CO Florida 2004

A Florida-Specific, MOBILE6-Based CO Screening Model for Air Quality Analyses of Transportation Projects

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Final Report
to
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Project Officer
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by

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NOTICE

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ABSTRACT

In order to ensure that a proposed highway transportation project will not adversely impact air quality, a carbon monoxide (CO) air quality modeling study must be done. A large number of motor vehicles idling near or traveling through a large intersection, in concert with adverse meteorological conditions, can produce concentrations of CO near that intersection that may exceed federal air quality standards. Federal Highway Administration (FHWA) and Florida Department of Transportation (FDOT) rules require that state or federal roadway projects be assessed for potential air quality impacts via a project-level CO analysis. A computerized screening model can save much time and effort for each intersection that is analyzed. Considering all the intersections that must be analyzed in any given year, a screening model saves much money for FDOT (either via saved employee time, or through reduced consultant fees).

For several years, FDOT has used a computerized screening model (COSCREEN98) to assess potential CO impacts. However, as of the end of 2003, this model had grown outdated, and needed to be replaced. FDOT contracted with the University of Central Florida to develop a replacement for COSCREEN98.

The research team (Dr. David Cooper and Ms. Debra Keely), having worked together on similar projects for FDOT as well as other state DOTs, undertook this project and completed it in a short amount of time and within budget. The product – CO Florida 2004 – is a much enhanced version of the previous model. It includes (1) the latest version of CAL3QHC, (2) the latest version of MOBILE (MOBILE6.1/6.2 released by EPA in late 2003), (3) five intersection types, (4) more receptors, (5) more wind angles, and (6) the selection and programming of many new and aesthetically pleasing photographs and graphics depicting various regions of Florida. The new model remains easy to use and because of the inclusion of EPA's new emission factor model (MOBILE6.1/6.2), produces CO concentrations that are significantly lower than those predicted from the older model for similar scenarios.

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STATEMENT OF OBJECTIVES

The main objective of this project was to develop a replacement for the outdated model, COSCREEN98. The new model had to incorporate the latest versions of MOBILE6 and CAL3QHC (EPA-approved software that must be used for detailed mobile source air quality modeling). Other objectives were to work in Windows, be quick and easy to use, be adaptable to several different types of intersections, be applicable to all the various regions of Florida, and be aesthetically pleasing to use. Also, it was requested by FDOT to provide an interim version early in the project so that FDOT could start using a MOBILE6-based model in February, 2004, to meet EPA and FHWA deadlines.

DEVELOPMENT AND DESCRIPTION OF THE NEW MODEL

Reasons for a Screening Model.

In federal or state roadway projects, intersections affected by the project must be analyzed for CO impacts. Large intersections may have significant impacts and must be assessed using the latest EPA- and FHWA-approved software (such as MOBILE6.1/6.2 and CAL3QHC). A computerized screening model that incorporates the latest software is a quick and easy method to do the initial assessment, and to screen all intersections, identifying those that are too small (that is, that have too few cars passing through them) to have a significant CO impact.

A screening model works for all intersections by using conservative assumptions and built-in inputs to run a quick model of a closely related “standardized” intersection in order to make a “worst-case” assessment. If the worst-case model does not predict a violation of standards, then it is safe to assume that a more detailed realistic model will not predict a violation either. The big advantage of the screening model is that it can be done very quickly compared with a detailed approach (minutes vs days). Keely and Cooper have published on the advantages of computerized screening models for project-level analysis.[1]

If the intersection passes the screening test, nothing further needs to be done; if the intersection fails the screening test, then a more detailed assessment is required. A detailed assessment requires using actual intersection and receptor geometry, actual traffic predictions for all legs of the intersection, and running MOBILE6 and CAL3QHC independently, and this may take several person-weeks of effort for one complicated intersection. Several states now have screening models, some of which were developed by the research team at UCF. These states include Florida, Colorado, Georgia, and most recently, Alabama. Both EPA and FHWA have accepted these screening models for use in the air quality impact assessment process.

Description of COFL2004

In this project, a modern updated screening model was developed for FDOT for use throughout the state of Florida. Initially, an interim version was produced (we simply took COSCREEN98 and replaced the MOBILE5a component with a MOBILE6 module) and given to

FDOT in February. However, the whole model really needed to be updated and improved, and the detailed model development work began in March.

Written in Visual Basic, the final version of the new model executes within a few minutes with minimal user input, and produces CO predictions for a variety of intersection types, including a diamond interchange. It is called COFL2004, and adds more flexibility and more features than the old screening model, but remains very quick and easy to use. The new model has many beautiful and significant photos and graphics for the state of Florida. The modeling is still done using an embedded MOBILE 6.1/6.2 model and an embedded CAL3QHC (version 2) model with pre-set FDOT-approved input scenarios and parameters appropriate to screening analysis. A new report page has been designed to let the user view all the inputs and outputs on one-page, and includes the summary statement that the intersection passes the screening test at the very bottom of the page. (If the intersection fails the screening test, an appropriate message is printed telling the user that a detailed modeling study must be performed.)

The program opens with an introductory screen that identifies the model and version number. A number of state-significant photos (such as a mockingbird, a manatee, an alligator, etc.) appear on this screen for a few seconds and then disappear, only to be replaced by other photos. Then a title screen appears allowing the input of the project title, facility name, and analyst's name. On the next screen, a map of Florida appears which is divided into several regions. The user clicks on a region and the computer automatically selects the correct default temperatures (and other parameters) for use in getting the emission factors from the MOBILE model. Another screen then comes up that lets the user choose the type of intersection and allows user input of required MOBILE6 and CAL3QHC parameters for the specific model run, such as year of analysis and land use (urban, suburban, or rural). The MOBILE files are then built automatically, requiring no further user input, thus providing increased accuracy but maintaining ease of use for the user.

Other screens are used for site specific inputs such as traffic approach volumes and speed limits on each leg of the chosen intersection configuration, and for selecting default and other receptor locations (for use in CAL3QHC). It should be noted that when the user selects the land use choice (on a previous screen), the model automatically inserts the appropriate values of the following parameters into the CAL3QHC input file: CO background concentration, surface roughness parameter, and atmospheric stability class. Keep in mind that the MOBILE6 and CAL3QHC input files are mostly pre-built, and the user needs to enter only a small amount of data to complete the input files for both MOBILE6 and CAL3QHC.

Assumptions Built into COFL2004

Any screening model must incorporate a number of assumptions. The assumptions should be conservative but realistic. The combination of many conservative (but realistic) assumptions will lead to an extremely conservative model without being completely unrealistic. One example of this is the temperature. A colder temperature gives a higher emission factor for CO. We selected the average January minimum temperature. A complete list of the assumptions and pre-set input values is included in the Tables specifically called out in the following paragraphs.

MOBILE6.1/6.2

Because MOBILE6.1/6.2 (hereinafter called MOBILE6) is embedded in CO FL 2004, it runs each time for each scenario. Thus, the model retains flexibility and has more up-to-date emissions accuracy than COSCREEN98 which used MOBILE5a. MOBILE6 can be complicated and hard to use, but most of the complexity has been removed by pre-selecting various inputs, and by pre-building input files for the analyst. Most of the MOBILE6 input parameters were set through agreements between FDOT and the Florida Department of Environmental Protection (FDEP). Only a few input values are selected during the run by the analyst, and then the program places them in the required MOBILE6 input format automatically. MOBILE6 requires many inputs; however, because of the pre-set values, the only direct inputs by the analyst are the *project title*, the *year to be analyzed* and the *speed*. The assumptions built into MOBILE6 are listed in Table 1.

CO emissions are most critical in winter months and are sensitive to ambient temperature. Because temperatures vary significantly in different areas of Florida during the winter, it is more accurate to divide the state into regions to account for these temperature variations. To remain consistent with COSCREEN98, six regions of the state were retained. These six regions are:

1) North Florida
2) Duval County (Jacksonville)
3) Central Florida
4) Hillsborough and Pinellas counties (Tampa/St. Petersburg area)
5) South Florida
6) Dade/Broward/Palm Beach counties (Miami/Fort Lauderdale/West Palm Beach area)

Indirectly, the analyst selects the *temperature and RVP* when selecting one of the six regions (project location) within Florida. Because of these region-specific default values, COFL2004 may only be applied to projects in Florida. The minimum temperature and absolute humidity for each region (two of the required inputs for running MOBILE6) are listed in Table 2.

CAL3QHC2

As with MOBILE6, CAL3QHC2 runs each time that COFL2004 runs. Most inputs are pre-set default values with only a few inputs to be determined by the analyst. Again, this feature simplifies the analyst's job, yet retains the accuracy of CAL3QHC2. CAL3QHC2 inputs are identified in Tables 3 and 4. The CAL3QHC2 data required to use COFL2004 are the project title; facility name; the intersection type, the traffic peak hour approach volumes, and the locations of any additional receptors.

CAL3QHC2 requires that an intersection be defined and its coordinates be input. Because this is a screening model and to save input time, several standard intersection geometries have been pre-defined. The hypothetical intersections are four at-grade intersections (4x4, 6x6, 4x6, and tee), plus a diamond interchange. The coordinate system for each has been developed and is internal to the program; the analyst has *no need* to input any real coordinates.

Table 1. MOBILE6 Input Parameters and Values - Pre-set and User Input[a]

Input Parameter	**Input Value**
Project Title	***** User Input *****
Altitude	Low Altitude
Temperature (°F)	See Table 2
Absolute Humidity (grains/pound)	See Table 2
RVP	11.5 psi
Month of evaluation	January
Sunrise/Sunset	7 a.m. / 6 p.m.
I/M program	None
Anti-tampering program	None
Refueling emissions	Zero-out refueling emissions
Output format	Descriptive
Output pollutant	VOC, CO, NOx
Scenarios Calendar year Approach speed Left-turn speed VMT Facility Mix	 ***** User Input ***** ***** User Input ***** 20 mph Arterial: 100% arterial; Freeway: Non-ramp; Freeway ramp:100% ramp
All other parameters use MOBILE6 defaults	

[a] Note: user inputs are highlighted with *** and are in bold font

Table 2. Temperature and Absolute Humidity Inputs by Regions

Input	**Region**[b]					
	1	**2**	**3**	**4**	**5**	**6**
Temperature (°F)	41	41	48	50	53	59
Absolute Humidity (grains/pound)	32	33	44	47	51	63

[b] Region 1 = North Florida
Region 2 = Duval County
Region 3 = Central Florida
Region 4 = Hillsborough/Pinellas counties
Region 5 = South Florida
Region 6 = Palm Beach/Broward/Dade counties

Table 3. CAL3QHC2 Input Parameter Values - Pre-set and User Input

Input	**Values**
Job title	***** User Input *****
Averaging time	60 minutes
Surface roughness Z_o Urban Suburban Rural	 175. cm 108. cm 10. cm
Settling and deposition velocity	0 and 0
Number & location of receptors (See Table 6 for specifics)	Default and optional ***** User Input *****
Receptor height	6 ft for Default receptors and ***** User Input ***** for additional receptors
Queue links Source height Number of travel lanes in queue Mixing zone width Average signal cycle length Average red time Clearance lost time Traffic volume Idle emission factor Saturation flow rate – arterial Saturation flow rate – off ramps Signal type Arrival rate	 0 Dependent on Intersection type selected 12 ft/lane x #lanes 120 sec See Table 5 3 sec ***** User Input ***** MOBILE6 1600 vph/lane 1500 vph/lane pre-timed average progression
Free flow links Traffic volume Emission factor Source height Mixing zone width through lanes left-turn lanes	 ***** User Input ***** MOBILE6 0 12 ft/lane x #lanes + 20 ft 12 ft/lane x #lanes + 20 ft

[a] Note: user inputs are highlighted with *** and are in bold font

(***This table is continued next page)***

Table 3 (cont.) CAL3QHC2 Input Parameters and Values - Pre-set and User Input

Input	Values
Meteorology	
Wind speed	1.0 m/s
Wind angle	360° search
Wind angle variation data	by 5^{o}
Stability class	
urban	D
suburban	D
rural	E
Mixing height	1000 m
Ambient background CO (8-hr)	
urban	3.0 ppm
suburban	2.0 ppm
rural	1.0 ppm
Other Considerations	
Total persistence factor	0.6
% Left turn (except T-intersection and diamond interchange; see Table 4 for T-intersection traffic)	15

[a] Note: user inputs are highlighted with *** and are in bold font

Table 4. Traffic Volume Distribution of a T-Intersection

Approach Leg	Traffic Volume Distribution
North	Through – 85 percent Left-turning – 15 percent
East	Left-turning – 50 percent Right-turning – 50 percent
South	Through – 75 percent Right-turning – 25 percent

In COFL2004, the user inputs the traffic volumes for each approach, and the program selects the worst-case (volume and speed) for each direction and applies that volume to both legs. The analyst simply inputs the peak-hour *approach* volumes and speeds. The model assumes appropriate turning movements for each type of intersection. For conservatism, these through and left-turning traffic volumes are duplicated for each approach of the intersection, and are used to calculate departures. The intersection signal timings are given in Table 5.

Table 5. Intersection Signal Red Times Used in COFL2004

4-way Intersections	T-Intersection	Diamond Interchange
Thru lanes – 60 seconds Left-turn lanes – 90 seconds	North leg: Thru lanes – 40 sec Left-turn lane – 80 sec	Off ramps: Left-turn lane – 90 sec Right-turn lane – 80 sec
	East leg: Left-turn lane – 80 sec Right-turn lane – 40 sec	West intersection: Eastbound lanes – 60 sec Westbound thru – 30 sec Left-turn lane – 90 sec
	South leg – 80 sec	East intersection: Westbound lanes – 60 sec Eastbound thru – 30 sec Left-turn lane – 90 sec

The methodology described above makes the model more conservative than reality, as befits a screening model, which was also the case with COSCREEN98. However, unlike COSCREEN98, COFL2004 uses more receptors, and they are located in two to four quadrants in order to capture the worst-case CO concentration. The analyst may input additional receptors if desired, but the ones that are pre-set are typically at the worst-case (closest distances). These distances are documented in Table 6. Also, the wind directions are searched by 5 degrees (rather than 10 degrees) throughout the whole compass to ensure finding the highest CO concentrations. Due to the greater speed of modern PCs, it is no longer necessary to "cut corners" to save computer time during the analysis.

The output of CAL3QHC2 is the one-hour CO concentration excluding the background CO concentration. For air quality analyses, it is necessary to convert the one-hour CO concentration to an eight-hour CO concentration by multiplying by a total persistence factor (TPF) as shown in the following equations, and to include background concentrations:

$$CO_{1\text{-hr}} = CO_{CAL3QHC2} + \text{background } CO_{1\text{-hr}}$$

$$\text{Background } CO_{1\text{-hr}} = \text{Background } CO_{8\text{-hr}} / TPF$$

$$CO_{8\text{-hr}} = CO_{CAL3QHC2} \times TPF + \text{background } CO_{8\text{-hr}}$$

where: $CO_{1\text{-hr}}$ = the one-hour CO concentration, ppm
$CO_{8\text{-hr}}$ = the eight-hour CO concentration, ppm

Conservative background CO concentrations for Florida are used by COFL2004 and were listed in Table 3. The total persistence factor used in COFL2004 is 0.6. The TPF reflects the fact that the specified atmospheric conditions and specified traffic conditions will not be constant at the worst-case conditions for eight continuous hours.

Table 6. Default Receptor Locations (X,Y,Z), units in feet

Input	Standard Intersections	Diamond Interchange
Number of Receptors	10	16
Receptor 1	(10, 150, 6)	(10, 1020, 6)
Receptor 2	(10, 50, 6)	(10, 50, 6)
Receptor 3	(50, 10, 6)	(50, 10, 6)
Receptor 4	(150, 10, 6)	(150, 10, 6)
Receptor 5	(50, 50, 6)	(10, -1020, 6)
Receptor 6	(10, -150, 6)	(10, -50, 6)
Receptor 7	(10, -50, 6)	(50, -10, 6)
Receptor 8	(50, -10, 6)	(150, -10, 6)
Receptor 9	(150, -10, 6)	(-10, -1020, 6)
Receptor 10	(50, -50, 6)	(-10, -50, 6)
Receptor 11	--	(-50, -10, 6)
Receptor 12	--	(-150, -10, 6)
Receptor 13	--	(-10, 1020, 6)
Receptor 14	--	(-10, 50, 6)
Receptor 15	--	(-50, 10, 6)
Receptor 16	--	(-150, 10, 6)

Notes: X = Receptor's East/West distance from the edge of the roadway, feet (a negative value for X will locate the receptor to the west of the roadway.)
Y = Receptor's North/South distance from the edge of the roadway, feet (a negative value for Y will locate the receptor south of the roadway.)

COMPARISON OF COFL2004 WITH COSCREEN98

Differences in Models

The old model, COSCREEN98, was very easy to use but went out of date and lacked accuracy once EPA released MOBILE6. COSCREEN98 lacked flexibility in that it used only one type of intersection, there were fewer receptors, and fewer wind angles. Importantly, COSCREEN98 was validated only for years to 2020.

COFL2004 remains easy to use and has *increased* accuracy in that it includes MOBILE6 and CAL3QHC2 as the main operating components of the model. COFL2004 can be used out to the year 2050. It has more intersection types, more receptors, and more wind angles. It has more conservative assumptions for several of the input parameters, such as RVP, minimum temperature, and distance to closest receptor. It also has many more aesthetically pleasing graphics depicting various scenes from around the state of Florida.

Both models are Windows-based programs, and are easy to use. The outputs of both models show the modeled one-hour and calculated eight-hour CO concentrations at each receptor; including the background concentrations for the specified land use type. However, the output report for COFL2004 also includes a printed statement that the intersection passes or fails the screening test. Thus, the analyst is not required to interpret the results.

Differences in Results

The results of the CO screening tests using these two models are different for many reasons, the main ones being that MOBILE6 is being used instead of MOBILE5a, and for CO intersection analysis, MOBILE6 produces much lower emissions factors than MOBILE5a. This point was verified by other research done and reported by Cooper.[2,3] Offsetting this to some extent is the fact that many of the assumptions in COFL2004 are more conservative than those in COSCREEN98. Because of the many differences in the types of intersections, it is hard to compare the two models side by side, but in general, the CO concentrations predicted by COFL2004 are significantly lower than those predicted by COSCREEN98.

As an example to illustrate the differences, both models were run for a 4 x 4 intersection for the year 2010 and 2020 for two different traffic volumes. In both cases the region was Central Florida, and the land use was suburban. The results are shown in Table 7. As can be seen, the CO concentrations from COFL2004 are significantly lower than those from COSCREEN98. MOBILE6 is EPA's latest emission factor model, and is more accurate than MOBILE5a, especially for the newer model cars (after all, MOBILE5a was created in the early 1990's so its predictions for emissions from 2004-model cars were educated guesses at best). The lower emission factor predictions simply reflect the fact that cleaner cars are now available that emit much less CO than before. This comparison demonstrates that COSCREEN98 (with MOBILE5a) was over-predicting CO impacts, and that COFL2004 is a more accurate model for use in CO screening of Florida intersections.

Table 7. Comparison of Results of COFL2004 with COSCREEN98

	Highest 8-hour CO Concentration Predicted, ppm			
Highest Traffic Volume	Year 2010		Year 2020	
Peak hour flow, vph	COFL2004	COSCREEN98	COFL2004	COSCREEN98
1500	4.9	6.7	4.2	6.7
3000	6.7	8.4	5.5	8.2

USE OF THE NEW MODEL

The model should be used for every air quality analysis of roadway projects in the state of Florida. It should quickly eliminate from further consideration a large percentage of the intersections analyzed each year.

The model is very easy to use. From the “Start Programs” menu on the PC, the user selects “CO Florida 2004.” The opening screen appears and the user clicks “Continue,” and then follows the self-explanatory screens in sequence. After entering all data, at the command of the user, the program automatically runs MOBILE6 and extracts the appropriate emission factors for input into CAL3QHC. Then it runs CAL3QHC and finds the appropriate worst-case 1-hour CO concentration. The program then multiplies by an FDOT-approved persistence factor, and adds the appropriate background concentration to get a worst-case total 8-hour CO concentration at all receptors. It then reports the values on screen and asks the user if a print-out is needed. If so, a 1-page report is generated for documentation. The report includes a statement as to whether the intersection has passed or failed the screening test.

A detailed description of each screen and the input options available to the user is presented in the User’s Guide (published as a separate document and included as an appendix to this report).

CONCLUSIONS AND RECOMMENDATIONS

This project was finished on time and on budget, and to the satisfaction of the FDOT project manager. The new model uses the latest EPA-approved software (MOBILE6.1/6.2 and CAL3QHC), allows for analysis of five intersection types, provides more receptors and more wind angles than the older model, and includes many new and aesthetically pleasing photographs and graphics depicting various regions of Florida. It operates quickly and easily from within Windows, and is accessible and understandable to almost anyone who needs to do this task. It is concluded that this new model achieves the goals of this project for FDOT, will perform well for FDOT and others for intersection analyses within the state of Florida, and will save FDOT a considerable amount of time, effort, and money throughout the next several years.

It is recommended that FDOT continue to use this model and to place it on their web site for free downloading by interested individuals. They should remove the older model and the interim version that was supplied early in this project.

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