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Guidance for the Development of Facility Type VMT and Speed Distributions

DRAFT

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Assessment and Modeling Division
Office of Mobile Sources
U.S. Environmental Protection Agency

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Final Report

GUIDANCE FOR THE DEVELOPMENT OF FACILITY TYPE VMT AND SPEED DISTRIBUTIONS

SYSAPP-98/32r

September 1998

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1.0 PURPOSE, BACKGROUND, AND GENERAL APPROACH

1.1 Purpose

This guidance is provided to assist users of the MOBILE6 highway vehicle emission factor model in the preparation of traffic activity inputs. It offers the U.S. Environmental Protection Agency's (EPA) recommendations on how to develop distributions of vehicle miles traveled (VMT) by time of day, facility type and average speed. These distributions are required by MOBILE for the development of an areawide emission factor for light duty vehicles, as well as facility-specific emission factors. Although national default distributions have been developed, there is sufficient variation in roadway network characteristics between areas that the use of locally developed distributions is strongly preferred. In almost all urbanized areas, some local data will be available that can be used to develop improved activity inputs for MOBILE6.

The methods presented here were developed based on a review of locally available data and tools that could support facility-specific VMT and speed estimates and existing transportation planning tools and methods. The report documenting this review[1] contains both the detailed results obtained for five selected urban areas on which the methods were tested (summaries of which appear here), and estimated national time-of-day and speed distributions of urban VMT derived by extrapolation of results for four of the selected urban areas.

The purpose of this guidance is to give suggestions which will help states prepare region-specific on-road vehicle area-wide emission factors using the MOBILE6 model. MOBILE6 produces facility-specific emission factors, unlike previous versions of the model, which produced emission factors corrected only to user-input average speeds without regard to facility type. This guidance provides approaches for the determination of the distribution of VMT among the facility types and speeds modeled in MOBILE6. This distribution of VMT can be used to prepare regional average emission factors, to disaggregate regional VMT among MOBILE6 facility types, and to more accurately estimate emission factors for specific areas and/or time periods. Most nonattainment and maintenance areas will develop emission inventories on a link[2]-by-link basis using emission factors for a specific facility type and average speed in a post processor. Area-wide emission factors will be used primarily for planning purposes, and for some smaller areas which submit inventories in this format.

Many areas will already have more sophisticated methods to determine the distributions for VMT than those described here. Direct measurement or modeling of vehicle activity has traditionally been conducted in support of highway planning and traffic engineering decisions. State and local transportation and traffic management agencies collect traffic count data at both permanent and temporary locations. In addition to their use in the analysis of traffic patterns and trends, these data are commonly used in the development and calibration of travel demand models[3]. In addition to counts, a variety of data collection

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[1]SAI (1998). "Development of Methodology for Estimating VMT Weighting by Facility Type," Final Report SYSAPP-98/11r2, Systems Applications International, Inc., San Rafael, California, September 1998.

[2]The language of transportation planning and traffic engineering assigns specific meanings to many common words. For example, roadway segments in transportation networks are commonly referred to as "links." A glossary at the end of this document presents a number of the more commonly used terms that air quality planners may encounter in the development of traffic activity inputs for emission modeling.

[3] Most commonly used travel demand models follow the "four-step" process in which socioeconomic data are used to describe the number and type of trips between zones in an urban area, and assign trips to specific paths along the roadway network. The results are used to evaluate the performance of the roadway network and the effects of growth, highway construction, etc. on roadway congestion and travel time.

techniques are used to characterize travel, including household surveys and trip diaries, license plate surveys, and "floating car" studies. None of these methods provide truly comprehensive data on all travel activity, and the costs of data collection further limit the availability of sound vehicle activity data. Nevertheless, both routine monitoring and special studies enhance local knowledge of travel patterns and traffic characteristics. In response to the EPA transportation conformity rules, many Metropolitan Planning Organizations (MPOs) are conducting a range of efforts to enhance the quality of vehicle activity estimates for air quality planning. These efforts focus on both expanded and improved data collection, as well as studies targeted on model improvement[4].

State and local air quality planners are strongly encouraged to coordinate closely with their local transportation agencies, as well as their EPA regional office, before deciding on the approach to be used to develop VMT and speed distributions for MOBILE. This coordination is vital to facilitate state implementation plan (SIP) emission budget development, transportation conformity analyses[5], and EPA approval. In most urban areas, the designated metropolitan planning organizations (MPOs) will be the primary source of information on regional traffic activity, but data available from MPOs may be supplemented with information collected by city traffic departments. Because the comprehensiveness of traffic data collection systems, the sophistication of existing traffic modeling, and the level of involvement of city, regional and state traffic and environmental agencies varies greatly between areas, an initial assessment of all potential sources of information is desirable. Any method chosen for providing VMT inputs for MOBILE6 should be technically sound, based on local data collection and represent a consensus of transportation and environmental concerns.

It is strongly preferred that local VMT-weighted speed distributions be prepared as inputs to MOBILE6 so that emission estimates are as representative of local conditions as possible, and so that emission forecasting procedures can accurately characterize changes in emissions attributable to anticipated growth and roadway network changes. The emission factors will be much more meaningful, whether used for planning purposes or for an official submittal to EPA. Extrapolating data from other similar cities is discouraged. If the needed types of data are not available, EPA strongly recommends that the area start an appropriate data collection program

In addition to this guidance, states should refer to the EPA's Section 187 VMT Forecasting and Tracking Guidance[6] and EPA's Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources[7] for guidance on the preparation of regional on-road vehicle emission inventories.

[4]See, for example, papers by Janik ("Enhancing the Highway Performance Monitoring System in Northeastern and Southeastern Illinois: An Assessment of the State of the VMT Estimating Practice in Illinois"), Stopher and Fu ("Feasible Improvements to Travel-Forecasting Procedures for Air Quality Analysis"), and Suhrbier et al. ("Improved Transportation Air Quality Analysis Methodologies") in *Transportation Planning and Air Quality III--Emerging Strategies and Working Solutions*, Conference Proceedings, August 17-20, 1997, Lake Tahoe, California, American Society of Civil Engineers, Reston, Virginia.

[5]40CFR51 Subpart T, and 40CFR93 Subpart A.

[6] EPA, 1992. Section 187 VMT Forecasting and Tracking Guidance. Prepared by the U.S. Environmental Protection Agency. January 1992.

[7] EPA, 1992. Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources. Prepared by the U.S. Environmental Protection Agency. 1992. EPA-450/4-81-026d (Revised).

1.2 Overview of MOBILE6 Changes Necessitating This Guidance

The Clean Air Act Amendments of 1990 (CAAA) mandated a closer look at "real world driving," that is, driving modes not covered by the Federal Test Procedure (FTP) upon which MOBILE historically was based, and which is used for certifying vehicle compliance with emission standards. Emission factors developed from FTP data were said to represent standard conditions of average speed, temperature, and fuels. These factors were adjusted to "non-standard" conditions using relationships encoded in MOBILE. For example, the emissions effects of average speeds other than the FTP's 19.6 mph were modeled using emissions versus speed relations developed from vehicle test data collected using several different test cycles with average speeds that differed from the FTP.

This historical treatment of speed effects did not readily allow emission modelers to address the fact that the distribution of speeds associated with a particular average speed could be dramatically different for different types of roadway. For example, an average speed of 30 mph for a freeway will typically involve relatively constant speeds, but for arterials, would more likely include periods of idle and acceleration to higher speeds. VMT estimates are available from both direct measurement programs and from regional transportation models, broken down by the roadway type (also referred to as facility type or functional class). MOBILE6 capitalizes on the availability of this information by providing different emission factors for different facility types. These emission factors will better represent driving patterns than factors from previous versions of MOBILE.

In its review of the FTP driving cycle, EPA collected both chase car data and instrumented vehicle data in Baltimore, Maryland, and Spokane, Washington, which was supplemented by an instrumented vehicle study conducted in Atlanta, Georgia and a chase car study conducted by the California Air Resources Board in Los Angeles, California. The driving patterns in the instrumented vehicle studies show that some types of facility-specific driving conditions contain more frequent and more extreme acceleration and deceleration than others, which reach a similar speed but remain at a steady cruise. Based on the instrumented vehicle and chase car data, EPA has developed a new set of driving cycles that represent passenger car and light truck operation on a variety of roadway types and under a variety of congestion levels and average speeds.[8] Four types of roadways are treated: freeways, arterials and collectors, local roads, and freeway on- and off-ramps. The MOBILE6 facility-specific emission factors are an attempt to quantify the emission differences for facility-specific driving activity.

The disaggregation of emission factors by facility type results in an emission factor most appropriate for short time periods, as compared to the those provided by earlier versions of MOBILE which could be applied to daily total VMT for a single average speed. The user-input requirements are significantly different with these new cycles, in that the user can specify hourly link-by-link traffic volumes and speeds for detailed spatially and temporally resolved emission inventories.

The guidance presented here describes how vehicle count data or traffic model volumes can be used to calculate hourly, link-specific speeds based on the link characteristics and level of congestion. By aggregating the link-specific VMT across all links into fifteen speed "bins" (0-2.5 mph, 2.5-7.5 mph, and so on up to 67.5-72.5 mph), hourly areawide speed distributions can be developed. To develop area-wide emission factors using MOBILE6, the user must input a 24-by-4 matrix containing the percent of VMT for each of the four facility types for each hour. In addition, because emission factors for freeways and arterials/collectors are speed dependent, the user must provide speed distributions for each hour for these two facility types for each hour of the day. In summary, the MOBILE6 input requirements addressed here are: a 24-by-4 matrix containing hourly VMT for each facility type; and a 24-by-15-by-2 matrix containing

[8] Sierra Research, 1997. Development of Speed Correction Cycles. Prepared for U.S. Environmental Protection Agency by Sierra Research, Sacramento, California. April 30, 1997. Report No. SR97-04-01.

the fraction of two facility types' VMT that occurs in each speed bin for each hour. The MOBILE6 user does not have the option of specifying speed distributions for local roads or ramps, as emission rates for these facility types are based on one driving cycle to represent local driving and one driving cycle to represent ramp driving. The VMT fractions are used to weight the facility-specific emission factors at each speed to produce an areawide running emission factor which is representative of the urban area.

1.3 Summary of Guidance

As presented above, the MOBILE6 model provides facility-specific emission factors and uses separate speed correction curves for each facility type to adjust these factors for the user-input speed. This is quite different from past versions of the model, which used the same speed correction relationships regardless of facility type. To allow the continued use of MOBILE emissions for estimation of regional total, as opposed to link-level, emissions, this guidance has been prepared to instruct users on the allocation of VMT by facility type and speed, which can be weighted together to generate customized area-wide emissions.

Characteristics of the new facility-specific cycles in MOBILE6 are summarized in Table 1. The model produces emission factors for four facility classes: freeways, freeway ramps, arterials/collectors, and local roadways. The factors for freeways and arterials/collectors are based upon cycles developed to reflect specific levels of service (LOS) on these facilities. Level of service is a measure describing the operating conditions on a particular roadway as affected by the level of congestion. Although defined in terms of vehicle density (vehicles per lane-mile), LOS also relates to speed, freedom to maneuver, interruptions, and safety.

Table 1. Summary of speed cycles developed by Sierra Research.[9]

Cycle	Average Speed (mph)	Maximum Speed (mph)	Maximum Acceleration Rate (mph/s)
Freeway, High Speed	63.2	74.7	2.7
Freeway, LOS A-C	59.7	73.1	3.4
Freeway, LOS D	52.9	70.6	2.3
Freeway, LOS E	30.5	63.0	5.3
Freeway, LOS F	18.6	49.9	6.9
Freeway, LOS "G"	13.1	35.7	3.8
Freeway Ramps	34.6	60.2	5.7
Arterials/Collectors, LOS A-B	24.8	58.9	5.0
Arterials/Collectors, LOS C-D	19.2	49.5	5.7
Arterials/Collectors, LOS E-F	11.6	39.9	5.8
Local Roadways	12.9	38.3	3.7

Currently, agencies developing regional emission inventories are not required to disaggregate vehicle activity for a particular facility type by speed, LOS, or other measures of traffic density, such as the traffic volume to service capacity (V/C) ratio. EPA guidance on the level of detail required in reporting

[9] *See Id.*

on-road inventories requires, however, that VMT and emissions be disaggregated by vehicle class and facility type.[10] Two methods are typically available for arriving at these VMT estimates. The first derives VMT estimates from vehicle count data, roadway network information (lane-miles by facility class), and assumptions regarding the representativeness of the count data. The second uses the link-level traffic volumes and network information produced by regional transportation models. Both methods can be adapted to also provide distributions by speed through use of standardized relationships between congested speed, freeflow speed, and V/C ratio.

If local data on observed speeds by facility type are available, these data should be used to refine speed estimates produced by the methods discussed in this guidance. There are a variety of methods by which speed data may have been collected and processed, and it is extremely important that the analyst understand how to interpret specific speed data bases because of the variety of methods currently in use. For example, pairs of in-road loop detectors provide instantaneous speeds of individual vehicles at a fixed location which may not be representative of overall speed distributions along the roadway segment. Average speeds may be calculated, as either arithmetic means or harmonic means (the inverse of the average of the inverses of observed speeds). For speed measurements at a specific location, these are sometimes referred to, respectively, as "time-mean speed" and "space-mean speed"[11]. The harmonic mean is preferred because the arithmetic mean provides a positively biased estimate. Arithmetic means from some other measurement methods (e.g., second-by-second recording in instrumented vehicles) do provide unbiased space-mean speeds. It is recommended that EPA be consulted when making use of local speed observation datasets.

The development of VMT distributions from vehicle count data and from network-based transportation model outputs are described in detail in this guidance document. Examples of their application are presented for five urban areas in the U.S.

[10] EPA, 1992. "Example Documentation Report for 1990 Base Year Ozone and Carbon Monoxide State Implementation Plan Emission Inventories." Prepared by Radian Corporation for EPA Office of Air Quality Planning and Standards, Research Triangle Park, N.C. March 1992. EPA-450/4-92-007.

[11]Dowling et al., 1996."Planning Techniques to Estimate Speeds and Service Volumes," NCHRP 387, Final Report prepared for National Cooperative Highway Research Program project 3-55(2), Transportation Research Board, September 1996..

2.0 VMT DATA SOURCES

The methods available to a particular urban area for developing VMT fractions by facility class depend upon the quality and types of local data available for determining the location of vehicle activity and speeds or traffic density. At a minimum, the Highway Performance Monitoring System (HPMS) provides data representative of urban areas in each state[12]. The HPMS data provide state level urban and rural data on an annual average basis. These data can be obtained directly through the Federal Highway Administration (FHWA). Summaries of HPMS data are also available on the Internet at

http://www.fhwa.dot.gov/ohim/1994/section5.htm.

HPMS summaries provide a reasonable starting point for estimating urban area VMT, but more detailed information specific to a particular city can be developed by supplementing HPMS data with additional local count data. Such data will usually allow the development of VMT distributions by facility class, time of day, and speed. Vehicle count locations may provide either long-term records or intermittent data at temporal resolutions from daily to 15-minutes. Within a given area, it is likely that several different data collection procedures will be in use, necessitating assumptions in the analysis. For example, high temporal resolution data (e.g., hourly counts) may only be available from a few locations for each facility class, or for a limited period of time, and the representativeness of these data must be evaluated in developing a weighting scheme to estimate temporal variation in traffic volumes. Consultation with state, regional and city traffic engineers regarding the purpose for which data were collected and the representativeness of different count sites and data sets is necessary if local data are used. Working with vehicle counts, one can estimate the average traffic count for a specified time period by facility class which, when combined with total centerline miles of roadway for a facility class, yields total VMT for the time period. Hourly traffic volumes at count locations (either from direct measurement or the application of temporal profiles from other sites) can be used to estimate speeds through the use of standard relationships between freeflow speed, level of congestion (expressed as the ratio of traffic volume to roadway capacity, or "V/C ratio"), and congested speed.

Similarly, the link-level traffic volumes and link lengths from network-based transportation models can be used to calculate total VMT by link. Summing VMT by facility class then provides a distribution of VMT by facility class. As for count data, speed-congestion relationships can be applied to each link to obtain distributions by speed when working with local transportation models.

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[12]FHWA (1987). "Highway Performance Monitoring System Field Manual," U.S. Department of Transportation, Federal Highway Administration, FHWA Order M 5600.1A, 1 December 1987.

3.0 WORKING WITH TRAFFIC COUNT DATA

State and local agencies will have available, at a minimum, traffic count data collected from the HPMS for specific Federal Aid Urbanized Areas (FAUA). HPMS data represent traffic counts taken on a sample of an area's roadway network and are adjusted for day-of-week and season and expanded to include the area's entire roadway network. HPMS data may be supplemented by locally collected data. The local data often provide more widespread, but not necessarily statistically balanced, coverage of local roadways. Count data are available at different temporal resolutions: typically daily data are available at all count sites, with a selection of continuous monitors providing data which can be used to arrive at hourly traffic distributions.

3.1 Reconciling Local Count Data with HPMS Data

HPMS datasets are designed to provide a statistically balanced representation of the traffic characteristics of the region for which they are collected. Local data can substantially enhance the richness of this characterization, but may introduce biases due to over- or under-representation of specific facility types, subregional characteristics, etc. or by the inclusion of data from atypical sites or dates. Therefore, caution should be used in supplementing HPMS traffic count data with local data, and care taken to ensure that biases are not incorporated into the dataset which can lead to inaccuracies in the VMT distributions derived from them. It is recommended that EPA be consulted, as well as data providers and transportation planners, when supplementing HPMS data with those from local traffic count programs. If uncertainties are large, or analytical results prove to be sensitive to values derived from limited data sets, the collection of additional data, potentially including both targeted short term studies and expanded long term monitoring, is recommended.

3.2 Issues with Local Count Data Sources

Common problems with local count data sets include biases because of the roadway sample or because of idiosyncrasies of the counting device. For example, areas using road tube counters may have undercounts on multilane facilities. These result from two cars crossing the tube at the same time. In-road loop detectors connected to central computer facilities are widely used in some urban areas, but malfunctions are common, resulting in the need for procedures for identifying and correcting for missing data. Also, data for a particular area that originates from different sources may be combined without correcting for underlying differences in the data collection or processing methods. For example, a state may collect data for a facility and derive average daily traffic (ADT) counts, while a county may collect average annual weekday traffic (AAWT) counts. Differences in averaging periods would need to be accounted for if the data were combined.

The traffic count data set may need to be adjusted to remove inherent biases. For example, counts on freeways in high-density travel areas may be over-represented, leading to an overestimate of the average freeway volume. If count locations can be matched to area type and distributions of land use by area type are available, the counts can be proportionately weighted to ensure that they reflect average land use characteristics. Although many areas have fairly detailed GIS databases that provide area types, at a minimum, estimates of the proportion of land in different area types should be available from standard USGS databases. Assigning specific count locations to area types may, in the absence of GIS databases, require cumbersome review by planning personnel who are familiar with local land use patterns.

In some areas, either the number of counting sites for a particular facility type (or combination of facility and area type) may be too small, or the duration of count data sets may be too short for the data to provide a good representation of that facility types volumes and temporal profiles. In these cases, it may be necessary to either combine similar facility types or to use data from another, similar class. For example, if no hourly traffic volume data are available for local roadways, temporal distributions obtained for minor arterials or collectors could be assumed to be representative of local roadway VMT. The overall result, however, is an increase in the associated uncertainty of these estimates.

3.3 Estimating VMT by Functional Class Using Count Data

It is relatively straightforward to estimate total VMT from vehicle count data. Most regions have used similar methods to that described in this guidance to estimate VMT for regional inventories. The procedural steps are:

1. Calculate the sum of counts in each facility type (by area type if that information is retained in the data);
2. Determine the sample size in each facility type (i.e., the number of count sites);
3. Determine the average volume for a facility type by dividing total count by sample size (this will usually be average daily volume, unless a representative body of hourly data are available to perform the calculation on an hourly basis);
4. Obtain total centerline miles of each facility type in the modeling domain (these are available from Departments of Transportation or geographic information system (GIS) databases);
5. Multiply average volume by the number of centerline miles for each facility type to estimate total VMT for each facility type.

Although there are four facility types explicitly modeled in MOBILE6 (freeways, arterial/collectors, freeway ramps, and locals), there are a number of facility type definitions in use throughout the country. For example, HPMS tracks travel activity in urban areas for interstate, other freeway or expressway, other principal arterial, minor arterial, and collector. It will commonly be necessary to group functional classes together to obtain VMT totals according to the MOBILE6 classes. In the examples shown in this document, local terminology has been accepted as the basis for such grouping (e.g., major arterial, minor arterial, major collector and minor collector would all be assigned to the arterial/collector facility class). Some caution may be needed in making such assignments, as the principal criteria for such assignment should include vehicle speeds and the nature of traffic control. As noted later, cases have been observed in which observed speeds on roadways classified as “local” significantly exceed the 12.9 mph average of the local roadway driving cycle underlying MOBILE6 emissions. In such cases, some portion of local roads should be grouped with the arterial/collector class. Ideally, measured speed distributions for each locally defined class of roadways should be compared with the speed distributions of the MOBILE6 driving cycles to select the class that matches best.

Many traffic count databases, including HPMS, do not include counts for freeway ramps. It may be necessary to assume that ramp VMT represents a specific fraction of freeway VMT. Such ramp VMT fractions may be developed from the data in local transportation models, or they may be estimated by comparison with ramp VMT data which are available for regions with similar characteristics to the one modeled. Ramp emissions have the potential for being a significant component of total emissions, and data and assumptions should be carefully documented and reviewed with transportation planners and EPA.

The result of this procedure is a distribution of VMT by facility type. Often, total centerline miles for each functional class can also be obtained by area type from geographic information system (GIS) databases used in conjunction with regional travel demand models. If such data are available, one can use the data in the above procedure in order to obtain VMT by functional class and area type. At a minimum, it is expected that most urban areas will have the capability to arrive at these types of estimates using similar methods to those described above.

Typically, the above procedure is carried out with average annual daily traffic (AADT) counts. However, one can extrapolate from available hourly count data to develop time of day distributions of vehicle activity by facility type. Most regions will have hourly count data, although these data may only be representative of average weekdays and may not fully represent the combination of facility and area types in the region. It is strongly recommended that areas collect appropriate data, but in the event that local data are lacking it may be possible to extrapolate from data that have been collected for other cities. One should look for cities with somewhat similar population and meteorological characteristics. The result of these calculations is VMT distributions by facility type and time of day. It is recommended that states consult with EPA before applying data from other areas in order to avoid later problems. Seasonal effects may also be important, both for VMT totals and distribution by time of day. These effects are particularly noticeable in areas with seasonal tourist influx. Weekday/weekend differences are large in most areas, and day of week variation may be important in some areas. Obtaining raw (disaggregated) count data in electronic form can facilitate the development of appropriate temporal allocation and day of week, monthly, and seasonal adjustment factors. Care should be taken to consciously select and document the data used for VMT distribution estimates.

3.4 Speed Estimation Procedures for Count Data

The next level of desired detail is the speed distribution of VMT for the two facility types with speed-dependent emissions: freeway and arterial/collector. Although many urban areas track level of service (LOS) for arterials and freeways for peak and off-peak periods, EPA does not believe that agencies will generally have available robust databases of observed speed. Also, LOS classifications cannot be directly used as inputs to MOBILE6 in place of speed distributions. Therefore, procedures are needed to estimate speeds from the traffic count data.

Much of the information presented here on speed estimation procedures is taken from the previously cited National Cooperative Highway Research Program (NCHRP) study of speed and service volume estimation procedures[13]. There are generally two methods available for estimating speeds. The first uses procedures from the Highway Capacity Manual[14] (HCM). The second uses the speed-congestion relationships based on the ratio of traffic volume to roadway capacity (V/C ratio) of the Bureau of Public Roads (BPR), known as the “BPR curves” or “modified BPR curves.” As traffic volumes approach roadway capacity (which is determined by factors affecting driving behavior, such as lane width, median width, roadway curvature, distance between side streets, etc.), speeds can drop and vehicle densities can increase rapidly. The accuracy of speed predictions under severely congested conditions is limited, regardless of the methods used. Also, for arterials, the effects of cross traffic and traffic signals on congested speed are difficult to reduce to a manageable calculation scheme, and the accuracy of both HCM and BPR procedures for arterials is limited. Table 2 summarizes features of both methods. Each method is discussed below.

3.4.1 Highway Capacity Manual Procedure

HCM procedures separately address “uninterrupted flow” and “interrupted flow” facilities (i.e., freeways and arterials/collectors). For freeways, the basic procedure involves: (1) the calculation of an adjusted segment volume that addresses lane and shoulder width, driver aggressiveness, fraction of large vehicles, among other considerations; and (2) the use of a speed lookup chart based on the nominal

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[13] Dowling et al., 1996.“Planning Techniques to Estimate Speeds and Service Volumes,” NCHRP 387, Final Report prepared for National Cooperative Highway Research Program project 3-55(2), Transportation Research Board, September 1996.

[14]TRB (1994). “Highway Capacity Manual,” Special Report 209, Third Edition, Transportation Research Board, 1994.

freeflow speed of the facility. For interrupted flow facilities, the procedure again includes calculating adjusted volumes, but speed calculation requires separate calculations of the running time between signals (based on distance and freeflow speed) and the intersection delay (based on signal timing, V/C ratio, and other factors), which are then combined into an average speed.

For general information, the data requirements for the HCM procedure are as follows.

Uninterrupted Flow Facilities (Freeways):

- Hourly volume
- Number of lane
- Free-flow speed
- Peak hour factor
- Lane and shoulder widths
- Percent trucks
- Percent recreational vehicles
- Terrain type
- Predominant driver type.

Interrupted Flow Facilities Techniques (Arterial/Collectors):

- Hourly volumes
- Number of lanes
- Free-flow speed
- Arterial class
- Density of signals per mile
- Peak hour factor
- Percentage turning traffic from exclusive lanes
- Medians
- Exclusive turn lanes
- Green time per cycle
- Cycle length
- Quality of signal progression
- Signal controller type.

Note that, for both facility types, default look-up tables can be created for many of these variables allowing one to apply these methods provided one has facility and area type. Of course, use of defaults rather than facility-specific data reduces the accuracy of the resultant speeds.

The HCM method requires more facility-specific information than is likely to be available, and in some cases cannot be applied for V/C ratios greater than 1.0. Therefore, because of its lower data requirements and ease of application, and despite its limitations, the BPR method appears the most practical for typical urban areas and it is our recommended method for speed estimation. We note, however, that with the expanding use of GIS for developing integrated data bases with roadway characteristics for transportation planning, analysis and modeling, urban areas are beginning to develop richer databases that could allow application of the HCM procedure on a regional basis, or perhaps hybrid approaches that specifically address signal timing, coordination, and congestion.

Table 2. Summary of Speed Estimation Method Features

Criteria	**Volume/Capacity Curves (BPR)**	**Highway Capacity Manual**
I. Data Requirements		

Amount	-volume, capacity, free speed	-volume, free speed, plus numerous additional facility characteristics
Precision	-a 10% error in volume or capacity translates into a 19% change in the estimated speed at v/c = 1.00	-complexity of procedures make it difficult to determine impacts of data errors
Feasibility	-all required data are feasible for all agencies to easily obtain	-40% of MPOs indicated it is not feasible to obtain some of the required data items (% heavy vehicles, quality of coordination were most difficult)
2. Ease of Use		
Complexity	-single equation	-multiple equations
Training Required	-few minutes to learn	-one-day training
Spreadsheet	-spreadsheet friendly	-adaptable to spreadsheets, but figures must be translated to look-up tables
3. Reliability		
Accuracy	-not accurate at high v/c ratios	-most accurate of available techniques not in traffic model software
Facilities	-all, but not reliable for interrupted flow facilities	-no planning technique for uninterrupted flow facilities systems
Area Types	-all	-interrupted flow technique designed for only urban application -rural road procedure limited to 60 mph design speed
Planning Applications	-Good only for RTP models	-good for all except RTP models
4. User Confidence and Acceptance		
Overall Use	-used by 22% of all respondents	-used by 33% of respondents
Planning Applications	-predominant technique for RTPs	-predominant technique for site impact and congestion management
Agencies	-most popular with MPOs -least popular with local traffic agencies	-most popular with state DOTs -least popular with MPOs
Geographic Spread	-used throughout USA	-most frequently used across the country but less popular on west coast
5. Significant Strengths and Deficiencies		
Strengths	-simple, quick, well-behaved function	-comprehensive, sensitive to many factors
Deficiencies	1. Not accurate at V/C's > 1.00 2. Needs to be refitted to new HCM data 3. Not sensitive to signal timing	1. Extensive data required 2. Complex procedures 3. No procedure for freeway systems 4. Can't do V/C > 1.00 5. Rural roads procedure limited

3.4.2 Bureau of Public Roads Procedure

In contrast to the HCM procedure, the BPR is not data intensive. Default tables of capacity by functional class are available, although the accuracy of the method is improved if individual facility capacities are used. The standard BPR equation is:

$$s = s_f/(1 + a(v/c)^b)$$

where:

s = predicted mean speed
s_f = free flow speed
v = volume
c = practical capacity
a = 0.05 for signalized facilities (arterials, collector, and local)
a = 0.20 for unsignalized facilities (freeways, highways, and expressways)
b = 10

Different values of the parameters a and b have been developed by some urban areas based upon speed data sets, resulting in customized BPR curves. Practical capacity is defined as 80% of maximum capacity. Free-flow speed is defined as the space mean speed[15] of traffic when volumes are so light that they have negligible effect on speed and is estimated to be 1.15 times the speed at capacity. Relationships for space mean speed have been developed by Dowling et al, as follows:

Uninterrupted facilities with posted speed limits > 50 mph:
Mean speed (mph) = 0.88 * (posted speed limit in mph) + 14

Uninterrupted facilities with posted speed limits < 50 mph:
mean speed (mph) = 0.79 * (posted speed limit in mph) + 12

By entering either coded capacities by facility type or using default look-up tables, along with the link volumes from traffic count data, link speeds can be predicted with the BPR equation. VMT within each functional class can be grouped by speed, resulting in distributions of VMT by speed for freeways.

The accuracy with which the BPR curves predicts speeds for both arterials and freeways can reportedly approach those of the HCM and traffic simulation models, provided that accurate free-flow speeds and capacities for each facility are known. Predicted speeds are proportional to free-flow speed, but drop rapidly as v/c approaches 1.0, making it particularly important to use reliable capacity values.

As noted above, the accuracy of these speed relationships is reduced for arterials and locals because of traffic control effects. However, unless local data on control parameters by facility and area type are available to at least construct look-up tables, regional planners are probably limited to the BPR curves for estimating arterial speeds as well. A simple method to better estimate speeds as a function of facility type is to differentiate the parameter "a" for signalized (a = 0.05) and unsignalized (a = 0.20) facility classes. As discussed in the following section regarding travel demand models, speed processors have been developed that make use of look up tables of default signalization data in order to improve speed estimates for arterials, but the accuracy of these methods is still limited.

3.4.2.1 Time of Day Variations

Time of day variations in speeds can be accounted for by distributing traffic volumes by time of day, as discussed above, and then applying the BPR equation with the appropriate capacities and volumes. If available, day-of-week and seasonal effects can also be incorporated by applying appropriate adjustments to link volumes or using traffic count data specific to the temporal period of interest. The use of adjustment factors, particularly for time of day, can result in peak hour traffic volumes that exceed roadway capacity, conditions under which uncertainties in the BPR relationships are greatest. While significant congestion does occur in many areas, it is possible for adjustments to cause unrealistically low estimated speeds for some roadways, requiring care and judgment on the part of the analyst.

[15]Space mean speed is the "true" average speed along a roadway as given by the total distance traveled by all vehicles divided by the total travel time for the vehicles.

3.4.2.2 Future Year Estimates

Future year estimates can be developed by projecting VMT estimates by functional class and area type (and speed bin if data permit) to the desired year based either on past trends or travel demand model predictions. Regional growth and its effects on congestion, travel demand, and spatial distribution of travel can cause significant shifts in VMT between functional classes and areas. Therefore, agencies should review and update their VMT distributions when projecting inventories.

3.4.2.3 Distributions by Vehicle Class

The fraction of VMT accumulated by each vehicle class (light versus heavy duty or by FHWA classifications) can be obtained from HPMS data by functional class for each state. Obtaining similar distributions for a specific urban area or by speed bin is more difficult. The survey conducted as part of the NCHRP planning techniques study found that forty percent of respondents would not be able to obtain data on percent trucks by roadway type.[16] In the absence of local data, the state HPMS estimates could be assumed to be applicable. HPMS estimates do differentiate between urban and rural area types. In some cases, the particular urban area under study may be the predominate source of data for the HPMS statistics which makes this less of an extrapolation. EPA is unaware of any other readily available sources of data that would allow agencies to develop distributions of VMT on freeways and arterials by vehicle class and speed, although relatively limited data collection efforts could provide information that could either verify state-level estimates or refine vehicle class information for specific regions..

[16] Dowling et al. (1996).

4.0 WORKING WITH REGIONAL TRANSPORTATION MODEL OUTPUTS

Travel demand models (TDMs) provide another source of estimates of vehicle activity by functional class, time of day, and speed. The modeling process assigns trips (defined by an origin and a destination within the roadway network) to roadway segments. To the extent that model inputs capture all trips within a region, TDMs provide comprehensive regional VMT estimates and avoid the uncertainties associated with extrapolation of traffic volumes from count data at selected locations. They provide less detail, however, regarding volume fluctuation by time of day, vehicle type, and speeds than can be obtained from measurements, except to the extent that available data are used to provide such detail in model output. Agencies with access to TDMs can readily obtain VMT distributions from the link-level traffic volumes and other outputs of these models. The November 1993 transportation conformity regulations require network-based modeling for metropolitan planning areas in ozone and carbon monoxide nonattainment areas classified as serious and higher (40CFR51.452). Modeling improvements have been made in many areas in response to these regulations, as well as other planning needs.

4.1 Processing TDM Outputs

TDMs produce information for thousands of individual links, depending on the size of the network being modeled. Several software systems, such as statistical software or inventory software, exist that will automatically provide summaries similar to those that would be needed to estimate regional VMT distributions. These software systems process TDM data that in some cases may be pre-processed to reformat datasets or add specific parameters, such as capacity, to the data.

4.2 Speed Estimation Procedures Using Travel Demand Model Data

The assignment of traffic to the roadway network in travel demand models uses calculated speeds and route choices to minimize travel time. The effect of speeds on assignments is evaluated primarily in terms of how well the assigned traffic volumes agree with count data. Historically, lack of agreement between TDM speeds and observed speeds was of little concern provided that congestion and traffic volumes were well characterized. TDM inputs (especially the “trip tables” identifying numbers of trips between each pair of zones) are prepared for specific time periods, and simulation results provide a single assignment representative of that period. For average daily travel (ADT) assignments, it is not possible within the model to describe hourly variation in congestion and speeds. Even if modeling is conducted separately for different times of day (e.g., AM peak, midday, PM peak, and overnight), congestion and speeds can vary within each period. Consultation with transportation planners and modelers should include assessment of whether TDM speeds have been calibrated or evaluated against observations. Post-processing techniques are available that use HCM procedures and the BPR curve to calculate hourly congested speeds. The general algorithm is:

1. Distribute link-level volumes by hour of day using user input temporal distributions (usually from count data sets);
2. Calculate hourly VMT by multiplying link distance by hourly volume;
3. Calculate v/c using either link-specific capacities or lookup tables;
4. Apply the BPR curve, using link-specific free flow speeds or lookup tables, to arrive at hourly congested speeds.

Exogenous volume adjustments can be applied to the loaded networks to account for variations by day of week or season prior to post-processing speeds. Note that this results in higher inaccuracies in the assignments, since ideally traffic should be assigned with the actual trip productions and attractions that correspond to the modeling episode. These types of data are unlikely to be available. However, future year loaded networks are usually available from local planners which simplifies the development of future year VMT distributions. The procedure described above is simply repeated, this time with the future year assignment.

There are several areas in which TDMs may fail to provide comprehensive VMT estimates. These relate to both the preparation of inputs used in modeling and in the level of detail incorporated in trip and network inputs. For example, "intrazonal" travel (trips whose origin and destination are within the same zone of the TDM) and other travel on local roads[17] are not directly assigned to the network, and must be separately addressed. This is typically accomplished through calculations based on assumptions about intrazonal trip lengths, the sizes of zones, and local roadway speeds. Alternatively, local road travel can be estimated from count data. Like local roads that are not "coded" into the TDM network, separate freeway on- and off-ramp links may not be included in network specification. Ramp travel may therefore be either omitted from TDM VMT estimates, or included as a portion of freeway VMT.

Information on travel by vehicle class is typically not available directly in TDMs. The "trip table" inputs that identify the number of trips for each purpose (e.g., home-based work trips) between each pair of spatially defined zones in the model, and this information can be used if data exist on fleet composition for different trip purposes. However, as TDMs focus primarily on travel by individuals rather than goods movement, this approach provides little value for identifying medium and heavy truck activity. Goods movement models are under development, but at present, simple adjustment factors are more commonly used to estimate incremental freight-related VMT to be added to modeled volumes. Time of day, day of week, and seasonal variation of freight travel should be evaluated separately, based on local data.

[17] TDM networks typically include all freeways and arterials, but may not explicitly include minor streets.

5.0 APPLICATION OF METHODOLOGY TO DATA FROM FIVE CITIES

These two methodologies for developing distributions of VMT by facility type and average speed are tested in this section using representative datasets for five urban areas. The urban areas selected for this analysis were:

- Chicago, Illinois;
- Houston, Texas;.
- Charlotte, North Carolina;
- Ada County, Idaho (Boise region); and
- New York, New York.

5.1 Data Collected

Two types of data were collected for this exercise. For some cities, actual hourly or daily traffic count data were obtained. These data generally included some information about the count locations, such as functional class and/or area type, as well as temporal information for each count (e.g., time of day, day of year). For other cities, transportation activity estimates and network information from the regional transportation model were obtained. The choice of method to be tested in each city was dependent upon the type of data obtained. Both types of datasets were not obtained for one city, therefore it was not possible to perform a side-by-side comparison of methods. Tables 3a through 3f present a summary of the traffic count and transportation model output data that were gathered for each city.

Each of the cities studied used its own set of functional classes, which did not directly correspond to the four MOBILE6 classes. For example, although estimates of VMT on ramps existed, none of the five areas had either count data or model link VMT for ramps, and Houston used a total of nine distinct arterial and collector classes. In applying the speed estimation methodologies to each city, functional classes were grouped, and in some cases, freeflow speeds and capacities were assigned based on a combination of local recommendations and judgment. Speed estimation procedures were carried out for all functional classes possible for purposes of demonstration. As noted in the presentation of results for these cities, actual space-mean speeds for the different functional classes in a city should be determined so that appropriate assignment of local functional classes to those of MOBILE6 are made.

As noted, none of the datasets obtained for this project contained direct count or volume estimates for freeway ramps. A methodology for developing ramp VMT estimates, developed by the Charlotte DOT, was provided with the Charlotte dataset. This methodology was used to develop rough estimates of ramp VMT for all five cities as discussed in this section of the guidance.

Table 3a. Charlotte Department of Transportation (CDOT) counts for 1995.

Item	**Description**
Card Number	= 1 (card 1)
Location	Description of count site
LNKNM	Link number, as used in the transportation model (not available for all links)
CODE	Internal CDOT code
DATE	mmddyy
DAYWEEK	0=Sunday, 1=Monday, ...
TIME	Time counter placed (counts stored 001 - 2400)
TWOWAY	Two-way count? T/F
COMPASS DIR	Direction (NEWS) of A direction counts
AADT	Average-annual daily traffic
AAWT	Average-annual weekday traffic
SUMCNT	Sum of counts
AAWT factor	Month/Day factor to calculate AAWT
Card Number	= 2 (card 2)
Vol0000-0015	Volume 0000-0015 - compass direction A
Vol0016-0030	Volume 0016-0030
...	
Vol1145-1200	Volume 1145-1200 - compass direction A (total of 48 15-min counts)
	Repeat for 1201 - 2400 - compass direction A (total of 48 15-min counts)
	Repeat for 001 - 1200 - compass direction B (total of 48 15-min counts)
	Repeat for 1201 - 2400 - compass direction B (total of 48 15-min counts)

Table 3b. Charlotte DOT and North Carolina DOT count data (CDOT counts are AAWT, NCDOT counts are ADT).

Item	Description
FUNCL	CDOT functional class
AREATP	CDOT area type (1 = CBD, 2 = CBD fringe, 3 = residential, 4 = commercial area, 5 = rural)
DOTF	FHWA functional class (First letter: I = interstate, F = oth. Freeway, P = principal arterial, M = minor arterial, C = collector, L = local; Second letter: U = urban, R = rural)
LINKLEN	Link length (miles)
LNKNM	Travel demand model ID (matches data set above as well)
LOCATION	From demand model - different method than count dataset
85VOL	Volume - 1985
86VOL	Volume - 1986
87VOL	Volume - 1987
88VOL	Volume - 1988
89VOL	Volume - 1989
90VOL	Volume - 1990
91VOL	Volume - 1991
92VOL	Volume - 1992
93VOL	Volume - 1993
94VOL	Volume - 1994
95VOL	Volume - 1995

Table 3c. New York traffic count dataset (Data are organized into four subsets, designated TF1 through TF4).

TF1 Records	TF2 Records	TF3 Records	TF4 Records
Region	Region	Region	Region
County	County	County	County
Route	Route	Route	Route
Milepoint	Milepoint	Milepoint	Milepoint
Station	Station	Station	Station
Card Code ("1")	Card Code ("2")	Card Code ("3")	Year
Section Length	Year	Year	Count Number
Year	Month	Month of First Days Count	Section Length
Functional Class	Day of Month	Day-of-Month of First Days Count	Beginning Description
Factor Group	Direction	Direction	Ending Description
Description	Day of Week	Factor Group	AADT
Not Used	Week of Year	Reference Marker	Design Hour
Not Used	Reference Marker	Hourly Counts (24 Times)	Reference Marker
Not Used	Hour Counts (4 positions)	Not Used	Direction
Not Used	Not Used	Not Used	Bridge Identification Number
Not Used	Not Used	Not Used	Functional Class
Not Used	Not Used	Not Used	Factor Group
Not Used	Not Used	Not Used	HPMS Number

Table 3d. Chicago 1996 transportation model outputs.

Description
Anode - link end point
Bnode - link end point
Link distance
Functional class (0 = dummy links; 1 = freeway; 2 = major highway; 3 = area service (arterial); 4 = other principal arterials; 5 = minor arterial (urban); 6 = collector (urban); 7 = local; 8 = major collector (rural); 9 = minor collector)
Daily link volume
Link capacity
Link freeflow speed
Anode coordinates
Bnode coordinates

Table 3e. Ada County 1995 and 2015 transportation model outputs.

Description
Anode - link end point
Bnode - link end point
Link distance
Functional class (1 = freeway; 2 = arterial; 3 = collector; 4 = local)
Daily link volume
Link freeflow speed
Anode coordinates
Bnode coordinates

Table 3f. Houston 2020 transportation model outputs.

Description
Anode - link end point
Bnode - link end point
Link distance
Functional class (0 = locals; 1 = radial freeways w/o frontage road; 2 = radial freeways w/ frontage road; 3 = crc freeways w/o frontage road; 4 = crc freeways w/ frontage road; 5 = radial tollways w/o frontage road; 6 = radial tollways w/ frontage road; 7 = crc tollways w/o frontage road; 8 = crc tollways w/ frontage road; 9 = principal arterial w/ grade separator; 10 = principal arterials divided; 11 = principal arterials undivided; 12 = other arterials divided; 13 = other arterials undivided; 14 = one-way pairs; 15 = one-way facilities; 16 = collectors divided; 17 = collectors undivided; 18 = ferries; 19 = saturated arterials; 20 = transitways; 21 = saturated arterials)
Peak and Offpeak period link volumes
Link capacity
Link freeflow speed
Anode coordinates
BNODE COORDINATES

5.2 Application of Travel Demand Model Output Methodology

The first method used to determine vehicle miles traveled (VMT) distributions by functional class and speeds that is presented uses transportation model outputs. This method was applied for Ada County, Houston, and Chicago.

5.2.1 Use of Inventory Software

This method was carried out by applying a standard software package, the Direct Travel Impact Model (DTIM2), which is available from the California Department of Transportation.[18] In some instances, supplemental preprocessor programs were created in FORTRAN to reformat datasets or to add specific parameters, such as capacity, to the data. The DTIM2 model includes a speed processor that uses

[18] Fieber et al. 1994. "DTIM2 User's Guide." Final Report SYSAPP94-94.051, Prepared for the California Department of Transportation, Systems Applications International, Inc., San Rafael, California, June 30, 1994.

hourly V/C ratios, freeflow speeds, and the standard Bureau of Public Roads (BPR) speed curve to arrive at hourly link-level speeds.[19] Although this speed processor can modify speeds to reflect the impacts of signalization and queuing, these two functions were turned off for this analysis. Signalization was partially accounted for by using different parameters in the BPR equations as outlined in Section 3.4.2.

The DTIM speed processor requires that the functional class and capacity be explicitly coded for each link in the network. These parameters were available for both Houston and Chicago. Therefore, the DTIM speed processor was used for both cities. For Ada County, functional class was available but capacity was not available. Therefore, the predicted speeds from the local transportation model, which are provided by link, were used in developing the VMT distributions for Ada County.

5.2.2 Ada County, Idaho Transportation Model Outputs

The transportation model estimates of traffic volumes and network characteristics that were obtained for the Ada County region were processed using the DTIM software system. Current (1995) predictions of vehicle activity were analyzed. Initially, distributions were developed for an entire day of travel. Subsequently, distributions were developed separately for the AM-, PM-, and Off-Peak travel periods. Distributions for the AM period are presented here. The Ada County network assigns roadway links to one of the following four functional classes: 1) freeway; 2) arterial; 3) collector; and 4) local.

In many ways, this was the least detailed database used in this analysis. For example, data for developing hourly distributions of VMT were not available. As a result, the Ada Planning Association had used distributions developed by the California Department of Transportation for San Luis Obispo, California,[20] which has a similar population to Boise, Idaho. Extrapolating data from another city is strongly discouraged for SIP purposes. Each area should start to collect their own data if a program is not already in place. Individual link capacities were also not available. Therefore, the DTIM speed processor was not applied for this region. Rather, the link-level speeds provided by the local transportation model were assumed to be applicable regardless of time-of-day or congestion. As a result, the speed distribution for each hour of the day was identical, regardless of hourly variation in traffic volume (and congestion).

Table 4a shows the 8 a.m. (morning peak) distribution of VMT by speed and functional class from the 1995 Ada County transportation files. Table 4b provides similar information expressed as fraction of total miles. Here, local roadway speed estimates fall mostly in the 15 mph speed bin, with all other speeds higher. This may indicate either classification of roads as local that would more appropriately be classed as arterial/collector, or possible errors in assigned freeflow speeds. Users should remain aware in their development of facility-class-specific VMT distributions that MOBILE6 is not speed-dependent for local roadways and ramps. Speed distributions are shown here for local roadways based on available data, and for purposes of demonstrating the results of the BPR speed methodology. Agencies are encouraged to test and evaluate the VMT and speed estimation procedures presented here, and to critically assess their results and revise, if appropriate, the facility type classifications or other inputs to the speed estimation procedure. Consultation with local transportation planning agencies can be extremely valuable, as many MPOs have made significant investments in developing reliable speed estimates.

Calculating link- and hour-specific speeds with the speed processor could not be done due to the absence of hourly congestion (v/c) inputs in the 1995 Ada County transportation files. Thus, the speed

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[19] Dowling, 1994. “Technical Memorandum 8-1 User’s Guide for Speed Processor.” Prepared for the California Department of Transportation by Richard Dowling, Dowling Associates, June 14, 1994.
[20] Caltrans, 1993. “1991 Statewide Travel Survey.” Prepared by the California Department of Transportation, Office of Traffic Improvement. December 1993.

distribution shown in Table 4b applies to all hours of the day. Table 4c summarizes the distribution of daily VMT between functional class, after merging Ada County's arterial and collector classes to coincide with those of MOBILE6. Also, because the Ada County model does not track ramp VMT, assumptions based on analyses by the Charlotte Department of Transportation (CDOT) were used to derive ramp VMT as a fraction of freeway VMT.[21] These fractions are summarized in Table 4d. The ramp VMT varies greatly among land use type, and for this study, the fraction for commercial land uses was selected as most applicable on a regional basis. Thus, ramp VMT was estimated as 8.7% of freeway VMT.

Table 4a. Distribution of 1995 hourly VMT by functional class and speed during the morning peak (8 a.m.) for Ada County.

Speed Range	**Vehicle Miles**				
	Freeway	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0
2.5 - 7.5	0	0	0	0	0
7.5 - 12.5	0	0	0	0	0
12.5 - 17.5	147	5	0	26,989	27,142
17.5 - 22.5	230	1,669	6,705	2,593	11,197
22.5 - 27.5	2,318	7,720	6,135	441	16,614
27.5 - 32.5	468	56,278	7,241	493	64,481
32.5 - 37.5	0	67,940	3,214	912	72,067
37.5 - 42.5	0	15,866	3,381	513	19,760
42.5 - 47.5	7,407	20,578	0	0	27,985
47.5 - 52.5	42,903	0	0	0	42,903
52.5 - 57.5	14,612	0	0	0	14,612
57.5 - 62.5	15,574	0	0	0	15,574
62.5 - 67.5	0	0	0	0	0
67.5 - 72.5	0	0	0	0	0
Total	83,659	170,056	26,676	31,942	312,332

[21] CDOT (1997). "Charlotte Travel Demand Models, Vehicle Miles Traveled." Draft Report prepared by the Charlotte Department of Transportation, Charlotte, NC. July 1997.

Table 4b. 1995 VMT distribution by functional class and speed for Ada County.

Speed Range	Fraction of Total VMT				
	Freeway	Arterial	Collector	Local	Total
0.0 - 2.5	0	0	0	0	0
2.5 - 7.5	0	0	0	0	0
7.5 - 12.5	0	0	0	0	0
12.5 - 17.5	0.0005	0	0	0.0864	0.0869
17.5 - 22.5	0.0007	0.0053	0.0215	0.0083	0.0359
22.5 - 27.5	0.0074	0.0247	0.0196	0.0014	0.0532
27.5 - 32.5	0.0015	0.1802	0.0232	0.0016	0.2064
32.5 - 37.5	0	0.2175	0.0103	0.0029	0.2307
37.5 - 42.5	0	0.0508	0.0108	0.0016	0.0633
42.5 - 47.5	0.0237	0.0659	0	0	0.0896
47.5 - 52.5	0.1374	0	0	0	0.1374
52.5 - 57.5	0.0468	0	0	0	0.0468
57.5 - 62.5	0.0499	0	0	0	0.0499
62.5 - 67.5	0	0	0	0	0
67.5 - 72.5	0	0	0	0	0
Total	0.2679	0.5445	0.0854	0.1022	1.0000

Table 4c. Overall VMT distributions for Ada County in 1995 (miles/day).

Functional Class	1995 VMT	1995 VMT Fraction
Freeway	1,486,240	0.26
Arterial & Collector	3,495,042	0.62
Ramp	129,303	0.02
Local	567,470	0.10

Table 4d. Fraction of freeway VMT used to calculate ramp VMT by CDOT[22].

Area Type	Fraction
Central Business District	0.194
Commercial	0.087
Residential	0.024

5.2.3 Chicago Transportation Model Data Outputs

[22] *See Id.*

Transportation model data for 1996 traffic volumes and network characteristics were processed using the DTIM system to arrive at VMT distributions by functional class and speed for the Chicago region. The DTIM speed processor was used to calculate speeds as a function of hourly volume to capacity and freeflow speeds. Tables 5a and 5b summarize total VMT by functional class and speed for light and heavy duty traffic, respectively, during the AM peak travel period. Separate results in this form are obtained from DTIM for each of 24 one-hour periods. The estimates for heavy duty travel activity are arrived at by applying an overall fraction of VMT assumed to be attributable to heavy duty vehicles to link volumes, producing heavy duty vehicle volumes by link. This fraction does not vary by area type or functional class. However, a separate temporal distribution is then applied to the heavy duty portion of the fleet, which results in different VMT distributions for this portion of the fleet. Tables 5c and 5d summarize fractional VMT distributions by functional class and speed for AM peak travel. The values shown in these two tables are fractions of hourly total VMT for all functional classes.

Tables 5e through 5g summarize VMT distributions by MOBILE6 functional classes for light duty, heavy duty, and total fleet, respectively. Ramps are not tracked as a separate functional class within the Chicago model, so based on Charlotte NC data, it was assumed that ramp VMT was equal to 8.7% of freeway VMT. For Chicago, the freeway and highway facility classes were combined, as were the arterial and collector classes. For this document, no attempt was made to segregate roadways identified as “local” for which freeflow speeds and congestion allowed speeds significantly higher than the 12.9 mph average for the local roadway speed cycle. It is likely that many of the roadways classified as local would be better classified as arterial/collector for this data set.

Table 5a. Summary of 1996 light duty vehicle VMT distribution by functional class and speed during AM peak (8 a.m.) for Chicago (miles/day).

Speed Range	**Vehicle Miles**					
	Freeway	**Highway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	3,362	856	4,970	7,607	6,416	23,211
7.5 - 12.5	0	17,769	29,132	25,812	3,652	76,365
12.5 - 17.5	105,660	66,463	137,749	123,324	10,492	443,688
17.5 - 22.5	182,753	201,406	530,801	340,752	51,658	1,307,370
22.5 - 27.5	181,568	327,280	929,526	409,209	115,174	1,962757
27.5 - 32.5	156,724	348,149	804,607	224,273	72,144	1,605,897
32.5 - 37.5	251,344	240,993	538,417	161,452	44,870	1,237,076
37.5 - 42.5	198,653	160,016	222,657	152,032	102,912	836,270
42.5 - 47.5	133,224	117,340	116,133	101,917	61,213	529,827
47.5 - 52.5	517,441	57,882	22,251	35,996	34,334	667,904
52.5 - 57.5	309,012	18,407	1,153	881	1,131	330,584
57.5 - 62.5	107,232	0	0	0	0	107,232
62.5 - 67.5	135,870	0	0	0	0	135,870
67.5 - 72.5	0	0	0	0	0	0
Total	2,282,844	1,556,560	3,337,395	1,583,256	503,996	9,264,051

Table 5b. Summary of 1996 heavy duty vehicle VMT distribution by functional class and speed during AM peak (8 a.m.) for Chicago (miles/day).

Speed Range	**Vehicle Miles**					
	Freeway	**Highway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	981	86	403	605	588	2,663
7.5 - 12.5	0	1,914	2,658	2,150	290	7,012
12.5 - 17.5	23,528	8,074	12,554	9,896	771	54,823
17.5 - 22.5	37,181	21,387	51,742	28,838	4,249	143,397
22.5 - 27.5	35,764	36,103	85,488	33,821	8,755	199,931
27.5 - 32.5	31,576	36,346	70,946	17,884	5,243	161,995
32.5 - 37.5	51,636	23,862	47,134	12,242	2,924	137,798
37.5 - 42.5	42,259	16,994	20,102	11,981	8,067	99,403
42.5 - 47.5	31,789	12,817	10,093	9,361	5,895	69,955
47.5 - 52.5	143,395	6,516	3,156	3,269	3,968	160,304
52.5 - 57.5	100,161	1,978	126	59	45	102,369
57.5 - 62.5	35,520	0	0	0	0	35,520
62.5 - 67.5	64,592	0	0	0	0	64,592
67.5 - 72.5	0	0	0	0	0	0
Total	598,382	166,076	304,401	130,104	40,793	1,239,756

Table 5c. Summary of 1996 light duty VMT fraction by functional class and speed during AM peak (8 a.m.) for Chicago.

Speed Range	**Fraction of Total VMT**					
	Freeway	**Highway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	0.0004	0.0001	0.0005	0.0008	0.0007	0.0025
7.5 - 12.5	0	0.0019	0.0031	0.0028	0.0004	0.0082
12.5 - 17.5	0.0114	0.0072	0.0149	0.0133	0.0011	0.0479
17.5 - 22.5	0.0197	0.0217	0.0573	0.0368	0.0056	0.1411
22.5 - 27.5	0.0196	0.0353	0.1003	0.0442	0.0124	1.1149
27.5 - 32.5	0.0169	0.0376	0.0869	0.0242	0.0078	0.1733
32.5 - 37.5	0.0271	0.0260	0.0581	0.0174	0.0048	0.1335
37.5 - 42.5	0.0214	0.0173	0.0240	0.0164	0.0111	0.0903
42.5 - 47.5	0.0144	0.0127	0.0125	0.0110	0.0066	0.0572
47.5 - 52.5	0.0559	0.0062	0.0024	0.0039	0.0037	0.0721
52.5 - 57.5	0.0334	0.0020	0.0001	0.0001	0.0001	0.0357
57.5 - 62.5	0.0116	0	0	0	0	0.0116
62.5 - 67.5	0.0147	0	0	0	0	0.0147
67.5 - 72.5	0	0	0	0	0	0
Total	0.2464	0.1680	0.3603	0.1709	0.0544	1.0000

Table 5d. Summary of 1996 heavy duty VMT fraction by functional class and speed during AM peak (8 a.m.) for Chicago.

Speed Range	Fraction of Total VMT					
	Freeway	Highway	Arterial	Collector	Local	Total
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	0.0008	0.0001	0.0003	0.0005	0.0005	0.0021
7.5 - 12.5	0	0.0015	0.0021	0.0017	0.0002	0.0057
12.5 - 17.5	0.0190	0.0065	0.0101	0.0080	0.0006	0.0442
17.5 - 22.5	0.0300	0.0173	0.0417	0.0233	0.0034	0.1157
22.5 - 27.5	0.0288	0.0291	0.0690	0.0273	0.0071	0.1613
27.5 - 32.5	0.0255	0.0293	0.0572	0.0144	0.0042	0.1307
32.5 - 37.5	0.0417	0.0192	0.0380	0.0099	0.0024	0.1111
37.5 - 42.5	0.0341	0.0137	0.0162	0.0097	0.0065	0.0802
42.5 - 47.5	0.0256	0.0103	0.0081	0.0076	0.0048	0.0564
47.5 - 52.5	0.1157	0.0053	0.0025	0.0026	0.0032	0.1293
52.5 - 57.5	0.0808	0.0016	0.0001	0	0	0.0826
57.5 - 62.5	0.0287	0	0	0	0	0.0287
62.5 - 67.5	0.0521	0	0	0	0	0.0521
67.5 - 72.5	0	0	0	0	0	0
Total	0.4827	0.1340	0.2455	0.1049	0.0329	1.0000

Table 5e. Light Duty Vehicle VMT distributions for Chicago in 1996 (miles/day).

Functional Class	1996 LDV VMT	1996 LDV VMT Fraction
Freeway	47,071,489	0.40
Arterial & Collector	59,593,980	0.51
Ramp	4,095,213	0.04
Local	6,098,846	0.05

Table 5f. Heavy Duty Vehicle VMT distributions for Chicago in 1996 (miles/day).

Functional Class	1996 HDV VMT	1996 HDV VMT Fraction
Freeway	9,928,019	0.59
Arterial & Collector	5,642,914	0.33
Ramp	863,738	0.05
Local	529,783	0.03

Table 5g. Total VMT distributions for Chicago in 1996 (miles/day).

Functional Class	1996 TOTAL VMT	1996 TOTAL VMT Fraction
Freeway	56,999,508	0.43
Arterial & Collector	65,236,894	0.49
Ramp	4,958,957	0.04
Local	6,628,629	0.05

5.2.4 Houston Transportation Model Data

Transportation model outputs for the Houston region were processed using DTIM to arrive at VMT distributions by functional class and speed. The model's network uses a total of 21 different facility type designations (e.g., it separately identifies one-way pairs, undivided and divided collectors, transitways, etc.). These facility types were preserved in the speed analysis, and later grouped based on local recommendations. Three speed estimation procedures were applied in this analysis. Initially, the model was run using the speed processor. However, it was determined that the capacities and freeflow speeds coded on the network were providing unreasonable results. New capacities and freeflow speeds were then recoded using standard assumptions based on data seen for several other cities, FHWA recommendations, and engineering judgment. Table 6a summarizes these speed and capacity assumptions. This provided somewhat better results. The model was then rerun using the link-specific speeds originally provided by the Houston-Galveston Area Council (HGAC) transportation model. This also resulted in reasonable speeds, but failed to capture any variation in speed by time of day.

The VMT distributions by functional class and speed as calculated by the speed processor (using the assumed capacities and freeflow speeds in Table 6a) are summarized in Table 6b for the AM peak (7 a.m.) travel period. The fractional VMT distributions for this run are provided in Table 6c. The VMT distributions by functional class and speed for the run using the speeds output by the HGAC transportation model are summarized in Table 6d.

The fractional VMT distributions for this run are provided in Table 6e. In Table 6f, the overall distribution of VMT by functional class has been remapped into the functional classes used in MOBILE6, with expressways grouped into the freeway class. Again, ramp VMT is estimated as 8.7 percent of freeway VMT due to the absence of separate ramp volume data.

Table 6a. Freeflow speeds (mph) and capacities for Houston.

	Freeway	Expressway	Arterial	Collector	Local
Speed	61	49	41	41	25
Capacity	1750	1660	1400	1400	10000[23]

[23]In transportation modeling, local roadways are least likely to be comprehensively represented in the model network of links. A "centroid connector" link is a single artificial link representing local roads within each traffic analysis zone. The length of this link is the assumed average distance traveled on local roads leading to collectors or arterials. A high capacity is set for such links to prevent the TDM or the speed processor from assuming that large traffic volumes (i.e., large numbers of trips originating in a zone) cause local roadway congestion.

Table 6b. Summary of 2020 PM Peak (5 p.m.) VMT by functional class and speed for Houston using speed processor (miles/day).

Speed Range	**Vehicle Miles – PM Peak (5 p.m.)**					
	Freeway	**Expressway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	40,328	1,945	52,579	6,241	0	101,094
7.5 - 12.5	19,328	0	28,473	590	0	48,391
12.5 - 17.5	37,612	0	21,826	1,252	0	60,690
17.5 - 22.5	32,532	0	18,235	310	0	51,077
22.5 - 27.5	28,383	0	33,471	0	866,111	927,965
27.5 - 32.5	111,107	0	67,263	1,410	0	179,780
32.5 - 37.5	31,885	173	435,580	25,626	1654	494,917
37.5 - 42.5	70,849	0	992,053	2,061	151,609	1,216,572
42.5 - 47.5	138,444	0	319,085	6,095	0	463,623
47.5 - 52.5	263,919	4,565	422,125	58,011	0	748,619
52.5 - 57.5	893,947	14,715	156,327	2,391	0	1,067,380
57.5 - 62.5	1,743,590	0	256,274	38,804	0	2,038,668
62.5 - 67.5	25,997	0	0	0	0	25,997
67.5 - 72.5	16,152	0	0	0	0	16,152
Total	3,454,072	21,398	2,803,290	142,789	1,019,374	7,440,921

Table 6c. Summary of 2020 PM Peak (5 p.m.) VMT fractions by functional class and speed for Houston using speed processor (miles/day).

Speed Range	**Vehicle Miles – PM Peak (5 p.m.)**					
	Freeway	**Expressway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	0.0054	0.0003	0.0071	0.0008	0	0.0136
7.5 - 12.5	0.0026	0	0.0038	0.0001	0	0.0065
12.5 - 17.5	0.0051	0	0.0029	0.0002	0	0.0082
17.5 - 22.5	0.0044	0	0.0025	0	0	0.0069
22.5 - 27.5	0.0038	0	0.0045	0	0.1164	0.1247
27.5 - 32.5	0.0149	0	0.0090	0.0002	0	0.0242
32.5 - 37.5	0.0043	0	0.0585	0.0034	0.0002	0.0665
37.5 - 42.5	0.0095	0	0.1333	0.0003	0.0204	0.1635
42.5 - 47.5	0.0186	0	0.0429	0.0008	0	0.0623
47.5 - 52.5	0.0355	0.0006	0.0567	0.0078	0	0.1006
52.5 - 57.5	0.1201	0.0020	0.0210	0.0003	0	0.1434
57.5 - 62.5	0.2343	0	0.0344	0.0052	0	0.2740
62.5 - 67.5	0.0035	0	0	0	0	0.0035
67.5 - 72.5	0.0022	0	0	0	0	0.0022
Total	0.4642	0.0029	0.3767	0.0192	0.1370	1.0000

Table 6d. Summary of 2020 PM Peak (5 p.m.) VMT by functional class and speed for Houston using HGAC transportation model speeds (miles/day).

Speed Range	**Vehicle Miles - PM Peak (5 p.m.)**					
	Freeway	**Expressway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	0	0	0	0	0	0
7.5 - 12.5	0	0	0	0	0	0
12.5 - 17.5	0	0	0	0	0	0
17.5 - 22.5	0	0	0	0	0	0
22.5 - 27.5	0	0	2,992	0	866,111	869,103
27.5 - 32.5	0	0	0	0	0	0
32.5 - 37.5	3,015	173	370,739	28,228	0	402,154
37.5 - 42.5	4,435	0	1,139,260	663	153,263	1,297,621
42.5 - 47.5	0	0	322,949	11	0	322,959
47.5 - 52.5	1,938	6,510	512,976	69,979	0	591,403
52.5 - 57.5	63,828	14,715	140,765	1,542	0	220,849
57.5 - 62.5	3,338,709	0	313,608	42,366	0	3,694,683
62.5 - 67.5	5,103	0	0	0	0	5,103
67.5 - 72.5	37,045	0	0	0	0	37,045
Total	3,454,072	21,398	2,803,288	142,789	1,019,374	7,440,920

Table 6e. Summary of 2020 PM Peak (5 p.m.) VMT fractions by functional class and speed for Houston using HGAC transportation model speeds (miles/day).

Speed Range	**Fraction of Total VMT – PM Peak (5 p.m.)**					
	Freeway	**Expressway**	**Arterial**	**Collector**	**Local**	**Total**
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	0	0	0	0	0	0
7.5 - 12.5	0	0	0	0	0	0
12.5 - 17.5	0	0	0	0	0	0
17.5 - 22.5	0	0	0	0	0	0
22.5 - 27.5	0	0	0.0004	0	0.1164	0.1168
27.5 - 32.5	0	0	0	0	0	0
32.5 - 37.5	0.0004	0	0.0498	0.0038	0	0.0540
37.5 - 42.5	0.0006	0	0.1531	0.0001	0.0206	0.1744
42.5 - 47.5	0	0	0.0434	0	0	0.0434
47.5 - 52.5	0.0003	0.0009	0.0689	0.0094	0	0.0795
52.5 - 57.5	0.0086	0.0020	0.0189	0.0002	0	0.0297
57.5 - 62.5	0.4487	0	0.0421	0.0057	0	0.4965
62.5 - 67.5	0.0007	0	0	0	0	0.0007
67.5 - 72.5	0.0050	0	0	0	0	0.0050
Total	0.4642	0.0029	0.3767	0.0192	0.1370	1.0000

Table 6f. Overall VMT distributions for Houston in 2020 (miles/day).

Functional Class	**2020 VMT**	**VMT Fraction**
Freeway	54,357,162	0.43
Arterial & Collector	50,073,142	0.40
Ramp	4,729,073	0.04
Local	16,366,908	0.13

5.3 Application of Traffic Count Data Methodology

The second methodology utilized traffic count data to directly estimate VMT distributions and speeds. This methodology was applied to traffic count data from Charlotte, North Carolina and New York. In many cases, FORTRAN programs were developed to manipulate the traffic count data to accomplish this. Each example is presented below.

5.3.1 Charlotte Traffic Count Data

The traffic count databases obtained for Charlotte, North Carolina were processed using simple FORTRAN routines. Two sets of count data were available from CDOT, only one of which had functional class identified. Therefore, the LNKNM variable (see Table 3b) was used to match the functional class for each count location from one data set with count locations in the other data set. Further, only counts on freeways, major arterials, and minor arterials were available. VMT for collectors, locals, and ramps are estimated using procedures developed by CDOT[24].

For collectors, VMT is estimated as a fraction of total VMT on major and minor arterials. The fractions vary by area type and are drawn from the 1990 calibrated transportation model. These fractions are:

CBD	0.5 percent
Commercial	4.9 percent
Residential/Rural	12.9 percent.

Local street VMT was estimated by CDOT using local GIS data and then distributed by area type using the following assumptions for fraction total local VMT by area type:

CBD	1.6 percent
Commercial	12.9 percent
Residential/Rural	85.6 percent.

Total 1995 local street VMT was estimated by CDOT as 1,118,051 miles/day.

Ramp VMT was estimated as a fraction of freeway VMT, with area-specific fractions developed by CDOT:

CBD	19.4 percent
Commercial	8.7 percent
Residential/Rural	2.4 percent.

The CDOT procedures for estimating collector, local, and ramp VMT were combined with the information derived from the count data to arrive at overall VMT distributions.

Count data were allocated by hour of day (based upon the 15-minute counts supplied by CDOT) and then used in the BPR formula to calculate speed by hour by count site. Table 7a presents the hourly distributions of VMT for each functional class (i.e., the fraction of daily functional class VMT occurring in each hour), and total across functional classes, as derived from the count data. As noted above, the count sites did not include either local roads or ramps, so no temporal pattern is available for those facilities. In the absence of such data, it would be necessary to assume temporal distributions for these functional classes (e.g., using freeway distributions for ramps and minor arterials for locals). Table 7b summarizes total link VMT calculated by functional class.

Table 7a. Hourly distributions of travel by functional class for Charlotte.

[24] See CDOT (1997).

Hour	Total	Freeway	Major	Minor
1	0.0080	0.0076	0.0080	0.0084
2	0.0046	0.0057	0.0046	0.0051
3	0.0035	0.0074	0.0035	0.0037
4	0.0030	0.0066	0.0029	0.0032
5	0.0040	0.0126	0.0038	0.0052
6	0.0112	0.0365	0.0106	0.0147
7	0.0352	0.0691	0.0342	0.0426
8	0.0708	0.0688	0.0701	0.0797
9	0.0765	0.0511	0.0772	0.0713
10	0.0538	0.0460	0.0543	0.0494
11	0.0492	0.0474	0.0496	0.0455
12	0.0537	0.0530	0.0540	0.0500
13	0.0612	0.0568	0.0616	0.0562
14	0.0623	0.0571	0.0627	0.0586
15	0.0618	0.0676	0.0618	0.0611
16	0.0674	0.0717	0.0670	0.0707
17	0.0754	0.0805	0.0750	0.0794
18	0.0866	0.0658	0.0868	0.0865
19	0.0665	0.0456	0.0668	0.0653
20	0.0460	0.0368	0.0463	0.0446
21	0.0359	0.0376	0.0359	0.0353
22	0.0294	0.0306	0.0294	0.0286
23	0.0203	0.0241	0.0202	0.0208
24	0.0137	0.0141	0.0137	0.0139
Total	1.0	1.0	1.0	1.0

Table 7b. Distribution of link VMT by functional class for Charlotte.

Functional Class	VMT (miles/day)	VMT Fractional Distribution
Freeway	1,729,473	0.17
Major Arterial	5,584,962	0.55
Minor Arterial	1,227,056	0.12
Ramps	150,464	0.02
Collectors	333,789	0.03
Local	1,118,051	0.11

The hourly count estimates were used to arrive at VMT distributions by speed by functional class. This procedure is very sensitive to the assumptions made for the number of lanes, freeflow speed and capacity for each count site. Different assumptions for these parameters were used for each area and functional class combination. Assumptions for speeds and capacities are summarized in Tables 7c and 7d, respectively. They are based on a combination of datasets that have been developed for other areas of the country, FHWA assumptions in the Highway Capacity Manual, and engineering judgment. Freeflow speeds were determined by using an assumed posted speed limit with the equations for space mean speed as outlined in Section 3.4. It was assumed that freeways had three lanes in each direction, major arterials had two lanes in each direction, and minor arterials had one lane in each direction. The data were also run through the programs assuming that freeways had two lanes in each direction; this produced nearly identical results to the first run. Table 7e summarizes the resulting VMT distributions for the AM-peak hour of 8 a.m. for the three functional classes for which count data were available: freeways, major arterials, and minor arterials. For use in MOBILE6, a VMT-weighted average of the major and minor arterial speed distributions would be used for the arterial/collector facility type inputs.

Overall, the distributions appear to underestimate congestion and overestimate speeds for freeways. The results for major arterials appear reasonable. The VMT distributions by speed for minor arterials appear to overestimate congestion somewhat. The results suggest that this method should be applied cautiously, and preferably local or link-level data on the number of lanes, freeflow speeds, and capacities should be used. Table 7f summarizes the number of count sites in the Charlotte database for each functional class. There were only four freeway sites, which is not enough data for deriving good speed distributions. This probably explains the lack of congestion seen here.

Table 7c. Freeflow speeds for Charlotte. (mph)

Area Type	CBD	CBD fringe	Residential	Commercial	Rural
Freeway	62	62	62	62	62
Major	32	48	40	48	40
Minor	32	40	32	40	32

Table 7d. Capacities for Charlotte. (volume per hour)

Area Type	CBD	CBD fringe	Residential	Commercial	Rural
Freeway	3,500	3,500	3,500	3,500	3,500
Major	1,200	1,600	1,600	1,600	1,600
Minor	600	550	550	550	550

Table 7e. Summary of AM Peak (8 a.m.) VMT distributions by functional class and speed for Charlotte.

Speed	Freeway	Major Arterial	Minor Arterial
0.0 - 2.5	0	0	0
2.5 - 7.5	0	0	0.0213
7.5 - 12.5	0	0	0
12.5 - 17.5	0	0	0
17.5 - 22.5	0	0	0.0213
22.5 - 27.5	0	0	0.0106
27.5 - 32.5	0	0.1281	0.5319
32.5 - 37.5	0	0	0
37.5 - 42.5	0	0.2838	0.4149
42.5 - 47.5	0	0.0023	0
47.5 - 52.5	0	0.5858	0
52.5 - 57.5	0	0	0
57.5 - 62.5	1	0	0
62.5 - 67.5	0	0	0
67.5 - 72.5	0	0	0
72.5 - 77.5	0	0	0

Table 7f. Total number of count sites by functional class for Charlotte.

	Freeway	Major	Minor
Counts	4	437	94

5.3.2 New York Traffic Count Data

The New York traffic count databases were processed using similar procedures to those described for Charlotte. As with Charlotte, FORTRAN programs were used to develop VMT distributions by time of day, functional class, and speed. Assumptions were made regarding the freeflow speeds and capacities for each functional class, as these data were not available in the count database. Speed estimates proved to be quite sensitive to these assumptions, and in practice, specific information regarding number of lanes, freeflow speeds, and capacities for each count site should be obtained.

The hourly distributions of travel as calculated from count data are summarized in Table 8a for urban count sites. Freeflow speed and capacity assumptions are summarized in Table 8b. The hourly congested speed at each count site was calculated using the BPR equations, the hourly counts, and the corresponding assumed freeflow speeds and capacities in Table 3b. This reliance on assumptions, particularly with regard to capacity (number of lanes), introduces some risk of introducing bias into speed calculations. For example, speed estimates for freeway count locations with more than three lanes would be negatively biased, particularly during high volume periods. Table 8c provides total calculated VMT by functional class, and the corresponding VMT fractions, on a daily basis. Table 8d summarizes speed distributions by functional class for urban count sites during the AM peak (8 a.m.) travel period. The total number of counts by functional class for urban New York is presented in Table 8e.

The grouping of functional classes identified in the data base to correspond to the MOBILE6 facility types should consider the estimated speeds. Speeds are shown for all functional classes in Table 8d to facilitate this evaluation. A notable feature of the speed distributions in this table is that for all functional classes at or below principal arterial, more than 90 percent of VMT during the AM peak is estimated to occur in the speed bin corresponding to the freeflow speed. This indicates that either counts are quite low relative to capacities, or that the assumed capacities are overestimated. Moreover, the speed estimates shown for local roadways are probably overstated due to an unreasonably high assumed speed. If possible, with a count data set as rich as this in terms of number of locations and temporal distribution, it would be well worth the effort to survey actual speeds at a representative number of count sites for each functional class, as well as to obtain site-specific information regarding at least the number of lanes at each count site. This would provide a sound empirical basis for assigning functional classes to the MOBILE6 categories, and would improve the quality of speed distribution estimates for the sites classified as either freeway or arterial/collector.

Table 8a. Hourly distributions of travel by functional class for urban New York.

Hour	Interstate	Freeways & Expressways	Principal Arterial	Minor Arterial	Collector	Local
1	0.0137	0.0152	0.0120	0.0086	0.0087	0.0097
2	0.0093	0.0090	0.0071	0.0049	0.0050	0.0051
3	0.0082	0.0064	0.0050	0.0035	0.0034	0.0034
4	0.0086	0.0062	0.0043	0.0030	0.0030	0.0030
5	0.0116	0.0097	0.0058	0.0046	0.0041	0.0042
6	0.0251	0.0213	0.0141	0.0123	0.0105	0.0118
7	0.0523	0.0487	0.0360	0.0335	0.0307	0.0358
8	0.0742	0.0713	0.0589	0.0618	0.0610	0.0666
9	0.0700	0.0700	0.0623	0.0647	0.0653	0.0705
10	0.0540	0.0558	0.0542	0.0546	0.0538	0.0539
11	0.0490	0.0483	0.0527	0.0530	0.0530	0.0488
12	0.0495	0.0476	0.0565	0.0584	0.0590	0.0524
13	0.0499	0.0481	0.0602	0.0636	0.0651	0.0571
14	0.0505	0.0489	0.0593	0.0618	0.0618	0.0554
15	0.0553	0.0543	0.0627	0.0660	0.0650	0.0615
16	0.0634	0.0624	0.0687	0.0734	0.0737	0.0722
17	0.0690	0.0677	0.0736	0.0782	0.0795	0.0802
18	0.0687	0.0698	0.0739	0.0786	0.0789	0.0821
19	0.0555	0.0597	0.0607	0.0610	0.0622	0.0649
20	0.0445	0.0490	0.0500	0.0484	0.0506	0.0503
21	0.0373	0.0408	0.0415	0.0386	0.0397	0.0394
22	0.0327	0.0361	0.0347	0.0313	0.0309	0.0319
23	0.0273	0.0304	0.0263	0.0216	0.0207	0.0231
24	0.0205	0.0232	0.0194	0.0147	0.0145	0.0166

Table 8b. Urban Freeflow speeds, capacities, and number of lanes for New York.

Functional Class	Freeflow Speed	Capacity	# Lanes
Interstate System	62	5,250	3
Other Freeways and Expressways	48	2,400	3
Other Principal Arterial	40	1,600	2
Minor Arterial	32	600	1
Collector	32	800	1
Local	32	550	1

Table 8c. Distribution of link VMT by functional class for Urban New York.

Functional Class	VMT	VMT Fractional Distribution
Interstate	25,368,696	0.12
Other Freeways and Expressways	19,505,362	0.09
Other Principal Arterial	27,778,980	0.13
Minor Arterial	37,607,872	0.18
Collector	14,566,768	0.07
Local	85,913,472	0.41
Ramps	2,207,077	0.01

Table 8d. Summary of AM Peak (8 a.m.) VMT distributions by functional class and speed for urban New York.

Speed	Interstate	Freeways & Expressways	Principal Arterial	Minor Arterial	Collector	Local
0.0 - 2.5	0	0.1116	0.0030	0.0213	0.0029	0.0250
2.5 - 7.5	0	0.0223	0	0.0085	0	0.0058
7.5 - 12.5	0	0.0134	0.0010	0.0075	0	0.0038
12.5 - 17.5	0	0.0134	0.0020	0.0085	0.0029	0
17.5 - 22.5	0.0192	0.0045	0	0.0085	0	0.0019
22.5 - 27.5	0.0064	0.0045	0.0010	0.0043	0	0.0019
27.5 - 32.5	0.0128	0.0045	0.0030	0.9414	0.9942	0.9616
32.5 - 37.5	0.0192	0	0.0050	0	0	0
37.5 - 42.5	0.0064	0.0268	0.9849	0	0	0
42.5 - 47.5	0.0192	0.0536	0	0	0	0
47.5 - 52.5	0.0321	0.7455	0	0	0	0
52.5 - 57.5	0.0641	0	0	0	0	0
57.5 - 62.5	0.8205	0	0	0	0	0
62.5 - 67.5	0	0	0	0	0	0
67.5 - 72.5	0	0	0	0	0	0
72.5 - 77.5	0	0	0	0	0	0

Table 8e. Total number of count sites by functional class for urban New York.

	Interstate	Freeways & Expressways	Principal Arterial	Minor Arterial	Collector	Local
Counts	127	152	521	574	44	19

Glossary of Terms and Acronyms[25]

Arterial	A class of street serving major traffic movement that is not designated as a highway. There are principle and minor arterials which are designated to primarily provide mobility and are a higher class than local or collector streets which are designed to primarily provide access.
Assignment	The principal output of a travel demand model, which identifies the number of vehicles assigned to each link of the highway network
Average Daily Traffic	The average number of vehicles passing a fixed point in a 24-hour time frame. A convention for measuring traffic volume. Annual average daily traffic (AADT) is determined by using a factor to adjust for the changing amounts of traffic at different times of the year.
Capacity	The maximum number of vehicles that can pass over a given section of a lane or roadway in one direction during a given time period under prevailing roadway and traffic conditions.
Centerline Miles	A measure of the total length of roadways, ignoring the number of lanes (Cf. lane miles)
Central Business District (CBD)	The most intensely commercial sector of a city. Often referred to as the downtown.
Collector	A class of street serving neighborhood circulation, and providing a balance between accessibility to land and through movement of traffic.
Counter	A machine that provides a count of traffic volume on a particular point of the highway system. The detector is generally embedded into the pavement in a relatively permanent installation.
Cordon Line	An abstract line encompassing a study area such as a central business district, a shopping center or a larger planning area. Origin-destination surveys and traffic counts are typically conducted along points on this line to determine the characteristics of travel entering and leaving the study area. It measures the transportation activity generated by the study area. The line is usually associated with physical barriers, such as rivers, or major highways with limited crossings.
Corridor	Broad geographical band connecting major sources of trips. Usually associated with transportation facilities.

[25]The definitions presented here are in most cases taken from “Talking the Talk–A Pocket Guide to the Language of Transportation Planning,” prepared by the Northwestern Indiana Regional Planning Commission.

Cutline	An arbitrary line strategically drawn across the corridor of a transportation network to connect all the paths in the corridor. Its purpose is to check the larger scale comparability of the model with real-world knowledge of the area.
Expressway, Freeway	A divided arterial highway for through traffic with controlled access, the intersections on which are usually separated from other roadways by differing grades. It can be a toll road.
External Trip	A trip with one end inside a study area and the other end outside the study area.
Forecasting	The processing of estimating the future values of specific variables used in the transportation modeling process, including population, income and employment.
Functional Classification	The categorization of streets and roadways based on their intended use. The classifications range from interstate, which is a controlled access facility that serves through traffic movement and provides no access to adjacent land, to the local street that primarily serves access to adjacent land, and provides little movement of through traffic.
Highway Capacity Manual (HCM)	A guide for engineers and planners to estimate the capacity of the elements of the highway stem, including freeways, ramps, arterial streets and intersections, based on factors that cause the reduction of capacity, such as parking, curves, topography and other similar factors.
Highway Performance Monitoring system (HPMS)	The system used by the FHWA to provide information to Congress, the States, and the public on the extent and physical condition of the nation's highway system, its use, performance and needs. For clean air act conformity analyses, the HPMS provides an official base estimate of vehicle-miles of travel, which is used to adjust model-derived estimates of vehicle-miles of travel for base and future years.
Lane Miles	A combined measure of the length and capacity of roadways (Cf. centerline miles). In estimating VMT from count data, the units of the count data (vehicles per hour, vehicles per hour per lane) are known.
Level of Service (LOS)	A set of qualitative descriptions of a transportation system's performance. The Highway Capacity Manual defines levels of service for intersections and highway segments, with ratings that range from A (best) to F (worst). Transportation projects are usually planned and designed to result in a LOS of C or D, depending on the severity of the congestion problems, and the ability to make improvements.

Link	A representation of a road segment on transportation model networks. One part of a chain of trips.
Local Street	A street intended solely for access to properties contiguous to it.
Loop Detector	A vehicle detection device imbedded in pavement used to control traffic signals and count vehicles. Speeds can be estimated from single loop detectors based on the duration of single vehicle presence over the loop (with an assumed average vehicle length). More accurate speed data can be derived from two detectors closely spaced in the same lane.
Metropolitan Planning Organization (MPO)	The organizational entity designated by law with lead responsibility for developing transportation plans and programs for urbanized areas of 50,000 or more in population. MPOs are established by agreement of the Governor and units of general purpose local government.
Mode	The method used for personal travel or the movement of goods on a particular trip. Modes include automobile, bus, commuter rail, bicycle, walking, rail freight and trucking.
Network	A system of links and nodes that represent highway segments and intersections, and transit services, used in a transportation model to estimate the utilization of the transportation system.
Node	An element of a transportation model network that represents either an intersection or the centroid of a traffic analysis zone.
Off-Peak	Referring to the times and directions of travel not associated with the major commuting direction; that is, all times and directions other than toward the central business district or activity center(s) in the morning and away from it in the late afternoon and early evening.
Peak Hours or Peak Period	The period in the morning or evening in which the largest volume of travel is experienced. Travel peaks are typically the result of trips to and from work.
Screen Line	An imaginary line bisecting an area. Traffic counts are taken at regular intervals at all streets intersecting the screen line. The line is associated, where possible, with physical barriers, such as rivers, or major highways with limited crossings. Counts taken along the screen line determine the traffic moving between two areas. These counts are intended to detect long-range changes in volume and direction of traffic due to significant changes in land use and travel patterns.

Space-mean Speed	An average speed derived by dividing total distance traveled by total time of travel. This definition of average speed is the one used in MOBILE6. To derive a space-mean speed from VMT distributions across speeds, the total travel time for the VMT in each speed bin is determined and summed to divide into the total VMT across all speed bins. This is equivalent to computing the harmonic mean speed (inverse of the average of the inverses). (Cf. time-mean speed)
Speed	Depending on the context, speed in transportation planning or traffic engineering may refer to an instantaneous vehicle speed, an average speed of vehicles at a specific location (e.g., from loop detectors), an average speed for a single vehicle along a particular roadway segment, or an average speed for all vehicles along a particular roadway segment. The manner in which data are collected, or speed estimates are derived, determines which meaning of the term applies (see space-mean speed and time-mean speed).
Time-mean speed	An average speed derived as the arithmetic mean of instantaneous vehicle speeds (e.g., from loop detector data). This definition of average speed differs from that used in MOBILE6, and should be avoided in emissions analysis (Cf. space-mean speed).
Traffic Analysis Zone	A subdivision of the metropolitan area used for transportation modeling. The characteristics of the traffic analysis zone are used to estimate the number of trips that start and end in the zone, for a base year, and for specific forecast years.
Travel Demand model (TDM)	A process to estimate the utilization of the transportation system under various scenarios, using specific computer software, combined with socioeconomic data, forecasts and the transportation system presented by a network of links and nodes.
Vehicle Hours of Travel (VHT)	A standard measure of total travel time, expressed in vehicle hours. Regional average speed is determined by dividing VMT by VHT.
Vehicle Miles of Travel (VMT)	A standard areawide measure of travel activity. The most conventional VMT calculation is to multiply average length of trip by the total number of trips, or to sum the traffic volumes on links multiplied by link length.
Volume to Capacity Ratio (V/C)	A measure of the performance or utilization of a specific element of the transportation system, such as a road segment or an intersection. The capacity of the facility can be calculated using methods described in the Highway Capacity Manual. The traffic volume is determined through the traffic counting programs, and adjusted using factors to relate the data collection date to the annual average for the data collection year. The v/c is the percentage of the capacity that is being consumed by traffic. A v/c ratio above 1.0 means that the volume of traffic exceeds capacity and the road segment or intersection is becoming deficient and congested.