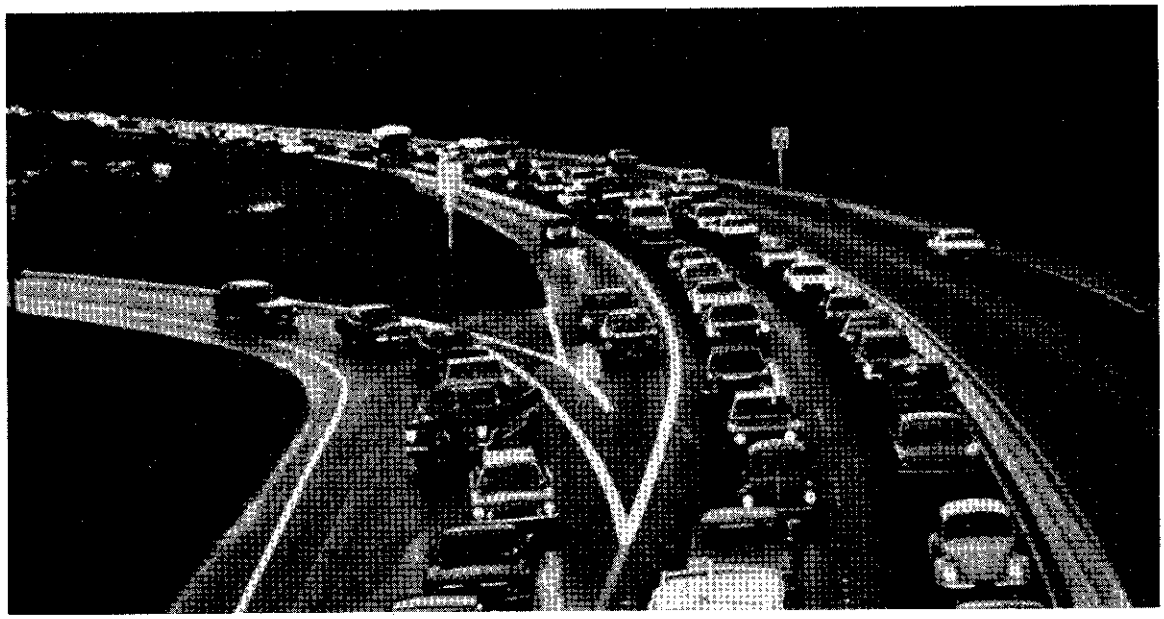
U.S. Department
of Transportation
**Federal Highway
Administration**

Summary and Recommendations of the Workshop on

NATIONAL URBAN CONGESTION MONITORING



**U.S. Department of Transportation
Federal Highway Administration
Office of Highway Information Management**

Report No. FHWA-PL-90-029 **September 1990**

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Summary and Recommendations
of the Workshop on

NATIONAL URBAN CONGESTION MONITORING

Prepared for the
U. S. Department of Transportation
Federal Highway Administration
Office of Highway Information Management

by

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FHWA-PL-90-029

PREFACE

This document reports on a 2 1/2-day workshop convened at U.S. DOT from May 30 to June 1, 1990. It is intended to summarize the discussion, and to present the general findings and overall recommendations of the workshop rather than exhaustively report on the detailed proceedings of the sessions. A list of workshop participants is contained in Appendix A.

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SECTION I

OVERVIEW

Congestion - A definition

> An excessive fullness of an artery; to clog; to concentrate in a small or narrow space.
> "Webster's Collegiate Dictionary," 1967

Congestion - A definition

> An imbalance between traffic flow and capacity that causes increased travel time, cost and modification of behavior.
> Federal Highway Administration (FHWA) Urban Congestion Monitoring Workshop, May 1990 1/

CONFERENCE ASSUMPTIONS AND OBJECTIVES

The conference "givens" and objectives were laid out in an opening statement by David McElhaney, Director of the Office of Highway Information Management, sponsor of the workshop. The main "givens" were:

- The focus of the Working Group's activities was on the development of a process to provide a national urban congestion reporting system for FHWA. That reporting system would ..."measure, monitor and trend severity of congestion in urban areas on a repeatable basis."
- The existing Highway Performance Monitoring System (HPMS) was to form the nucleus of the reporting system. The Group's main task was to determine the extent to which to expand and modify HPMS reporting to achieve a stronger congestion reporting capability.
- The system must be practical and within reasonable resource levels.
- An annual system, to be put in place as rapidly as possible using 1991 State submittals, was intended.
- The focus of the reporting system was on urbanized areas covering at least those above 500,000 population.

1/ The Urban Congestion Monitoring Work Group is referred to as the "Group" from this point on in this report.

- While the emphasis necessarily was on Federal needs and reporting requirements, benefits to State and local agencies are also expected as a result of this workshop.

The Workshop would attempt to be as explicit and detailed as possible in its recommendations on changes to be made to achieve the reporting system goal. The formal objectives were as follows:

1. Recommend to FHWA the specifics for the collection of practical, meaningful, national congestion information that is reasonable to expect States and Urbanized Areas to collect and report as part of HPMS.

2. Identify and define data elements, measurements, and indices to be reported on an annual basis, with variations by functional system.

3. Recommend specific analyses procedures for HPMS data -- perhaps changes and/or enhancements to existing published methodology.

4. Identify long range congestion information activities that may be needed at the national level -

   - Data collection
   - Research
   - Data analysis
   - Data dissemination

The laying out of these objectives led to indepth discussions of the scope and capabilities expected of national congestion monitoring. The subsequent agenda addressed the topics of scope and capabilities first, followed by detailed treatment of actual Measures and Methods.

These discussions began by attempting to define congestion. After a discussion of six or seven varying approaches, the definition accepted as expressing the appropriate sense of the subject as required in the workshop setting was:

> Congestion: An imbalance between traffic flow and capacity that causes increased travel time, cost and modification of behavior.

This definition was preferred because it focused on the relationship of supply and demand, rather than on whether capacity was inadequate or demand excessive. It also focused on the effects of congestion - its costs and other consequences - rather than on purely physical system relationships.

SCOPE

It was established that the array of possible congestion measures could be categorized into three major groups: (1) operations-based; (2) systems-based; and (3) person-based, in which operations-based measures considered volume changes but did not take capacity into account. System-measures relate volume changes to capacity measures, and person-based measures focused on personal trip characteristics and preferences. It was clear that the strength of the HPMS and the appropriate focus of the current activity was on system-based measures, recognizing that the other approaches also have important roles to play.

The Group's discussions of scope focused on several areas. They included:

- Urban/suburban area coverage,
- Peak travel period coverage,
- Weekday vs. weekend coverage, and
- Road system coverage.

With respect to these areas of concern, the Group established the following positions regarding scope:

- Urban/suburban area coverage - The "lowest population threshold feasible" for application was identified as urbanized areas over 200,000 population. This threshold implied a reporting requirement of 116 areas at this time. In addition, urban and suburban components should be uniquely identified for each of these areas.
- Peak travel period coverage - The Group favored recognition of broad peak periods as the basis for congestion measurement rather than the more traditional and narrow peak hour boundaries.
- Weekday vs. weekend coverage - It was agreed that for the main purposes of deliberations, the Group would focus on weekday travel. However, it was recognized that non-work, typically weekend oriented, travel was rapidly becoming a key congestion issue.
- Road system coverage - Basically, an HPMS-oriented scoping of the system to be measured was accepted, including: Interstate, non-Interstate freeways and expressways, and principal and minor arterials. Collectors were excluded.

CAPABILITIES

In the discussion of capabilities, the Group considered and recognized a broad array of capabilities that had to be included within any reporting system. Some of these were highly specific in character, others were more general. They were as follows:

- Data should be comparable from city to city on a nationwide basis.
- Data should be repeatable from year to year so that data are comparable over time.
- Data must reflect the severity of congested conditions.
- Data must reflect changing conditions and be sensitive to both growing problems and highway capacity and operating improvements.
- Data must reflect the impact congestion has on motorists.
- Data should be amenable to forecasting and projections.

Further attributes of the reporting system recognized that the data would have to be feasible to collect, recognizing special labor needs and other costs. The data must be compatible with other data sets and be consistent across jurisdictional boundaries. In addition, the data must be useful to a broad array of users at the local and State level.

With the necessary discussions of scope and capabilities resolved, the Group focused its attention on the detailed treatment of specific measures, data quality, and overall system design.

SECTION II

DETAILED WORKING GROUP TECHNICAL DISCUSSIONS

THE THRESHOLD OF CONGESTION

As a point of departure for the discussions, the Group addressed topic of identifying the appropriate threshold for the inception of congestion in the traffic continuum. Using a level of service (LOS) concept, discussion centered on various LOS boundaries as the inception of congestion. The representatives of the larger urbanized areas indicated that they used LOS F as their basis for measurement of the problem. Other, usually smaller, areas considered this inappropriate, feeling that such a threshold would leave out areas that considered themselves to have serious problems.

It was noted that the boundary definition was not critical to the kinds of data to be collected (or in the quantification of impacts), because most of the cost and delay implications of congestion occurred in the volume/capacity range of 0.9 or greater. While this is the region in which major effects occur, there is a need to better understand the relationships between each LOS and travel occurring at each LOS.

THE DIMENSIONS OF CONGESTION

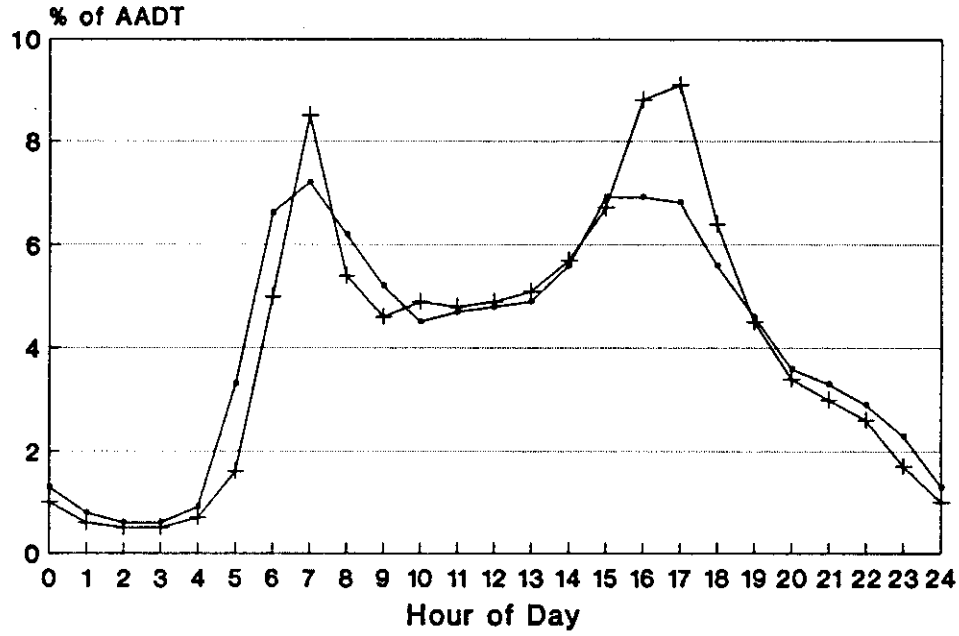
The treatment of the threshold question led into a far ranging discussion of the congestion issue, centering on the need for the measurement and reporting of all the dimensions of congestion. Discussion then focused on the dimensions of the problem to be treated.

The discussion of dimensioning quickly concluded that the use of averages in a national system is almost forced on the system designer, yet it was clear that there were substantial dangers in the use of averages. For example, if only a few facilities are heavily congested, averaging them with other uncongested facilities in the area would not demonstrate significant problems. Similarly, averaging a facility's travel over a day or week, when its congestion is limited to brief morning and evening periods, would mask the problem. Inherent in the Nation's congestion problem is, in fact, that congestion is a distributional problem, not a problem of average conditions. In addition, because the distribution of congestion has been changing significantly, the effective description of congestion requires that the nature of the distribution must be better understood and better expressed. The "intensity," "extent," "depth,"and "breadth" of the problem were important and had to be tangibly defined and expressed to achieve a robust treatment of congestion.

Some of the attributes of the distribution to be dealt with were:

- Daily congestion duration - The peak hour has been superseded by the "peak period." Peak hour/peak period relationships are not well understood, nor are peak period/all day relationships. As traffic volumes increase, the shape of the 24-hour travel distribution of a facility (see Figure 1) changes and takes on a number of profile forms. These profiles need to be more fully understood.

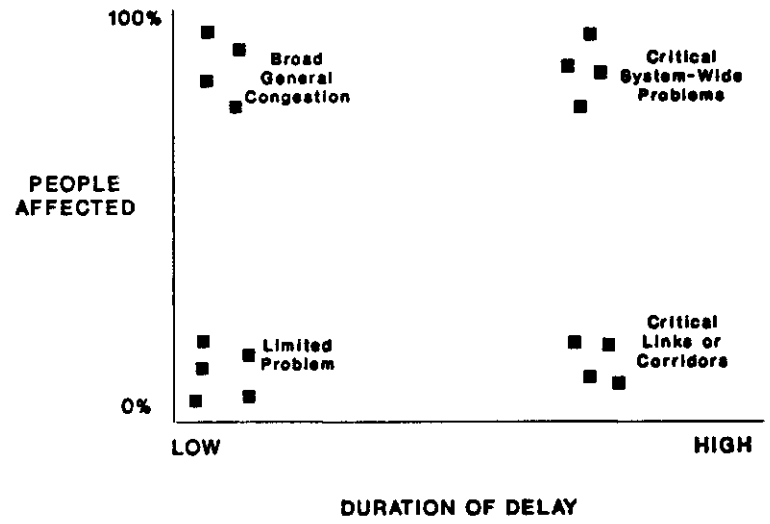
Figure 1 - 24-Hour Traffic Volume Distribution



- Spatial breadth - A key question related to gaining control of the description of congestion for national purposes will be describing congestion's geographic pervasiveness over facilities in a region. Congestion that is limited to a small share of total facilities or is broadly distributed will significantly change the character of the problem and of prospective solutions.

- Intensity and extent - The intensity or "total amount" of congestion, most likely expressed as total minutes of delay, was recognized as a characteristic to be statistically represented. The extent of congestion, intended to clarify the numbers (or shares) of persons, vehicles or travel affected by delay, also was identified as needing to be represented in a data base. These attributes of the distribution of the problem are needed to distinguish the vast potential differences in the character and effects of congestion in two areas with identical statistics for average delay per capita. Figure 2 depicts these relationships.

Figure 2 - Intensity of Congestion



- Intertemporal trends - Changing patterns of congestion among various time periods (days of the week, weeks of the month, etc.) have always been known to be significant to understanding congestion patterns. Often, variations in days of the week will exceed changes in the average from year to year. These patterns affect the relationships between the "30th," "100th" or "Nth" highest hours in the annual traffic distribution.

- Diversion and suppression - One of the aspects of the current growth in congestion patterns is the tendency to force travel demand away from desired times and places because of crowding or fear of crowding. These shifts may occur between facilities, or between time periods, or result in suppression in travel. They may be "positive" in redistributing traffic to less congested periods, or "negative" in limiting services and opportunities. These effects of congestion are poorly understood and extremely difficult to characterize statistically.

- Reliability and variability - One of the effects of increasing congestion is the potential decline in the reliability of travel times on the system. Consistent, known travel times, even if at slow speeds, may be more acceptable to motorists than highly variable travel times -sometimes good, sometimes bad - that place heavy burdens on planning and scheduling. It is not clear how overall system travel time reliability has changed in recent times. One factor is that as traffic volumes increase, the effects of vehicle breakdowns or minor accidents become very significant factors in causing delay. Other factors to consider are the increased participation of women with children in the work force and the role of "just-in-time" freight delivery, which puts a premium on system reliability. An innovative way of describing reliability may be a significant part of an effective congestion measurement system.

Having identified the key dimensions of the congestion phenomenon, the discussion turned to how to properly express these dimensions with a limited, but effective set of measures. In the broadest sense, the measures had to at least include the following:

- Absolute number and percent persons/vehicles affected,
- Absolute number and percent PMT/VMT affected,
- Absolute number and percent of system affected, and
- Absolute number and percent traveltime affected.

MEASURES

As a starting device, the measures to be discussed were assembled according to the broad categories cited above.

Person and Vehicle Measures

Among the measures cited and discussed by the group were:

- Cars/lane/hour,
- Minutes of delay/capita,
- Minutes of delay/vehicle,
- Minutes of delay/person delayed, and
- Minutes of delay/commuter.

This area of measurement raises some important distributional questions. It would be highly desirable to be able to quantify and trend these vehicle and person trip characteristics. However, this would require development of knowledge of average vehicle occupancies (passenger vans and pickup occupancies may be as significant a concern as passenger vehicles), at least on an area basis, but more effectively, on a facility level basis. The attempted use of person-based measures raises other questions as well. The use of average occupancies in conjunction with vehicles in the traffic stream produces measures of "persons delayed," in contrast to more easily recognized groups such as all commuters or the total population. The equating of congested travel with peak hour travel and, therefore, "commuter" travel is increasingly inappropriate, since commuters constitute only a portion of peak travel. The variation in these measures is critical to understanding the degree of exposure society has had to this problem.

PMT and VMT Measures

Among the measures cited and discussed were:

- Minutes of delay/VMT,
- Minutes of delay/trip,
- Thruput (persons/hour),
- VMT/LOS category, and
- VHT/LOS category.

Use of the term "thruput," defined as "persons per hour," again raises the question of average vehicle occupancies. This will be of particular importance in regard to the treatment of HOV facilities. Perhaps the most important measure in this category is the count of total VMT by level of service category. This permits the development and use of percentage measures by category, e.g., percent VMT over LOS "X."

System Measures

Among the measures cited and discussed were:

- Number of 15 minute periods > LOS "X",
- Minutes of delay/lane mile,
- Percent lane miles > LOS "X",
- Peak period speeds,
- Peak/off peak speed ratio,
- Peak period nominal speeds, and
- Number of speed change cycles.

These various measures attempt to relate congestion to facilities and the activities on them. One of the central issues in this category concerns measures related to a specific facility and those related to all facilities for a given area. To transition from facility-specific measures to areawide measures requires careful consideration of appropriate weighting schemes, for limited access facilities, other arterials, and various volume grouping. One of the more interesting facility specific measures is the number of 15-minute segments in a day that exceeded a threshold LOS level. Speed measurement generated considerable discussion that is treated elsewhere in this report. One speed related measure of interest is the concept of "nominal speed" calculated from the weighted speeds of a city's facilities, both freeways and surface arterial. This value facilitates calculations of peak/off-peak speed ratios and also permits effective weighting of actual speeds to permit comparisons between Urbanized areas. The tabulation that follows contains the calculated nominal speeds developed by the Texas Transportation Institute.

SAMPLE NOMINAL SPEEDS 2/

Albuquerque	43	Atlanta	49	Austin	49
Baltimore	47	Boston	48	Chicago	46
Cincinnati	50	Cleveland	49	Corpus Christy	45
Dallas	50	Denver	45	Detroit	45
El Paso	45	Fort Worth	50	Houston	50
Indianapolis	48	Kansas City	50	Los Angeles	46
Louisville	49	Memphis	45	Miami	42
Milwaukee	47	Minn-St. P.	50	Nashville	45
New York	47	Oklahoma	48	Philadelphia	44
Phoenix	40	Pittsburgh	43	Portland	49
Sacramento	46	Salt Lake	49	San Antonio	48
San Diego	50	S.F. CA.	50	Seattle	48
St Louis	47	Tampa	44	Wash D.C.	46

Time and Cost Measures

Among the measures cited and discussed were:

- Average travel time/trip,
- Average travel time/peak period trip,
- Total delay,
- Total delay/trip,
- Total delay/million VMT, and
- Percent of total travel under conditions of delay.

The most difficult element in this category to construct is a total minutes-of-delay figure for entire areas. This is dependent on the application of a consistent definition of delay and total areawide measurement. The value of having a distribution of total delay by incremental time segments was identified as very high in terms of quantifying the duration of person (and/or vehicle) delay. For example, total delay resulting from having thousands of persons delayed only a minute each might be larger, but far less significant than having hundreds of persons delayed more than 10 minutes.

The issue of spot speeds vs. measured travel speeds vs. travel time measurements also arose as a key statistical concern.

2/ Nominal speeds are composed of the weighted arterial and freeway speeds in an area computed at 55 MPH for freeways and 35 MPH for arterials.

OTHER MEASUREMENT ISSUES

Speed Measurement

It was recognized that typical public understanding of congestion was closely linked to the notion of speed, but at the same time, it was very difficult and expensive to obtain reliable speed measures. The utility of "spot speeds" were seen as ineffective resources for signalized arterials, and of limited value on freeways, but are the most feasible to obtain. The more desirable measurements of speed, travel time runs, are the most difficult and expensive to obtain. The use of travel time runs for fixed courses in given cities was discussed in terms of its ability to monitor change within and between areas and over time.

Freeway/Arterial Measures

The tendency to focus too heavily on freeway measures instead of measures applicable to signalized arterial streets in the measurement of congestion was cited. The importance of developing arterial street measures was identified and the special problems involved were discussed. The important future role of arterial streets in providing needed capacity emphasizes this concern. The broad variation in the actual capacity of arterial streets was seen as a key computational problem.

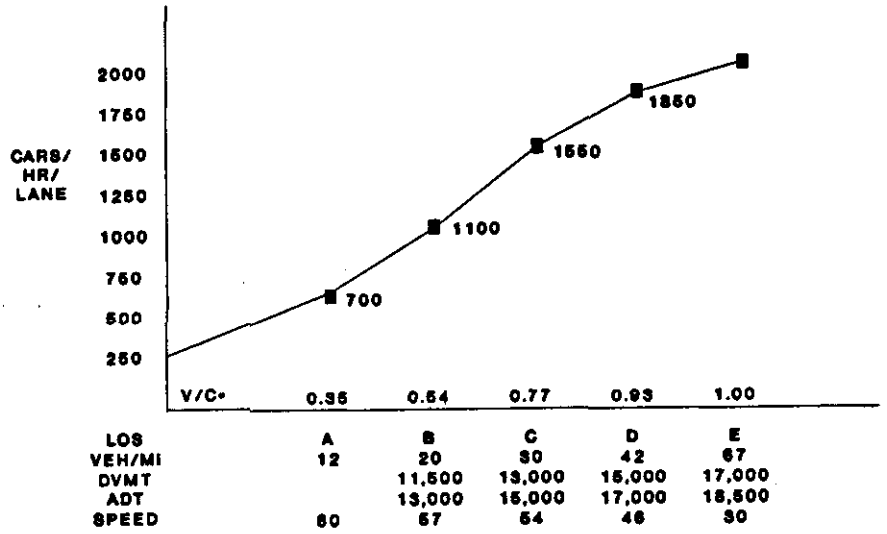
Nonrecurring delay

The role of nonrecurring delay - i.e., delay caused by breakdowns, incidents and accidents - in causing and exacerbating congestion was identified as a significant research area. Various estimates place the share of all congestion caused by nonrecurring delay at anywhere from 40 percent to 70 percent. Nonrecurring delay must be further refined and understood both for purposes of statistical representation as well as for policy and planning applications. In addition, it was also recognized that construction and maintenance projects are potentially significant contributors to congested conditions and required greater understanding of their congestion impacts.

Comparators

Presentations made by three Group participants who are urban congestion analysts, indicated that many different statistical expressions for the congested conditions are used, many of which were effectively equivalent. It was agreed that continued work in relating these measures statistically was required. Figure 3, based on a U.S. General Accounting Office's summary of Highway Capacity Manual material, attempts to link on a common scale the frequently mentioned measures discussed in the Workshop.

Figure 3 - Congestion Measure Comparators



METHODS

The utility of candidate congestion measures was determined based on whether the following criteria can be met:

- Credible - i.e., acceptable intuitively as a reasonable expression of the problem,
- Easily defined - Permitting easy, uniform interpretation on a nationwide basis,
- Feasible to collect - Within the reasonable range of activities of the collecting agencies,
- Utility - Measures should be useful at the state and local levels as well, and
- Cost and labor sensitive - proposed collection activities must reflect the realities of the skills and resource availabilities of the collecting agencies.

Evaluation of individual candidate measures in terms of the criteria quickly led to recognition that it is the collection of data items rather than the construction of particular measures using those data items that was critical in terms of feasibility and costs. Questions of collection of individual data items quickly focused on topics related to the HPMS data set, such as collection of detailed traffic counts for discrete time periods (5 minute or 15 minute increments), collection of speed data by direct

observation, the identification of truck percentages in the traffic stream (direct observation), and a limited set of other direct observation data.

Deliberations on appropriate methods to obtain the needed data at reasonable cost and quality for the HPMS became paramount. Also discussed were research efforts to better understand the magnitude and role of nonrecurring delay as part of total congestion and the effect of variations in speed and travel time on overall congestion estimates.

A number of other elements of congestion external to the traditional HPMS data set were identified and discussed as possible case studies or special research activities. Among these were monitoring of average trip lengths, monitoring of modal split trends, and measurement of public perceptions of congestion.

Within HPMS, it was clear that the focus was on obtaining more detailed data in certain areas and on overall quality improvement. It would be very costly and probably technically inappropriate to attempt to expand the reporting for all HPMS sections to obtain better congestion distribution data. An alternative proposal was developed by which a separate large scale sample of the automatic traffic recorder (ATR) data could be used to produce the kinds of relationships required. These ATR's would serve two purposes: on a representative sample basis, they would permit valuable data analyses of the many distributional questions about congestion patterns that had been raised; and they would also permit assessment of the further warrants for expanding data reporting for HPMS sample sections (see Appendix C).

A parallel effort would place emphasis on a national effort to improve the quality and accuracy of HPMS reporting. In a discussion of available data in the field, the point was raised that there was considerable variation in the availability of data useful to HPMS from State to State and area to area. Changes in data reporting should not wait until it was certain that the last State could comply. Just as it was inappropriate to expect all areas to be able to report a given data item because some areas were capable of doing it, it was also inappropriate to fail to obtain data that were available in many places because it was not uniformly available everywhere. An effective compromise process was proposed by two Group members that detailed data should be requested as part of regular HPMS reporting and that the data be provided if available. A stratified process was also proposed which suggests that more extensive reporting to be requested of larger urbanized areas. The detailed description of these data items is contained in the recommendations section of this report.

Improved HPMS Reporting

The Group turned its attention to the potential opportunities for improvement in the timeliness, level of detail, and quality of present levels of reporting HPMS data. Each of the items in the HPMS data set (see Appendix C) were considered and discussed, as necessary, to make recommendations on desired improvements. They are as follows:

- Expanded and improved FHWA and State oversight of data quality and evaluating procedures were crucial to an improved reporting process.

- In some cases, the need was for new procedures to improve reporting; in others, the need was for improved adherence to procedures.

- In many instances, reported items were not really "observed data" but rather calculated from relationships in the Highway Capacity Manual or other resources. These could be differentiated.

- Some States were going to more frequent update cycles of their traffic counts.

- Local governments had a great deal to contribute to the process in both data collected and more refined demand forecasts.

- An important issue is cost. More funds would enable more refined and more current data reporting.

A Congestion Index

The subject of developing a congestion index could only be briefly treated in the meeting. Drawing from previous comments throughout the meeting, the Group quickly agreed that a single "Index of Congestion" was infeasible and probably undesirable. A number of different conceptual perspectives of an index were developed. Examples include:

- A congestion index could be divided into system, economic, and individual utility components; the first reflecting highway system effects, the second the economic impacts, and the third, effects on individuals and their life-styles.

- Another stratification of congestion should emphasize the duration, breadth, and depth of congestion. Duration could be measured by the percentage of peak period travel with respect to total travel or by the number of 15-minute segments above a given LOS threshold. Breadth

would reflect the share of persons or vehicles affected as in percent VMT operating under conditions of delay. Depth would attempt to discriminate the intensity of congestion using average delay per capita and percentage of VMT with greater than "X" minutes delay.

- Another perspective divides the problem into four component elements: percent system affected, percent travel affected, percent of day affected, and intensity of delay.

- A similar conceptual approach emphasized system, trip-making, and socio-economic components. As a system measure, percent of lane at or below LOS "X" was mentioned. Trip making measures included average trip delay or percent VMT occurring at or below LOS "X." Among socio-economic measures mentioned were: delay/capita, or delay/person delayed as a measure of persons affected; Persons or Vehicles delayed more than 10 minutes; truck VMT at greater than LOS "X" or trucks delayed more than 10 minutes.

While no definitive picture could be developed in the time available, the Group sensed that further research would be very valuable in the above area recognizing that a single measure of congestion is often misleading, even propagandistic; whereas, a set of measures will provide a more balanced perspective. The Group made the following key observations/recommendations.

- No definitive single measure is desirable for expressing congestion.

- Any set of congestion measures will lead to extensive press scrutiny and possible misinterpretation. The generators of such an index will have to be prepared to fully describe and support their approach and products.

- Candidate measures must be carefully screened for their tendency to distort aspects of the problem.

Dissemination of Congestion Information

In the closing discussion, the Group pointed out that a great deal of excellent data on the congestion subject already existed within the FHWA statistical system. This information needed to be made more broadly available. Greater dissemination of congestion information was needed to the profession, public officials, the press, and the general public.

CLOSING

In closing, a number of thoughts were expressed that bear repetition:

- The Group had worked with great cooperation and effectiveness and had proven a substantial technical resource.

- An excellent start had been made in which the Group could take great pride, but a formidable quantity of work lay ahead in this subject area.

- As is so often the case, funding was identified as the prime constraint on the development of a viable national congestion monitoring. Technical and institutional issues also exist, but are surmountable with adequate resources.

- The current national focus on congestion and the present concern for new Federal-aid highway legislation have created an important opportunity for the development of better statistical systems. It was asserted that this will be the most significant time for transportation data development since the inception of the Interstate program in 1956, more than 30 years ago.

SECTION III

WORKING GROUP FINDINGS AND RECOMMENDATIONS

SCOPE

The Group felt that the HPMS provided an excellent base for the reporting of urban congestion information. Its greatest weakness in terms of scope is that some States only provide collective urbanized area monitoring and, therefore, individual urbanized areas are not reported separately. This will have to change if it is to be a viable and comprehensive system. A number of changes and enhancements to the HPMS are recommended, as follows, to assure a comprehensive monitoring of urban congestion and trends:

- Recommendation - An HPMS-based congestion monitoring activity for urbanized areas should be provided for reporting for individual urban areas above a threshold of 200,000 population. Monitoring of urban congestion must provide detail for all major urbanized areas nationwide. The States currently reporting aggregate urbanized area sample section data for the urbanized areas in their State should provide statistics for individual areas above 200,000 population.

- Recommendation - Current location and coverage of continuous traffic recorders in some states will need to be evaluated to determine the need for relocated or new sample points, particularly in urbanized areas.

- Recommendation - Urbanized area HPMS coding procedures should facilitate unique suburban analyses. The current five-level geographic division of the HPMS needs to be evaluated to establish the best structure for congestion and other suburban analyses.

While the Group recognized that it was outside of its scope to make detailed funding recommendations, over and over again, it identified the cost consequences of expanding the existing data set. State officials, in particular, pointed out the need for greater HPR and HPL resources to meet the expanded obligations of the States under these proposals.

DATA QUALITY

The Group established that changes in the quality of some HPMS reporting will be required to assure that congestion statistics are well founded and statistically valid. Discussion within the Group identified areas of concern regarding quality and developed

recommendations for improvements. In some cases, greater adherence to existing procedures was needed; in others, the need for new procedures was identified. For the most part, reporting of the physical characteristics of facilities was considered to be adequate. In measuring the dynamic elements in the HPMS, the key concerns were about differences between "data" that were estimated or developed from handbooks and data obtained by direct observation. Another key concern was the frequency with which directly observed measures are updated. Statistical measures of concern were road capacity calculations, traffic volume reporting, truck percentages, and K and D factor estimation. Costs and personnel resources become major factors in all of these areas, particularly in the most dynamic of these, traffic volume monitoring. The need for better traffic volume data was cited as also critically related to many other issues. It was noted that many management systems and Federal-aid apportionment formulae under consideration for future use were heavily reliant on current, accurate VMT data.

- Recommendation - FHWA and State oversight of HPMS data quality should be expanded and strengthened, especially at the field office level.

- Recommendation - Actual data based on direct observations rather than estimates should be employed to the extent practical for the data items that are critical to the quantification of congestion, e.g., AADT, K-factor, and truck percentages. Perhaps reported data entries on submissions could be identified whether the data are directly observed or are estimated by using default values.

- Recommendation - States should make greater use of data developed by local governments in their submissions. The urban focus of this program supports the need for a cooperative effort and strengthened relationships between States, metropolitan planning organizations (MPO's), and various local jurisdictions. This is particularly true for travel forecast data.

- Recommendation - New electronic technologies, including new automated signal control systems, can produce a wealth of traffic data. These data need to be retained and more fully utilized.

- Recommendation - More refined estimates of peak hour capacity should be developed and incorporated in HPMS reporting. These are needed to properly reflect the great variation in freeway and arterial street capacities, particularly arterial streets.

- Recommendation - More specific and direct measurement and reporting of truck percentages in the volume stream are needed for a number of important purposes, among which is congestion monitoring.

- Recommendation - A major concern, central to the HPMS, but not to present congestion monitoring, was expressed by some regarding the quality of 20-year forecast volumes. These detailed facility estimates need to be compatible with local planning process forecasts.

ENHANCEMENTS TO THE HPMS

It was recognized that to make all the desired additions to the HPMS is likely to be currently infeasible in terms of cost and manpower requirements. A two-part approach was developed to expand HPMS in the most cost-effective way and to use other means, consisting of making use of a nationally representative sample of ATR's, to gain more detailed traffic distribution information. With respect to changes in the HPMS traffic monitoring, it was observed that in many cases, excellent statistics are available on needed data items, although a few items may be only selectively available across the country. Use should be made of these data, even if standardized, uniform data reporting does not exist. Recognizing this, a program of data improvements, structured to utilize best available sources in the near term, while building toward better long term reporting, was supported by the Group.

- Recommendation - The need to recognize the greater passenger thruput capacity of HOV lanes was identified. The ability to represent this capability regarding capacity for special HOV lanes should be introduced as a part of the regular HPMS reporting process. This would involve greater manpower for data collection and editing.

- Recommendation - In support of better quality in forecasting and to provide a better link to ongoing programs, 5-year facility volume forecasts should be developed in addition to the existing 20 year forecasts.

- Recommendation - The direct measurement of speeds was deemed highly desirable to the validity of an overall congestion monitoring program. This was particularly a needed action where non-geometric improvements have been made.

- Recommendation - The Group recommended the following HPMS sample section data development program for large urbanized areas:

- Near Term
  - Identify the appropriate 24-hour traffic volume profile.
  - Report observed speed data, if available, or HCM speed/volume relationship.
  - Report vehicle occupancies, if available.
  - Report whether reported percent trucks is estimated or observed.

- LONG TERM
  - Report 24-hour volume count by 15-minute segments.
  - Report spot speed data for freeways.
  - Report vehicle occupancy, with emphasis on preferential corridors.
  - Report vehicle classification

DEVELOPMENT OF A NATIONAL SYSTEM SAMPLE

One of the central concerns of the Group was the need for better information about the temporal distribution of travel and the dimensions of congestion. To report the detailed distribution of all HPMS reporting segments was deemed inadvisable, given the lack of supporting research and analysis to justify such a large scale change. It was felt that the expanded use of the roughly 3000 ATR's around the country that are reported monthly to the FHWA represented a major resource that should be better utilized in national congestion monitoring. These systems could be used to establish better knowledge of the distributions of congestion nationwide. At least some ATR's will need to be capable of reporting traffic by 15-minute intervals to be fully effective. It is recognized that this quadruples the data output of these monitors with all the costs and increased staffing that entails.

- Recommendation - The national ATR data set should be statistically analyzed to assure that it is statistically sound, effective, representative, and useful in monitoring urban congestion. Long range reporting goals should include 15-minute reporting of volumes by vehicle type, stratified by functional system, suburb/central city and region. It is envisioned that FHWA would develop up to two dozen daily volume profiles that would be used

by State highway agencies to identify characteristic volume patterns on each arterial sample section.

- Recommendation - A large number of traffic volume distributional relationships need to be better quantified. In addition, trend measurement capabilities need to be established to permit long term monitoring of these distributional relationships, which include:
  - Peak hour to 24-hour relationships,
  - Peak hour to peak period relationships,
  - Peak period to 24-hour relationships,
  - K factor and other Nth hour trends,
  - D factor trends,
  - Traffic volume to 24-hour distribution patterns,
  - Volume/capacity to 24-hour distribution patterns,
  - Development of 24-hour travel distribution profiles,
  - Weekday and weekday/weekend trends, and
  - Development of traffic variability measures.

OTHER REQUIREMENTS

Although the HPMS was identified as the centerpiece of a national urban congestion reporting, it was recognized that there were other elements of the congestion picture that needed measurement, monitoring and reporting that may not be within the scope of the HPMS. Some of these elements would be useful to expand the capability of the HPMS-based process, such as data on auto occupancy, speed/travel time, system reliability /variability, and nonrecurring congestion patterns. Others would permit a broader understanding of the meaning of congestion and its consequences, such as travel time monitoring, modal split changes, average trip lengths, travel avoidance behavior, and changes in access to land use opportunities.

To achieve these purposes, a family of activities would need to be staffed and funded, including case studies, special data collection efforts, and research projects. The following are separated into a priority group of measures critical to near term effective congestion monitoring; a secondary group will provide valuable insights into better understanding of congestion characteristics and effects, but that is not crucial to near term congestion monitoring. Priority items are viewed as having high payoff in the near term, while secondary items will often require more extensive long term developmental research.

Priority

- Recommendation - National travel time data are required to permit trend analysis of travel times by urban area groups. A number of possible methods are available for consideration and a number of metropolitan areas/cities do conduct frequent travel time surveys. These could be identified and synthesized in a TRB synthesis-type project. A more uniform and rigorous random sampling method could be developed to obtain comparable travel time runs by major cities to be repeated annually for trend and intercity comparison purposes. An option would include examining specific generic corridors for their travel time trend patterns, e.g., city hall to the airport or once around a beltway. An ideal system would monitor average travel times by the major flow patterns, suburb to center city, center city to center city, etc. The design, synthesis, and development of collection techniques are viewed as priority items.

- Recommendation - Changes in the average vehicle occupancy rate are occurring, with significant impact on congestion. Currently, average occupancy figures are available for work trips only every 10 years from the decennial census, or for all trips from the NPTS conducted occasionally on a sample basis. These survey approaches are not capable of providing facility specific data. Research is needed to develop low cost observation techniques to produce current, facility-specific estimates of average vehicle occupancies. This is particularly important to the monitoring of HOV facilities.

- Recommendation - The impact of nonrecurring causes of delay, i.e., accidents, breakdowns, in overall congestion is unclear. Estimates of the share of the problem represented by these events vary dramatically. Research is needed to assess and quantify the relationship between recurring and nonrecurring contributions to delay. The effects of construction delay are also a part of this issue and need to be assessed as part of this research.

- Recommendation - New electronic systems have the potential to improve the quality and cost-effectiveness of congestion-related data. These may include new traffic signal devices that sense traffic changes, IVHS concepts, satellite and radio tracking devices, etc. These new tools should be assessed in a research effort to determine their potential contribution to improved, more rapid, lower cost data collection.

Secondary

- Recommendation - One of the keys to the future development of congestion is the set of changes occurring in patterns of average trip length. Many different forces

are acting on the determinants of trip length, pulling them in opposite directions, causing volatile changes, although only limited data are available to confirm these trends. Current data permit only limited insight into trip length trends based on very infrequently conducted surveys. The most recent nationally representative data are from the 1983 NPTS, and new data is expected from the current survey. Research is required on means of obtaining reliable trend monitoring data at low cost.

- Recommendation - In addition to overall increases in travel time, congestion also contributes to lack of reliability in travel times. Increased variance in average travel times may have as significant an economic effect as does actual increases in travel time. Variance trends in travel time need to be obtained by monitoring processes to establish whether variance is increasing for a nationally representative sample of areas and facility types. Complimentary research on the economic effects of changing variability/reliability is required.

- Recommendation - Just as lack of travel time reliability caused by prospective delay can induce costs, even when traffic is uncongested, so too can costs and lost opportunities be generated by trips that are diverted from a preferred time and place, or even completely discouraged from occurring because of prospective congestion. This is among the most difficult of consequences of congestion to assess. Just as the population discouraged from actively seeking work is a key element in assessing the unemployment condition of the country, so may discouraged travelers be a key economic indicator of the cost consequences of congestion. A small investigatory research effort into innovative ways of assessing the scale and implications of travel diversion and discouragement is needed. This may be critical to the appropriate assessment of congestion management strategies.

- Recommendation - Broader treatment of congestion issues will require a multi-modal perspective. At a minimum, this will require the development of viable modal shares data for nationally representative areas. Modal shares are now obtained infrequently by expensive survey approaches. Mechanisms to obtain at least broad annual estimates need to be researched and undertaken.

- Recommendation - Ultimately, the product of congestion is changes in access to opportunities afforded by the transportation system. A long term research effort into meaningful measurement and monitoring of access to opportunities needs to be undertaken. The use of isochronal mapping has been productive in this area.

- Recommendation - A significant factor to be considered in the public policy treatment of congestion is that the

public does not react to congestion in uniform ways, i.e., to the public, not all minutes of congestion are equal. Public perceptions of congestion and delay and their effects need to be better understood. Attitudinal charting of individual reactions to various kinds, conditions, and extent of delay is required to assess the behavioral responses of various groups to congestion. The mapping of the relationship of public tolerance of delay to engineering measures of system performance is required to permit assessment of likely forms and degrees of public acceptance and reaction. A synthesis project could be effective here.

- Recommendation - Mapping display techniques are a very effective tool in presenting meaningful descriptions of congestion for policy and public information uses. These tools need to be expanded in their applications to congestion display. Applications research is required on enhanced systems of display and presentation.

TOWARD AN INDEX OF CONGESTION

The Group was only able to develop the beginning outlines of a possible index or family of indexes of congestion in the time available. The view was that a system of indexes representing congestion would be highly desirable and research to this goal was an important next step. It was also noted that the subject of construction of indexes was distinct from the present concerns regarding data collection requirements. It was felt that the Group had identified the major data to be collected from which all significant indexes would derive.

- Recommendation - The Group asserted its view that no single measure could provide a useful index of congestion. All efforts in this area must focus on developing a family of indexes to cover the range of the topic.

- Recommendation - An index system must relate to congestion in terms of:

  - The absolute/relative shares of the road system affected,

  - The absolute/relative shares of total travel affected,

  - The absolute/relative shares of persons/vehicles affected,

  - The absolute/relative shares of travel time affected, and

  - The intensity, breadth and distribution of delay.

- Recommendation - An index system must be structured to provide both temporal and spatial measures of congestion to monitor trends in a given area over time and to permit geographic comparisons between areas of interest.

- Recommendation - Measures of congestion and other congestion statistics must be developed so that the general public can understand them and are informed by them. An active program of public dissemination of statistical trends and research findings is crucial to a successful program.

APPENDIX A

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APPENDIX B

FHWA'S PERMANENT TRAFFIC COUNTER DATA BASE

Permanent traffic counters have been in operation in the States for over 50 years. The basic purpose of these counters has been to establish traffic variation over time, maintain traffic trends, and estimate a variety of traffic factors used in traffic engineering and planning. The counters, often referred to as automatic traffic recorders (ATR's), are intended to provide continuous count information for all hours of the year.

Data from most but not all the State counters are available in the FHWA database and are potentially available for analysis. The permanent counters are concentrated on arterial roads in rural areas, as shown in the following table:

Functional Class	Number of Locations	
Rural Interstate	465	
Rural Other Principal Arterial	771	
Rural Minor Arterial	546	
Rural Major Collector	206	
Rural Minor Collector	32	
Rural Local	37	
Rural Subtotal		2,159
Urban Interstate	324	
Urban Other Freeway & Expressway	112	
Urban Other Principal Arterial	328	
Urban Minor Arterial	175	
Urban Collector	53	
Urban Local	29	
Urban Subtotal		1,021
Grand Total		3,180

Many of the locations include more than one counter and can provide information by direction of travel and lane. The 3,180 locations are supported by 4,795 individual counters. The number of existing locations in the States range from 6 in Hawaii to 152 in Texas.

The State ATR programs are developed independently in each of the individual States to address specific management needs for traffic information. As such, States developed their ATR programs to capture the needed data using the methods they felt were most efficient. Many of the sites selected were based not on a rigorous statistical design but rather on the need for data perceived by a senior traffic engineer. Many sites were chosen because they were assumed to carry a significant portion of the travel in the State (i.e., a major farm-to-market route), or because the travel occurred in an area of special interest to the State (i.e., industrial area, high tourist travel, or the State line).

The current coverage of the Interstate System typifies the types of influences identified above. The 1988 Highway Statistics shows 33,303 Rural miles and 11,326 Urban miles in the Interstate System.

Similarly, the Rural Interstate carries 41% of the Interstate VMT and the urban carries 59%. The ATR report shows 465 locations (one for every 72 miles) in the Rural and 324 locations (one for every 35 miles) in the Urban Interstate, corresponding to 59% rural and 41% urban. The system representation characteristics are summarized in the following tabulation:

Interstate System Rural/Urban Representation

	Rural	Urban
Mileage	33,303 (75%)	11,326 (25%)
VMT (millions-1988)	181,284 (41%)	258,662 (59%)
ATR locations	465 (59%)	324 (41%)

The above information indicates that the Interstate ATR's are not representative of rural/urban mileage or VMT, but rather reflect both system extent and travel.

The FHWA has for many years received the hourly data collected by the States at their permanent traffic counters. This data has been archived on a monthly basis. The information is used to prepare a monthly traffic trends report which is widely distributed. Many States also prepare periodic reports which are used to provide information for internal programs.

The ATR data processing system is undergoing major changes intended to update the processing, convert to a microcomputer operation, and increase the analytical accessibility to the data.

Data from previous years (as far back as 1975) is available, but storage is by State file by year using the FHWA format. Recently, efforts to implement a national standardized format (for use by the States, FHWA, and the SHRP program) were initiated. The lack of a standardized national master files structure for present and earlier data means that analysis requires extensive data processing support. The data have been used for a number of in-house analyses. For example, an Office of Highway Information Management report titled "Analysis of National and Regional Travel Trends" used this data to show traffic patterns by region of the country, time of day, day of week and urban versus rural.

The ATR database contains extensive information that can be of use in establishing urban travel patterns or congestion trends. Data from each State is available and can be used to conduct national, regional, State, or individual area analyses as long as sufficient locations are available. Since hourly data are available for most locations, a clear examination of traffic patterns at urban locations is possible. For some of the locations, data has been collected for many years, thereby, providing historical traffic patterns with the corresponding assessment of growth or changes over time.

The major weakness of the ATR database is the lack of statistical control over the number or location of ATR sites since, as discussed above, these have been installed over many years according to the specific needs of each State. The FHWA ATR

program collects available State data on a somewhat voluntary basis without any significant control over the existing State permanent counter programs. The end result is that national analyses must consider the implication of adequate representation and the availability of sufficient locations to support inference.

Another weakness of the database is the historical propensity of some States to impute missing data based on subjective or historical assessments without keeping track of estimates generated. Missing data is a major problem caused by equipment or detector loop failure due to old age, weather, pavement deterioration, accidents, construction, maintenance, etc. Many States are becoming more aware of this problem and are beginning to flag estimates to allow a better assessment of actual data versus estimated data.

In the last few years, as a result of the FHWA's Traffic Monitoring Guide, many States have conducted analyses of the ATR systems. These have resulted in changes to improve statistical representation including the addition of locations in urban areas and lower functional systems. Likewise, ongoing efforts to address the estimation of traffic in high volume roads using ramp counts will necessitate the installation of additional ATR sites in most urban areas.

Examples of the type of analyses that may be possible using the ATR data include:

1) Day-of-week assessment of traffic and peak-hour patterns by type of road, urban area, State, region, or the Nation.

2) Historical tracking of traffic growth or changes over time.

3) Examination of peak-period pattern changes over time and recurring annual patterns over the seasons or months of the year.

4) Comparison of traffic pattern differences by location, system, area, State, or region.

These examples are not intended to be all-inclusive and other uses are anticipated.

APPENDIX C

HPMS DATA ITEMS

Universe Data

Item No.	Pos	Len	Required Universe Items			Data Item
			Int	Sam	All	
						Identification
1	1-100	100				State Control Field
2	101-102	2	X	X	X	Year
3	103-104	2	X	X	X	State code
4	105-107	3	X	X	X	County code
5	108	1	X	X	X	Rural/Urban Designation
6	109-113	5	X	X	X	Urbanized Area Code
7	114	1	X	X	X	Type of Section/Grouped Data
8	115-126	12	X	X	X	Section/Grouped Data Identification
						System
9	127-128	2	X	X	X	Functional System
10	129	1	X	X	X	Generated Functional System Code
11	130	1	X	X	X	Federal-aid System
12	131	1	X	X	X	Federal-aid System Status
13	132	1	X			Route Signing
14	133-137	5	X			Route Number
						Jurisdiction
15	138-139	2	X	X	X	Governmental Level of Control
16	140-141	2	X	X	X	Special Systems
						Operation
17	142	1	X	X	X	Type of Facility
18	143	1	X	X	X	Designated Truck Route/Parkway
19	144	1	X	X	X	Toll
						Other
20	145-150	6	X	X	X	Section/Group Length
21	151-156	6	X	X		AADT
22	157-158	2	X	X		Number of Through Lanes
23	159-163	5	X	X	X	Record Continuation Code

Sample Data

Item No.	Pos	Len	<------ Required Sample Items ----------> <------ Rural -----> Int	OPA	MA	MaC	MiC	<------ Urban -----> Int	OFE	OPA	MA	Col	Data Item
24	164-175	12	X	X	X	X	X	X	X	X	X	X	Sample Number
25	176	1	X	X	X	X	X	X	X	X	X	X	Sample Subdivision
													Identification Computational
26	177-178	2	X	X	X	X	X	X	X	X	X	X	AADT Volume Group Identifier
27	179-184	6	X	X	X	X	X	X	X	X	X	X	Expansion Factor
													Pavement
28	185-186	2	X	X	X	X	X	X	X	X	X	X	Surface/ Pavement Type
29	187-188	2	X	X				X	X	X			Concrete Joint Spacing
30	189	1	X	X				X	X	X			Load Transfer Devices
31	190	1	X	X	X	X	X	X	X	X	X	X	Pavement Section
32	191-192	2	X	X				X	X	X			SN or D
33	193	1	X	X				X	X	X			Type of Base
34	194	1	X	X				X	X	X			Type of Subgrade
35	195	1	X	X				X	X	X			Subsurface Drainage
36	196-198	3	X	X	X			X	X				Measured Roughness
37	199-210	12											Reserved - Federal
38	211-212	2	X	X	X	X	X	X	X	X	X	X	PSR
39	213-215	3	X	X	X	X	X	X	X	X	X	X	Overlay or Pavement Thickness
													Improvements
40	216-219	4	X	X	X	X	X	X	X	X	X	X	Year of Surface Improvement
41	220-221	2	X	X	X	X	X	X	X	X	X	X	Type of Improvement

Sample Data (Cont.)

Item No.	Pos	Len	Required Sample Items: Rural Int	Rural OPA	Rural MA	Rural MaC	Rural MiC	Urban Int	Urban OFE	Urban OPA	Urban MA	Urban Col	Data Item
													Geometrics
42	222	1	X	X	X	X	X	X	X	X	X	X	Access Control
43	223-224	2	X	X	X	X	X	X	X	X	X	X	Lane Width
44	225	1	X	X	X	X	X	X	X	X	X	X	Shoulder Type
45	226-229	4	X	X	X	X	X	X	X	X	X	X	Shoulder Width
46	230	1	X	X	X	X	X	X	X	X	X	X	Median Type
47	231-232	2	X	X	X	X	X	X	X	X	X	X	Median Width
48	233-235	3	X	X	X	X	X	X	X	X	X	X	ROW Width
49	236	1	X	X	X	X	X	X	X	X	X	X	Widening Feasibility
50	237	1				X	X						Horz. Align. Adeq.
51	238-328	91	X	X	X			X	X	X			Curves by Class
52	329	1				X	X						Vert. Align. Adeq.
53	330-371	42	X	X	X			X	X	X			Grades by Class
54	372-374	3	X	X	X	X	X						% Passing Sight Distance
													Traffic/Capacity
55	375-376	2	X	X	X	X	X	X	X	X	X	X	Speed Limit
56	377-378	2				X	X						Wtd. Des. Speed (calculated)
57	379-382	4	X	X	X	X	X	X	X	X	X	X	Percent Commercial Vehicles
58	383-384	2	X	X	X	X	X	X	X	X	X	X	K-Factor
59	385-387	3	X	X	X	X	X	X	X	X	X	X	Dir. Factor
60	388-392	5						X	X	X	X	X	Peak Capacity
61	393-395	3	X	X	X	X	X	X	X	X	X	X	V/SF Ratio (calculated)
62	396-397	2						X	X	X	X	X	Turning Lanes
63	398	1						X	X	X	X	X	Signalization
64	399-400	2						X	X	X	X	X	% Green Time
65	401	1						X	X	X	X	X	Peak Parking
66	402-407	6	X	X	X	X	X	X	X	X	X	X	Future AADT
67	408-409	2	X	X	X	X	X	X	X	X	X	X	Future AADT Year

Sample Data (Cont.)

Item No.	Pos	Len	<------ Required Sample Items ---------> <----- Rural -----> Int	OPA	MA	MaC	MiC	<----- Urban -----> Int	OFE	OPA	MA	Col	Data Item
													Environment
68	410-411	2	X	X	X	X	X	X	X	X	X	X	Climate Zone
69	412	1	X	X	X	X	X	X	X	X	X	X	Drainage Adeq.
70	413	1	X	X	X	X	X						Type of Terrain
71	414	1	X	X	X	X	X						Type of Development
72	415	1						X	X	X	X	X	Urban Location
73	416-417	2	X	X	X	X	X	X	X	X	X	X	# Grade Sep. Interchanges
74	418-423	6	X	X	X	X	X	X	X	X	X	X	# At-Grade Intersections
75	424-425	2	X	X	X	X	X	X	X	X	X	X	# Structures
76	426-427	2	X	X	X	X	X	X	X	X	X	X	# At-Grade RR Crossings
													Supplemental
77	--varies--		X	X	X	X	X	X	X	X	X	X	Structure ID's
78	--varies--		X	X	X	X	X	X	X	X	X	X	At-Grade RR Crossing ID's