Simplified and Rational Approach To Address New Modeling Requirements for Conformity Analysis

PATRICK DECORLA-SOUZA, JERRY EVERETT, BRIAN GARDNER, AND MICHAEL CULP

Recent conformity regulations require air quality nonattainment areas in serious or higher categories to use many model features that are not currently used in the travel forecasting processes of most urban areas. Many of these requirements are related to speed and travel time estimates. For example, travel times used in trip distribution are required to be in reasonable agreement with travel times resulting from trip assignment, which assumes that reasonable speeds are output from trip assignment. In addition, peak and off-peak travel demand and speed estimates are required. The issues relating to each of these requirements are discussed; procedures to satisfy these requirements in a simple but rational way are developed; the potential impacts of the simplified procedures on emissions estimates and conformity tests are investigated. Another issue relating to speeds and travel time is whether trip speeds instead of link speeds should be used as inputs to emissions analysis. In current practice, a link-based approach is used to obtain speed and vehicle activity inputs for EPA's MOBILE5 emission factor model. Nevertheless, a trip-based approach is more rational because it is consistent with the way speed cycles are used to develop emission factors. The impact a trip-based approach might have on the results of conformity analysis is examined through a case study application of a conformity analysis for a typical large urban area.

The role of travel models has expanded as a result of mandates in the Clean Air Act Amendments (CAAA) of 1990 and conformity regulations issued in November 1993 pursuant to CAAA. The conformity rule has defined certain standards that travel models are required to meet for conformity analyses in urban areas that are designated as serious or above nonattainment areas for ozone or carbon monoxide. These urban areas were required to develop enhanced travel modeling capabilities by January 1, 1995. Issues relating to the new modeling requirements are discussed, and procedures to accomplish these requirements in a simple but rational way are demonstrated. The procedures are suggested for use where improved models have not yet been developed or where improved models do not address the issues satisfactorily.

In serious and above nonattainment areas, the conformity rule either requires or encourages many model features that are currently not used in the forecasting processes of most urban areas. The next section discusses the issues relating to features required in two steps of the travel forecasting process: trip distribution and traffic assignment. A later section, Simplified Procedures, discusses proposed simplified procedures to address the issues.

The issues are all primarily related to the accuracy of estimated speeds, an important variable in conformity tests. Specifically, speeds used as input into trip distribution are required to be in reasonable agreement with speeds output from traffic assignment; free-flow speeds based on empirical observation are to be provided on network links for input into traffic assignment; speeds are to be calculated at the link level; and finally, estimates of speed and vehicle miles of travel (VMT) are to be provided for peak and off-peak periods.

Speed is also an important factor in accounting for differences in emissions estimates if a trip-based approach (*1*) is used for analysis instead of the conventional link-based approach. However, the conformity rule appears to be silent on the approach to be used to calculate average speeds. Therefore, in a later section, Analysis Results, the potential impact of using a trip-based approach for conformity analysis through a case study for a large urban area is investigated. Conformity test results using a trip-based approach are compared with test results using a link-based approach. Also, for the link-based approach, results using link speeds estimated with the simplified procedures were compared with results using "best practice" procedures to estimate link speeds.

CONFORMITY ANALYSIS ISSUES

This section discusses speed-related issues in conformity analysis. These issues are categorized as follows:

- Comparison of assignment output speeds with trip distribution input speeds,
- Peak spreading under congested conditions,
- Assignment input speeds,
- Peak and off-peak speed estimation, and
- Trip-based versus link-based emissions estimation.

Comparison of Output and Input Speeds

The conformity rule requires travel times used in trip distribution to be in reasonable agreement with travel times resulting from trip assignment. It is believed that congestion, in addition to other effects such as shifts in mode use, route choice, and time of travel, causes trips to be sent to closer destinations. Thus, in a "no-build"

Federal Highway Administration, 400 Seventh Street, S.W., HEP-22, Washington, D.C. 20590.

scenario, travel distances (and therefore VMT) could be less than in a "build" scenario. Analysts attempting to implement this feature in the forecasting process face two main questions:

- Do travel time inputs to trip distribution measure the same variable as travel time outputs from trip assignment?
- Are current state-of-the-practice analysis techniques capable of producing accurate post-assignment travel times or speeds?

Unfortunately, the answer to both questions is "no" for the current state of the practice for the reasons discussed.

Do travel time inputs to trip distribution measure the same variable as travel time outputs from trip assignment?

The basic problem is that congested speeds output from trip assignment are peak hour (i.e., low) speeds, even if daily trips instead of peak trips are assigned, whereas trip distribution is generally done for daily trips. Congested travel times, which occur mainly during peak periods, should not be used to distribute daily trips—most of which actually occur in off-peak periods. Although people make decisions on which destinations they should go to during peak periods based on peak period speeds, it is irrational to assume that they make decisions on where they should go at other times of the day based on the same peak period speeds. Therefore, average daily speeds are more appropriate for use as input into trip distribution, because average daily trips, not peak period trips, are being distributed. Consequently, average daily speeds should be obtained from trip assignment before valid comparisons can be made to check for reasonable agreement.

The next section discusses a simple way to estimate average daily speeds from assigned daily traffic volumes based on recently completed (FHWA) research (*2,3*). Note that when urban areas develop advanced state-of-the-art travel models with separate trip distribution models for each time period, estimates of average peak and off-peak speeds will be needed not average daily speeds. The procedures discussed can be extended to calculate such estimates.

Another compatibility problem is that travel times output by traffic assignment are not true travel times but actually "impedances." In other words, they represent more than just travel time; they include other factors that may affect route choice (e.g., preferences by drivers for using different facility classes.) These impedances are developed by adjusting free-flow speed inputs during model calibration to reflect non–time-related factors. Adjustments are made through an iterative process until a good balance of traffic by facility or area type is obtained to match counted traffic. Thus, even in those rare cases where trip distribution may be done by peak and off-peak periods, the impedances output by trip assignment should not be compared with travel times used in trip distribution. Such a comparison would be appropriate only if "true" congested travel times are first estimated using a speed postprocessor. (The next section of this paper discusses a simple procedure to obtain peak and off-peak travel times by hour of the day, directly from assigned daily traffic volumes.)

Are current analysis techniques capable of producing accurate post-assignment travel times or speeds?

The output post-assignment speeds may be inaccurate even if (a) the assignment procedure uses "accurate" relationships of volume-to-capacity (V/C) ratios to speed, including free-flow input speeds based on empirical observation or (b) speeds are corrected through postprocessing. There are two reasons for this. First, most assignment procedures do not incorporate the effects of peak spreading [i.e., the tendency of trip makers to shift from the preferred time of travel (during the peak) to off-peak periods or to shoulders of the peak, when they are faced with peak period congestion.] Therefore, peak-hour volumes are usually overestimated under congested conditions and, consequently, so are V/C ratios. A peak spreading model has been developed in only one urban area—Phoenix, Arizona (*4*). However, even this model is limited in its application, allowing shifts to the 1-hr periods before and after the peak hour, but not to off-peak periods. This may be sufficient if capacity is available within these 1-hr shoulders of the peak period, but not if the total 3-hr travel demand is close to or exceeds the total 3-hour capacity, as is currently the case in many of the largest urban areas.

The procedures proposed in this paper consider the effects of peak spreading, including not only shifts from the peak hour to its shoulders, but also shifts from peak periods to off-peak periods that may occur under severe congestion. Basically, assigned daily traffic volumes are distributed over all hours of the day based on severity of congestion, using the results of previous FHWA research (*2,3*).

Second, speeds output from state-of-the-practice postprocessors do not accurately represent true speeds because these postprocessors do not fully consider queueing. For example, a link may have a low V/C ratio but still have a low speed if it is affected by queueing due to a downstream bottleneck (i.e., spillback) or due to queues formed in a previous time period during which demand volumes exceeded capacity. The procedures proposed in this paper develop appropriate techniques to address the issues raised by queueing due to excess demand from a previous time period.

Peak Spreading Analysis Issues

The conformity rule requires models to provide peak and off-peak travel demand and travel time estimates. There appear to be two relevant impacts of time-of-day (T-O-D) analysis. First, emissions models predict higher emissions at the low and the high ends of the speed range [bottoming out at about 88.7 km/hr (55 mph) for HC and CO and at about 48.4 km/hr (30 mph) for NO_x]; therefore separate (low) peak and (high) off-peak speeds should generate higher modeled emissions than a composite peak/off-peak (mid-range) speed, if all other model parameters are the same for peak and off-peak periods. Second, a no-build scenario might show less congestion and emissions if the T-O-D analysis procedure incorporates peak spreading effects (i.e., the tendency of travelers to shift time of travel in response to congestion, as discussed earlier). In other words, under a no-build scenario for which peak spreading is modeled, estimated peak hour speeds may not be as low, and high off-peak speeds may be moderated, reducing relative emissions. On the other hand, under a build scenario, peak spreading effects may not be as significant because of the reduction or elimination of congestion.

Addressing the T-O-D analysis requirement is not easy if congestion influences are to be considered. One option is to perform T-O-D splits in earlier steps of the four-step process, as is done in a few large urban areas. However, in the few urban areas where this option is applied, peak spreading effects are not modeled (*4*). Instead, observed T-O-D splits are used from base-year home interview surveys to split future daily trips into a.m., p.m., and off-peak trips. Splitting may be done either (a) before trip distribution (i.e., daily trip ends are split), (b) before mode choice (i.e., person trip tables are split), or (c) before traffic assignment (i.e., vehicle trip tables are split). To validate the assigned volumes, traffic counts by T-O-D are needed. Because of its complexity and its data requirements (both travel survey and count data are needed by T-O-D), this type of procedure is probably impractical in the future in many nonattainment areas. Also, because the T-O-D factors used are developed from base-year data, they do not reflect shifts in time of travel in the future as a result of congestion, and additional research will be needed to develop models that relate T-O-D splits to congestion.

The procedures proposed in this paper split assigned daily traffic by hour of the day using simple T-O-D and directional distribution procedures that account for peak spreading under congested conditions, yet avoid the complexity of the above T-O-D analysis procedures.

Input Speeds for Trip Assignment

The conformity rule requires input free-flow speeds to be based on empirical observations. The contention is that many urban areas use posted speeds as inputs instead of observed free-flow speeds. Therefore, these speeds are often underestimated because motorists often exceeded speed limits. Lower speeds tend to underestimate NO_x emissions, and on high speed facilities, HC and CO emissions tend to be underestimated as well.

At first glance, addressing this conformity requirement appears simple. It appears that all that is required is to recode the network speeds to match sampled observed free flow speeds on various facility classes. However, such recoding could result in major shifts in assigned traffic volumes so that they no longer match ground counts. This is because modelers often adjust free-flow speed inputs during model calibration to obtain a better match of assigned volumes to ground counts; the rationale is that the adjustments reflect factors other than travel time (e.g., driver preferences for using some facility types) that affect route choice. In other words, free flow speeds used as input in many assignment models are not meant to be accurate speeds but only calibrated impedance parameters. Using a postprocessor to get more accurate average daily and hourly speeds appears to be a more reasonable approach to address the intent of the conformity rules.

The procedures proposed in this paper do not attempt to adjust input free-flow speeds but instead focus on estimating output speeds more accurately using a postprocessor, which accounts for empirically observed free flow speeds as well as peak spreading and queueing phenomena.

Peak and Off-Peak Link Speeds

Along with estimates of peak and off-peak VMT, the conformity rule requires estimates of peak and off-peak speeds. The conformity rule also implicitly requires estimates of traffic speeds and delays to be based on estimates of traffic volumes and capacities on network links.

A common practice is to average speeds by functional class. Such average speeds tend to be in the middle of the speed range where emission factors are lowest for HC and CO and not usually very sensitive to small differences in speed.

The requirement for more accurate link speeds has been addressed in some areas using sophisticated approaches based on the *Highway Capacity Manual* (HCM) (*5*) with default input parameters (e.g., signal cycle lengths) by functional class. The Houston-Galveston Area Council's procedure (*6*) is a good example. An intermediate level of detail uses relationships of V/C ratios to highway level of service (LOS) and LOS to speed from look-up tables (*7*). However, none of the current approaches can capture the effect of queueing from a previous time period, as explained earlier.

The procedures outlined in this paper may be used to obtain hourly speeds that incorporate vehicular delay due to queueing from a previous time period. A simple postprocessor was developed to obtain queueing-sensitive average daily speeds, and the procedures are being extended under FHWA sponsorship to obtain average hourly speed estimates directly from assigned daily traffic, using relationships that vary by facility type and area type.

Trip-Based Versus Link-Based Analysis

In current practice, estimates of travel activity (i.e., VMT) and speed are link based. However, emission factors in EPA's MOBILE model are based on data that represent trip travel characteristics instead of link-level travel characteristics. In the Federal Test Procedure, which is the basis for developing baseline emission factors, "bags" of pollutants are collected from entire trips about 20 min long. Therefore, developing travel characteristics for limited segments of the highway network is inconsistent with the base from which MOBILE factors are developed (i.e., entire trips.) In particular, average speeds on which MOBILE factors are based represent speed cycles for an entire trip, not speed cycles on any specific link. (This problem could be solved by developing emission factor models based on facility type-specific speed cycles. The California Air Resources Board is attempting to develop such models for freeways and arterials.)

A previous paper (*1*) describes a method to derive VMT and average speeds based on trips instead of links. The application of the procedure to this case study is described in a later section, Case Study.

SIMPLIFIED PROCEDURES

Figure 1 provides an overview of the simplified procedures proposed in this paper to address the speed-related conformity analysis issues discussed in the previous section. The top part of Figure 1 indicates the process used to estimate average daily speeds from assigned traffic volumes, which are used to check for reasonable agreement between output speeds from trip assignment and speeds input into trip distribution. The bottom part of Figure 1 indicates postprocessing procedures to obtain travel demand estimates by time-of-day that are sensitive to peak spreading and obtain peak and off-peak speeds that incorporate peak spreading and queueing effects. The procedures are discussed in greater detail in the following subsections.

Average Daily Speeds

The procedures rely heavily on recent FHWA research (*2,3*) to develop average daily speed determination models based on data for freeways and signalized arterials. The procedures developed in the research effort to estimate average daily speeds involve three steps:

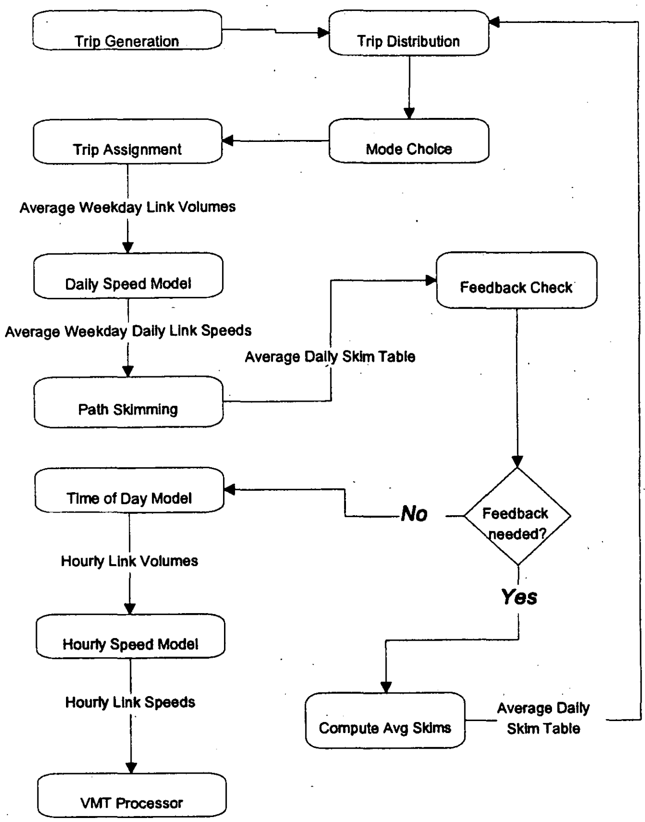

FIGURE 1 Travel analysis procedures.

1. Daily traffic is first split into volumes by hour and direction,
2. Hourly directional traffic is used to estimate hourly traffic delays, and
3. Delays are accumulated over all hours to obtain total delays over a 24-hr period. Average daily speeds are then calculated.

For Step 1, the research used data from automatic traffic recorders to develop T-O-D distribution profiles of directional link traffic for various levels of congestion. Congestion was measured in terms of the ratio of average daily traffic to link capacity (ADT/C). ADT was measured on either an annual average basis or an average weekday basis, AADT or AWDT.

For Step 2, the research used traffic simulation models, i.e., NETSIM and FRESIM (*8*), and the demand estimates by hour (generated by the T-O-D distributions) to simulate queueing delay effects by hour for typical freeways and arterials operating at varying ADT/C ratios.

In Step 3, these delays were accumulated over all hours of the day and aggregated with travel times at free-flow speeds to obtain total daily travel time and average (VMT weighted) daily speeds.

The study developed empirical relationships to estimate hourly link volumes and total daily delay for varying ADT/C ratios (*2*). These equations were later refined (*3*). The refined equations developed to estimate average daily speed for arterials are

$$\text{AADT/C} <= 7: \quad \text{DR} = (1 - e^{-n/24.4})\,(68.7 + 17.7x)$$
$$\text{AADT/C} > 7: \quad \text{DR} = (1 - e^{-n/24.4})\,[192.6 + 14.4\,(x - 7) - 1.16(x - 7)^2] + 0.160\,(x - 7)^2$$

and the refined equations developed to estimate average daily speed for freeways are

$$\text{AADT/C} <= 8: \quad \text{DR} = 0.0797x + 0.00385x^2$$
$$8 < \text{AADT/C} <= 12: \quad \text{DR} = 12.1 - 2.95x + 0.193x^2$$
$$\text{AADT/C} > 12: \quad \text{DR} = 19.6 - 5.36x + 0.0342x^2$$

where

x = AADT/C,
DR = daily vehicle hours of delay/1,000 VMT,
n = signals per mile,
AADT = average annual daily traffic, and
C = highway capacity (vehicles/hour).

For this case study analysis, the earlier unrefined equations to estimate average daily speed were used. Zone-to-zone travel time skims were then developed using these speeds and compared with skims used as input into trip distribution.

T-O-D Traffic Splitting

The T-O-D model uses average daily assigned traffic as input. Daily traffic is split into traffic for each hour of the day using profiles of the hourly distribution of traffic, which vary by ADT/C ratio. Thus, peak spreading effects are automatically incorporated. Examples of the profiles are shown in Figure 2 and in Table 1.

Peak and Off-Peak Speeds

The simplified procedures for estimation of hourly speed presented here are not yet fully developed and computerized. Research sponsored by FHWA is underway to extend the basic procedures used to develop the average daily speed determination models to provide hourly speeds. The procedures will use the hourly delay estimates generated for the purpose of developing the average daily speed equations to calculate hourly speeds. Information on free-flow speeds will be combined with hourly delay estimates to obtain average hourly speeds. Because free-flow speeds vary by facility type and area type, separate delay relationships (based on ADT/C ratios) will be developed by facility type and area type.

CASE STUDY

This case study had four objectives:

1. To demonstrate how the above simplified procedures could be applied in a real-world situation—compute from assigned daily traffic (a) peak and off-peak traffic volumes and (b) average daily link speeds. (Note: The demonstration of the procedures for estimating average peak period and off-peak link speeds is awaiting completion of FHWA research on hourly speed models.)
2. To compare link-based emissions estimates using average daily link speeds (estimated with these simplified procedures) with estimates using best practice speed estimation procedures. (Note: In best practice, emissions are estimated using average peak period and off-peak link speeds.)

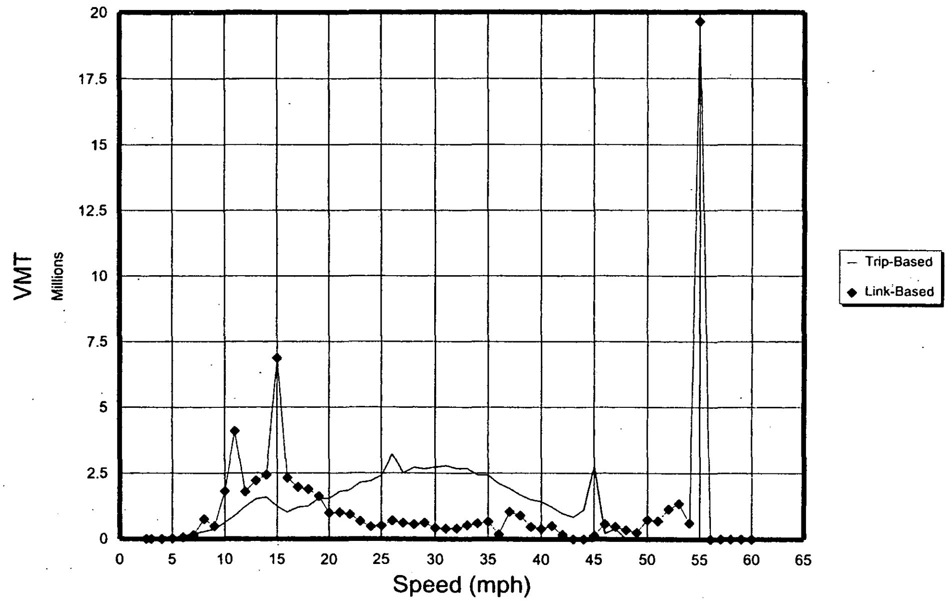

FIGURE 2 Distribution of total daily trip- and link-based VMT for build.

3. To investigate the potential impact of using these simplified procedures for conformity analysis by comparing conformity test results that used the simplified procedures with test results that used best practice speed estimation procedures. (Note: Emissions estimates in both cases would be link based.)

4. To investigate the potential impact of using a trip-based approach for conformity analysis, by comparing conformity test results that used a trip-based approach with test results that used a link-based approach. (Note: Speed estimates in both cases would be average daily link speeds using the simplified procedures; the only difference would be that in the trip-based approach speeds would be averaged over the entire trip instead of on individual links.)

The case study analysis was conducted for a large urban area (Baltimore, Maryland). The case study involved a conformity test for a "theoretical" financially unconstrained long-range plan that would return highway levels of service to those existing in 1990. To focus on the effects of differences in average speed estimates under the various approaches, the no-build network assigned daily traffic volumes (and VMT estimates) were used for both the build and no-build alternatives. Note that the use of feedback loops in travel models generally has the effect of lowering VMT estimates for the no-build alternative (relative to the build alternative), as a result

TABLE 1 Daily Emissions for Baltimore Study Area

	VMT	2010 NO-BUILD EMISSIONS(tons)		2010 BUILD EMISSIONS(tons)	
		HC	NOx	HC	NOx
TRIP-BASED:	68,173,072	149.16	117.09	147.47	117.35
LINK-BASED: (Avg Daily)					
NETWORK LINKS	63,694,496				
INTRAZONAL	4,478,576				
TOTALS	68,173,072	162.21	128.66	157.49	126.42
BEST PRACTICE: (Sum of Periods)					
NETWORK LINKS	63,687,736				
INTRAZONAL	4,485,336				
TOTALS	68,173,072	143.22	129.37	139.77	126.74

of shortening of trip lengths (distances) by the trip distribution model under congested conditions. Occasionally, this effect may be offset by increases in VMT because of drivers seeking (longer) uncongested routes in trip assignment.

No-build network average daily speeds were estimated using daily traffic volumes from the no-build network traffic assignment. Build network average daily speeds were estimated using base year 1990 network assigned traffic volumes and capacities because it was assumed that the build network would return ADT/C ratios to 1990 levels. The following subsections discuss the application procedures used for the case study.

Postprocessing Link Data

Postprocessing of assigned daily traffic involved developing.

- Average daily speeds, using the simplified procedures outlined in this paper,
- Peak and off-peak traffic volumes using the simplified procedures, and
- Peak and off-peak speeds using best practice procedures.

The postprocessor used for this study was developed as a stand-alone module outside the travel demand model. Link characteristics were passed between the demand model and the postprocessor using an ASCII data base. Extracting, post processing, and recompiling the network required approximately 10 min of computer time. The post processing procedures will be discussed in greater detail.

Average Daily Speeds

Average daily speeds were calculated as described previously in the section, Simplified Procedures.

Estimating Peak and Off-Peak Traffic Volumes

The postprocessor estimated hourly link volumes using AADT/C relationships developed for the average daily speed determination models (2). Peak and off-peak hours were identified based on the percentage of daily traffic in each hour, and total traffic was then aggregated for three time periods: a.m. peak, p.m. peak, and off-peak.

Peak-direction information was unavailable within the network data for this case study urban area. However, this information was needed for the best practice speed estimation procedures. Therefore, links with odd A-node numbers were assumed to have an a.m. peak direction and links with even A-node numbers a p.m. peak direction. This provides a reasonable estimate of peaking effect and does not affect estimates of aggregate link emissions (i.e., total emissions from traffic in both directions).

Peak and Off-Peak Speeds

The simplified procedures outlined earlier could not be used, pending completion of the FHWA-sponsored research (also described earlier) to extend the average daily speed determination models to hourly speed estimation.

Currently best practice, peak, and off-peak speeds are estimated using HCM procedures. Because one case study objective was to compare emissions estimates that used simplified procedures with emissions estimates that used best practice, a postprocessor was developed to incorporate best practice procedures for estimating hourly speeds. The procedures are complex because they require signal locations to be identified and coded, instead of using defaults by facility type and area type, as proposed in the simplified procedures.

The procedures consist of two submodels, one for freeways and one for arterials. The procedures are derived primarily from the HCM procedures and estimate link speeds by hour of the day. Although the HCM procedures do not explicitly model delays due to queueing in a previous hour or spill-back, they predict through delays on simple signal approaches as well as on freeway links for reasonable V/C ratios (i.e., less than 1.3). Because the input hourly traffic was obtained from the T-O-D model described (which incorporates peak spreading effects), reasonable V/C ratios were estimated on almost all links.

The freeway model used the updated HCM saturated flow rate of 2,200 vphpl (*9*). The speed limit was used as the average free-flow speed for V/C ratios of up to 0.70. A crawl speed of 12.9 km/hr (8 mph) was used for V/C ratios over 1.1. The regime from 0.70 to 1.1 was assumed to be linear.

The arterial model was substantially more complex. Previous studies have shown that traffic control (i.e., signal and stop sign density) governs the travel impedance on signalized arterials (*2,10,11*). The HCM uses signal approach through delay and arterial running speed to estimate average hourly arterial travel times and speeds. This requires data on signal locations, arterial class, access intensity, and approach capacity. Although these data were not explicitly contained within this case study data base, much of it was inferred from available information, and the remaining elements were synthesized. For example, because data on actual signal locations were unavailable, signal density assumptions were made on the basis of area type, facility type, and segment length. Arterial class and running speed were estimated on the basis of area type, segment length, speed limit, and facility type. Approach capacities were estimated on the basis of earlier work by the Florida Department of Transportation (*12*).

Applying the Trip-Based Approach

Figure 3 presents the procedures used to apply the trip-based approach. The Baltimore travel models estimate trips for six trip purpose categories and for a 24-hr period. Using national survey data from Nationwide Personal Transportation Study (*13*), estimates of operating mode percentages (i.e., cold and hot start percentages) and vehicle mix for each trip purpose were derived for the trip-based approach. Trip length (i.e., duration) distributions were obtained for each trip purpose from the travel models, based on post-assignment average speeds. Average daily link speeds were estimated as described earlier.

Emissions estimates were based on daily VMT and average daily speeds. The assigned networks with postprocessed estimates of average daily link speeds were skimmed to obtain zone-to-zone travel times and distances, which were then used to obtain zone-to-zone average speeds. Zone-to-zone daily vehicle trips were obtained from daily vehicle trip tables by purpose output from the mode choice model. Zone-to-zone VMT was computed as zone-to-zone vehicle trips times zone-to-zone distance. A previous paper (*1*) discusses these procedures in greater detail.

Applying the Link-Based Approach

Two different methods were used to estimate daily emissions with the link-based approach: (a) using daily VMT and average daily

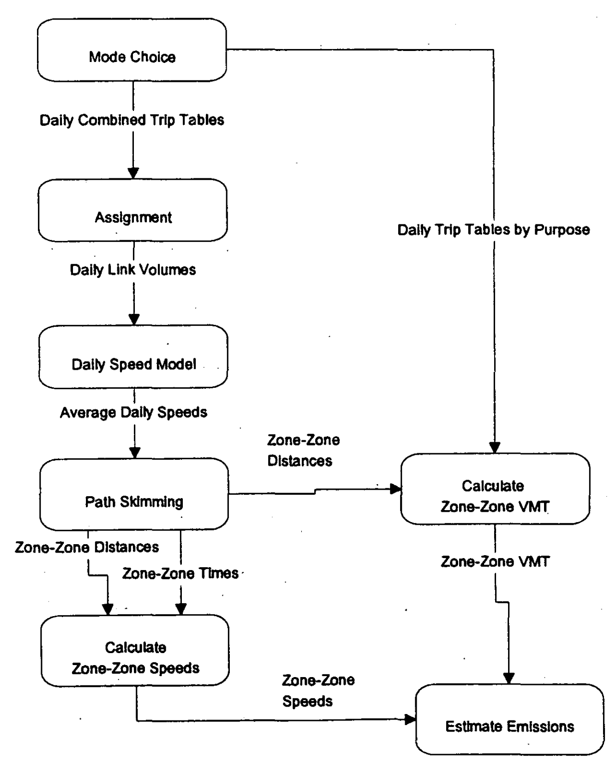

FIGURE 3 Emissions estimation procedure for trip-based approach.

speeds estimated using the simplified procedures and (b) using peak and off-peak VMT estimated using the simplified procedures, along with corresponding peak and off-peak speeds estimated using best practice.

Daily link-based VMT was developed from the "combined purpose" traffic assignment. To ensure consistency with travel characteristics developed for the trip-based approach, the cold and hot start percentages, vehicle mix, and trip length (i.e., duration) distribution were obtained by computing weighted averages of the parameters used by trip purpose in the trip-based approach.

Because this case study focused on evaluating the sensitivity of emissions estimates to differences in speed estimation procedures, operating mode percentages were not varied by time of day for the peak and off-peak application, although recent research by Venigalla et al., in another paper in this Record, could be used to develop such inputs in future work. Vehicle mix was not varied by time of day either.

ANALYSIS RESULTS

Table 1 compares HC and NO_x emissions estimates for the no-build and build alternatives. It should be noted that Baltimore-specific MOBILE settings were not used for technology parameters [i.e., the emission factors used do not reflect inspection and maintenance (I/M) programs]. Thus the emissions estimates developed are not directly comparable to those developed for inventory or other regulatory purposes.

Table 1 indicates that the three approaches, each based on a different speed estimation procedure, result in significant differences in the amount of HC emissions estimated for the no-build alternative. Similar differences are observed for the build alternative. The table indicates that HC emissions are substantially higher if the link-based approach is used with average daily speeds estimated using the simplified procedures. Although the trip-based approach (with average daily speeds) shows lower emissions for HC, they are still higher than emissions estimated with the best practice link-based "sum of periods" (i.e., peak and off-peak periods) approach.

Figures 2 and 4 present profiles of VMT by speed for the three approaches. The profiles suggest the reasons for the significant differences in emissions estimates. In Figure 2, the trip-based approach is compared with the link-based approach. Even though average trip speeds for the trip-based approach are derived from the same link speeds (i.e., based on links on the assigned paths between zones), the trip-based approach results in a concentration of VMT in the center of the speed range, where HC emissions tend to be lower. VMT under the link-based approach tends to concentrate in the low and high ends of the speed range.

Figure 4 compares the simplified procedures, using the link-based approach, with best practice procedures. The best practice procedures result in significantly fewer VMT in the low end of the speed range below 24.2 km/hr (15 mph), where emission factors tend to be highest. The main difference in the two procedures is that queueing delay is handled more thoroughly in estimation of speeds with the simplified procedures, leading to the significantly higher estimates of low speed VMT.

Table 2 presents the results for the build versus the no-build conformity tests for HC and NO_x. The comparison indicates that the build alternative passes the HC test regardless of the approach used. However, the build alternative fails the NO_x test if the trip-based approach is used, although it passes the test if the link-based approach is used with either the simplified procedures or best practice procedures. In other words, for the NO_x test, passing the test depends on which approach is used.

CONCLUSIONS

Serious and above nonattainment areas will need to address specific modeling requirements in the conformity rule issued in November 1993. This paper has developed simple and rational procedures to respond to these needs and demonstrated application of the procedures to the conformity analysis for a large urban area.

The main contribution of this effort is the operationalization of simplified procedures for time-of-day analysis and estimation

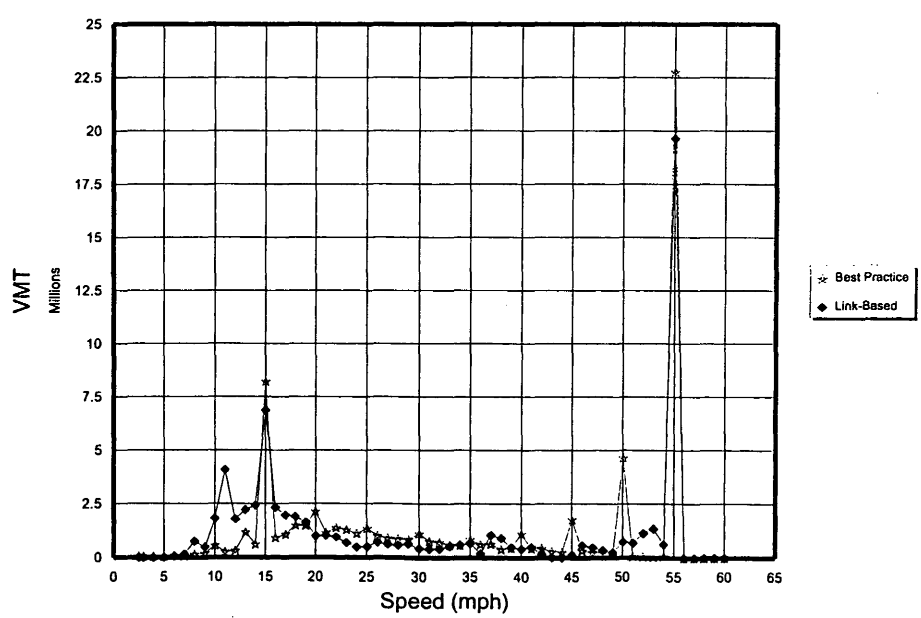

FIGURE 4 Distribution of total daily best practice and link-based VMT for build.

TABLE 2 Conformity Test

	EMISSIONS (tons/day) 2010 BUILD	2010 NO-BUILD	DIFFERENCE Absolute (tons)	Percent	PASS
HC					
TRIP-BASED	147.47	149.16	1.69	1.13%	YES
LINK-BASED	157.49	162.21	4.72	2.91%	YES
BEST PRACTICE	139.77	143.22	3.45	2.41%	YES
NOx					
TRIP-BASED	117.35	117.09	-0.26	-0.22%	NO
LINK-BASED	126.42	128.66	2.24	1.74%	YES
BEST PRACTICE	126.74	129.37	2.63	2.03%	YES

of average daily speeds. FHWA is undertaking further research to extend the capability of the average daily speed determination models to estimate hourly speed.

The paper also demonstrated that using the simplified procedures, which handle queueing delay more thoroughly, can result in significantly higher emissions. In addition, using a trip-based approach to perform emissions analysis can have a significant impact on the results of conformity tests.

The contradictory conformity test results with alternative approaches suggest that further investigation is necessary to determine the cause of these differences and to determine which approach would provide a better conformity test. Further investigation is also needed to evaluate the effect of using peak and off-peak analysis procedures with the trip-based approach (including varying operating mode and VMT mix by time-of-day).

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