based trip percentages for each land use. If the commercial-based commute trip value exceeds 50 percent, then the commercial-based non commute trip percentage equals 100 percent minus the commute trip percentage, multiplied by 50 percent. If the commercial-based commute trip value is less than 50 percent, then the commercial-based non commute trip percentage equals one half of the commercial-based commute trip value. Finally, for each land use, customer based trips are assumed to equal the 100 percent minus the total of the commercial commute and non commute percentages.

The "Trip Characteristics" screen also allows you to modify default percentages for urban and rural trip lengths by trip type. The initial URBEMIS2002 screen used to open an existing or new project contains a checkbox that allows the user to identify the project as being located in an urban or a rural setting. If you have identified the project as urban, then the urban trip lengths are used to estimate vehicle miles traveled and, ultimately, emissions. In contrast, if you have identified the project as rural, then the rural trip lengths are used. Once you have selected the correct year, you can save it to memory by hitting the "OK Apply Changes" button.

Temperature Data. By clicking on the temperature data in the left pane, temperature options are presented in the right pane. You have the option of modifying both winter and summer ambient temperatures, which are used to estimate winter and summer emission estimates and which

correspond to the summer versus winter gasoline specifications used in California outside of the South Coast Air Basin (greater Los Angeles). Selecting "OK Apply Changes" from the "Temperature Data" screen saves the information to memory.

Variable Starts. You may modify the "Variable Starts" information by clicking on the "Variable Starts" settings button shown in the left pane. This action causes URBEMIS2002 to display variable starts information in the right pane. That screen includes information on "Variable Start Percentages by Trip Type and Time since Engine Stopped". EMFAC2002 requires the vehicle engine shut-off percentages for 18 time increments, ranging from 5 minutes to 720 minutes. The information provided in this screen by trip type represents statewide averages of pre-start cool-down profiles from an ARB analysis of the 1991 California Department of Transportation household travel survey. These percentages should not be modified unless better information is available. Selecting "OK Apply Changes" from the "Temperature Data" screen saves the information to memory.

Road Dust. You may turn the Road Dust option on or off by clicking the check box in the left pane. This action will also display in the right pane information on "Entrained Road Dust Emissions". You have the option to modify the distribution of travel between paved and unpaved roads. You also have the option to modify the paved road or unpaved road defaults by clicking on the accompanying tabs.

If you click on the "Change Paved Road Defaults..." tab, you are taken to the "Paved Road Dust Emissions" screen. From within that screen, you may modify the default emission factors and percentage of travel for each of four road types.

You may also click on the "Change Unpaved Road Defaults" tab, where URBEMIS2002 will display the "Unpaved Road Dust Emissions" screen. From this screen, you can select either the U.S. EPA methodology for calculating emissions or you can use the California Air Resources Board's emission factor. If you select the U.S. EPA methodology, you are allowed to modify one or more of the five variables used to estimate unpaved road dust emissions.

Double Counting. Another option available to URBEMIS2002 users is to adjust for double-counting.. The double-counting adjustment is designed to reduce double counting of internal trips between residential and nonresidential land uses. Consequently, selecting this option is available only when you have selected both residential and nonresidential land uses. You must click the check box in the left pane where URBEMIS2002 displays the "Double Counting Correction".

Then you are shown the number of residential and nonresidential trips that would be generated based on the land uses selected. You are given the option of entering the number of internal trips between residential and nonresidential land uses. The value entered represents the number of internal trips that will not be included in the emissions estimate. Once you are comfortable with the internal trip estimate, clicking on the "OK/Return" button returns to the "Settings for Operational-Related Emissions" screen.

Pass-by Trips. You may select the "Pass-By Trips" button from the left pane list. When you select "Pass-By Trips", no optional information is presented in the right pane. Selecting the "Pass-By Trips" button allows URBEMIS2002 to calculate emissions from vehicle trips that are generally lower than estimates without the pass-by trip option. The pass-by trip algorithm is described in Appendix C.

III.8.2 Specifying Vehicle-Related Mitigation Measures

From the Operational Emissions" screen, you have the option of turning operational mitigation measures by selecting one or more of eight optional "Mitigation Measures" options in the left pane:

- Mix of uses
- Local serving retail
- Transit use
- Bike and pedestrian
- Affordable housing
- Transportation demand management
- Parking supply; and
- On-Road Trucks

Operational Mix of Uses Mitigation

The following procedure is used to adjust trip generation rates as a function of the mix of land uses for any particular project.

Trip reduction = (1- (ABS (1.5 * h e) / (1.5 * h + e)) 0.25) / 0.25 * 0.03

Where:

h = study area households (or housing units)

e = study area employment

This formula assumes an "ideal" housing balance of 1.5 jobs per household and a baseline diversity of 0.25. The maximum possible reduction using this formula is 9%. Negative reductions of up to 3% can result when the housing to jobs ratio falls to levels less than the baseline diversity of 0.25. This reduction takes into account overall jobs-population balance.

The number of households or housing units and employment should be based on the area located within a 1/2 mile radius of the project's center.

Operational Local Serving Retail Mitigation

The presence of local serving retail can be expected to bring further trip reduction benefits, and an additional reduction of 2% is assumed. This is towards the lower end of the values presented in the research, in order to avoid double counting with the diversity indicator.

Operational Transit Mitigation

The Transit Service Index emphasizes frequency but with greater weighting given to rail services. Greater weight is also given to dedicated shuttles, in recognition of the fact that these are likely to be more closely targeted to the needs of the development. Information on transit availability and frequency can be obtained from transit agency maps and schedules.

The Transit Service Index is determined as follows:

- Number of average daily weekday buses stopping within 1/4 mile of the site; plus
- Twice the number of daily rail or bus rapid transit trips stopping within 1/2 mile of the site; plus
- Twice the number of dedicated daily shuttle trips;
- Divided by 900, the point at which the maximum benefits are assumed. (This equates to a BART station on a single line, plus four bus lines at 15-minute headways.)

Developments that are larger than 0.5 miles across in any direction must be broken into smaller units for purposes of determining the transit service index. The average of all units would then be used.

The figure shown below provides some examples of how service frequencies translate into Transit Service Index scores (note these are additive, if a location has more than one component).

Example Transit Service Index Scores

Transit Service	Score	Assumptions
BART (single line)	0.33	150 trips per day (15-20 minute headways in each direction from 4 AM-12 AM)
15-minute bus, 5 AM 12 AM	0.17	
30-minute bus, 5 AM 7 PM	0.06	
Amtrak San Joaquin	0.03	6 trips per day in each direction
Dedicated commute shuttle	0.02	5 trips per commute period (single direction)

As well as existing service, planned and funded transit service should be included in the calculation. Purely demand responsive service should not be included. A maximum trip reduction of 15% is assumed.

To account for non-motorized access to transit, half the reduction is dependent on the pedestrian/bicycle friendliness score. This ensures that places with good pedestrian and bicycle access to transit are rewarded.

Trip reduction = t * 0.075+ t * ped/bike score * 0.075

Where t = transit service index

Operational Bike and Pedestrian Mitigation

The pedestrian/bicycle factor is calculated as follows:

Ped/bike factor = (network density + sidewalk completeness + bike lane completeness) / 3

Where:

Network density = intersections [sum of valences] per square mile / 1300 (or 1.0, whichever is less)

Note: In most GIS applications, intersections are counted based on the number of line segment terminations, or each "valence." Intersections have a valence of 3 or higher. A valence of 3 is a "T" intersection, 4 is a four-way intersection. Therefore, if intersections are counted manually on a map or project plan, care needs to be taken to distinguish between 3-, 4- and 5-way intersections, and factor them up accordingly. The 1,300 value roughly equates to a dense grid with four-way intersections every 300 feet. Intersections with dedicated routes for pedestrians and/or bicyclists should be included in this calculation.

Sidewalk completeness = % streets with sidewalks on both sides + 0.5 * % streets with sidewalk on one side

Bike lane completeness = % arterials and collectors with bicycle lanes, or where suitable, direct parallel routes exist

A maximum reduction of 9% is assumed. The trip reduction is calculated as:

Trip reduction = 9% * ped/bike factor

No reduction is allowed if the entire area within a half-mile walk of the project center consists of a single use. (Note that this applies to a half-mile walk, rather than straight-line distance, to account for barriers such as freeways.) However, the ped/bike factor can still be used to calculate pedestrian access to transit, as part of the transit mitigation measure.

Information on the number of intersections can be obtained from street plans or maps. Information on sidewalk completeness and bike lane completeness can be obtained from site observations or from aerials such as those obtainable from http://terrraserver.microsoft.com.

Operational Affordable Housing Mitigation

It is difficult if not impossible to account for the exact incomes of residents in URBEMIS, most obviously because the occupants are not known at the pre-development stage. However, the percentage of deed-restricted below-market-rate (BMR) housing does offer a way to incorporate this effect.

URBEMIS assumes a 4% reduction in vehicle trips for each deed-restricted BMR unit. Thus, the total reduction is as follows:

Trip reduction = % units that are BMR * 0.04

A development with 20% BMR units would thus gain a 0.8% reduction. A development with 100% BMR units would gain a 4% reduction.

Operational Transportation Demand Management

Daily Parking Charge

URBEMIS assumes a maximum trip reduction of 25% for projects that commit to introducing parking pricing. The maximum reduction applies to prices of $6 per day or greater (in 2004 dollars).

The trip reduction will therefore be as follows:

Trip reduction = daily parking charge / 6 * 0.25

If the parking charge is more than $6, the 25% reduction is taken. If parking charges do not apply to all trips to a site (e.g. customers are exempt), the reduction is pro-rated by the percentage of trips that the charges apply to. If little or no on-site parking is provided, the parking charges are applied to those of surrounding public facilities.

Free Transit Passes

Some California transit agencies, most notably VTA in Santa Clara County, have EcoPass or similar programs, whereby employers or property managers bulk-purchase transit passes for (free) distribution to their employees or tenants. Eco Pass programs have been shown to increase transit ridership by 50-79% and reduce vehicle trips by 19%. (Note that many of these new riders were making new trips, or ones previously made by walking or cycling.)

We therefore recommend that any project committing to providing free transit passes would receive an additional credit equivalent to 25% of the reduction granted for transit service. Thus, the credit is more valuable in places that have good transit service. This reduction only applies to the portion of trips generated by those granted the free transit passes (e.g. residents and/or employees, but excluding shoppers and other visitors).

Telecommuting

As with the reductions for other mitigation measures, there must be an enforceable commitment (e.g. development agreement) for telecommuting programs, which cover both the take-up rate (employees actually telecommuting or using compressed work schedules) as well as the provision of the option.

The percentage reduction is not additive (in contrast to most other trip reduction measures). For example, if 20% of employees telecommute, and other trip reduction measures are estimated to reduce vehicle trips from 1,000 to 800 per day, the 20% reduction is applied to the 800 trips, not the original 1,000.

Other TDMs

Other TDM program elements that do not include financial incentives tend to have a smaller impact on travel behavior. Trip and associated emission reductions for other TDMs selected within URBEMIS are based on the number of the following elements incorporated into the program.

- Secure bicycle parking (at least one space per 20 vehicle parking spaces)
- Showers/changing facilities
- Guaranteed Ride Home
- Car-sharing services
- Information on transportation alternatives, such as bus schedules and bike maps
- Dedicated employee transportation coordinator
- Carpool matching programs
- Preferential carpool/vanpool parking

The impact of a TDM program also depends on the travel alternatives available. A program will have more impact if the site is served by frequent transit, for example (although note that a TDM program can do much to promote carpooling even in other locations). For this reason, part of the TDM credit is used to adjust the credits granted for transit service and pedestrian/bicycle friendliness (see table below).

Recommended TDM Program Reductions

Level	Number of Elements	Trip Reduction
Major	At least 5 elements	2%, plus 10% of the credit for transit and pedestrian/bike friendliness
Minor	At least 3 elements	1%, plus 5% of the credit of transit and pedestrian/bike friendliness
No program	Less than 3	None

Operational Parking Supply Mitigation

The parking supply mitigation measure uses the Institute of Transportation Engineers Parking Generation, 3rd Edition handbook as the baseline. It applies only to non-residential land uses. The trip reduction is calculated as follows:

Trip reduction = 1- (Actual parking provision / (ITE Parking Generation rate * # units)

Since ITE parking generation rates use the same land use codes as the trip generation rates, URBEMIS calculates the ITE estimated values of parking demand. The user is only required to enter the actual parking provision for each land use.

The Parking Generation handbook covers most common land uses. For some land uses, however, no parking generation rates are available: in these cases, this particular mitigation measure may not be used. Those land uses without parking generation rates include:

- City Park
- Gas/Service Station

To avoid double counting with other trip reduction measures, the impacts of parking supply are assessed in conjunction with all other non-residential trip reduction measures as follows:

The total of all other non-residential trip reduction measures is used if this is greater than or equal to the trip reduction from parking supply measures. For example, if parking supply is reduced 10% from ITE levels, and transit, mixed use and pedestrian/bicycle trip reductions amount to 20%, the 20% figure is used.

If the total of all other non-residential trip reduction measures (r1) is less than the trip reduction from parking supply measures (r2), the total trip reduction is as follows:

$r1 + 0.5 * (r2 - r1)$

In effect, the parking supply reduction is only used if it is greater than the impact from other trip reduction measures, and the difference is discounted by 50%. For example, if parking supply is reduced 25% from ITE levels, and transit, mixed use and pedestrian/bicycle credits amount to 15%, the total reduction would be:

$15 + 0.5 * (25-15) = 20\%$.

This reduction should only be granted if measures to control overspill are in place, such as Residential Permit Parking programs, time limits or meters.

Operational On-Road Truck Mitigation

For project applicants wishing to provide on-road mitigation for diesel trucks, the applicant has two choices.

The first choice requires that the user enter an estimate of the pounds per day and tons per year emission reductions associated with the project. This information will typically be provided as a result of consultation with the applicable air district. The district-approved emission reductions should be entered into the operational mitigation: on-road trucks screen.

The second choice requires that the user select a mitigation measure by diesel truck (or bus) fleet type category. This mitigation measure will only be applied to truck trips associated with non-residential land uses and only to the non-commute portion of those trips. Each mitigation measure has a specific emission reduction percentage applied to it. The user also has the option of entering their own mitigation and the associated emission reduction by pollutant class (ROG, NOx, CO, SO2,

and PM10). The percentage reductions are only applied to the percentage of diesel vehicles within each truck class.

III.9 Outputting Results

To view the emissions output, you must click on the rightmost icon on the Icon Bar – the results icon - that appears as a yellow sheet of paper with lines on it. This will open up the output or results report.

The results output is similar to construction, area sources and operational screens in that the window is divided into a left and a right pane (see Figure 16). The left pane contains an expandable/collapsible list, with each item of the list designated as a node.

When first opened, the results screen presents the user with three nodes in the left pane:: lbs per day summer, lbs per day winter, and tons per year. By clicking on either of those three nodes, the user can expand the list to show summary and detailed report nodes. The Detail node can be expanded even further by clicking on either detail or the box to its left. Emission results for the current project can be seen in the right pane by clicking the cursor on the desired node in the left pane. The checkboxes associated with each node in the left pane are important because they identify the information sent to a printer or output file.

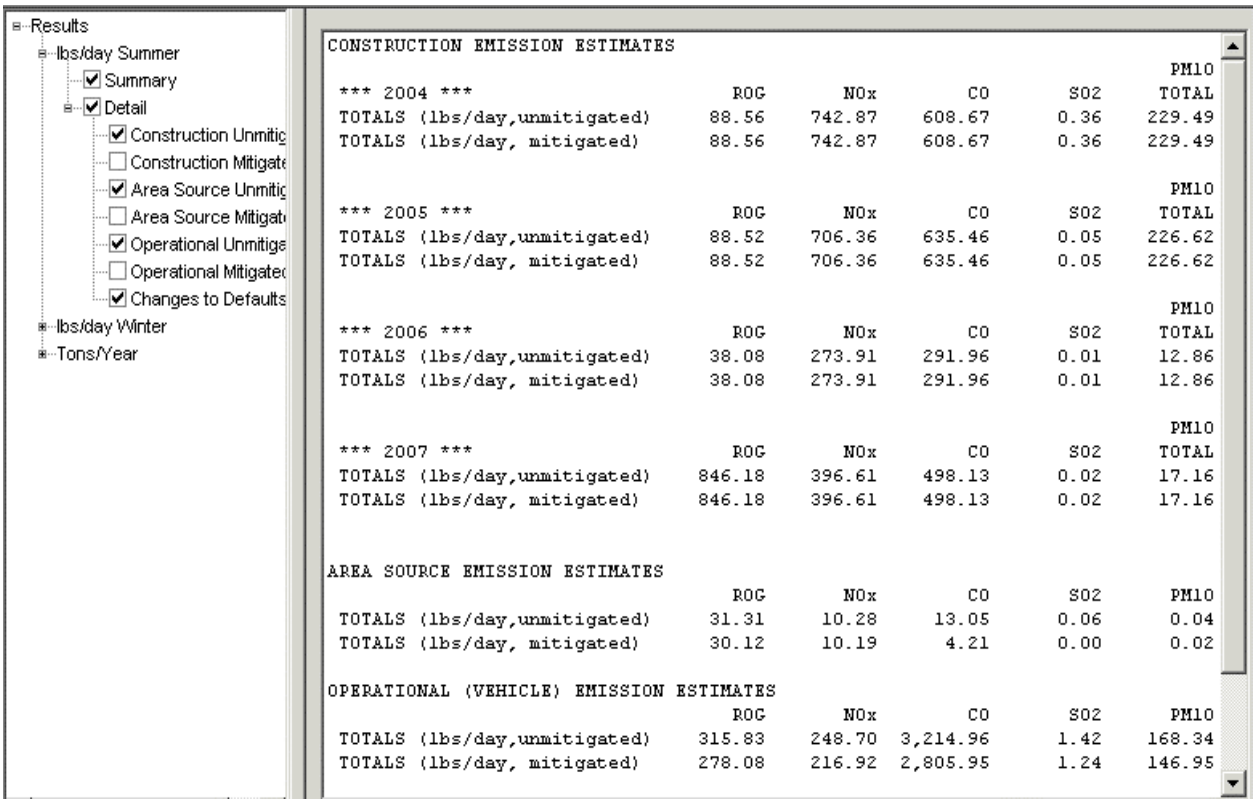

Figure 16. Output Emissions Screen

To send the output to the printer, the user can proceed in one of two ways. The easiest method is to click on the printer icon. Alternatively, the user can select “File” from the Menu, then “Print

Selected Results". If problems arise when printing, you may need to check the print destination by selecting "File" from the Menu, then "Select Print Destination" from the drop down menu.
The user also has the option of sending output to a file instead of a print, which is accomplished as follows. The user must first select "File" from the Menu, then the "Select Print Destination" from the drop down menu. A screen appears that allows the User to select a check box that sends the output to a ascii file instead of to the printer. By selecting that check box, however, all future print jobs are sent to the output file until "Select Print Destination" is selected again by the user. One note of caution. Following this procedure tells URBEMIS2002 that the print destination is to a file rather than to the printer. You must still send the information to the printer by clicking on the printer icon or by selecting "File" from the Menu, then selecting "Print Selected Results". When you tell it to print (to a file), URBEMIS2002 will then ask for the name and location of the file to which you wish to send output.

The user must be aware of the color of the results icon when running URBEMIS2002. The results icon is found at the far right of the menu bar. The results icon is represented as a yellow pad with either black, red, or green lines. Initially, when the URBEMIS program is started but before any information has been added, the results icon is yellow with black lines. However, when information has been added or edited, the lines on the results icon turn green. This indicates that the icon must be clicked to get emission results that reflect the most recent changes. When the results icon lines are red, this indicates that the results reflect the most recent changes made to the current project. If the results icon is clicked when the lines are green, URBEMIS will recalculate the emission estimates. If the result icon is clicked when the lines are red, URBEMIS will simply show the results without recalculating emissions.

One key point to remember. You can view emission results by clicking on the results icon. Those results can be viewed as shown in Figure 15. However, those results may not represent the most recent changes made to a project unless the results icon has red lines. This can occur if you opt to view the emission results, leave the emission results screen open, then go back and change some project assumptions.

III.10 Setting Default Drives and Directories

Setting the correct default drives and directories is essential to running URBEMIS2002 successfully. Four sets of files are included with URBEMIS2002: land use project files, emission rate files, air district default files, and executable or "*.exe" files.

At startup, the program looks for a file called DIRECTRY.SAV on the default drive. The DIRECTRY.SAV file tells URBEMIS2002 the default drives and directories. If URBEMIS2002 finds the DIRECTRY.SAV file, then the program loads the main menu. If URBEMIS2002 cannot find the DIRECTRY.SAV file, then the program immediately sends you to the "Set Default Drives and Directories" screen.

Once there, you are prompted to select a default drive and directory for each of the three sets of files. To select a default drive or directory, you must position the cursor on the appropriate drive or directory and double click the left mouse button. Make sure that the three sets of directories are on the same drive; otherwise, the program will not run properly.

Once drives and directories have been selected, you must either press "OK" or "Cancel". Pressing "OK" saves the newly selected drives and directories to the DIRECTRY.SAV file. Pressing

“Cancel” takes you back to the main menu without saving any changes to the DIRECTRY.SAV file. The “Cancel” button will not work if the DIRECTRY.SAV file does not exist on disk in the default executable directory, which is the program from which the program is started.

III.11 Saving to a File

Saving the project file to a disk file is essential if you want to rerun the program later. To save a file, either select the third icon (diskette icon) from the left on the Icon Bar, or click on “File” from the Menu and select “Save This Project” from the drop down menu. If a file with the same name already exists on disk, then URBEMIS2002 warns the user that a file with the same name already exists. The user can opt to save the file as a different name. URBEMIS2002 automatically gives files it creates a .urb extension.

III.12 Exiting the Program

URBEMIS2002 will not allow you to exit without closing all projects. Open projects, in turn, cannot be closed until all forms have been closed. Once all projects have been closed, URBEMIS2002 can be closed by either clicking on the X button in the top right hand corner of the screen or by selecting “File” from the Menu, then selecting “Close this Project” from the drop down menu.

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Appendix A. Construction Emissions

Construction Emissions

URBEMIS2002 allows users to generate estimates of construction emissions (inhalable particulate matter [PM10], carbon monoxide [CO], reactive organic gases [ROG], sulfur oxides [SOx], and oxides of nitrogen [NOx]). Emissions can be estimated as pounds per day or tons per years. Emissions are estimated separately by phase and by phase component. Those phases and their associated components are as follows:

Phase 1 – Demolition Dust
Phase 1 – Demolition On-Road Diesel Exhaust
Phase 1 – Demolition Off-Road Diesel Exhaust
Phase 1 – Demolition Worker Commute Trips
Phase 2 – Site Grading Dust
Phase 2 – Site Grading On-Road Diesel Exhaust
Phase 2 – Site Grading Off-Road Diesel Exhaust
Phase 2 – Site Grading Worker Commute Trips
Phase 3 – Subphase 1: Building Construction Off-Road Diesel Exhaust
Phase 3 – Subphase 1: Building Construction Worker Commute Trips
Phase 3 – Subphase 2: Architectural Painting Off-Gas Emissions
Phase 3 – Subphase 2: Architectural Painting Worker Commute Trips
Phase 3 – Subphase 3: Asphalt Paving Off-Gas Emissions
Phase 3 – Subphase 3: Asphalt Paving Off-Road Diesel Exhaust
Phase 3 – Subphase 3: Asphalt Paving On-Road Diesel Exhaust
Phase 3 – Subphase 3: Worker Trips

The methodology used to estimate emissions associated with each of the phase components is described below. The user should be aware that off-road diesel exhaust SOx emissions are not currently calculated by URBEMIS2002.

Phase 1 – Demolition Emissions

Demolition Dust

If the user chooses to estimate construction emissions, the user will be prompted to select the types of construction emissions that they would like to estimate. If the user selects demolition emissions, then the user is prompted to enter the total volume of all buildings to be demolished and the maximum volume of all buildings to be demolished in a single day. URBEMIS2002 calculates the total days required to complete demolition activities.

The following equation is used to estimate daily PM10 generated by demolition:

$$\text{PM10 (pounds/day)} = (0.00042 \text{ pounds of PM10 / feet}^3) * (N * O * P) / Q.$$

Where: N = building width (feet)
O = building length (feet)
P = building height (feet)
Q = number of days required to demolish the building(s).

This equation is based on Table A9-9-H of the South Coast Air Quality Management District's (SCAQMD's) California Environmental Quality Act (CEQA) Air Quality Handbook (South Coast Air Quality Management District 1993).

URBEMIS2002 does not provide default information on building dimensions slated for demolition. The user must provide URBEMIS2002 with that information to estimate demolition emissions. The user has the option of entering building width, length, and height or entering total building volume.

Demolition On-Road Diesel Exhaust

The demolition emission estimates also include exhaust emissions from the construction equipment involved in the demolition, including the on-road vehicles used to haul demolished materials to the nearest landfill. Based on information provided by the user regarding the building volume to be demolished, URBEMIS generates default information regarding demolition hauling. That information, shown in Table A-1, can be overridden by the user. For example, URBEMIS assumes a hauling round trip of 20 miles and a truck capacity of 20 cubic yards unless overridden by the user. Similarly, URBEMIS generates a default estimate of the number of round trips required per day using the following equation:

Round trips/day = Total yd^3 to be demolished/days demolition * trip/20 yd^3

The total cubic yards to be demolished will be entered into URBEMIS by the user, and the number of days required for demolition will be calculated using the Phase 1 length entered by the user. The vehicle miles traveled per day for demolition is estimated by multiplying the miles per round trip by the round trips per day. That value is then multiplied by the appropriate EMFAC2002 emission factor for heavy-duty on-road vehicles using the following equation:

Haul Emissions (pounds/day) = vehicle miles traveled/day * grams pollutant/mile (from EMFAC2002) * pound/454 grams

Table A-1. Demolition Truck Hauling Assumptions

Demolition Hauling	User Override
Truck capacity (cubic yards)	20
Miles/round trip	20
Round trips/day	10 (Calculated from user input)
Vehicle miles traveled/day (calculated)	200

Demolition – Off Road Diesel Exhaust

In addition to truck hauling, demolition emissions are generated by the operation of other construction equipment, such as concrete saws, cranes, and bulldozers. The URBEMIS user is presented with a list of construction equipment, as shown in Table A-2. Because of the widely varying nature of demolition, default values for these types of equipment are not generated by URBEMIS. Instead, the user is required to select the number of each type of equipment that will be used. The user will have the option of overriding the default values for horsepower, hours per day, and load factor.

Table A-2. Construction Equipment Used for Demolition

Equipment	Pieces of Equipment	Default Values		
		Horsepower	Load Factor	Hours/Day
Bore/drill rigs		218	0.75	8.0
Concrete/ industrial saws		84	0.73	8.0
Cranes		190	0.43	8.0
Crawler tractors		143	0.575	8.0
Crushing/ processing equipment		154	0.78	8.0
Excavators		180	0.58	8.0
Graders		174	0.575	8.0
Off-highway tractors		255	0.41	8.0
Off-highway trucks		417	0.49	8.0
Other construction equipment		190	0.62	8.0
Pavers		132	0.59	8.0
Paving equipment		111	0.53	8.0
Rollers		114	0.43	8.0
Rough-terrain forklifts		94	0.475	8.0
Rubber-tired dozers		352	0.59	8.0
Rubber-tired loaders		165	0.465	8.0
Scrapers		313	0.66	8.0
Signal boards		119	0.82	8.0
Skid steer loaders		62	0.515	8.0
Surfacing equipment		437	0.49	8.0
Tractors/loaders/ backhoes		79	0.465	8.0
Trenchers		82	0.695	8.0

Source: Default values for horsepower, load factor, and hours per day of operation from the California Air Resources Board's off-road model. These default values can be overridden by the user.

For each piece of equipment selected, URBEMIS generates an emission estimate. The emission equation used by URBEMIS for each piece of equipment is as follows:

Equipment Emissions (pounds/day) = # of pieces of equipment * grams per brake horsepower-hour * equipment horsepower * hours/day * load factor

Where: grams per brake-horsepower hour is based on the construction year and on the average life expectancy of the equipment type. Grams per brake horsepower per hour emissions and average equipment life expectancy are from Appendix B of the California Air Resources Board's (ARB's) off–road model (California Air Resources Board 2000). The pounds per day emission factors are found in Appendix H of this manual.

Demolition Worker Commute Trips

Worker trips are estimated separately by each of the three construction phases. For demolition, the number of workers will be estimated as 125% of the total number of construction equipment (vehicles and machines) selected. The emission estimates assume a construction worker commute fleet mix of 50% light duty autos and 50% light duty trucks. The worker commute travel distance, speed, and temperature are based on the worker.

Phase 2: Site Grading Emissions

Phase 2 - Site Grading Fugitive Dust

The fugitive dust emission estimates within URBEMIS2002 use the methodology developed for SCAQMD by the Midwest Research Institute. That four-tiered methodology allows for more refined PM10 estimates based on the level of detail known for the construction project. Previous versions of URBEMIS only provided emissions for the Level 1 or default level. URBEMIS now estimates emissions using the level of detail known for a project, as shown in Table A-3.

Table A-3. Fugitive Dust Estimation Approach

Basis for Emission Factor	Recommended PM10 Construction Emission Factor
Default Level: Only area and duration known	Apply 0.11 tons/acre-month (average conditions) Apply 0.42 ton/acre-month (worst-case conditions)
Low Level of Detail: Area and amount of earthmoving known	Apply 0.11 ton/acre-month for each month of construction activity Plus 0.059 ton/1,000 yd^3 of onsite cut/fill Plus 0.22 ton/1,000 yd^3 of offsite cut/fill These values assume that one scrapper can move 70,000 yd^3 of earth in one month and 35,000 yd^3 of material can be moved by truck in one month. If the on-/offsite fraction is not known, assume 100% onsite.
Medium Level of Detail: More detailed information available on duration of earthmoving and other material movement	Apply 0.13 lb/acre-work hr Plus 49 lb/scraper-hr for onsite haulage Plus 94 lb/hr for offsite haulage
High Level of Detail: Detailed information known on acres, hours or construction work, number of truck units or VMT, and truck travel distances.	Apply 0.13 lb/acre-work hr Plus 0.21 lb/ton-mile for onsite haulage Plus 0.62 lb/ton-mile for offsite haulage

A key component of the site grading dust emissions is the maximum acreage that will be disturbed on a daily basis. URBEMIS2002 estimates a default acreage graded per day based on the land use sizes specified by the user. For single-family residential units, URBEMIS2002 assumes five units per acre. For multifamily units, URBEMIS2002 assumes 20 units per acre. For commercial uses, URBEMIS2002 assumes that the total project acreage equals twice the size of each building's square footage. For example, URBEMIS2002 assumes that a 100,000-square-foot industrial park would require 200,000 square feet (4.6 acres) of land disturbance. As a default estimate, the revised version of URBEMIS2002 will assume that 25% of total land acreage slated to be disturbed will actually be disturbed on the worst-case day, up to a maximum of 10 acres. If the total acreage to be disturbed on the worse-case day exceeds 10 acres, then URBEMIS caps the total at 10 acres unless overridden by the user. URBEMIS will provide the user with a form similar to that shown in Table A-4. The user will have the option of modifying URBEMIS' estimates of the maximum acreage to be disturbed per day.

In the example shown in Table A-4, a project that includes 100 units of single-family residential, 100 units of multi-family residential, and 100,000 square feet of commercial development will result in a total estimated acreage of 29.6 acres. Assuming that 25% of that total acreage is graded on the worse-case day, the maximum acreage disturbed equals 7.5 acres. However, the user has overridden that value, indicating that a maximum of 5 acres will be disturbed.

Table A-4. Acreage Estimates for Grading

Land Use	User-Entered Values	Estimated Acreage	Estimated Maximum Acreage Disturbed per Day
Residential—Single Family	100 units	20	5
Residential—Multi-family	100 units	5	1.3
Commercial	100,000 sq. ft.	4.6	1.2
Totals	Not applicable	29.6	5

Phase 2 - Site Grading Equipment Off-Road Diesel Exhaust

Site grading emissions are generated by the operation of off-road construction equipment, such as scrapers, bulldozers, and loaders. The URBEMIS user is presented with a list of construction equipment, as shown previously in Table A-2. The user has the option of either select the number of each type of equipment that will be used or having URBEMIS generate estimates of construction use.

To estimate off-road construction equipment-related construction exhaust emissions, URBEMIS uses an approach based on ARB's off-road emissions model (California Air Resources Board 2000). That model uses a methodology in which emission factors for construction equipment are based on an average fleet mix that accounts for the turnover rate and average emissions for specific types of construction equipment. URBEMIS generates default values and allows the user to override the defaults for equipment horsepower and load factors.

For each piece of equipment selected, URBEMIS generates an emission estimate. The emission equation that will be used by URBEMIS for each piece of equipment is as follows:

Equipment Emissions (pounds/day) = # of pieces of equipment * grams per brake horsepower-hour * equipment horsepower * hours/day * load factor

Where: grams per brake-horsepower hour is based on the construction year and on the average life expectancy of the equipment type. Grams per brake horsepower per hour emissions and average equipment life expectancy are from the California Air Resources Board's (ARB's) off–road model (California Air Resources Board 2000). (See Appendix I of this manual for off-road vehicle emission rates.)

Phase 2 - Site Grading On-Road Diesel Exhaust

One additional enhancement to URBEMIS' treatment of grading equipment exhaust involves specifying whether the project will require soil to be imported to or exported from the site. If soil is to be imported or exported, the user must to enter the volume of soil. URBEMIS will use that information to calculate the number of on-road vehicle trucks trips and vehicle miles traveled per day (as shown in Table A-5). The user will have the option of overriding the default assumptions programmed into URBEMIS.

Table A-5. Construction Grading Soil-Hauling Assumptions

Soil Import/Export Hauling	Parameter
Amount of soil to import (cubic yards)	0
Amount of soil to export (cubic yards)	0
Total soil imported + exported (cubic yards)	0
Haul-truck capacity (cubic yards)	15
Number of days to conduct hauling	20
Round trips/day	3.3
Round-trip distance (miles)	20
Vehicle miles traveled/day (calculated)	66

Once vehicle miles traveled per day is known, URBEMIS calculates haul-trip emissions using the following formula:

On-Road Haul Truck Emissions (pounds/day) = vehicle miles traveled/day * grams pollutant/mile (from EMFAC2002) * pound/454 grams

Site Grading Worker Commute Trips

Worker trips are estimated separately by each of the three construction phases. For site grading, the number of workers is estimated as 125% of the total number of construction equipment (vehicles and machines) selected. The emission estimates assume a construction worker commute fleet mix of 50% light duty autos and 50% light duty trucks. The worker commute travel distance, speed, and temperature are based on the trip characteristics information for home to work trips found under the trip characteristics node of the operational emissions module.

Phase 3: Building Construction

Phase 3 – Subphase 1: Building Construction Off-Road Diesel Exhaust

Building construction emissions consist of emissions produced during building construction. Building construction equipment includes sources such as compressors, generators, gas-powered saws, and forklifts.

Table A-6 lists equipment typically used during building construction. The number and type of equipment can vary substantially, depending on the type of building and its location. The amount of concrete, masonry, wood, and metal products used in building construction varies widely, and can have a large impact on the type of construction equipment needed for a construction project.

The default values shown in Table A-6 are worst-case estimates for each 2,000 square feet of building construction (Frank R. Walker Company 1999). These estimates assume the use of one forklift to unload materials from supply trucks and move them around the site, one concrete/industrial saw (or similar type of equipment), and two other types of construction equipment, such as supply trucks bringing materials like concrete, wood, steel, or other building products to the site. The user should always use project specific information, when available. If unavailable, however, the user can let URBEMIS calculate the equipment type and number by hitting the Recalc with Land Uses Button.

Table A-6. Construction Equipment Used for Building Construction

Equipment	URBEMIS Estimate—Pieces of Equipment	User Override—Pieces of Equipment	Default Values		
			Horsepower	Load Factor	Hours/Day
Bore/drill rigs			218	0.75	8.0
Concrete/ industrial saws	1		84	0.73	8.0
Cranes			190	0.43	8.0
Crawler tractors			143	0.575	8.0
Crushing/ processing equipment			154	0.78	8.0
Excavators			180	0.58	8.0
Graders			174	0.575	8.0
Off-highway tractors			255	0.41	8.0
Off-highway trucks			417	0.49	8.0
Other construction equipment	2		190	0.62	8.0
Rollers			114	0.43	8.0
Rough-terrain forklifts	1		94	0.475	8.0

Equipment	URBEMIS Estimate—Pieces of Equipment	User Override—Pieces of Equipment	Default Values		
			Horsepower	Load Factor	Hours/Day
Rubber-tired dozers			352	0.59	8.0
Rubber-tired loaders			165	0.465	8.0
Scrapers			313	0.66	8.0
Signal boards			119	0.82	8.0
Skid steer loaders			62	0.515	8.0
Surfacing equipment			437	0.49	8.0
Tractors/loaders/ backhoes			79	0.465	8.0
Trenchers			82	0.695	8.0

Sources: Default values for horsepower, load factor, and hours per day of operation from the California Air Resources Board's off-road model (200). Pieces of equipment are based on 2,000 square feet of building construction and on information in Walker's Building Estimator's Reference Book (Frank R. Walker Company 1999).

Phase 3 – Subphase 1: Building Construction Worker Commute Trips

Emissions from construction worker vehicle commute trips are estimated by multiplying total daily employee vehicle miles traveled (VMT) by an emission rate (grams per mile). URBEMIS2002 estimates construction-related employee trip generation as follows. Each land use type selected as part of the project is grouped into one of four general land use categories: multifamily, single-family, commercial/retail, and office/industrial. Then, for each category, the number of trips is estimated using the following equations:

Multifamily Trips = 0.36 trips/unit * number of units
Single-Family Trips = 0.72 trips/unit * number of units
Commercial or Retail Trips = 0.32 trips/1,000 feet^2 * number of 1,000 feet^2
Office or Industrial Trips = 0.42 trips/1,000 feet^2 * number of 1,000 feet^2

These trip generation rates are based on information contained in the Sacramento Metropolitan Air Quality Management District's Air Quality Thresholds of Significance Handbook (Sacramento Metropolitan Air Quality Management District (1994).

URBEMIS2002 then totals trips from the four general land use categories and multiplies by the average trip length to obtain daily VMT. Trip length is found under the trip characteristics node of the operational emissions module of URBEMIS. URBEMIS2002 uses the construction year identified by the user to select EMFAC emission rates that will be multiplied by VMT/day.

Phase 3 – Subphase 2: Architectural Painting Off-Gas Emissions

URBEMIS2002 estimates ROG emissions resulting from the evaporation of solvents contained in paints, varnishes, primers, and other surface coatings. Separate procedures are used to estimate evaporative emissions from application of residential and nonresidential architectural coatings. The following emission factors are used for residential coating emissions:

ROG (pounds / day) = ((0.0185 pounds of ROG per foot^2 surface area) * ((Number of single-family units * square feet per unit) + (Number of multi-family units * square feet per unit)) * 2.7)) * mil thickness) / (number of days to paint)

The following equation is used for estimating nonresidential architectural coatings emissions:

ROG (pounds/day) = (((0.0185 pounds ROG / foot^2 surface area) * (Sum of Individual Building Square Footage * 2.0)) * mil thickness) / (Number of Days to Paint)

For the residential equation, the factor 2.7 is used to convert building area to surface area. For nonresidential coatings, the value of 2.0 is used to convert building area to surface area. URBEMIS2002 uses the length of the painting subphase as the time required to complete the painting. URBEMIS2002 also assumes that single-family homes average 1,800 feet^2 and multifamily homes average 850 feet^2. The number of units to be painted is based on land use information provided by the user.

The URBEMIS2002 calculation assumes a ROG emission rate of 0.0185 pounds of ROG per square foot, which represents a waterborne coating assumed to have 47.67 percent by weight solids, 10.54 pounds per gallon density, 250 grams per liter VOC content, and a coating thickness of one mil (0.001 inch).

The user has the option of altering the ROG emission rate, paint thickness, conversion ratio (building area to surface area), and the number of days required to complete the painting.

Phase 3 – Subphase 2: Architectural Painting Worker Commute Trips

The worker commute trip emissions associated with architectural painting is assumed to equal those for Subphase 1.

Phase 3 – Subphase 3: Asphalt Paving Off-Gas Emissions

URBEMIS2002 estimates ROG emissions associated with asphalt paving. The emissions are estimated based on the procedure identified in the SMAQMD manual (Sacramento Metropolitan Air Quality Management District 1994). ROG emissions are estimated using the following formula:

ROG (pounds per day) = (2.62 pounds ROG / acre) * (total acres paved / paving days)

Phase 3 – Subphase 3: Asphalt Paving Off-Road Diesel Exhaust

URBEMIS2002 now includes emissions from the heavy-duty equipment involved in laying asphalt. The typical procedure used in asphalt paving includes final grading (grader), rolling (roller), applying a base course of rock or aggregate (two on-road trucks, one off-road water truck), additional rolling (roller), spraying a tack coat (paving equipment), paving (paver), and final rolling (roller) (Asphalt Institute 2002).

Table 11 shows the equipment that URBEMIS assumes will be used in paving each 0.5 acre per day. URBEMIS takes the total acreage to be paved (as entered in the asphalt off-gas emissions screen) and divides by the length in days of asphalt paving. Unless overridden, URBEMIS assumes the number of pieces of equipment in Table A-7 for each 0.5 acre paved per day.
The equation that will be used to estimate equipment emissions is as follows:

> Off-Road Equipment Emissions (pounds/day) = # of pieces of equipment * grams per brake horsepower-hour * equipment horsepower * hours/day * load factor

Table A-7 Construction Equipment Used for Paving/Asphalt Installation

Equipment	URBEMIS Estimate—Pieces of Equipment	User Override—Pieces of Equipment	Default Values		
			Horsepower	Load Factor	Hours/Day
Bore/drill rigs			218	0.75	8.0
Concrete/ industrial saws			84	0.73	8.0
Cranes			190	0.43	8.0
Crawler tractors			143	0.575	8.0
Crushing/ processing equipment			154	0.78	8.0
Excavators			180	0.58	8.0
Graders	1		174	0.575	8.0
Off-highway tractors			255	0.41	8.0
Off-highway trucks	1		417	0.49	8.0
Other construction equipment			190	0.62	8.0
Pavers	1		132	0.59	8.0
Paving equipment	1		111	0.53	8.0
Rollers	2		114	0.43	8.0
Rough-terrain forklifts			94	0.475	8.0
Rubber-tired dozers			352	0.59	8.0
Rubber-tired loaders			165	0.465	8.0
Scrapers			313	0.66	8.0
Signal boards			119	0.82	8.0
Skid steer loaders			62	0.515	8.0
Surfacing equipment			437	0.49	8.0
Tractors/loaders/ backhoes			79	0.465	8.0
Trenchers			82	0.695	8.0

Phase 3 – Subphase 3: Asphalt Paving On-Road Diesel Exhaust

URBEMIS estimates vehicle miles traveled per day for asphalt hauling using information entered by the user regarding acreage to be paved per day. Using that information, URBEMIS estimates the total volume per day of asphalt required by multiplying acreage by an assumed asphalt thickness of 3 inches (Frank R. Walker Company 1999). The asphalt volume is then used to estimate the number of

truck trips, assuming a truck volume capacity of 20 cubic yards. Vehicle miles are estimated based on the number of truck trips, and haul emissions are estimated using the following equation:

On-Road Asphalt Haul Truck Emissions (pounds/day) = vehicle miles traveled/day * grams pollutant/mile * pound/454 grams

Phase 3 – Subphase 3: Asphalt Worker Trips

Asphalt worker trips are estimated separately by each of the three construction phases. For asphalt paving, the number of workers is estimated as 125% of the total number of construction equipment (vehicles and machines) selected. The emission estimates assume a construction worker commute fleet mix of 50% light duty autos and 50% light duty trucks. The worker commute travel distance, speed, and temperature are based on the trip characteristics information for home to work trips found under the trip characteristics node of the operational emissions module.

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Appendix B. Area Source Emissions

Area Source Emissions

URBEMIS2002 has been enhanced so that both novice and experienced users can generate accurate estimates of area source emissions. Novice users can generate estimates using default assumptions programmed into URBEMIS2002. Users experienced in estimating area source emissions can modify the area source assumptions to suit their particular project.

URBEMIS2002 allows the user to estimate area source emissions from:

- fuel combustion emissions from space and water heating, including wood stoves, fireplaces, and natural gas fired stoves;
- fuel combustion emissions from landscape maintenance equipment;
- consumer product ROG emissions; and
- architectural coatings.

FUEL COMBUSTION EMISSIONS FROM WATER AND SPACE HEATING

Natural Gas Combustion

URBEMIS2002 can be used to estimate fuel combustion emissions from water and space heating using the approach described in Tables A9-12, A9-12-A, and A9-12-B in the South Coast Air Quality Management District CEQA handbook (South Coast Air Quality Management District 1993) and emission factors developed by the U.S. Environmental Protection Agency (U.S. EPA 1995). With one exception, all emission estimates assume natural gas is used as the primary source of water and space heating. The one exception is wood used for fireplaces and wood stoves. The equation used to estimate CO, ROG, NOx, and PM10 emissions from natural gas combustion is as follows for each land use type:

Emissions = H * ({[F*G]/30}/1,000,000) * P

Where: H = emission factor for each criteria pollutant in pounds of pollutant per million cubic feet of natural gas consumed (CO: 40 pounds/MMfoot^3; ROG: 7.26 pounds/MMfoot^3; NOx: 94.0 pounds/MMfoot^3 [residential], NOx 100.0 pounds/MMfoot^3 [nonresidential]; PM10: 0.18 pounds/MMfoot^3)

F = units per land use type: residential (number of units)
industrial (customers)
hotel/retail/office (square feet)

G = Natural gas usage rates:

Residential: Single-Family: 6,665.0 $feet^3$ / unit / month
Multifamily: 4,011.5 $feet^3$ / unit / month

Nonresidential: industrial: 241,611 $feet^3$ / customer / month
hotel/motel: 4.8 $feet^3$ / square feet / month
retail/shopping: 2.9 $feet^3$ / square feet / month
office: 2.0 $feet^3$ / square feet / month

P = percentage using natural gas

Residential 100%
Nonresidential 100%

Hearth Fuel Combustion

The hearth fuel combustion category consists of wood stoves, fireplaces, and natural gas fired stoves. The user is required to enter the percentage of each associated with a project. If the San Joaquin Valley Air District is selected, the percentage of each hearth type is limited based on the District's wood stove rule.

Wood Combustion –Wood Stoves

Wood stove emissions can be estimated using the following equation:

Wood Stove Emissions (pounds per day) = ((A * C) + (B * D) + (E * F) + (J * K)) * (G) * (H * I)

Where:

A = EPA-certified noncatalytic stove emission rate (grams pollutant per ton of kilogram wood burned)
B = EPA-certified catalytic stove emission rate (grams pollutant per kilogram of wood burned)
C = Percent of all stoves assumed to be noncatalytic
D = Percent of all stoves assumed to be catalytic
E = Conventional wood stove emission rate (grams pollutant per kilogram wood)
F = Percent of all stoves assumed to be conventional
G = Cords of wood burned per year per residential unit
H = Number of residential units
I = Percentage of residential units with wood stoves
J = Pellet stove emission rate (grams pollutant per kilogram wood burned)
K = Percent of all stoves assumed to be pellet

URBEMIS2002 assumes the following defaults for wood stove emissions:

A = 9.8 grams PM10 / kilogram, 70.4 grams CO / kilogram, 7.5 grams ROG / kilogram, 1.4 grams NOx / kilogram
B = 10.2 grams PM10 / kilogram, 52.2 grams CO / kilogram, 7.8 grams ROG / kilogram, 1.0 grams NOx / kilogram
C = 50% (entered as 0.50)
D = 50% (entered as 0.50)
E = 15.3 grams PM10 / kilogram, 115.4 grams CO / kilogram, 21.9 grams ROG / kilogram, 1.4 grams NOx / kilogram
F = 0.0%
G = 1.48 cords per year per residential unit
H = based on land uses specified by the user
I = 35% (entered as 0.35)
J = 2.1 grams PM10 / kilogram, 19.7 grams CO / kilogram, 0.01 grams ROG / kilogram, 6.9 grams NOx / kilogram
K = 0.0%

The emission factors shown above are based on EPA's AP-42 document (U.S. Environmental Protection Agency 1995). The emission factor assumes an even split between noncatalytic, catalytic, and pellet stoves. The default assumption assumes that no conventional nor stoves will be included, although the equation will allow the user to include conventional stoves in the emission calculation. Annual emissions assume 2.71 tons wood (1.48 cords) would be burned per stove per residential unit during the heating season.

Wood Combustion –Fireplaces

Fireplace emissions are estimated using the following equation:

Fireplace Emissions (pounds per day) = (J * K * L * M)

Where:

J = Fireplace emission rate (pounds of pollutant per residential unit per ton of wood burned)
K = Cords of wood burned per day year residential unit
L = Number of residential units
M = Percentage of residential units with wood stoves

URBEMIS2002 will assume the following defaults for fireplace emissions:

J = 34.6 pounds of PM10 / ton, 252.6 pounds of CO / ton, 229.0 pounds of ROG / ton, 2.6 pounds of NOx / ton
K = 1.48 cords burned per year per residential unit
L = residential units are based on the residential land uses specified by the user
M = 10% (entered as 0.10)

These emission rates are based on information published by EPA (U.S. Environmental Protection Agency 1995). As with wood stove emissions, the user can modify each of the variables used to estimate fireplace emissions. Annual emissions are estimated based on annual wood combustion.

Natural Gas Fired Stoves

URBEMIS uses AP-42 emission factors to estimate emissions from natural gas combustion in natural gas fireplaces/stoves. The emission equation assumes that the average stove is 30,000 Btus for single family, 20,000 Btus for multi-family, that there are 1,020 Btus per standard cubic foot of natural gas, that the stove is used for an average of two hours per day during the winter months, and 100 days per year (200 hours per year).

FUEL COMBUSTION EMISSIONS FROM LANDSCAPE MAINTENANCE

Landscape maintenance equipment generates emissions from fuel combustion and from evaporation of unburned fuel. Emissions include NOx, ROG, CO, and PM10. Equipment in this category includes lawn mowers, roto tillers, shredders/grinders, blowers, trimmers, chain saws, and hedge trimmers used in residential and commercial applications. This category also includes air compressors, generators, and pumps used primarily in commercial applications (California Air Resources Board 1992a).

The California Air Resources Board has enacted regulations to limit emissions from landscape maintenance equipment (California Air Resources Board 1992b). Beginning in 1994 these regulations impose emission limits on all landscape maintenance equipment sold. Those regulations become more stringent for equipment sold in 1999 and later. Consequently, the emissions from this source category are similar to automobile emissions in that the turnover in the equipment fleet plays an important part in how quickly emission reductions are achieved.

URBEMIS2002 estimates emissions from this source category based on the year in which the user is attempting to estimate emissions. The California Air Resources Board has prepared estimates of emissions in 1989 and emission reductions expected by 2010. The proposed equations for this source category are divided into residential and commercial categories. The residential equation applies only to SFHU. The commercial equation is based on emissions per business unit and includes multifamily residential land uses.

<u>1989 Emissions - Residential</u>
ROG (pounds/day) = 0.003 pounds ROG / SFHU/day * SFHU
CO (pounds/day) = 0.024 pounds CO / SFHU/day * SFHU
NOx (pounds/day) = 0.0002 pounds NOx / SFHU/day * SFHU
PM10 (pounds/day) = 0.00006 pounds PM10 / SFHU/day * SFHU
SO_2 (pounds/day) = 0.0007 pounds SO_2 / SFHU/day * SFHU

<u>1989 Emissions - Commercial</u>
ROG (pounds/day) = 0.175 pounds ROG / Business Unit * Number Business Units
CO (pounds/day) = 1.149 pounds CO / Business Unit * Number Business Units
NOx (pounds/day) = 0.007 pounds NOx / Business Unit * Number Business Units
PM10 (pounds/day) = 0.0041 pounds PM10 / Business Unit * Number Business Units
SO_2 (pounds/day) = 0.0001 pounds SO_2 / Business Unit * Number of Business Units

2010 Emissions - Residential

ROG (pounds/day) = 0.00054 pounds ROG / SFHU/day * SFHU
CO (pounds/day) = 0.00576 pounds CO / SFHU/day * SFHU
NOx (pounds/day) = 0.00014 pounds NOx / SFHU/day * SFHU
PM10 (pounds/day)= 0.000005 pounds PM10 / SFHU/day * SFHU
SO_2 (pounds/day) = 0.0002 pounds SO_2 / SFHU/day * SFHU

2010 Emissions - Commercial

ROG (pounds/day) = 0.0315 pounds ROG / Business Unit *Number Business Units
CO (pounds/day) = 0.276 pounds CO / Business Unit * Number Business Units
NOx (pounds/day) = 0.005 pounds NOx / Business Unit * Number Business Units
PM10 (pounds/day)= 0.00037 pounds PM10 / Business Unit * Number Business Units
SO_2 (pounds/day) = 0.0001 pounds SO_2 / Business Unit * Number Business Units

The residential emission factors shown in the 1989 emission equations are based on total residential emissions from this source category in the San Joaquin Valley divided by the San Joaquin Valley's total 1989 SFHUs. Similarly, the commercial emission factors for 1989 are based on total San Joaquin Valley commercial emissions divided by the Valley's total 1989 business units (U.S. Department of Commerce 1991). For the commercial equations, URBEMIS2002 bases the number of business units on the number of individual land use categories specified by the user (excluding single family residential).

The 2010 emission rates are based on ARB's estimates that, by 2010, the regulation will reduce ROG emissions by 82%, CO by 76%, PM10 by 91%, NOx by 28%, and SO_2 by 50%.

The regulations for this source category took effect in 1994 and became more stringent in 1999. URBEMIS2002 uses the emission rates shown for 1989 for 1990 through 1993. For 1994 through 2009, URBEMIS2002 interpolates emission factors by assuming a uniform decrease in the emission rate each year. In 2010 and succeeding years, the 2010 emission rates will be used.

Average annual emissions assume that daily emissions would occur only during the summer period of 180 days. The end user will be able to modify the length of the summer period.

CONSUMER PRODUCT EMISSIONS

Consumer product emissions are generated by a wide range of product categories, including air fresheners, automotive products, household cleaners, and personal care products. Emissions associated with these products primarily depend on the increased population associated with residential development (California Air Resources Board 1990). Consequently, URBEMIS2002 can be used to estimate consumer product emissions when one or more residential land uses have been selected by the user. Emissions would be based on the following equation:

ROG (pounds/day) = 0.0171 pounds of ROG per person * Number of residential units * 2.861 persons per unit

The ROG emission factor is based on the total estimated ROG emissions from consumer products divided by the total California population (California Air Resources Board 1990; California Department of Finance 1994). Persons per household is based on the 1990 census information for California (California Department of Finance 1994).

URBEMIS2002 will base the number of residential units on information provided by the user on residential land uses. The user can modify each of the variables in the ROG emissions equation.

Annual emissions are estimated by multiplying pounds of ROG emitted per day by 365 days per year.

ARCHITECTURAL COATINGS

Architectural coatings emissions associated with area sources is estimated using the same set of equations as construction related architectural coatings (described in Appendix A), with one exception. In the area source architectural coatings screens, the user can enter the percentage of total building square footage to be repainted each year. The default is set to 10% for both residential and nonresidential land uses.

AREA SOURCE MITIGATION MEASURES

URBEMIS includes three mitigation measures for natural gas combustion. Each measure is based on building energy efficiency relative to Title 24, California's energy efficiency regulation for residential and non-residential buildings. The user can turn on the appropriate measure and enter the percentage increase in energy efficiency above Title 24. Emission reductions are assumed to be proportional to the increase in building energy efficiency beyond Title 24.

Title 24 requires that compliance (with Title 24) be demonstrated before a building permit can be issued. This requirement applies to any heated building in California. Consequently, the percentage increase in energy efficiency beyond Title 24 should be based on the required compliance documentation.

URBEMIS includes two mitigation measures for landscape maintenance equipment. The first measure applies to residences, the second measure applies to commercial and industrial landscape equipment. For each of these measures, the user can specify the percentage of landscape equipment that would be electrically powered.

Appendix B References

California Air Resources Board. 1990. Proposed regulation to reduce volatile organic compound emissions from consumer products, staff report. Sacramento, CA.

California Air Resources Board. 1992a. Attachment C. technical support document for California exhaust emission standards and test procedures for 1994 and subsequent model year utility and lawn and garden equipment engines.

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California Department of Finance. 1994. California statistical abstract. Sacramento, CA.

South Coast Air Quality Management District. 1993. CEQA air quality handbook. Diamond Bar, CA.

U.S. Department of Commerce. 1991. County business patterns 1989 California. Bureau of the Census, Washington, DC.

U.S. Environmental Protection Agency. 1995. AIR CHIEF CD-ROM Version 4.0. Research Triangle Park, North Carolina.

Appendix C. Operational (Motor Vehicle) Emissions

Exhaust Emission Factors

URBEMIS2002 estimates vehicle exhaust emissions using several pieces of input entered by the user. That information is found within the URBEMIS input screens of the operational emissions module. The operational emissions module input screens include project year, vehicle fleet percentages, winter and summer temperature, trip characteristics, variable start information, and the percentage of travel on paved versus unpaved roads.

Once the user has entered the appropriate information into the operational emissions input screens and selects the emissions output, URBEMIS2002 calls the appropriate summertime and wintertime EMFAC2002 files based on the analysis year selected by the user. URBEMIS then goes to the appropriate locations within those files based on the average vehicle speeds and temperature. For each pollutant, URBEMIS obtains information from several locations within the EMFAC input file. For certain pollutants, URBEMIS generates pounds per mile emission estimates by multiplying the grams per mile values for each technology class within EMFAC (fleet mix vehicle type and technology class [non-catalyst, catalyst, diesel] by the percentage supplied by the user in the fleet mix screen. This results in a fleet average grams per mile value, which is then converted to pounds per day.

A similar approach is used to estimate trip emissions for certain pollutants. Separate tables in EMFAC2002 contain grams per trip emissions based on the length of time since the vehicle engine was turned off. URBEMIS uses the variable starts table, which shows the percentage of vehicles in several time classes (minutes since the vehicle engine was turned off) and for the six trip modes. URBEMIS uses the information in the variable starts table and the grams per trip values within EMFAC2002 to estimate weighted grams per trip values. The weighted grams per trip value is then multiplied by the number of trips calculated from the land use information to estimate total emissions per trip per pollutant.

Once the EMFAC2002 file has been read, URBEMIS2002 calculates criteria pollutant emissions for:

- running exhaust (grams per mile of ROG, CO, NOx, PM10),
- tire wear particulates (grams per mile, PM10),
- brake wear particulates (grams per mile, PM10),
- variable starts (grams per trip, ROG, CO, NOx),
- hot soaks (grams per trip, ROG),
- diurnals (grams per hour, ROG) ,
- resting losses (grams per hour, ROG), and
- evaporative running losses (grams per mile, ROG).

The estimated operational criteria pollutant emissions are summed in the emissions output page.

Entrained Road Dust Emissions

Entrained road dust emissions are generated by vehicles traveling on both paved and unpaved roads. URBEMIS2002 provides end users with a default percentage of VMT for paved versus unpaved

roads. End users are asked whether they want to modify those percentages. Default percentages assume that 100 percent of VMT occurs on paved roads and 0 percent on unpaved roads.

Paved Roads.

For paved roads, URBEMIS2002 uses the following equation:

$$PAVED = k\,(sL/2)^{0.65}\,(W/3)^{1.5}$$

Where:

PAVED = particulate emission factor (lb/VMT);
k = particle size multiplier for particle size range and units of interest;
sL = road surface silt loading (grams per square meter);
W = average weight of the vehicles traveling the road (megagrams).

The following default assumptions are used by URBEMIS2002:

k = 0.016 (for the 10 microns and under particle size cutoff)
sL = 0.1 (allowable range of 0.02 – 400 grams per square meter)
W = 2.2 (allowable range of 1.8-38 megagrams)

This equation is based on the paved roads emission factor found in AP-42 (U.S. Environmental Protection Agency 2003a). URBEMIS2002 allows the user to modify silt loading (sL) and average vehicle fleet weight (W). The equation was developed using silt loads ranging from 0.02 – 400 grams per square meter and mean average fleet vehicle weight ranging from 1.8-39 megagrams (2.0-42 tons). The equation was also developed using vehicles traveling at speeds ranging from 10-55 miles per hour, although speed is not used in the equation. A particle size multiplier (k) of 0.016 lbs PM10 per VMT is used by URBEMIS2002. This particle size multiplier cannot be changed by the user.

URBEMIS2002 uses the emission factor equation to calculate emissions per vehicle mile traveled. That value is then multiplied by the total vehicle miles traveled per day and by the percentage of vehicles traveling on paved roads

Unpaved Roads

The unpaved road equation is as follows:

$$UNPAVED = (k\ (s/12)^{1.0}\,(S/30)^{0.5})/\ (\,(M/0.5)^{0.2})$$

Where:

UNPAVED = the fleet average unpaved road dust emissions (pounds/VMT)
k = the fraction of particles less than or equal to the particle size cutoff of 10 microns

s = surface material silt content (%)
S = the average vehicle speed (mph, input by the user)
M = surface moisture content (%)

This equation is based on EPA's emission factor equation for unpaved roads (Environmental Protection Agency 2003b). The following default assumptions are used by URBEMIS2002:

k = 1.8 (for the 10 microns and under particle size cutoff)
s = 4.3 % (allowable range [1.8 - 25.2 %])
S = 40 miles per hour (allowable range [10 - 43 mph])
M = 0.5 % (allowable range 0.03 – 13 %)

Of these default assumptions, all except k can be modified by the user. Once calculated, the emission rate in pounds per vehicle mile traveled is multiplied by the total VMT for the project and then by the percentage of travel on unpaved roads.

Minimize Double Counting for Multiuse Projects and Pass-By Trips

This discussion is divided into two sections: double counting of multiuse projects and double counting of pass-by and diverted link trips.

Double Counting of Multiuse Projects

URBEMIS2002 contains a procedure that reduces double counting of internal trips in a mixed-use project or community plan area. The procedure only applies when at least one residential and one non-residential land use are specified by the URBEMIS2002 user and the user selects the double-counting correction algorithm.

Because trip generation rates account for both trip productions and attractions, adding the gross trip generation for two land uses in a project double counts the trips between them. The procedure described below is designed to count the internal trips only once.

URBEMIS2002 displays a screen showing the number of residential and nonresidential trips. Then the user is prompted to enter the gross internal trip number, which limits the number of internal trips estimated by URBEMIS2002. The gross internal trip limit reported by the program is based on a comparison of residential trips versus nonresidential trips; the smaller of the two is the limiting value.

As presented above, the proposed double-counting correction is applied only to trips between residential and nonresidential land uses. A small amount of double counting may remain for trips between different residential land uses and/or between non-residential uses.

Pass-By Trips

According to the Institute of Transportation Engineers' (ITE) document Trip Generation, 5th

Edition (ITE 1991), vehicle trips associated with a trip generator can be divided into three categories:

- *Primary Trips* are trips made for the specific purpose of visiting the generator. The stop at that generator is the primary reason for the trip. For example, a home to shopping to home combination of trips is a primary trip set.

- *Pass-By Trips* are trips made as intermediate stops on the way from an origin to a primary trip destination. Pass-by trips are attracted from traffic passing the site on an adjacent street that contains direct access to the generator. These trips do not require a diversion from another roadway.

- *Diverted Linked Trips* are trips attracted from the traffic volume on roadways within the vicinity of the generator but which require a diversions from that roadway to another roadway to gain access to the site. These roadways could include streets or freeways adjacent to the generator, but without access to the generator.

In calculating the emissions associated with a proposed project, the distinction between these three categories of trips is important. Pass-by and diverted linked trips associated with a proposed project generate substantially lower levels of net emissions than a primary trip.

For air quality impact analysis, the major difference between a pass-by trip and a diverted linked trip is the added vehicle miles traveled associated with the diverted linked trip. Pass-by trips, by definition, do not require a diversion from the original trip route. Conversely, diverted linked trips do involve diversion from the original trip route. A major difficulty in estimating the additional travel associated with a diverted linked trip is that the amount of additional travel is sensitive to local site factors. In particular, the distance from the project site to major arterials or freeways strongly influences the amount of additional travel.

Pass-by and diverted linked trips are most important for retail commercial land uses. As an example of how important these trips are, the February 1995 update to ITE's Trip Generation, 5th Edition, notes that an average of 87% of trips made to gasoline stations in the p.m. peak hour are pass-by and diverted linked trips. Not accounting for pass-by and diverted linked trips substantially overstates the amount of indirect source emissions associated with a proposed gasoline station.

URBEMIS2002 has an option that allows the user to account for pass-by and diverted linked trips. The primary data sources for appropriate pass-by and diverted linked trip adjustments are ITE's Trip Generation, 5th Edition, and the February 1995 update (ITE 1991; ITE 1995). The San Diego Association of Governments (SANDAG) has also produced a document that includes estimates of pass-by and diverted linked trips for specific land uses (SANDAG 1990). These three documents present pass-by and diverted linked trip values as a percentage of total trips for several land use categories. One distinction between the ITE versus SANDAG estimates are that for pass-by trips, SANDAG assumes that any diversion requiring 1 additional mile or less is a pass-by trip. In contrast, ITE assumes that any diversion off of the intended travel route is a diverted linked trip.

Table 3 shows estimates of pass-by and diverted linked trip percentages using data contained

in ITE's Trip Generation, 5th Edition, the February 1995 update to the 5th edition, and the SANDAG report (ITE 1991, ITE 1995; SANDAG 1990). The ITE and SANDAG trip generation data primarily describe peak-hour versus average daily conditions. Jones & Stokes Associates has developed average daily percentages of primary trips, diverted-linked trips and pass-by trips associated with each land use for the URBEMIS2002 model.

When the pass-by trip correction algorithm is selected by the user, URBEMIS2002 adjusts trip end emissions (i.e., cold start, hot start, and hot soak) associated with pass-by and diverted linked trips

For traffic impact analyses, pass-by trips are generally eliminated from consideration; they have no net effect on traffic volumes. Similarly, diverted linked trips may have a minimal effect on traffic volumes. Conversely, pass-by and diverted linked trips may have a substantial effect on air quality, and this effect may increase in the future as trip end emissions become a larger portion of total vehicle trip emissions. A pass-by or diverted linked trip associated with a shopping center is a good example of how these trips can affect air quality. Such a trip would have little or no net effect on traffic volumes. However, if the shopper stays at the shopping center for 1 hour, a substantial portion of a hot soak episode would occur and, for a catalytic converter-equipped vehicle, the trip leaving the shopping center would begin in a cold-start mode.

URBEMIS2002 estimates trip end emissions associated with pass-by and diverted linked trips and additional travel associated with diverted linked trips. Jones & Stokes Associates has modified URBEMIS2002 so that it makes separate emission estimates for primary trips, pass-by trips, and diverted-linked trips.

For primary trips, the emission estimating procedure do not change except that the trip generation rate for each land use would be multiplied by that land use's primary trip percentage shown in Table 3.

For pass-by trips, the trip generation rate for each land use are multiplied by that land use's pass-by trip percentage shown in Table 3. In addition, the trip length for each trip type (e.g., home-work, home-shop) is set to 0.01 miles. The change in trip length reflects the pass-by trip definition in that these trips result in virtually no additional travel. However, emissions associated with pass-by trips still occur. Consequently, the hot and cold start percentages are increased by 10 percent to reflect additional emissions from these operating modes.

For diverted-linked trips, the trip generation rate for each land use is multiplied by that land use's diverted-linked trip percentage shown in Table 3. The trip length is also adjusted downward to equal 25 percent of the primary trip length for each trip type. By doing so, it accounts for the additional travel associated with diverted-linked trips. Also, the hot and cold start percentages for each trip type are increased by 10 percent to reflect additional emissions from these operating modes.

Method for Calculating Default Trip Lengths from Travel Survey Data

Trip lengths are one of the most important data elements used in calculating project emissions. Air districts or other agencies responsible environmental review should ensure that default trip length values used in their area have a sound basis. Unfortunately, the data most

readily available from regional travel models for this purpose is typically formatted differently than is used in URBEMIS. This section provides a method for converting available data for use as URBEMIS2002 defaults.

One source of data is the Caltrans Statewide Travel Survey. The most recent version was published in 1991. The data is stratified by trip purpose. The trip categories are home to work (H-W), home to shop (H-S), home to other (H-O), other to work (O-W), and other to other (O-O). The survey provides trip lengths for only H-W and total trips. More detailed breakdowns may be available from the Regional Transportation Planning Agency in your area. The survey and most RTPA models provide trip lengths in terms of minutes. The average speed is used to convert minutes to miles.

The H-W, H-S, and H-O trip lengths can be used directly in URBEMIS. However, for non-home based trips, URBEMIS uses work (W) and non-work (N-W) trips when analyzing all non-residential projects (commercial, industrial, institutional, etc). To produce work-related trip lengths for non-residential projects analyzed in URBEMIS, a composite work trip length is calculated that is a composite of H-W and O-W trip lengths. For URBEMIS, non-work trips are a composite of H-S, H-O, and O-O trip lengths. Both are based on the relative occurrence of the individual trip types.

The following table illustrates this concept using Southern California data as an example:

Travel Survey Trip Types:	**H-W**	**H-S**	**H-O**	**O-W**	**O-O**	**Total**
Percent trip type:	20%	9%	43%	11%	17%	100%
Trip length in minutes:	19.63	7.91	9.58	15.06	8.96	
Trip length in miles:	11.5	4.87	6.02	9.07	5.66	

URBEMIS non-residential Work trip lengths = composite of H-W + O-W
URBEMIS non-residential Non-Work trip lengths = composite of H-S + H-O + O-O

Work Trip Length Formula:

(%H-W / (%H-W + %O-W) x H-W TRIP LENGTH) +

(%O-W / (%H-W + %O-W) x O-W TRIP LENGTH)

Non-Work Trip Length Formula:

(%H-S / (%H-S + %H-O + %O-O) x H-S TRIP LENGTH) +

(%H-O / (%H-S + %H-O + %O-O) x H-O TRIP LENGTH) +

(%O-O / (%H-S + %H-O + %O-O) x O-O TRIP LENGTH)

Example Calculation Using South Coast Data:

Commute Trip (W)

(20%/(20%+11%) X 11.5 mi.)+ (11%/(20%+11%) X 9.07 mi.) = 10.6 mile W trip

Non-Work Trip (N-W)

(9%/(9%+43%+17%) X 4.87 mi.) + (43%/(9%+43%+17%) X 6.02 mi.) +
(17%/(9%+43%+17%) X 5.66 mi.) = 5.78 mile N-W trip

Default Values for Emission Calculations

Diurnal Soak Hours per Day: 7.1

Resting Loss Hours per Day: 12.9

Vehicles per Household: 1.8

Appendix C References

Institute of Transportation Engineers. 1991. Trip generation. 5th edition, Washington, DC.

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U.S. Environmental Protection Agency. 2003b. 2002 paved road emission factors: Website: http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s02-1.pdf

Appendix D. URBEMIS2002 Mobile Source Mitigation Component

Mobile Source Mitigation Component

Background

The purpose of this appendix is to document the basis of the emission reduction quantification system used in the URBEMIS 2002 Mobile Source Mitigation Measures module. The mitigation measures module is based on an approach developed by Nelson\Nygaard Consulting Associates specifically for the URBEMIS module. Nelson\Nygaard's findings are described in the remainder of this appendix.

Introduction

This report sets out recommendations to revise the operational mitigation component of URBEMIS 2002. These have been developed with three main aims in mind:

- **Simplify** the existing mitigation component (of URBEMIS version 7.5), which while extremely detailed, is daunting to new users and has extensive data requirements. In particularly, the division between "environment factors" and "mitigation measures" can be confusing.
- **Improve consistency.** Many of the inputs to the URBEMIS 7.5 mitigation component are extremely subjective (e.g. whether some, few or no bike routes provide wide paved shoulders and have few curb cuts). We propose making these more quantitative, and/or providing additional guidance in the users' manual or within the program itself.
- **Improve accuracy and transparency.** While many of the inputs to the current mitigation component (of URBEMIS 7.5) have been proven to have an impact on travel behavior, research is still at an early stage of assessing quantitative impacts, and how these interrelate with other mitigation strategies. The recommendations here update the current mitigation component in the light of new research.

An extensive body of research has been compiled as to the impacts of particular mitigation strategies on travel behavior. However, in general, this has either had an academic focus, or been undertaken for the purposes of developing citywide or regional travel models. For example, many agencies have sophisticated procedures for assessing non-single occupancy auto travel at the level of TAZ or above, but not at the development level. There is extremely little guidance on how to use this data in the type of application needed for URBEMIS 2002 – namely, to provide quantitative estimates of the impact on trip generation and vehicle miles traveled (VMT) at the development level.

Many agencies do provide credits for individual developments that implement mitigation measures, for example when assessing impact fees or conducting traffic studies. Some California examples include C/CAG in San Mateo County and VTA in Santa Clara County. A brief, national review was also conducted for purposes of this report.[1] In general, however, these credit programs are only loosely based on the latest travel research, and it could be argued that they function more at a policy level, in providing incentives for developers to incorporate elements such as demand management programs that the agency considers desirable.

The recommendations here therefore attempt to bridge the gap between academic studies and complex regional or area-wide models on the one hand, and more site-specific traffic assessments on the other hand. The emphasis is on providing the best possible estimate while minimizing data requirements. The overall effect, compared to

[1] Agencies contacted included: New York Metropolitan Transportation Council; Atlanta Regional Commission; Alameda County, CA; and San Luis Obispo County, CA.

the existing mitigation component, is to reduce the number of inputs required, but make them more quantitative.

It cannot be too highly stressed that the trip reductions recommended here are valid at a sketch-planning level only, and are subject to considerable uncertainty. While they should ideally be expressed as a range, in order to expressly account for this uncertainty, a single value is needed for purposes of the Indirect Source Review in order to allow the appropriate fee to be calculated. The same limitations noted in the documentation for the existing mitigation component still apply, and are worth repeating here:

> The URBEMIS 2002 mitigation component is a significant advance over past attempts to quantify the benefits of air quality mitigation measures, however, users should recognize that travel behavior is very complex and difficult to predict. The component relies on the user to determine factors critical to travel behavior that are somewhat subjective. As GIS and electronic traffic monitoring and data collection become a reality in many cities, the ability to identify factors critical to walking, bicycling, and transit use will be enhanced. The URBEMIS 2002 mitigation component provides a starting point for using currently available data to demonstrate the benefits of urban design and traditional mitigation measures in reducing air quality impacts.

The mitigation component results, however, should still be interpreted as the mid-point of a range. Recent research has pointed towards the dangers inherent in reporting precise values, when the results are the subject of considerable uncertainty (Shoup, 2003). However, although the methodological dangers are obvious, there is generally no question about the *direction* of the relationship, only its size and the appropriate variable. Some adjustment is better than none at all – which is what most conventional trip generation methodologies provide (Ewing & Cervero, 2001). In addition, existing project-level trip generation methodologies, even though well-accepted within the transportation planning and engineering profession, are themselves subject to considerable uncertainty, and results are reported with unwarranted precision (Shoup, 2003).

Other considerations that should be noted include:

- The key output that is sought here is reduction in *vehicle trips.* Research results, however, often report results in terms of VMT. Where no alternative is available, we assume that VMT is proportional to vehicle trips.
- Elasticities are generally used to make the calculations, since when used with care, they provide a satisfactory, means of preparing first-cut aggregate response estimates for various types of transportation system changes (Pratt *et. al.,* 2000). They also provide a transparent and accessible method of reporting results, that can be transferred from one region to another (Ewing & Cervero, 2001).
- There are major theoretical issues regarding the direction of causality that have still to be resolved in the research. For example, does an increase in density lower vehicle trip generation rates, or do more dense places attract

people who tend to make fewer vehicle trips? For the purposes of this analysis, however, the distinction is unimportant. The key issue (using the same example) is that more dense places are associated with fewer vehicle trips.

- Local planning controls and development economics are assumed to provide an important "reasonableness" check on the recommended trip reductions. For example, reductions in parking supply will not normally be allowed unless the local jurisdiction is confident that complementary trip reduction measures will be applied. Equally, it is unlikely that frequent transit service will be provided to a destination with low potential ridership, given competing demands on an agency for service.

About the Trip Generation Manual

At its heart, the URBEMIS mitigation component is a tool for modifying the average trip rates reported in the Institute for Transportation Engineers' *Trip Generation* manual to make them more accurate, so that they fairly reflect the particular characteristics of a proposed development. Before modifying these average rates, it is therefore useful to understand the manual itself: how the average rates were derived; the original data sources that underlie the manual; and the manual's own recommendations about when, and why, its average trip generation rates should be modified. Some key points are these:

- The ITE manual normally predicts trip generation from new buildings using just two variables. Typically, the user first selects a broad *land use type* (e.g. "High-Rise Residential Condominium/Townhouse"). Second, the user inputs the *quantity* of that land use type (e.g. "100 dwelling units").
- An important advantage of this simple approach is that very little information about a project is needed to predict trip generation, and trip generation calculations are simple.
- A primary disadvantage of such two-variable formulas is that they do not take into account the multiple other variables (parking price, transit service, etc.) that transportation research has shown to strongly affect trip generation, and so the variation in trip rates *within* each land use category is frequently very high.

Recognizing these points, the *Trip Generation* manual therefore advises the reader that the average trip generation rates reported in the manual "represent weighted averages from studies conducted throughout the United States and Canada since the 1960s. Data were primarily collected at suburban locations having little or no transit service, nearby pedestrian amenities, or travel demand management (TDM) programs. At specific sites, the user may wish to modify trip generation rates presented in this document to reflect the presence of public transportation service, ridesharing or other TDM measures, enhanced pedestrian and bicycle trip-making opportunities, or other special characteristics of the site or surrounding area."

However, while the studies may have been *primarily* conducted at such suburban sites,

it appears from the sources referenced that for some land uses, particularly higher density residential land uses, many sites studied included at least some transit service, sidewalks, and other characteristics associated with lower vehicle trip rates. For the "High-Rise Residential Condominium/Townhouse", for example, the manual's text shows that sites were surveyed in such cities as Vancouver, Canada: a city where it is difficult to find high-density condominiums that lack sidewalks, transit service, and a mix of uses nearby.

As part of our research, we made several calls to and exchanged correspondence with the staff at the Institute for Transportation Engineers. The staff was unable to provide any additional data (beyond the text of the manual itself) on the characteristics of the developments used in its trip generation studies, and was also unable to provide the actual studies – the original data – which underlie the manual's conclusions. Therefore, it is not possible to define with certainty the precise characteristics of an "average site".

Given this paucity of information available on the original sources for the *Trip Generation* manual's, conclusions about the average characteristics of the different land uses in the manual (e.g., average residential density, or the percentage of neighborhood streets with sidewalks) necessarily must be estimated, rather than precisely calculated. Fortunately, a large body of other research on travel behavior and land use is available, and reasonable estimates can be made based upon this research.

Recommendations

1. Combine "environmental factors" and "mitigation measures."

URBEMIS 2002 distinguishes between "environmental factors" for pedestrians, cyclists and transit (i.e., the character of the existing neighborhood), and "mitigation measures" (i.e. those added by the development). The environmental factors both provide a mitigation measure in themselves (e.g. the credit for existing or planned transit service), and are also used to weight the mitigation measures (i.e., a lower credit is given for a mitigation measure in an area that has a low environmental factor).

The distinction does make it easier to give credits for specific mitigation measures (e.g. bus bulbs, sidewalks and bicycle parking). However, we recommend that the distinction be removed, since it also brings several important disadvantages. Most of these relate to either complexity, or the relative advantages of infill vs. greenfield development, as follows:

- The pedestrian environmental factors appear to be given less weight than the mitigation measures, even when it is taken into account that the environmental factors are also used to weight the mitigation measures. The credit for the surrounding pedestrian environment is 2%, compared to the maximum allowable reduction of 9%. This means that smaller, infill developments will be eligible for lower credits, since by their nature they will be more dependent on the surrounding environment and have more limited ability to fund mitigation

measures.

- On a related point, the importance of the environmental factors compared to mitigation measures is largely a function of scale, i.e. development size. Larger projects, particularly on greenfield sites, will be starting from a “blank sheet,” and on-site mitigation measures will be paramount. The appropriate trip reductions for smaller, infill developments, in contrast, will be more a function of the surrounding environment.
- Combining the environmental factors and mitigation measures would make the component easier to understand, particularly for inexperienced users. At present, the separation can be confusing.

2. Scale

This question relates to the area that should be analyzed. We recommend that this should be either the area within a half-mile radius from the center of the project, or the entire project area, whichever is larger. This is the same approach taken in the existing URBEMIS mitigation component. In effect, the smaller the development, the greater the consideration given to the wider project area.

3. Provide Post-Modeling Adjustments to Reward Other Mitigation Measures

One of the impacts of these recommendations would be to narrow the range of mitigation measures that are considered in the analysis. Some potential mitigation measures are excluded even though they are likely to have a travel behavior impact, either because they cannot be readily quantified, or because this would risk double counting an impact already quantified elsewhere (i.e. another variable, such as intersection density, serves as a proxy). We therefore recommend consideration of how post-model adjustments can be used to provide financial incentives for developers to incorporate these mitigation measures. This may include all those that are in the current mitigation component, but are not recommended for continued inclusion, including:

- Street trees
- Traffic calming
- Design maximizing visual interest for pedestrians, and “eyes on the street”
- Zero building setbacks
- Direct pedestrian connections
- Street furniture and artwork
- Pedestrian signalization and signage
- Street lighting
- Low speed limits on bicycle routes
- Safe routes to schools
- Bicycle parking ordinance
- Transit stop amenities
- Route signs and displays
- Bus turnouts and bulbs
- Structured parking

4. Modifying Average Trip Generation Rates

In general, both the recommended trip rate modifications and the overall philosophy of the mitigation component are similar to those in the existing URBEMIS model, and build extensively off this work. The major differences between the existing mitigation component and these recommendations are found in (a) the input variables, which are designed to be more quantitative and less subjective, and are fewer in number, and (b) the formulas, which take advantage of the latest research on residential travel behavior. Neighborhood-level trip generation and vehicle miles traveled vary by more than 80% in California cities (Figure D-1). As the documentation for the existing mitigation component recognizes, areas with low trip generation and VMT levels have the highest development densities, a wide variety of uses within walking distance, safe and comfortable pedestrian access, paid parking requirements, and a high level of transit service.

Similarly, residential trip rates reported in the *Trip Generation* manual vary widely, both *within* individual land use types, and *between* land use types (Figure D-2). For the land use type "Single Family Detached Housing", for example, reported rates ranged from a low of 4.31 daily trips per dwelling unit, to a high of 21.85 daily trips. The *Trip Generation* manual reports that, "This land use included data from a wide variety of units with different sizes, price ranges, locations and ages. Consequently, there was a wide variation in trips generated within this category." Between residential land use categories, the variation is still greater, as would be expected. For example, the average trip rate for the "Residential Condominium/Townhouse" land use type is 5.86 (or 39% lower than the average single-family detached house), while the lowest trip rate is 1.83 (or 80.9% lower). At the extremes, considering all residential land uses, the highest residential rate reported (21.85 trips/day) is more than ten-fold higher than the lowest rate reported (1.83 trips/day).

Figure D-1 Daily Trips by Density, San Francisco Bay Area

	Households/Residential Acre					
	<2	**2-5**	**5-10**	**10-20**	**20-50**	**>50**
Mean Households/Residential Acre	1.4	3.6	6.7	13.5	30.6	121.9
Daily Vehicle Trips/Household	6.4	5.9	5.0	3.8	2.9	1.2
% Reduction in Daily Vehicle Trips/Household compared to lowest density areas	0%	9%	23%	41%	55%	82%

Source: MTC Household Travel Survey, 1990, cited in Holtzclaw, 2002

Figure D-2. ITE Trip Rates for Selected Residential Land Uses

Land Use Code	Land Use Type	ITE Trip Rate		
		Low	Average	High
210	Single-Family Detached Housing	4.31	9.57	21.85
221	Low-Rise Apartment	5.1	6.59	9.24
230	Residential Condominium/Townhouse	1.83	5.86	11.79
222	High-Rise Apartment	3	4.2	6.45
232	High-Rise Residential Condo./Townhouse	3.91	4.18	4.93

Based on these data in Figures 1 and 2, and a wide range of additional transportation research, we have developed a set of formulas for modifying the average trip rates for residential land uses has been developed. For the URBEMIS user, the procedure for modifying residential trip generation rates will remain generally similar to the existing process, with three basic steps:

1. In the “Land Use Selection” screen, the user will enter the land use types (e.g. “Apartment, Low-Rise”) and the number of dwelling units of each type.
2. Next, if the mitigation component is used, the user will be prompted to review the default values for several key variables (e.g. residential density, level of transit service) for each residential land use type. If the project’s land uses have characteristics that are different from the default values (as they usually will be), the user will enter the correct values, in place of the default values.
3. Within the program, the formulas described hereafter will be used to calculate the resulting trip generation rates.

In keeping with the conclusions of current transportation research, a single set of formulas is used to modify the trip rates for all residential land use types. The input variables for these formulas assess five key land use characteristics (or “mitigation measures”, in URBEMIS terms):

- Net residential density (measured by Households per Residential Acre)
- Mix of uses (using a jobs/housing measure)
- Presence of local-serving retail
- Level of transit service (measured by a transit service index)
- Bicycle and pedestrian friendliness (measured by an “pedestrian factor” index based on intersection density, sidewalk completeness, and bike lane completeness)

For each ITE residential land use type, a set of default values for these variables has been defined. If the default values for a residential land use type are left unchanged when running the mitigation component, then the resulting trip generation rate will be

the standard ITE average trip generation rate for that land use type. For single-family detached housing, for example, the default values include a residential density of three units per residential acre, a transit service index score of 0 (representing no transit service within one-quarter mile of the site), and an intersection density of 250 intersections per square mile (typical of post-war cul-de-sac residential subdivisions). Figure D-4 shows the default values for each land use type.

To achieve the lowest residential trip rate reported in *Trip Generation* (a manual which primarily measures stand-alone, single-use projects with little or no transit service), the input values required would include a density of 160 units per residential acre, the maximum level of transit service, the best possible mix of uses and local retail, and a pedestrian score equivalent to a complete sidewalk coverage with a network of blocks no larger than 300 feet on a side. This would result in a rate of 1.83 trips/day, or an 81% reduction from the average single-family house rate).

This is similar to the 82% difference in household trip generation between the lowest density areas with the poorest transit service (6.4 vehicle trips per household per day), and the highest-density areas with good transit and a higher quality pedestrian environment (1.2 vehicle trips per household per day), as shown in Figure D-1. Figure D-4 shows the input values that would be required to achieve this rate, as well as the input values required to achieve maximum possible reduction allowed.

In theory, choosing the maximum possible values for each of the *physical design variables* described above could result in a residential trip generation rate as low as 0.9 daily trips per unit. This represents a 90% reduction from the average rate for a single-family detached house. To achieve this rate, however, a neighborhood would have to have remarkable characteristics, similar to Manhattan or Hong Kong: a density of 380 units per acre, or more than three times the average density of San Francisco's densest neighborhoods (North Beach and Chinatown), the highest possible level of transit service, and so on.[2]

The recommended reductions for the individual physical design mitigation measures for residential uses are summarized in Figure D-3. The remainder of the report discusses the justification for these levels, along with the mitigation measures for non-residential uses. In general, the recommended maximums for individual components have been set at a level so that this overall 90% maximum reduction from the average single-family house rate is maintained for residential land uses. While a greater reduction may sometimes seem warranted for an individual measure, a lower value has been selected to stay within this 90% maximum – a practice that helps avoid the considerable dangers of double counting.

[2] While rare in California, these extreme cases of Manhattan-like densities can be seen in projects such as San Francisco's single-room occupancy hotels for very low income residents, which achieve such densities by omitting parking and providing very small living quarters.

In addition to the variables above, which primarily measure physical design characteristics, the formulas include mitigation measures that assess *demand management programs and similar measure*s. A maximum additional reduction of 7.75% from the average single-family house rate is possible through these measures.

Non-Residential Land Uses

For non-residential land uses, the general procedure for modifying rates is similar, and based upon many of the same research results. To modify non-residential trip generation rates, the following procedure is used:

1. For *physical design* mitigation measures, the formulas to determine percentage reductions are identical to the formulas for residential land uses, except for the 'Residential Density' measure, which cannot apply.
2. Additional mitigation measures are applied for *demand management programs and similar measures.* For non-residential uses, the number of available demand management measures is greater, as is the possible percentage reduction.

However, there is a key difference between the formulas used to modify residential rates, and the formulas used to modify non-residential rates:

1. For residential land uses, the percentage reductions shown for each mitigation measure refer to the percentage reduction from 9.57 trips per day (the rate for single family homes). The default values for each residential land use (Figure D-4) are set at levels such that keeping these values generates the average trip rate for that land use.

2. For non-residential land uses, the percentage reductions shown for each mitigation measure refer simply to the percentage reduction from the average ITE trip generation rate for that land use. No special default values are required: they are simply set to create a 0% reduction as the starting value.

Figure D-3 Summary of Recommended Trip Reductions

	Residential	Non-Residential	Comments
Physical Measures			
Net Residential Density	Up to 55%	N/A	
Mix of Uses	Up to 9%	Up to 9%	
Local-Serving Retail	2%	2%	
Transit Service	Up to 15%	Up to 15%	
Pedestrian/Bicycle Friendliness	Up to 9%	Up to 9%	
Physical Measures sub-total	*Up to 90%*	*Up to 35%*	
Demand management and similar measures			
Affordable Housing	Up to 4%	N/A	
Parking Supply	N/A	No limit	Only if greater than sum of other trip reduction measures
Parking Pricing/Cash Out	N/A	Up to 25%	
Free Transit Passes	25% * reduction for transit service	25% * reduction for transit service	
Telecommuting	N/A	No limit	Not additive with other trip reduction measures (see text)
Other TDM Programs	N/A	Up to 2%, plus 10% of the credit for transit and ped/bike friendliness	
Demand Management sub-total[3]	*Up to 7.75%*	*Up to 31.65%*	

[3] This sub-total excepts the measures for parking supply and telecommuting, which have no limit.

Figure D-4 Default Values for Residential Land Use Trip Generation Formulas

Default Values for Residential Trip Rate Formulas

Land Use Code	Land Use Type	Residential Density	Housing Units	Employ-ees	Retail?	Transit Service	Inter-section Density	Side-walks	Bike Lanes	Ped factor	ITE Trip Rate Low	ITE Trip Rate Average	ITE Trip Rate High
210	Single-Family Detached Housing	3	100	17	no	0.00	250	0	0	0.06	**4.31**	**9.57**	**21.85**
221	Low-Rise Apartment	16	100	26	no	0.06	250	0.5	0	0.23	**5.1**	**6.59**	**9.24**
230	Residential Condominium/Townhouse	16	100	60	yes	0.10	400	1	0	0.44	**1.83**	**5.86**	**11.79**
223	Mid-Rise Apartment	38	100	60	yes	0.14	400	1	0	0.44	**NA**	**4.68**	**NA**
222	High-Rise Apartment	62	100	60	yes	0.14	400	1	0	0.44	**3**	**4.2**	**6.45**
232	High-Rise Residential Condo./Townhouse	64	100	60	yes	0.14	400	1	0	0.44	**3.91**	**4.18**	**4.93**

Trip Rates Resulting When Default Values Are Used

Land Use Code	Land Use Type	Residential Density	Mix of Uses	Reductions Local Retail	Reductions Transit	Reductions Bike/ Ped	Reductions Total	Resulting Trip Rate
210	Single-Family Detached Housing	0.0%	-0.6%	0.0%	0.0%	0.6%	0.0%	9.57
221	Low-Rise Apartment	27.9%	0.5%	0.0%	0.6%	2.1%	31.1%	6.59
230	Residential Condominium/Townhouse	27.9%	3.9%	2.0%	1.1%	3.9%	38.8%	5.86
223	Mid-Rise Apartment	39.8%	3.9%	2.0%	1.5%	3.9%	51.1%	4.68
222	High-Rise Apartment	44.8%	3.9%	2.0%	1.5%	3.9%	56.1%	4.20
232	High-Rise Residential Condo./Townhouse	45.1%	3.9%	2.0%	1.5%	3.9%	56.3%	4.18

Example Residential Trip Rate Calculations

Land Use Code	Land Use Type	Residential Density	Housing Units	Employ-ees	Retail?	Transit Service	Inter-section Density	Side-walks	Bike Lanes	Ped factor	ITE Trip Rate Low	ITE Trip Rate Average	ITE Trip Rate High
210	"Worst Case" Single-Family	0.1	100	0	no	0.00	80	0	0	0.02	-	**-**	**21.85**
230	"Best Case" Res. Condo/Townhouse	160	100	150	yes	1.00	1300	1	0	0.67	**1.83**	-	**-**
NA	Maximum Possible Reduction	380	100	150	yes	1.00	1300	1	1	1.00	**NA**	**NA**	**NA**

Trip Rates Resulting When Example Values Are Used

Land Use Code	Land Use Type	Residential Density	Mix of Uses	Reductions Local Retail	Reductions Transit	Reductions Bike/ Ped	Reductions Total	Resulting Trip Rate
210	"Worst Case" Singe-Family Detached	-20.7%	-3.0%	2.0%	0.0%	0.2%	-21.5%	11.63
230	"Best Case" Res. Condo/Townhouse	51.4%	9.0%	2.0%	12.5%	6.0%	80.9%	1.82
NA	Maximum Possible Reduction	55.0%	9.0%	2.0%	15.0%	9.0%	90.0%	0.95

5. Data Requirements

Figure D-5 shows the inputs that are required to complete the mitigation component in full, along with suggested data sources. Note, however, that the mitigation component can still be run, even if some of these inputs are missing. While no reduction would be granted for the particular mitigation measure for which the input was required, credits could be granted for other trip reduction measures.

Figure D-5 Data Requirements and Suggested Sources

Required Input	Suggested Source: Project	Suggested Source: Surrounding Development	Comments
Net residential density	Project plans	Block-level census data	Net residential data excludes land not devoted to residential uses
Number of housing units	Project plans	Block-level census data	Same basic source as for net residential density
Number of jobs	Project plans	Census Transportation Planning Package. Local jurisdiction may provide more current or fine-grained data	If data are only available per square foot, US Dept. Energy produces figures on average employee density
Local serving retail	Project plans	Site observations	
Below-market-rate units	Project plans	N/A	
Parking supply	Project plans	N/A	
Transit service	Transit agency maps/schedules		
Intersection density	Project plans	Street plans	Count can be automated if available in GIS
Sidewalk completeness	Project plans	Site observations	Count can be automated if available in GIS
Bike lane completeness	Project plans	Site observations	Count can be automated if available in GIS
Parking pricing	Development agreement or similar	Site observations (if applicable)	
Free transit pass provision	Development agreement or similar	N/A	
Telecommuting/flexible work schedules	Development agreement or similar	N/A	

Other TDM programs	Development agreement or similar	N/A	

6. Procedure for Small Projects
For developments in an established urban area below a certain size threshold, we recommend allowing them to adjust their trip generation rates based on the mode share in that census tract. This would avoid a disproportionate burden in gathering the data to document their likely trip reduction. (The analyst would need to certify that the project was similar in character to the existing development.) The recommended threshold is 50 average daily baseline vehicle trips, with the baseline being that calculated by URBEMIS before any of the reductions from mitigation measures are applied.

7. Substitute Methodologies
The recommended mitigation levels are, in our judgment, the most appropriate for a model that must apply to an extremely wide range of projects and geographic contexts. However, it must be recognized that there may be "special cases," where these standard reductions may not apply. For this reason, we recommend that any methodology for calculating reductions in VMT and vehicle trips may be substituted, provided that this is mutually agreed between the Air District and project proponent.

8. Measures Reducing VMT
The existing mitigation component allows for reductions in VMT (but not trip generation) for park-and-ride lots and satellite telecommuting centers. We do not recommend any changes to this aspect of the mitigation component.

9. Correction Factors
The existing mitigation component provides for trip type correction factors, based on evidence suggesting that certain trips are more likely to be captured by one mode rather than another. We do not recommend any changes to this aspect of the mitigation component.

A second correction factor in the existing mitigation component relates to trip distance, because, the documentation argues, bicycle and walking trips replace mostly shorter automobile trips. We recommend that this correction factor be eliminated, as there is little evidence to suggest that this phenomenon exists. Indeed, more complex changes in travel behavior are likely, such as mode shift to bicycling and walking trips being accompanied by a shift to closer destinations. For example, rather than drive to a grocery store on a freeway interchange, a household may walk to a smaller store in the neighborhood. Mixed use, compact neighborhoods are characterized by short overall trip lengths (see, for example, Kuzmyak et. al., 2003). Further evidence comes from the elasticities for trip reduction with respect to density, which are the same for both vehicle trips and VMT (Ewing & Cervero, 2001), suggesting that there is no impact on trip length.

Detailed Justification of Recommended Mitigation Levels

Default Values for Residential Land Uses

To develop the default values for residential land uses shown in Figure D-4, we had to overcome a significant hurdle: ITE retains no data on the characteristics of the developments used in their trip generation studies. Default values for average density, transit service levels, and other variables had to be estimated using two alternative methods. First, we reviewed representative projects through research of literature and discussions with professionals in the fields of architecture and town planning, to ascertain typical ranges for density and other characteristics of each land use type (for useful summaries, see Calthorpe, 1993, and Local Government Commission,2002).

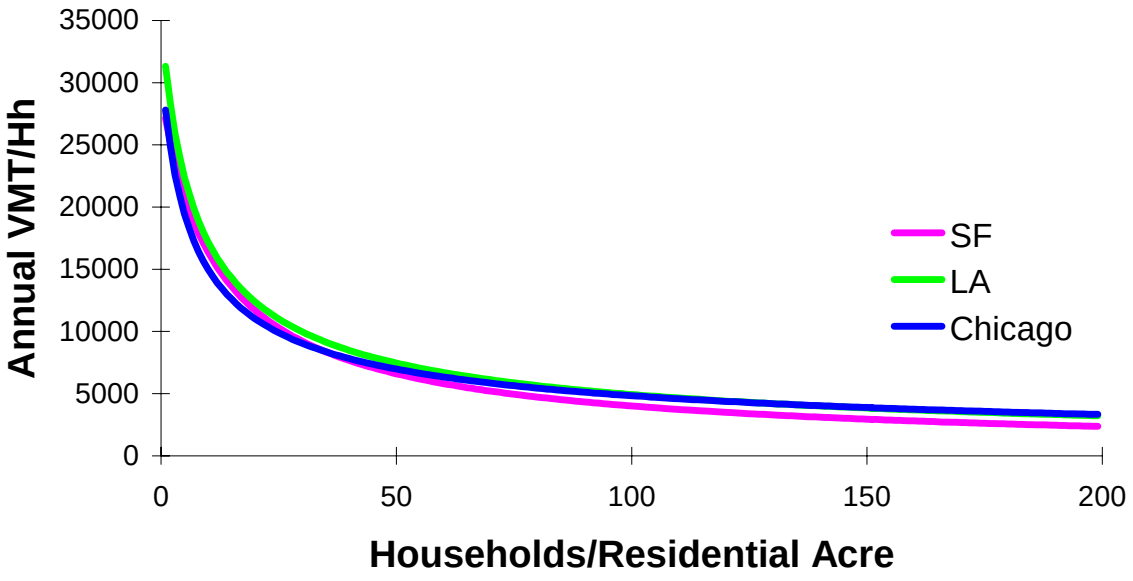
Second, these ranges of values were plugged into the formulas for the mitigation measures, and adjusted until the baseline values for each characteristic equaled the average ITE trip generation rates for each land use. For example, baseline density for Mid-Rise Apartments (64 units per residential acre) falls within the typical range observed from research of 45 to 125 units/acre, and when combined with other baseline characteristics for the land use, results in a 56.1% reduction in trip generation from the average rate for single family homes – the average reduction set forth in the ITE manual.

Finally, since the *Trip Generation* manual provides no daily trip generation rate for the "Mid-Rise Apartment" land use, we estimated a rate by extrapolating from the daily trip rate for the "High-Rise Apartment" land use type. The PM peak hour trip rate of 0.39 trips per unit for mid-rise apartments is 11.4% higher than the PM peak hour rate for high-rise apartments (0.35 trips/unit). Therefore, the daily trip rate for the "Mid-Rise Apartment" land use was estimated to be 4.68 trips per unit, or 11.4% higher than the daily trip for high-rise apartments (4.2 trips/unit).

Density

A considerable volume of research has investigated the links between density, particularly residential density, and travel behavior (for summaries, see Kuzmyak et. al, 2003; Boarnet & Crane, 2001). Overall, the conclusions can be summarized thus: there is a significant, quantifiable relationship between residential density and automobile use (see Figure D-6), but there is uncertainty regarding the degree to which this effect is due to the inherent effects of density, as opposed to factors for which density serves as a proxy, such as parking price, local retail, transit service frequency and pedestrian friendliness.

Figure D-6 Residential Density Vs. Vehicle Travel



Source: Holtzclaw et. al. (2002).

Fewer studies have attempted to disentangle the effects of density itself. Three of the main exceptions are:

- Typical elasticities for vehicular travel with respect to density are –0.1 to –0.04. These elasticities refer to the effect of density itself, isolated from variables that tend to be correlated with density such as transit frequency, and are additive to elasticities of other built environment factors. When these factors are not isolated, typical elasticities for VMT with respect to density are –0.22 to –0.27 (Kuzmyak et. al, 2003).
- The elasticity of density, when isolated from three other variables (diversity, design and destinations), is –0.043 with respect to vehicle trips, and – 0.035 with respect to VMT (Criterion and Fehr & Peers, 2001). However, this does not control for transit service levels.
- Cervero & Ewing (2001), in an update to this work, suggest a slightly higher elasticity of –0.05 with respect to both vehicle trips and VMT.

Note that density has been shown to have a nonlinear relationship with vehicle travel, with a threshold value of 25-30 units per acre below which the travel impacts of increased density are particularly large (Holtzclaw et. al, 2002). Holtzclaw et. al found that the best single variable equations to predict household vehicle travel (VMT per

household, or VMT/Hh) relied on Households per Residential Acre (Hh/RA). For the Los Angeles region, San Francisco and Chicago regions, these equations varied only slightly, producing the curves shown in Figure D-6. For the Los Angeles region, this formula takes the form:

$$\frac{\mathrm{VMT}}{\mathrm{Hh}} = 19749\left(\frac{4.814 + \mathrm{Hh/RA}}{4.814 + 7.140}\right)^{-0.639}$$

Based on this formula, the following elasticity formula is recommended for vehicle trips with respect to density. It is the same as Holtzclaw et. al' work, but reduced by 40% to take account of the fact that much of this impact will be realized through transit service, mix of uses and bicycle and pedestrian levels (which tends to correlate with density). The baseline assumed to correspond to a zero percent trip reduction is three units per acre, at which density the Holtzclaw formula results in 25,914 annual vehicle miles traveled per household. This translates into the following formula:

Trip reduction
=0.6*(1-(19749*((4.814+ households per residential acre)/(4.814+7.14))$^{-0.639}$)/25914)

An apartment development of 16 units per residential acre, for example, would be estimated to generate 27.9% fewer trips than a three unit per acre project. The maximum allowable reduction recommended is 55% (equivalent to a 380 unit per acre development).

With this formula, "negative" reductions also apply, with less dense developments below the baseline level of three units per acre (for example large-lot housing) resulting in higher trip generation rates. (However, as long as the mitigation component is optional for developers or project proponents to complete, they will be unlikely to use it for projects whose overall score, for all components, will result in a finding to their disadvantage. For purposes of more accurately predicting vehicle trips and emissions, however, this negative reduction is useful and reflects the findings of the research literature.

Trip generation at the non-residential end is also influenced by density, but to a much lesser degree (Cervero, 1989, cited in Kuzmyak et. al, 2003). There are also far fewer studies investigating this relationship, and there is no comparable dataset to that for residential density. No reduction is recommended here.

Mix of Uses

Many references point to the impact of "diversity" or mix of uses on travel behavior. This is true both at the macro-scale, e.g. jobs-housing balance, and the micro-scale, e.g. the availability of services within walking distance. Key references, related to both the direction and magnitude of this relationship, include:

- Higher densities are most beneficial to transit ridership when they result in a mix

of residential, commercial and office uses (Lund et. al., 2004).

- The elasticity of vehicle trips with respect to “diversity” is –0.051. The elasticity of VMT is –0.032. In this case, “diversity” is a measure of how the project affects regional population/employment balance. (Criterion and Fehr & Peers, 2001)
- Typical elasticities for vehicle trips with respect to local diversity (mix) are –0.03, and those for VMT are –0.05 (Ewing & Cervero, 2001).
- A balance of 1.5 jobs per household is estimated to produce a bus mode share 2 percentage points over the share for a single use area, although the degree of mix is not a useful estimating variable (Messenger & Ewing, 1996, cited in Kuzmyak et. al, 2003).
- Suburban activity centers with some on-site housing had 3-5% more transit, bike and walk commute trips (Cervero, 1989, cited in Kuzmyak et. al, 2003).
- The presence of retail reduces auto mode share by 2-5%, depending on neighborhood density. (Parsons Brinkerhoff, 1996, cited in Kuzmyak et. al, 2003).
- At suburban activity centers, the presence of retail in office buildings lowers vehicle trip rates by 6-8% (NTI, 2000, cited in Kuzmyak et. al, 2003).
- Employment sites with “good” nearby retail and commercial services have a vehicle trip rate 21.5% below the ambient rate. Sites with “fair” services showed an 8.3% reduction, and those with “poor” services a 5.3% reduction. This is attributed not just to the presence of these services, but the fact that they make TDM programs more likely to succeed (Comsis, 1994, cited in Kuzmyak et. al, 2003).

The analysis is complicated by the fact that some of the most beneficial developments from this perspective may be single-use, in an area where another use is predominant (e.g. residential in an employment area). To take this into account, the following procedure is proposed (adapted from Criteron and Fehr & Peers, 2001):

$$\text{Trip reduction} = (1- (\text{ABS} (1.5 * h – e) / (1.5 * h + e)) – 0.25) / 0.25 * 0.03$$

Where: h = study area households (or housing units)
e = study area employment

Negative reductions of up to 3% can result, and should be included.

This formula assumes an “ideal” housing balance of 1.5 jobs per household, based on Messenger & Ewing (1996), and a baseline diversity of 0.25. The maximum possible reduction using this formula is 9%.

This reduction takes into account overall jobs-population balance. The presence of local serving *retail* can be expected to bring further trip reduction benefits, and an additional reduction of 2% is recommended. This is towards the lower end of the values presented

in the research discussed above, in order to avoid double counting with the diversity indicator.

Transit

The existing URBEMIS 2002 mitigation model places its primary emphasis on mode, i.e. whether service is provided by high-speed rail, commuter rail or bus. Within this framework, consideration is given to frequency (e.g. bus headways of 15 minutes or less score more highly than headways of 15-30 minutes).

For example, the current mitigation component would award the maximum score of 100 to a development 0.5 miles from a BART station, even if no other transit were available. A part of the city with several bus lines offering 10-minute service, in contrast, would score much lower, even though these transit lines would carry many more passengers.

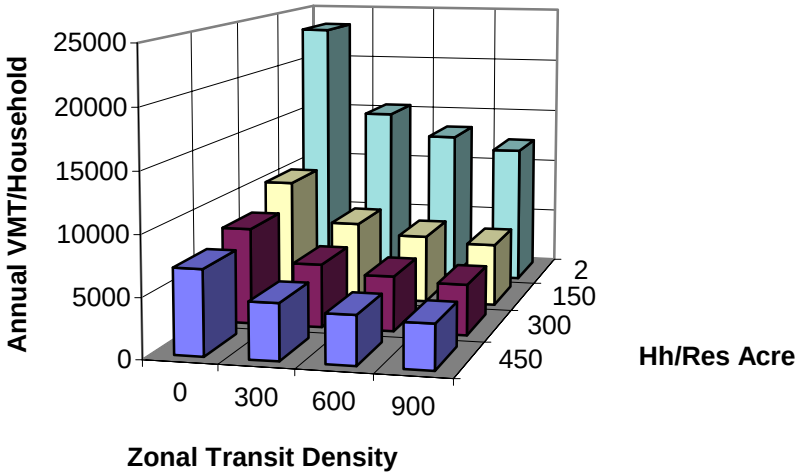
Current transit planning thinking, however, emphasizes that frequency and speed are two of the most important factors determining mode choice, rather than whether the service is provided by bus, bus rapid transit, or rail. Researchers have found that there is no *inherent* preference for rail over bus, provided that the quality of service is the same (for example, Ben-Akiva & Morikawa, cited in Transportation & Land Use Coalition, 2002).

Key references include:

- The average elasticity of ridership with respect to frequency is +0.3 to +0.5. Higher elasticities of +1.0 have been observed in suburban systems, with the +0.3 value more typical of urban systems. (Kittselson & Associates et. al, 2003).
- Pratt et. al. (2003) suggest an elasticity of ridership with respect to service hours (i.e. a combined measure of frequency and service span) of +0.5. Ridership is most sensitive to frequency changes when the past service was infrequent.
- Modeling in Massachusetts suggests that halving transit service headways from 30 to 15 minutes leads to an 8% drop in vehicle trips. A further decrease to 5 minutes leads to a further 4% drop in vehicle trips (Pratt et. al., 2003).
- Holtzclaw et. al. (2002) show that vehicle travel falls as transit service levels increase, even when holding density constant (Figure D-7). In the San Francisco Bay Area, a doubling of transit service from 300 to 600 (using the index described below) is associated with a 13% drop in VMT. An increase from 300 to 900 is associated with a 20% drop in VMT. In the Los Angeles region, the decreases in VMT are 12% and 18% respectively. However, the variable was omitted from the vehicle travel model presented in this paper, since density was used as a proxy for transit service.
- The maximum distance that people are willing to walk to transit tends to be 0.25 miles for bus, and 0.5 miles for rail (and, presumably bus rapid transit). (Kittelson & Associates et. al, 2003). It is unclear whether there is a “distance decay” effect, whereas people are more likely to use transit at closer distances within this range

(see Lund et. al, 2004).

Figure D-7 VMT vs. Residential Density and Transit Use, San Francisco Bay Area



Source: Holtzclaw et. al. (2002).

Unfortunately, the elasticity of service with respect to transit ridership is difficult to convert to vehicle trip reduction, firstly because the baseline ridership needs to be known, and secondly because only a proportion (18-67% is cited by Pratt et. al., 2003) of new transit trips were formerly made by private auto. While it is clear that there is a direct correlation between transit service and vehicle trips, it is difficult to employ these elasticities directly. For this reason, the approach here is more in line with the existing mitigation component, which assumes a maximum percentage reduction for transit, and then reduces this based on a transit environment factor.

Various frequency-based transit service indices have been developed which have shown strong correlations with ridership. For example:

- In Los Angeles, the quality of four components of transit service (MTA rail, Rapid Bus, local bus and regional services) were rated on a scale of 0-3 for each community area, and then summed to provide the Transit Service Index on a scale of 0-12. (Nelson\Nygaard, 2002b).
- The studies by Holtzclaw et. al. (2002) used Zonal Transit Density, defined as the daily average number of buses or trains per hour times the fraction of the zone within 1/4 mile of the bus stop, or 1/2 mile of the rail station or ferry terminal, summed for all transit routes in or near the zone.

The Transit Service Index recommended here would combine the important features of all these approaches, with emphasis on frequency but with greater weighting given to

rail services. Greater weight is also given to dedicated shuttles, in recognition of the fact that these are likely to be more closely targeted to the needs of the development. The Transit Service Index would be determined as follows:

- Number of average daily weekday buses stopping within 1/4 mile of the site; plus
- *Twice* the number of daily rail or bus rapid transit trips stopping within 1/2 mile of the site
- *Twice* the number of dedicated daily shuttle trips
- Divided by 900, the point at which the maximum benefits are assumed. (This equates to a BART station on a single line, plus four bus lines at 15-minute headways.)
- Developments that are larger than 0.5 miles across in any direction must be broken into smaller units for purposes of determining the transit service index. The average of all units would then be used.

Figure D-8 shows some examples of how service frequencies translate into Transit Service Index scores (note these are additive, if a location has more than one component).

Figure D-8 Example Transit Service Index Scores

Transit Service	Score	Assumptions
BART (single line)	0.33	150 trips per day (15-20 minute headways in each direction from 4 AM-12 AM)
15-minute bus, 5 AM – 12 AM	0.17	
30-minute bus, 5 AM – 7 PM	0.06	
Amtrak San Joaquin	0.03	6 trips per day in each direction
Dedicated commute shuttle	0.02	5 trips per commute period (single direction)

As well as existing service, planned and funded transit service would be included in the calculation. Purely demand responsive service would not be included.

A maximum trip reduction of 15% is recommended. This is the same as the existing URBEMIS 2002 trip reduction for existing and planned transit service.

In order to account for non-motorized access to transit, we also recommend that half the reduction be dependent on the pedestrian/bicycle friendliness score (calculated in the following section), similar to the approach taken in the existing mitigation component. This ensures that places with good pedestrian and bicycle access to transit are rewarded.

Trip reduction = t * 0.075+ t * ped/bike score * 0.075

Where t = transit service index

Bicycle and Pedestrian

Since bicycle mode share and pedestrian mode share depend on similar neighborhood characteristics, such as a fine-grained street grid, we recommend that a single factor be used to account for both modes. The bicycle and pedestrian components of the URBEMIS 2002 mitigation component are already well developed. However, the inputs are largely subjective, and there is still little evidence to justify the precise amount of credits for many of the individual mitigation measures (e.g. street trees).

Many street design factors have, however, been shown to promote walking and cycling. These include:

- Street connectivity, with traditional street networks that are more New Urbanist or grid-like, as opposed to the loops, lollipops and cul-de-sacs of most conventional subdivision. There are various measures of connectivity (summarized in Dill, 2003), such as:
    - Block length, size or density
    - Intersection density
    - Street density
    - Connected node ratio (number of street intersections divided by the number of intersections plus cul-de-sacs)
    - Link-node ratio (links are roadway or pathway segments between two nodes, which are intersections or cul-de-sac ends)
    - Grid pattern (percentage of intersections that are four- or more way).
    - Pedestrian Route Directness (ratio of route distance to straight line distance)
    - Effective Walking Area (% of parcels within 1/4 mile, that are also within 1/4 mile walking distance)
- Human-scale streetscapes with adequate pedestrian amenities, access to shopping and other amenities, and higher densities (Lund et. al., 2004)

Other relevant research includes:

- A composite indicator, the “Pedestrian Environment Factor,” provides a statistically significant correlation with trip generation and VMT. It is comprised of four inputs (Parsons Brinkerhoff, 1993):
    - Ease of street crossings
    - Sidewalk continuity
    - Local street characteristics (grid vs. cul de sac)
    - Topography
- In Portland, OR, an increase in the PEF from “pedestrian hostile” to “almost average” reduces daily vehicle trips by 0.4 per household (7%). An increase from “almost average” to “fairly good” provides a daily reduction of 0.2 trips (Parsons

Brinkerhoff, 1993, cited in Kuzmyak et. al, 2003).

- Sidewalk completeness, route directness and network density together have a vehicle trip elasticity of –0.05 (Ewing & Cervero, 2001).
- For a high degree of walkability, block lengths of approximately 300 feet are recommended. Short blocks provide more pedestrian crossing opportunities and direct walking routes, and mean that traffic is more likely to be dispersed. Downtown Los Angeles, for comparison, has about 150 intersections per square mile. (Ewing, 1999).

There is a strong tradeoff here between simplicity and low data requirements on the one hand, and robustness and accuracy on the other. Pedestrian and bicycle level of service work for the Florida Department of Transportation and FHWA, for example, has shown that there are numerous statistically significant factors that can be included to assess the quality of the bicycle and pedestrian environment. These include motor vehicle volumes and speeds, truck volumes, roadway widths, urban design, and lateral separation between pedestrians and motor vehicles (for example, FHWA, 1998; Landis et. al, 2001).

However, we recommend that in order to keep data requirements to a minimum, one or two of the street design indicators discussed by Dill (2003) and Ewing and Cervero (2001) be used, together with a single bicycle measure. Since route directness and network density measure similar characteristics, we recommend the use of one of these (network density, which is inversely related to block size) plus sidewalk completeness and bicycle network completeness. The pedestrian/bicycle factor would then be calculated as follows:

Ped/bike factor =
(network density + sidewalk completeness + bike lane completeness) / 3

Where:

Network density = intersections per square mile / 1300 (or 1.0, whichever is less)

Note: In most GIS applications, intersections are counted based on the number of line segment terminations, or each “valence.” Intersections have a valence of 3 or higher – a valence of 3 is a “T” intersection, 4 is a four-way intersection, and so on.[4] (Georgia Institute of Technology, 2002). Therefore, if intersections are counted manually on a map or project plan, care needs to be taken to distinguish between 3-, 4- and 5-way intersections, and factor them up accordingly. The 1,300 value roughly equates to a dense grid with four-way intersections every 300 feet, per the recommendation of Ewing (1999). Intersections with dedicated routes for pedestrians and/or bicyclists should be included in this calculation.

[4] A valence of 1 indicates that a line segment has terminated, e.g. in a cul-de-sac. A valence of 2 means that the street is continuing.

Sidewalk completeness =

% streets with sidewalks on both sides + 0.5 * % streets with sidewalk on one side

Bike lane completeness =

% arterials and collectors with bicycle lanes, or where suitable, direct parallel routes exist

A maximum reduction of 9% is proposed, based on the existing URBEMIS mitigation component.[5] The trip reduction would then be calculated as:

Trip reduction = 9% * ped/bike factor

No reduction should be allowed if the entire area within a half-mile walk of the project center consists of a single use. (Note that this applies to a half-mile walk, rather than straight-line distance, to account for barriers such as freeways.) However, the ped/bike factor can still be used to calculate pedestrian access to transit, as part of the transit mitigation measure.

Affordable and Senior Housing

A significant amount of evidence points to the fact that lower-income households and senior citizens own fewer vehicles and drive less. Research includes:

- Russo (2001) cites evidence from the San Francisco Bay Area travel survey, which shows that households earning under $25,000 per year make 5.5 vehicle trips per day, compared to a regional average of 7.6. High income households (earning more than $75,000 per year) make an average of 10.5 trips. Note that this data does not control for other factors, such as density and transit access.
- In the San Francisco Bay Area, Los Angeles and Chicago, income was one of four variables with sufficient independent explanatory power to include in the model of VMT and vehicle ownership (Holtzclaw et. al., 2002).

Obviously, it is difficult if not impossible to account for the exact incomes of residents in URBEMIS, most obviously because the occupants are not known at the pre-development stage. However, the percentage of deed-restricted below-market-rate (BMR) housing does offer a way to incorporate this effect.

We recommend a 3% reduction in vehicle trips for each deed-restricted BMR unit.[6] Thus, the total reduction is as follows:

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[5] Note that this excludes the bicycle reduction in the current mitigation component. However, this compensates for the fact that the reductions recommended for the mixed use and density variables will be realized in practice through pedestrian and bicycle mode share.

[6] Calculated from Holtzclaw et. al. (2002), assuming 12,000 average annual VMT per vehicle, median per capita income of $33,000 (2002 figures per California State Department of Finance), and an average income in BMR units

Trip reduction = % units that are BMR * 0.04

A development with 20% BMR units would thus gain a 0.8% reduction. A development with 100% BMR units would gain a 4% reduction.

Parking Supply

Significant correlations between parking supply and employee mode split have been observed. For example, a study of the link between parking availability and transit use in eight Canadian downtowns found an extremely high elasticity of –0.77 (Morrall & Bolger, 1996, cited in Kuzmyak et. al., 2003b). In California, the number of parking spaces per worker was found to be one of the main two elements of a binomial logit model predicting transit mode share among TOD office workers (Lund et. al, 2004).

As with residential density, the extent to which parking supply itself is a causal factor is uncertain. In practice, it probably serves as a proxy for variables such as price, high quality public transit, mix of uses, and pedestrian friendliness (Kuzmyak et. al., 2003b). Indeed, in practice there is a two-way relationship between parking supply and mode split. Free parking, for example, can be seen as both a cause of high parking supply (more parking is needed to satisfy the greater demand), and a consequence (the market price of parking is zero once an effectively unlimited supply is provided) (see, for example, Shoup, 1999).

Theoretically, it is possible to reduce parking provision to below the level of actual demand, should drivers park in neighboring lots or on-street in surrounding areas. However, planning approval is not likely to be granted for developments that significantly under-provide parking, unless complementary Residential Permit Parking programs or other measures to combat this type of overspill are introduced. Indeed, the main reason for minimum parking requirements levied by local jurisdictions is to address these overspill issues (Shoup, 1999).

Similarly, market realities are likely to prevent a developer from providing too little parking. The challenges in persuading lenders to finance developments that have below-code parking are difficult enough to overcome, even where there is clear, documented evidence to show that parking supply will be enough to meet demand (see for example, Parzen & Sigal, 2004). In contrast, the opposite tendency is likely to be apparent – that developments are prevented from taking full advantage of the opportunities to reduce parking supply by zoning codes (see, for example, Nelson\Nygaard, 2002).

The measure proposed here uses the Institute of Transportation Engineers' *Parking Generation* handbook as the baseline. This is assumed to equate to unconstrained demand. The trip reduction can therefore be calculated as follows:

25% below median. Holtzclaw calculate the coefficient of -0.0565. Therefore, expected VMT reduction can be calculated as 0.0565 * 33,000 * 0.25 / 12,000 = 4%

Trip reduction = Actual parking provision / ITE Parking Generation rate

Since ITE parking generation rates use the same land use codes as the trip generation rates, these could be provided within the URBEMIS model itself. The user would only be required to enter the actual parking provision for each land use.

For land uses with rates for both weekday and weekend, the formula will use whichever rate is higher. The *Parking Generation* handbook covers most common land uses. For some land uses, however, no parking generation rates are available: in these cases, this particular mitigation measure may not be used.[7] Those land uses without parking generation rates include:

- Single Family Detached Housing
- Mid-rise Apartments
- High-rise Condominium/Townhouse
- Mobile Home Parks
- Residential Planned Unit Development (PUD)
- Day-care center
- Elementary school
- Junior High school
- Library
- City Park
- Discount Superstore
- Discount Club
- Electronic Superstore
- Home Improvement Superstore
- Gas/Service Station
- Pharmacy/Drugstore with and with/out Drive Through
- Medical Office Building
- General Heavy Industry

To avoid double counting with other trip reduction measures, the impacts of parking supply are proposed to be assessed in conjunction with all other non-residential trip reduction measures as follows:

- The total of all other non-residential trip reduction measures should be used if this is greater than or equal to the trip reduction from parking supply measures. For example, if parking supply is reduced 10% from ITE levels, and transit, mixed

[7] The next edition of *Parking Generation,* currently under development by an ITE Task Force, is likely to provide date for some of these missing land uses. While it would be ideal to have parking generation data for every single land use before introducing this mitigation measure into URBEMIS, the data does not yet exist. Rather than abandoning this mitigation measure entirely until perfect data exists, we recommend allowing the measure to be used for the many land uses where reasonable data is available.

use and pedestrian/bicycle trip reductions amount to 20%, the 20% figure would be used.

- If the total of all other non-residential trip reduction measures (r_1) is less than the trip reduction from parking supply measures (r_2), the total trip reduction is as follows:

  $$r_1 + 0.5 * (r_2 – r_1)$$

  In effect, the parking supply reduction is only used if it is greater than the impact from other trip reduction measures, and the difference is discounted by 50%. For example, if parking supply is reduced 25% from ITE levels, and transit, mixed use and pedestrian/bicycle credits amount to 15%, the total reduction would be:

  $$15 + 0.5 * (25-15) = 20\%.$$

This reduction should only be granted if measures to control overspill are in place, such as Residential Permit Parking programs, time limits or meters.

Transportation Demand Management

Transportation Demand Management programs have been shown to have a major impact on travel behavior. Site-level employee vehicle trip reductions of up to 38% have been achieved, particularly for programs that have included parking pricing (Shoup & Willson, 1980; Comsis, 1993; Valk & Wasch, 1998; Pratt, 2000). Parking price elasticities of –0.1 to –0.3 have been reported (Pratt, 2000).

This component of the existing URBEMIS 2002 mitigation component is well developed. However, there is considerable scope to adapt it in two ways:

- Provide greater emphasis for the three elements that have the greatest impact on travel behavior – parking pricing/cash out; free transit passes; and telecommuting.
- Simplify the remaining elements, through offering broader options such as “major program”, “minor program”, and “no program,” for elements that are likely to have a smaller trip reduction potential.

We recommend that none of these reductions be permitted, unless they form part of a legally enforceable agreement specifying, for example, minimum parking prices and other TDM measures. This might form part of a development agreement, be enforced through any TDM ordinance in the local jurisdiction, or consist of another mechanisms mutually agreed by the air district and project proponent. Otherwise, there is little to guarantee that some of the promised measures (e.g. parking pricing) will actually be implemented and maintained.

Parking Pricing and Cash Out

We recommend that a maximum trip reduction of 25% be applied to projects that commit to introducing parking pricing. This is based on the approximate midpoint of observed reductions, which range from 15% to 38% (Shoup & Willson, 1990; Comsis, 1993; Pratt, 2000). Note that most of these studies apply to before-after or with-without comparisons, with no increase in transit service or other measures to reduce vehicle trips. This maximum reduction should apply to prices of $6 per day or greater (in 2004 dollars).

The trip reduction will therefore be as follows:

Trip reduction = daily parking charge / 6 * 0.25

If the parking charge is more than $6, the 25% reduction is taken. If parking charges do not apply to all trips to a site (e.g. customers are exempt), the reduction is pro-rated by the percentage of trips that the charges apply to. If little or no on-site parking is provided, the parking charges should be those of surrounding public facilities.

Parking cash-out programs should be eligible for 50% of the reduction for direct parking charges, in recognition of the fact that their impacts tend to be significantly lower (Pratt, 2000). This is partly due to the fact that cash-out payments are a taxable benefit.

Free Transit Passes

Some California transit agencies, most notably VTA in Santa Clara County, have EcoPass or similar programs, whereby employers or property managers bulk-purchase transit passes for (free) distribution to their employees or tenants. Eco Pass programs have been shown to increase transit ridership by 50-79% (City of Boulder, undated; Caltrans, 2002), and reduce vehicle trips by 19% (Shoup, 1999). (Note that many of these new riders were making new trips, or ones previously made by walking or cycling.)

We therefore recommend that any project committing to providing free transit passes would receive an additional credit equivalent to 25% of the reduction granted for transit service. Thus, the credit is more valuable in places that have good transit service. This reduction would only apply to the portion of trips generated by those granted the free transit passes (e.g. residents and/or employees, but excluding shoppers and other visitors).

Telecommuting

We recommend the retention of the reductions granted for telecommuting and compressed work schedules in the existing mitigation component, with two clarifications:

- As with the reductions for other mitigation measures, there must be an enforceable commitment (e.g. development agreement), which covers both the take-up rate (employees actually telecommuting or using compressed work schedules) as well as the provision of the option.
- The percentage reduction should not be additive (in contrast to most other trip reduction measures). For example, if 20% of employees telecommute, and other trip reduction measures are estimated to reduce vehicle trips from 1,000 to 800 per day, the 20% reduction would apply to the 800 trips, not the original 1,000.

Other TDM Programs

Other TDM program elements, that do not include financial incentives, tend to have a smaller impact on travel behavior. We recommend that reductions be based on the number of the following elements incorporated into the program, per Figure D-7:

- Secure bicycle parking (at least one space per 20 vehicle parking spaces)
- Showers/changing facilities
- Guaranteed Ride Home
- Car-sharing services
- Information on transportation alternatives, such as bus schedules and bike maps
- Dedicated employee transportation coordinator
- Carpool matching programs
- Preferential carpool/vanpool parking

The impact of a TDM program will also depend on the travel alternatives available. A program will have more impact if the site is served by frequent transit, for example (although note that a TDM program can do much to promote carpooling even in other locations). For this reason, we recommend that part of the TDM credit be used to adjust the credits granted for transit service and pedestrian/bicycle friendliness (see Figure D-9).

Figure D-9 Recommended TDM Program Reductions

Level	Number of Elements	Recommended Reduction
Major	At least 5 elements	2%, plus 10% of the credit for transit and pedestrian/bike friendliness
Minor	At least 3 elements	1%, plus 5% of the credit of transit and pedestrian/bike friendliness
No program	None	None

Examples

It is important to recognize that any type of calibration is beyond the scope of this

analysis, which relies on existing references to build on the ranges established in the existing mitigation component. Figure D-10, however, does provide some examples to indicate the trip reductions that would apply to specific places.

The data are drawn from the database compiled for the Location Efficient Mortgage program (for details, see Holtzclaw et. al., 2002), and from the San Francisco Bay Area Metropolitan Transportation Commission's TAZ files. For these reasons, the examples are limited to the San Francisco Bay Area. Transit service was estimated from schedules and route maps. Sidewalk and bike lane completeness were estimated based on local knowledge. For these reasons of limited data, the examples are intended as illustrations only, rather than to refer to a particular project.

The reductions are calculated for the physical and environmental factors only, for residential uses. They exclude any additional reductions from TDM programs and affordable housing.

The final column compares average vehicle miles traveled (no vehicle trip data were readily available) in these neighborhoods to the Brentwood baseline, as a rough comparison to the reductions granted through the proposed trip reductions for URBEMIS. As can be seen, while there are significant discrepancies, the overall correspondence is acceptable for this type of sketch planning model.

Figure D-10 Example Trip Reductions

		Vehicle Trip Reduction Granted For:						% Reduction in VMT from Brentwood
Example	**TAZ**	**Residential Density**	**Mix of Uses**	**Local Retail**	**Transit**	**Ped/bike friendliness**	**Total Reduction**	
Brentwood	899	1.4%	-3.0%	0.0%	0.1%	1.7%	0.3%	0.0%
Orinda	831	-9.5%	5.8%	0.0%	3.7%	1.4%	1.4%	5.6%
Pleasant Hill BART	806	14.4%	7.2%	3.0%	8.3%	3.3%	36.3%	40.2%
Emeryville	723	39.0%	1.7%	3.0%	4.4%	4.9%	53.1%	47.8%
Downtown Palo Alto	245	19.8%	4.4%	3.0%	6.1%	7.5%	40.8%	50.6%

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Appendix E. California Air District Contacts

CALIFORNIA AIR POLLUTION CONTROL DISTRICTS
(URBEMIS Contacts and General Phone Numbers)

AMADOR COUNTY APCD (all of Amador County)
665 New York Ranch Road, #3
Jackson, CA 95642-2310 (209) 257-0112

ANTELOPE VALLEY APCD (NE portion of Los Angeles County)
43301 Division St., Ste. 206
P.O. Box 4409
Lancaster, CA 93539-4409 (661) 723-8070

BAY AREA AQMD (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, W portion of Solano, and S portion of Sonoma counties)
939 Ellis Street
San Francisco, CA 94109-7714
Henry Hilken (415) 771-6000

BUTTE COUNTY AQMD (all of Butte County)
2525 Dominic Drive, Suite J
Chico, CA 95928-7184
Gail Williams (530) 891-2882

CALAVERAS COUNTY APCD (all of Calaveras County)
Government Center
891 Mountain Ranch Rd.
San Andreas, CA 95249-9709 (209)754-6504

COLUSA COUNTY APCD (all of Colusa County)
100 Sunrise Blvd. #F
Colusa, CA 95932-3246
Bonnie McCullough (530) 458-0590

EL DORADO COUNTY APCD (all of El Dorado County)
2850 Fairlane Ct., Bldg. C
Placerville, CA 95667-4100
Dennis Otani (530) 621-6662

FEATHER RIVER AQMD (all of Sutter and Yuba counties)
938 14th Street
Marysville, CA 95901-4149
Larry Matlock (530) 634-7659

CALIFORNIA AIR POLLUTION CONTROL DISTRICT CONTACTS
(continued)

GLENN COUNTY APCD (all of Glenn County)
P.O. Box 351 (720 N. Colusa St.)
Willows, CA 95988-0351
Kevin Toganowa (530) 934-6500

GREAT BASIN UNIFIED APCD (all of Alpine, Inyo, and Mono counties)
157 Short Street, Suite 6
Bishop, CA 93514-3537
Duane Ono (760) 872-8211

IMPERIAL COUNTY APCD (all of Imperial County)
150 South 9th Street
El Centro, CA 92243-2801
Deputy AQCO – Reyes Romero (760) 482-4606

KERN COUNTY APCD (E portion of Kern County)
2700 "M" Street, Suite 302
Bakersfield, CA 93301-2370 (661) 862-5250

LAKE COUNTY AQMD (all of Lake County)
883 Lakeport Blvd.
Lakeport, CA 95453-5405 (707) 263-7000

LASSEN COUNTY APCD (all of Lassen County)
175 Russell Avenue
Susanville, CA 96130-4215 (530) 251-8110

MARIPOSA COUNTY APCD (all of Mariposa County)
P.O. Box 2039 (5101 Jones St.)
Mariposa, CA 95338-2039 (209) 966-2220

MENDOCINO COUNTY AQMD (all of Mendocino County)
306 E. Gobbi St.
Ukiah, CA 95482-5511 (707) 463-4354
Chris Brown

MODOC COUNTY APCD (all of Modoc County)
202 West 4th Street
Alturas, CA 96101-3915 (530)-233-6419

CALIFORNIA AIR POLLUTION CONTROL DISTRICT CONTACTS
(continued)

MOJAVE DESERT AQMD (N portion of San Bernardino County, & E portion of Riverside County)
15428 Civic Drive, Suite 200
Victorville, CA 92392-2383 (760) 245-1661

MONTEREY BAY UNIFIED APCD (all of Monterey, San Benito, Santa Cruz counties)
24580 Silver Cloud Ct.
Monterey, CA 93940-6536
Janet Brennan (831) 647-9411

NORTH COAST UNIFIED AQMD
2389 Myrtle Avenue
Eureka, CA 95501 (707) 443-3093

NORTHERN SIERRA AQMD (all of Nevada, Plumas, Sierra counties)
200 Litton Dr., Suite 320
P.O. Box 2509
Grass Valley, CA 95945-2509
APCO – Gretchen Bennitt (530) 274-9360

NORTHERN SONOMA COUNTY APCD (N portion of Sonoma County)
150 Matheson Street
Healdsburg, CA 95448-4908
APCO - Barbara Lee (707) 433-5911

PLACER COUNTY APCD (all of Placer County)
DeWitt Center
11464 "B" Ave.
Auburn, CA 95603-2603
Dave Vintze (530) 889-7130

SACRAMENTO METRO AQMD (all of Sacramento County)
777 12th Street, 3rd Floor.
Sacramento, CA 95814
Greg Tholen (916) 874-4800

SAN DIEGO COUNTY APCD (all of San Diego County)
9150 Chesapeake Dr.
San Diego, CA 92123-1096
Robert Reider (858) 650-4700

CALIFORNIA AIR POLLUTION CONTROL DISTRICT CONTACTS
(continued)

SAN JOAQUIN VALLEY UNIFIED APCD (all of Fresno, Kings, Madera, Merced, San Joaquin, Stanislaus, Tulare, and W portion of Kern counties)
1999 Tuolumne, Ste. 200
Fresno, CA 93721-1638
(Central - Fresno)
Dave Mitchell (559) 230-6000-1075
(North - Modesto)
John Cadrett (209) 557-6400

SAN LUIS OBISPO COUNTY APCD (all of San Luis Obispo County)
3433 Roberto Court
San Luis Obispo, CA 93401-7126
Randy LaVack/Larry Allen (805) 781-1002

SANTA BARBARA COUNTY APCD (all of Santa Barbara County)
26 Castilian Dr. Suite B-23
Goleta, CA 93117-3027
Vijaya Jammalamadaka (805) 961-8800

SHASTA COUNTY AQMD (all of Shasta County)
1855 Placer Street, Ste. 101
Redding, CA 96001-1759 (530) 225-5674

SISKIYOU COUNTY APCD (all of Siskiyou County)
525 So. Foothill Dr.
Yreka, CA 96097-3036 (530) 841-4029

SOUTH COAST AQMD (Los Angeles County [except for area within the Antelope Valley APCD], Orange County, W portion of San Bernardino and W portion of Riverside counties)
21865 E. Copley Dr.
Diamond Bar, CA 91765-4182
Steve Smith / Mike Krause (909) 396-3054 or (909) 396-2526

TEHAMA COUNTY APCD (all of Tehama County)
P.O. Box 38 (1750 Walnut St.)
Red Bluff, CA 96080-0038 (530) 527-3717

TUOLUMNE COUNTY APCD (all of Tuolumne County)
22365 Airport
Columbia, CA 95310 (209) 533-5693

VENTURA COUNTY APCD (all of Ventura County)
669 County Square Dr., 2nd Fl.

Ventura, CA 93003-5417
Chuck Thomas (805) 645-1400

YOLO-SOLANO AQMD (all of Yolo and E portion of Solano counties)
1947 Galileo Ct., Ste. 103
Davis, CA 95616-4882
Dan O'Brien / Carl Vandagriff (530) 757-3650

Appendix F. State Of California Counties And Air Basins

A California Air Basin map is available on the internet at:
http://www.arb.ca.gov/knowzone/basin/basin.swf
and information on local air districts can be found at:
www.arb.ca.gov/capcoa/roster.htm

Appendix G. Average Summer and Winter Temperatures

Appendix G. Average Summer And Winter Temperatures

AVERAGE SUMMER OZONE TEMPERATURES						
AIR BASIN	**COUNTY**	6 a.m. to 9 Am.	9 a.m. to noon	noon to 3 p.m.	3 p.m. to 6 p.m.	Average Temperature
Great Basin	Alpine	57	70	72	68	67
	Inyo	72	90	97	93	88
	Mono	63	79	79	79	75
Lake County	Lake	71	87	94	91	86
Lake Tahoe	El Dorado*	55	74	78	75	71
	Placer*	55	74	78	75	71
Mountain Counties	Amador	80	87	90	89	87
	Calaveras	80	87	90	89	87
	El Dorado*	72	82	85	85	81
	Mariposa	80	87	90	89	87
	Nevada	71	80	84	83	80
	Placer*	80	85	88	88	85
	Plumas	71	80	84	83	80
	Sierra	71	80	84	83	80
	Tuolunme	80	87	90	89	87
North Coast	Del Norte	51	55	57	57	55
	Humbolt	51	55	57	57	55
	Mendocino	51	55	57	57	55
	Sonoma*	51	55	57	57	55
	Trinity	54	79	87	87	77
North Central Coast	Monterey	56	70	78	73	69
	San Benito	57	72	79	74	71
	Santa Cruz	52	70	83	78	71
North East Plateau	Lassen	60	74	82	83	75
	Modoc	47	70	80	80	69
	Siskiyou	60	74	82	83	75
South Coast	Los Angeles*	74	85	89	83	83
	Orange	70	80	83	80	78
	Riverside*	78	92	98	93	90
	San Bernadino*	76	92	98	93	90
South Central Coast	San Luis Obispo	64	80	85	79	77
	Santa Barbara	66	72	77	75	73
	Ventura	67	77	78	73	74

* Parts of some counties are located in more than one air basin. Use the county and air basin in which the project is located.

Appendix G. Average Summer And Winter Temperatures

AVERAGE SUMMER OZONE TEMPERATURES						
AIR BASIN	**COUNTY**	6 a.m. to 9 a.m.	9 a.m. to noon	noon to 3 p.m.	3 p.m. to 6 p.m.	Average Temperature
San Diego	San Diego	70	88	91	85	84
South East Desert	Imperial	90	99	105	103	99
	Kern*	84	96	101	99	95
	Los Angeles*	79	91	96	91	89
	Riverside*	86	97	101	99	96
	San Bernadino*	82	94	101	101	95
San Francisco	Alameda	64	74	82	80	75
	Contra Costa	66	82	92	95	84
	Marin	57	76	89	92	79
	Napa	66	82	93	91	83
	San Francisco	67	83	87	77	79
	San Mateo	62	73	83	80	75
	Santa Clara	66	80	90	89	81
	Solano*	67	83	94	96	85
	Sonoma*	59	81	94	92	82
San Joaquin Valley	Fresno	73	88	98	102	90
	Kern*	78	89	97	100	91
	Kings	73	88	96	100	89
	Madera	71	86	96	99	88
	Merced	70	84	94	96	86
	San Joaquin	66	77	91	93	82
	Stanislaus	67	73	91	94	81
	Tulare	73	87	95	97	88
Sacramento Valley	Butte	75	87	97	99	90
	Colusa	71	87	97	99	89
	Glenn	76	91	99	100	92
	Placer*	80	85	88	88	85
	Sacramento	69	84	97	100	88
	Shasta	74	93	103	105	94
	Solano*	67	83	94	96	85
	Sutter	77	92	99	100	92
	Tehama	75	92	101	103	93
	Yolo	66	82	95	97	85
	Yuba	77	92	99	100	92

* Parts of some counties are located in more than one air basin. Use the county and air basin in which the project is located.

Appendix G. Average Summer And Winter Temperatures

AVERAGE WINTER CARBON MONOXIDE TEMPERATURES						
AIR BASIN	**COUNTY**	6 a.m. to 9 a.m.	9 a.m. to noon	noon to 3 p.m.	3 p.m. to 6 p.m.	Average Temperature
Great Basin	Alpine	18	26	34	28	27
	Inyo	19	46	48	28	35
	Mono	18	26	34	28	27
Lake County	Lake	39	48	60	59	52
Lake Tahoe	El Dorado*	16	32	40	33	30
	Placer*	39	52	48	46	46
Mountain Counties	Amador	23	39	44	32	35
	Calaveras	23	39	44	32	35
	El Dorado*	16	32	40	33	30
	Mariposa	37	43	41	38	40
	Nevada	35	45	57	52	47
	Placer*	39	52	48	46	46
	Plumas	36	46	47	43	43
	Sierra	35	45	57	52	47
	Tuolunme	23	39	44	32	35
North Coast	Del Norte	39	48	60	59	52
	Humbolt	39	48	60	59	52
	Mendocino	39	48	60	59	52
	Sonoma*	39	48	60	59	52
	Trinity	39	48	60	59	52
North Central Coast	Monterey	41	51	60	58	53
	San Benito	50	59	65	60	59
	Santa Cruz	47	58	66	65	59
North East Plateau	Lassen	19	30	47	44	35
	Modoc	19	30	47	44	35
	Siskiyou	28	34	41	40	36
South Coast	Los Angeles*	52	68	72	64	64
	Orange	53	67	71	66	64
	Riverside*	56	72	75	68	68
	San Bernadino*	53	72	79	73	69
South Central Coast	San Luis Obispo	39	56	70	66	58
	Santa Barbara	51	64	70	64	62
	Ventura	55	64	68	64	63

- Parts of some counties are located in more than one air basin. Use the county and air basin in which the project is located.

Appendix G. Average Summer And Winter Temperatures

AVERAGE WINTER CARBON MONOXIDE TEMPERATURES						
AIR BASIN	**COUNTY**	6 a.m. to 9 a.m.	9 a.m. to noon	noon to 3 p.m.	3 p.m. to 6 p.m.	Average Temperature
San Diego	San Diego	48	68	76	69	**65**
South East Desert	Imperial	52	72	81	75	**70**
	Kern*	41	57	64	59	**55**
	Los Angeles*	35	52	63	60	**53**
	Riverside*	50	64	70	66	**63**
	San Bernadino*	48	61	71	68	**62**
San Francisco	Alameda	50	57	62	60	**57**
	Contra Costa	40	49	58	57	**51**
	Marin	42	58	66	62	**57**
	Napa	40	50	59	58	**52**
	San Francisco	47	57	61	55	**55**
	San Mateo	47	57	61	55	**55**
	Santa Clara	47	60	68	64	**60**
	Solano*	40	50	59	58	**52**
	Sonoma*	42	58	66	62	**57**
San Joaquin Valley	Fresno	38	51	64	67	**55**
	Kern*	34	45	57	57	**48**
	Kings	37	48	62	61	**52**
	Madera	43	53	56	50	**51**
	Merced	42	52	63	64	**55**
	San Joaquin	39	52	64	61	**54**
	Stanislaus	42	57	67	62	**57**
	Tulare	38	54	64	60	**54**
Sacramento Valley	Butte	39	51	62	62	**54**
	Colusa	37	52	64	61	**54**
	Glenn	39	55	67	63	**56**
	Placer*	39	52	61	63	**54**
	Sacramento	39	52	61	63	**54**
	Shasta	36	45	53	52	**47**
	Solano*	36	47	57	57	**49**
	Sutter	33	37	48	55	**43**
	Tehama	42	57	66	61	**57**
	Yolo	36	47	57	57	**49**
	Yuba	39	51	62	62	**54**

- Parts of some counties are located in more than one air basin. Use the county and air basin in which the project is located.

- Source: Calif. ARB

Appendix H. Construction Equipment Emission Factors

The grams per brake-horsepower-hour emission factors shown below were used to estimate total daily emissions for off-road construction equipment. The grams/brake-hp-hr values were developed using the following approach. Pre-1996 emission factors were based on actual emissions of off-road equipment included in the California Air Resources Board's Off-Road model database. They represent average emissions over all horsepower classes. Emission factors for 1996 and later years were based on allowable emission rates for California off-road construction equipment.

	grams/brake-hp-hr			
Year	ROG	CO	NOx	PM10
Pre-1996	1.00	4.09	11.73	0.59
1996-2000	1.00	8.5	6.9	0.4
2001+	1.00	8.5	5.8	0.16

The table below shows the daily emissions in pounds that URBEMIS calculates for each piece of construction equipment using the default horsepower, load factors, and hours per day included in URBEMIS2002.

Bore rigs have a default horsepower of 218, a 0.75 load factor, and are assumed to operate 8 hours per day. These values are multiplied together and by the appropriate emission rate to obtain daily emissions. URBEMIS uses a weighted emission rate that is based on the average composition of the fleet. Emissions are weighted by the average turnover of the particular vehicle. Vehicle turnover rates are found in the notes following the table below. Bore rigs have an average annual turnover rate of 33%. Therefore, by 2003, 100% of the emissions are based on the 2001+ emission rates. Using the 2001+ emission rates and the vehicle default values for horsepower, load factor, and hours per day, URBEMIS calculates emissions using the following equation to obtain the values shown in the table below:

Emissions (pounds/day) = grams/brake-hp-hour x horsepower x load factor x hours per day x pound/454 grams

As an example, NOx emissions for one bore rig in 2003 are calculated as follows:
NOx emissions (pounds/day) = 5.8 grams/brake-hp-hr x 218 hp x 0.75 (load factor) x 8 hours per day x pound/454 grams

NOx emissions = 16.71 pounds per day

Construction Equipment Emission Rates for 2000–2010 (pounds per day)									
Bore/Drill Rigs	ROG	CO	NOx	PM10	Paving Equipment	ROG	CO	NOx	PM10
2000	2.88	24.45	19.88	1.15	2000	1.03	5.66	10.59	0.55
2001	2.88	24.45	18.81	0.90	2001	1.03	5.95	10.20	0.52
2002	2.88	24.45	17.78	0.69	2002	1.04	6.23	9.82	0.49
2003	2.88	24.45	16.71	0.46	2003	1.04	6.52	9.44	0.46

Construction Equipment Emission Rates for 2000–2010 (pounds per day)									
2004	2.88	24.45	16.71	0.46	2004	1.04	6.81	9.05	0.44
2005	2.88	24.45	16.71	0.46	2005	1.04	7.09	8.77	0.41
2006	2.88	24.45	16.71	0.46	2006	1.04	7.38	8.28	0.38
2007	2.88	24.45	16.71	0.46	2007	1.04	7.66	7.90	0.35
2008	2.88	24.45	16.71	0.46	2008	1.04	7.95	7.52	0.33
2009	2.88	24.45	16.71	0.46	2009	1.04	8.23	7.13	0.30
2010	2.88	24.45	16.71	0.46	2010	1.04	8.52	6.75	0.27
Concrete/Industrial Saws	ROG	CO	NOx	PM10	Rollers	ROG	CO	NOx	PM10
2000	1.08	5.89	11.01	0.57	2000	0.86	5.91	7.52	0.41
2001	1.08	6.18	10.61	0.54	2001	0.86	6.39	6.88	0.36
2002	1.08	6.48	10.21	0.51	2002	0.86	6.86	6.24	0.31
2003	1.08	6.78	9.81	0.48	2003	0.86	7.34	5.60	0.27
2004	1.08	7.08	9.41	0.45	2004	0.86	7.34	5.48	0.24
2005	1.08	7.37	9.01	0.43	2005	0.86	7.34	5.36	0.22
2006	1.08	7.67	8.71	0.40	2006	0.86	7.34	5.24	0.19
2007	1.08	7.97	8.21	0.37	2007	0.86	7.34	5.13	0.16
2008	1.08	8.26	7.81	0.34	2008	0.86	7.34	5.01	0.14
2009	1.08	8.56	7.41	0.31	2009	0.86	7.34	5.01	0.14
2010	1.08	8.86	7.02	0.28	2010	0.86	7.34	5.01	0.14
Cranes	ROG	CO	NOx	PM10	Rough Terrain Forklifts	ROG	CO	NOx	PM10
2000	1.44	9.44	13.05	0.70	2000	0.79	5.40	6.87	0.37
2001	1.44	10.14	12.10	0.63	2001	0.79	5.83	6.29	0.33
2002	1.44	10.85	11.15	0.56	2002	0.79	6.27	5.70	0.29
2003	1.44	11.56	10.20	0.49	2003	0.79	6.70	5.12	0.24
2004	1.44	12.27	9.25	0.42	2004	0.79	6.70	5.01	0.22
2005	1.44	12.27	9.07	0.38	2005	0.79	6.70	4.90	0.20
2006	1.44	12.27	8.90	0.35	2006	0.79	6.70	4.79	0.17
2007	1.44	12.27	8.72	0.31	2007	0.79	6.70	4.68	0.15
2008	1.44	12.27	8.55	0.27	2008	0.79	6.70	4.57	0.13
2009	1.44	12.27	8.37	0.23	2009	0.79	6.70	4.57	0.13
2010	1.44	12.27	8.37	0.23	2010	0.79	6.70	4.57	0.13
Crawler Tractors	ROG	CO	NOx	PM10	Rubber-Tired Dozers	ROG	CO	NOx	PM10
2000	1.45	7.94	14.85	0.77	2000	3.66	20.03	37.45	1.93
2001	1.45	8.34	14.31	0.73	2001	3.66	21.04	36.10	1.84
2002	1.45	8.74	13.77	0.69	2002	3.66	22.05	34.74	1.74
2003	1.45	9.14	13.23	0.65	2003	3.66	23.06	33.38	1.64
2004	1.45	9.54	12.69	0.61	2004	3.66	24.07	32.02	1.54
2005	1.45	9.95	12.16	0.57	2005	3.66	25.09	30.66	1.45
2006	1.45	10.35	11.62	0.53	2006	3.66	26.10	29.31	1.35
2007	1.45	10.75	11.08	0.50	2007	3.66	27.11	27.95	1.25
2008	1.45	11.15	10.54	0.46	2008	3.66	28.12	26.59	1.15
2009	1.45	11.55	10.00	0.42	2009	3.66	29.13	25.23	1.06
2010	1.45	11.95	9.46	0.38	2010	3.66	30.14	23.87	0.96
Crushing/Proc. Equipment	ROG	CO	NOx	PM10	Rubber-Tired Loaders	ROG	CO	NOx	PM10
2000	2.12	11.60	21.68	1.12	2000	1.35	9.27	11.80	0.64
2001	2.12	12.18	20.89	1.06	2001	1.35	10.02	10.80	0.56
2002	2.12	12.77	20.11	1.01	2002	1.35	10.77	9.79	0.49

Construction Equipment Emission Rates for 2000–2010 (pounds per day)									
2003	2.12	13.35	19.32	0.95	2003	1.35	11.52	8.79	0.42
2004	2.12	13.94	18.53	0.89	2004	1.35	11.52	8.70	0.38
2005	2.12	14.52	17.75	0.84	2005	1.35	11.52	8.42	0.34
2006	2.12	15.11	16.96	0.78	2006	1.35	11.52	8.23	0.30
2007	2.12	15.69	16.18	0.72	2007	1.35	11.52	8.04	0.26
2008	2.12	16.28	15.39	0.67	2008	1.35	11.52	7.86	0.22
2009	2.12	16.86	14.60	0.61	2009	1.35	11.52	7.86	0.22
2010	2.12	17.45	13.82	0.55	2010	1.35	11.52	7.86	0.22
Excavators	ROG	CO	NOx	PM10	Scrapers	ROG	CO	NOx	PM10
2000	1.84	13.32	15.24	0.83	2000	3.64	21.58	35.39	1.85
2001	1.84	14.48	13.68	0.72	2001	3.64	22.92	33.59	1.72
2002	1.84	15.64	12.12	0.61	2002	3.64	24.26	31.79	1.59
2003	1.84	15.64	11.83	0.55	2003	3.64	25.60	29.99	1.46
2004	1.84	15.64	11.54	0.48	2004	3.64	26.94	28.19	1.33
2005	1.84	15.64	11.25	0.42	2005	3.64	28.28	26.39	1.21
2006	1.84	15.64	10.96	0.36	2006	3.64	29.62	24.59	1.08
2007	1.84	15.64	10.67	0.29	2007	3.64	30.96	22.79	0.95
2008	1.84	15.64	10.67	0.29	2008	3.64	30.96	22.46	0.87
2009	1.84	15.64	10.67	0.29	2009	3.64	30.96	22.13	0.80
2010	1.84	15.64	10.67	0.29	2010	3.64	30.96	21.79	0.73
Graders	ROG	CO	NOx	PM10	Signal Boards	ROG	CO	NOx	PM10
2000	1.76	11.09	16.42	0.87	2000	1.72	9.39	17.55	0.91
2001	1.76	11.87	15.37	0.79	2001	1.72	9.86	16.91	0.86
2002	1.76	12.65	14.33	0.72	2002	1.72	10.33	16.28	0.81
2003	1.76	13.43	13.28	0.64	2003	1.72	10.81	15.64	0.77
2004	1.76	14.21	12.24	0.57	2004	1.72	11.28	15.00	0.72
2005	1.76	14.98	11.19	0.49	2005	1.72	11.75	14.37	0.68
2006	1.76	14.98	11.00	0.45	2006	1.72	12.23	13.73	0.63
2007	1.76	14.98	10.81	0.41	2007	1.72	12.70	13.10	0.59
2008	1.76	14.98	10.61	0.37	2008	1.72	13.18	12.46	0.54
2009	1.76	14.98	10.42	0.32	2009	1.72	13.65	11.82	0.49
2010	1.76	14.98	10.22	0.28	2010	1.72	14.12	11.19	0.45
Off-Highway Tractors	ROG	CO	NOx	PM10	Skid Steer Loaders	ROG	CO	NOx	PM10
2000	1.84	10.07	18.83	0.97	2000	0.56	4.78	3.88	0.23
2001	1.84	10.58	18.15	0.92	2001	0.56	4.78	3.76	0.20
2002	1.84	11.09	17.47	0.87	2002	0.56	4.78	3.63	0.17
2003	1.84	11.60	16.78	0.83	2003	0.56	4.78	3.51	0.14
2004	1.84	12.11	16.10	0.78	2004	0.56	4.78	3.39	0.12
2005	1.84	12.61	15.42	0.73	2005	0.56	4.78	3.26	0.09
2006	1.84	13.12	14.74	0.68	2006	0.56	4.78	3.26	0.09
2007	1.84	13.63	14.05	0.63	2007	0.56	4.78	3.26	0.09
2008	1.84	14.14	13.37	0.58	2008	0.56	4.78	3.26	0.09
2009	1.84	14.65	12.69	0.53	2009	0.56	4.78	3.26	0.09
2010	1.84	15.16	12.00	0.48	2010	0.56	4.78	3.26	0.09
Off-Highway Trucks	ROG	CO	NOx	PM10	Surfacing Equipment	ROG	CO	NOx	PM10
2000	3.60	22.67	33.55	1.78	2000	3.77	20.62	38.56	1.99
2001	3.60	24.26	31.42	1.62	2001	3.77	21.66	37.16	1.89

Construction Equipment Emission Rates for 2000–2010 (pounds per day)									
2002	3.60	25.85	29.28	1.47	2002	3.77	22.70	35.76	1.79
2003	3.60	27.44	27.15	1.32	2003	3.77	23.75	34.36	1.69
2004	3.60	29.03	25.01	1.16	2004	3.77	24.79	32.97	1.59
2005	3.60	30.62	22.87	1.01	2005	3.77	25.83	31.57	1.49
2006	3.60	30.62	22.48	0.92	2006	3.77	26.87	30.17	1.39
2007	3.60	30.62	22.08	0.84	2007	3.77	27.91	28.77	1.29
2008	3.60	30.62	21.69	0.75	2008	3.77	28.95	27.37	1.19
2009	3.60	30.62	21.29	0.66	2009	3.77	29.99	25.98	1.09
2010	3.60	30.62	20.89	0.58	2010	3.77	31.03	24.58	0.99
Other Construction Equipment	ROG	CO	NOx	PM10	Tractors/Loaders/Backhoes	ROG	CO	NOx	PM10
2000	2.08	11.37	21.26	1.10	2000	0.65	3.56	6.66	0.34
2001	2.08	11.95	20.49	1.04	2001	0.65	3.74	6.42	0.33
2002	2.08	12.52	19.72	0.99	2002	0.65	3.92	6.17	0.31
2003	2.08	13.09	18.95	0.93	2003	0.65	4.10	5.93	0.29
2004	2.08	13.67	18.18	0.88	2004	0.65	4.28	5.69	0.27
2005	2.08	14.24	17.41	0.82	2005	0.65	4.46	5.45	0.26
2006	2.08	14.82	16.64	0.77	2006	0.65	4.64	5.21	0.24
2007	2.08	15.39	15.87	0.71	2007	0.65	4.82	4.97	0.22
2008	2.08	15.96	15.10	0.66	2008	0.65	5.00	4.73	0.21
2009	2.08	16.54	14.32	0.60	2009	0.65	5.18	4.48	0.19
2010	2.08	17.11	13.55	0.54	2010	0.65	5.36	4.24	0.17
Pavers	ROG	CO	NOx	PM10	Trenchers	ROG	CO	NOx	PM10
2000	1.37	9.36	11.91	0.64	2000	1.00	7.26	8.31	0.45
2001	1.37	10.12	10.90	0.57	2001	1.00	7.90	7.46	0.39
2002	1.37	10.87	9.89	0.50	2002	1.00	8.53	6.61	0.33
2003	1.37	11.62	8.87	0.42	2003	1.00	8.53	6.45	0.30
2004	1.37	11.62	8.78	0.38	2004	1.00	8.53	6.29	0.26
2005	1.37	11.62	8.50	0.34	2005	1.00	8.53	6.14	0.23
2006	1.37	11.62	8.31	0.30	2006	1.00	8.53	5.98	0.19
2007	1.37	11.62	8.12	0.26	2007	1.00	8.53	5.82	0.16
2008	1.37	11.62	7.93	0.22	2008	1.00	8.53	5.82	0.16

Construction Equipment Emission Rates for 2000–2010 (pounds per day)									
2009	1.37	11.62	7.93	0.22	2009	1.00	8.53	5.82	0.16
2010	1.37	11.62	7.93	0.22	2010	1.00	8.53	5.82	0.16

Notes: Emissions rates are based on ARB's off-road emissions model. Daily emissions are based on specified horsepower, hours per day of operation, and load factor used as defaults in the URBEMIS2002 model. Annual emission rates by construction vehicle type are in grams per horsepower hour and are fleet averages based on vehicle turnover rates. The turnover rates assumed by vehicle type are as follows:

Bore/Drill Rigs: 3 years
Concrete/Industrial Saws: 16 years
Cranes: 9 years
Crawler Tractors: 16 years
Crushing/Proc. Equipment: 16 years
Excavators: 7 years
Graders: 10 years
Off-Highway Tractors: 16 years
Off-Highway Trucks: 10 years
Other Construction Equipment: 16 years
Pavers: 8 years
Paving Equipment: 16 years
Rollers: 8 years
Rough Terrain Forklifts: 8 years
Rubber Tired Dozers: 16 years
Rubber Tired Loaders: 8 years
Scrapers: 12 years
Signal Boards: 16 years
Skid Steer Loaders: 5 years
Surfacing Equipment: 16 years
Tractors/Loaders/Backhoes: 16 years
Trenchers: 7 years