Enhancing Arizona Department of Transportation's Traffic Data Resource:

FINAL REPORT 492

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16. Abstract

The Arizona Department of Transportation(ADOT) undertook a review and evaluation of the technologies used by the agency to process, store, manage, and disseminate traffic data. Traffic Count Information constitutes the most elemental data that ADOT uses for planning, analysis and monitoring, and yet often remains the least accessible within the agency. ADOT found that different functional departments often duplicated traffic counts, count information was often little understood, and hence not trusted, and consistent data was not accessible throughout ADOT –there was not a single source where traffic data was collected and disseminated. Through the research ADOT identified a hierarchy of actions designed to more effectively manage this most basic resource, and to restore confidence among users. An implementation plan was developed and is now being acted upon within the department

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

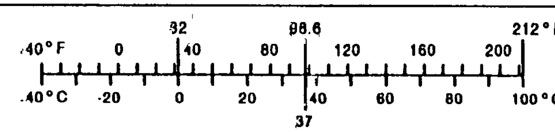
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Arizona is experiencing significant growth that is impacting transportation infrastructure, and leading to increased levels of congestion. To understand these impacts, the Arizona Department of Transportation (ADOT) and other jurisdictions rely upon field collected traffic data to monitor increases in congestion, and to plan for future improvements. Traffic data is a critical basic requirement for ADOT to meet its responsibilities for planning, building, operating, and maintaining a statewide highway system. This data is used by ADOT for specific traffic studies, roadway and bridge design, traffic forecasting, project prioritization, congestion management, air quality analysis, and many other purposes.

The demand for such data has increased while funding availability for collection has been reduced, prompting agencies such as ADOT to more closely investigate the acquisition, use, and sharing of such data. Because large amounts of data are currently collected throughout the state, it is desirable to coordinate these activities to reduce redundancies, increase data consistencies, and leverage the benefits of the current and future data that must be maintained.

In order to meet the growing demand for traffic data to assess the need for both operational and capital improvements, many states have begun, or are planning to implement traffic-related data systems centered on data from a variety of sources. Timely access to up-to-date and accurate traffic-related information collected by various agencies, and the ability to report, communicate and share this information, is an important aspect of ADOT's business and is ***vital for the prudent allocation of resources and the optimization of transportation infrastructure and services. Inaccurate or inadequate data leads to poor planning, design, system performance, and increased costs.***

Recognizing the critical nature of traffic data and the importance of acquiring and sharing this resource, the Vision 21 Task Force has recommended the development and adoption of transportation data collection and reporting standards and methodologies. Traffic data related standards and procedures and specifically recommended and outlined in this report.

PURPOSE OF PROJECT

This study was undertaken to assess and inventory ADOT's traffic data needs, identify and document statewide sources of traffic data, and to review and evaluate the technologies used by ADOT to process, store, manage, and disseminate disparate traffic data across the agency. To assist ADOT in this overall assessment, best practices from around the nation with respect to traffic data management systems are also reviewed.

A primary objective of this study is to identify issues and impediments to efficiently collecting, managing, and providing access to ADOT's vast traffic data resources. As a result, this study contains a set of recommendations along with an implementation plan designed to systematically address these issues. The objective of these recommendations is to bring together disparate working groups within ADOT, establish consistent standards and procedures, and bring about the phased development of information solutions to integrate, manage, and disseminate accurate and consistent traffic data across the agency and throughout the state. A comprehensive Implementation Plan is included in this project report

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SUMMARY RESEARCH FINDINGS

Accurate and reliable traffic data are essential to a variety of transportation applications, as well as legislative and administrative policy development. Traffic data constitute important components of the decision-making processes for administering the State's highway system. ***There should be a single focal point within ADOT to coordinate and administer all data collection, processing, and dissemination efforts throughout the Department.***

- **Based on the traffic data currently available, the agency may not have adequate information to determine these transportation needs with confidence. The Data Team, as the primary data provider, can not meet all of the Department's diverse needs with the staff and budget resources currently provided to them;**
- **Traffic data currently available to users within and outside of ADOT are perceived with a lack of confidence, especially in regards to the accuracy of available data. Current data collection and dissemination efforts are viewed as not being responsive enough, or accurate enough from the data user's perspective. This has led to disjointed data collection efforts within the organization, and amongst agencies.**
- **Data that is collected is not being highly utilized or disseminated as widely as is needed. Data resources could provide more value to the Department if they were more accurate, better understood by potential users, and made available to users across the Department.**

ADOT is currently collecting the types of data that are needed to meet its mission. However, the quality and quantity of the data collected should be improved to support critical decisions about developing, operating, and maintaining the State's transportation system. Other states collect no additional. Efforts are focused to provide quality data meeting standards for accuracy, frequency of collection, coverage, completeness, and documentation, etc., as established by the agencies in order to adequately perform their functions. Also, in other states, efforts have been made, or are underway, to increase users' accessibility to the data resources. Accessibility to quality data is critical for making decisions about allocating scarce resources.

The following sections of this report describe some of the deficiencies regarding traffic-related data at ADOT, and their causes.

Insufficient Resources

While the demand for statewide traffic data is continuously increasing, the personnel and budget resources available to collect, analyze, and disseminate the data have been substantially reduced. Data collection efforts remain close to (if not below) the minimum level necessary to meet the basic, immediate data needs of the Department and to address primary state and federal requirements. The ADOT Data Team's ten staff members currently administer the following data collection and data assembling efforts:

- Highway Performance Monitoring System and reporting to FHWA.
- Traffic count programs to determine traffic volumes, vehicle classifications, and weights.
- Video-log inventory of State Highway System (digital photographs of entire highway system) and acquisition of location data using GPS.
- Data processing and dissemination to provide correctly factored and appropriate data to users throughout the state.
- And others

Over the years, Data Team staffing has been reduced by 62%, from 26 to 10 staff. Only five of these staff members support traffic data acquisition, recorder maintenance, data processing and dissemination. Contractors and consultants supplement in-house capabilities when feasible.

➢ **With the current levels of resources dedicated to traffic data, the Data Team can only meet the basic requirements for the Highway Performance Monitoring System (HPMS).**

The lack of resources carries over to the maintenance of equipment required for traffic monitoring. To provide timely data of sufficient accuracy, ADOT must ensure that appropriate traffic collection equipment is available, continuously maintained in good working order, and calibrated to provide accurate results.

It has been reported that only 50% of the Freeway Monitoring System traffic sensors are likely to be operational at a given time. As another example, about 90% of the automatic traffic recorders (ATRs) used to collect data for the HPMS fail at least once each year. This failure rate is in part attributed to the lack of resources for ongoing maintenance. Due to this lack of resources, no maintenance schedule has been established, rather, the Data Team conducts maintenance in a reactive mode – as sites fail, they are visited, fixed, and maintenance is performed at that time.

Equipment failures or malfunctions can result in invalid data values that are not always identified and removed from the data product provided to the end user. In addition to these errors, data can be recorded during collection activities that are impacted by accidents, weather, special events, and construction activities, etc.

When reflected in data products, these erroneous data cause skepticism among users. If a user does not trust data that is provided by another source, he or she may be tempted to perform additional, redundant data collection at additional cost.

- **Inadequate and erroneous data due to equipment failures will continue as a problem until additional staff and financial resources are available to support adequate maintenance.**

Planning Vs Engineering Data

For the majority of ADOT's needs, a small number of data elements are sufficient - the most often requested include: average annual daily traffic (AADT), % traveling in the peak hour (K-Factor), % traveling in the peak hour direction (D-Factor), and number of trucks (T-Factor).

- **These constitute the most frequently requested traffic data items, and for these, the Data Team does a reasonably good job of data collection, given the limitations already cited. It is important to acknowledge their good efforts given considerable resource constraints.**

These data elements are often not sufficient for the more detailed requirements of some of the engineering groups, and for use in Design Concept Reports (DCR), or Operational Analysis and Signal Needs studies. In many traffic engineering studies for example, turning movement counts are required for intersection design or signal phasing. For "Warrants for Traffic Signals" for example, traffic count data on specific localities are needed. For these types of studies, the data provided through the traffic monitoring system does not provide enough accuracy and detail, or may be completely lacking.

Additional data elements required by the Traffic Engineering Group include speed, sub-hourly variations, turning movements, approach volumes and stopped time delay, among others. Because most of these data elements are not provided through the Data Team collection efforts, the Traffic Engineering Group specifically collects them for their own purposes. Once collected this information is rarely made available to others at ADOT, and as a result, few staff will even know of the existence of such underutilized resources.

This creates two separate problems. In the first instance, the Data Team is not viewed as sufficiently responsive to the traffic data needs of other groups, and often the aggregate data that they collect for purposes of statewide monitoring and reporting are compared to the more detailed counts collected by the engineering consultants. Secondly, such comparisons often lead to discrepancies, which are driven more by the different methodologies used for collection and generalization, than by any underlying accuracy considerations. The result is the same in both cases: perceptions of unresponsiveness and distrust of the underlying data collected by the Data Team.

These issues are likely to be inevitable given the resource constraints of the Data Team and are compounded by the relative lack of published standards.

Lack of Formally Published Standards

Currently there are no uniform standards across ADOT for traffic counting, factoring, and adjusting of raw data. While the Data Team's collection efforts conform to standards set forth in the FHWA Traffic Monitoring Guide (TMG) for the statewide traffic monitoring program, they have not published their methodologies for expansion, factoring, or normalization. As a result, some users are not aware of these basic details, and this lack of knowledge also leads to some distrust of the data.

In addition, there are no uniform standards for the special collection efforts that occur for Small Area Transportation Studies, Corridor Analyses, Design Concept Reports, etc. Data from special collection efforts have been used in conjunction with data from the traffic monitoring program. This can create a situation where dissimilar data are combined. Traffic data meant to represent uniform conditions across a broad area are sometimes derived from specific studies that may have employed different standards and procedures. Although tolerated, this problem has been a concern among those who use traffic data for decision support.

- **Developing and encouraging standard practices in traffic data collection and processing, and making this information available to data users, will lead to improved consistency and confidence, and facilitate the proper use of data for multiple purposes across the agency.**

In order to correctly employ available data, data users often need to judge the quality of data, its appropriateness for their application, and then relate the sensitivity of decisions to the quality of the data. To meet these needs, users must have access to pertinent information about the data. This information might include a description of the equipment used to collect the data, the time period over which the data were collected, the analysis methods used, and the accuracy of the estimate, and adjustments made, if any. The provision of such information is known as "truth-in-data".

- **Truth-in-data should be a standard requirement for every data collection effort sponsored by ADOT. Although not all data users wish to be bothered with such information, such data and standards should always be accessible to them and required of them.**

Additionally, because data for special studies are often collected by consultants, it is often unclear what methodologies were used to collect the data, how well collection devices were calibrated, or how the data was factored or adjusted. This constitutes another area where uniform standards are required.

A set of standards for collection methodologies and data documentation will help build confidence and ensure consistency in the data used throughout ADOT. This, in turn, will help make each data element usable to a wider range of traffic data users. Standards in methodologies should include the requirement to use competent and experienced data collection services, well calibrated, maintained, and properly applied equipment, and the provision of full documentation of the procedures used and any adjustments made to the raw data.

The implementation of such standards will require extra effort in administering data collection activities, which will be offset with more useful, more accurate, and more widely accessible data resources. Implementing standards for collection methodologies and documentation will ultimately add value to the data, and thus the planning and decision-making processes.

Distrust Of Data

Because of the lack of widely accepted and published standards, there is some distrust of available traffic data. This ***distrust can usually be traced to either users lack of awareness or understanding, or disapproval of the methods used to obtain or adjust the data.*** Additionally, traffic counts collected for widely different purposes, employing different methodologies, are often compared. Because errors or inconsistencies are then found, the fundamental accuracy of all data is questioned.

Because of the low levels of maintenance on the count equipment, data errors are likely to be included in not only the raw data, but may make their way into various data products and reports. Published practices for identifying errors and anomalies should be developed, along with base data integrity standards.

This is perhaps one of the most significant concerns expressed by users. The availability of data is not so great a concern to the users as the quality and validity of the data provided. The distrust of the data leads in certain instances to redundant data collection efforts by various user groups. These different collection efforts may employ different methodologies for collecting, factoring and projecting the data, which leads to data inconsistencies throughout ADOT.

- **The use of consistent standards and methodologies, together with base data integrity standards will go a long way to resolving these issues. This combined with some level of technical assistance to the data users, to help them understand how different data should be used and interpreted, would also prove helpful and valuable, as would a campaign to educate data users about the data, its collection and processing.**

Uneven Access / Redundant Collection

Various data are collected by a variety of ADOT groups and other agencies for a multitude of purposes. Some data are widely used, while others are used only for specific purposes. Many of these collection and processing efforts are not coordinated between the various groups and sections. As a result, many potential data users are unaware of the various collection activities and are not able to identify all existing sources of available data. This can lead to redundant collection efforts and does not promote the use of existing data resources, even when they might be suited to the particular purpose.

There is no mechanism within ADOT to coordinate the various traffic count activities, and thus to avoid the possible duplication of effort. ***Traffic-count activities are widely distributed within ADOT and there is a lack of internal coordination.***

Various divisions and groups are conducting efforts of general interest and wide applicability without the participation, and sometimes without the knowledge of others in the Department (see the Data Collection Efforts section of this report).

In most cases, data generated by specific data collection efforts are not published or disseminated to potential users. The data may be presented in a report, but is unknown to most traffic data users. ***Aside from the data provided by the Data Team, there is a general lack of awareness of what data is available. This condition leads to the duplication of traffic data collection.***

It is believed that a more team-oriented approach could resolve many of these issues at ADOT. Critical aspects of successful agency-wide data coordination will be education and understanding. One way of ensuring these issues are addressed would be to involve members from each interested ADOT group in data planning, collection, and processing activities on an infrequent basis. For example, a member of the Traffic Engineering Group might be assigned to work with the Data Team one day a month. This will facilitate knowledge transfer and an understanding of the data and issues faced in its collection and maintenance. The project Technical Advisory Committee supports such an interdisciplinary approach to internal coordination.

SUMMARY RECOMMENDATIONS

It must be acknowledged that traffic data is a major input for planning and conducting the maintenance, operation, and construction of the State Highway System and as such, has implications for the efficiency and safety of the system. The latest construction program allocates $2.7 billion to the preservation, improvement, and management of the system over the next five years. The selection of individual projects is often based on available traffic data. The impacts of insufficient traffic data on the long-term administration of the State Highway System must be recognized and resources allocated to provide adequate and accurate traffic data, upon which to base these important decisions. To support this goal, a number of recommendations have been developed as a result of this study.

The first recommendation concerns the reorientation of the Traffic Data Collection efforts at ADOT and the allocation of adequate resources. Drawing from the Manitoba Highway Traffic Information System, four information delivery principles are critical to ensuring an effective traffic monitoring program, as outlined in Table 1.1. The system must: be user responsive and user driven; exercise truth in data; follow consistent standards and practice; and, follow base data integrity practices. Additionally, data users should be provided more education about the data resources.

Table 1.1. Information Delivery Principles

Responsive to need	Provide information required by users; Follow convenient, easy to use format that meets users' needs;

	Handle request for information quickly; Provide timely information.
Truth in data	Document and disclose methods used for data sampling and expansion; Describe the methods used to collect and process the information presented; Provide estimates of the accuracy of all statistics.
Consistent practice	Adopt standard methods or press for standards to be established; Conform to standard practice (AASHTO, ASTM, FHWA).
Base data integrity	Screen data for errors and anomalies; Data must be accepted or rejected but not adjusted.

Source: *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation: A Case Study* [10]

Being responsive to users' needs is the first tenet of information delivery. There was a frequent perception among those interviewed that the Data Team was not responsive enough to the users needs. This may be understandable given the staffing shortages, and the common feeling that the Data Team's primary mission is the collection of data for mandatory federal reporting programs.

On the other hand, for ADOT's traffic monitoring system to succeed, there must be a fundamental shift in orientation, one that is directed to the end user's needs. This is what Manitoba refers to as the Information Delivery Principle: the most critical component of the system is the information delivery to the users and that the whole system must be user driven. This entails that all reports produced by the Data Team must meet the user's needs and requirements, be easily accessible to all users, be in an easy to use format, and be available in a timely manner.

The second component of information delivery is truth-in-data, which focuses the definition and provision of information about data collected, such as date, time, conditions, equipment, procedures, adjustments, formats, etc. This meta-data is required for the appropriate use of the traffic data. In too many cases, traffic data has been incorrectly used or not well understood, which has led to mistrust of the basic data.

The third component is the establishment of consistent practice throughout ADOT. There are several reference guides that define standard practice, such as the federal Traffic Monitoring Guide and those by AASHTO and ASTM, and these standards should be formally adopted and required. An agency-wide consensus should be achieved on standards, and they should be widely published, adopted, and adhered to.

Finally, base data integrity should be implemented, assuring users of the validity of the received information. This means that missing or inaccurate data should not be completed, filled-in, or replaced for any type of traffic measurement.

A set of well-defined principles can improve data collection efforts. Responsiveness to user needs, the principle of Truth-in-Data, consistent practice, and base data integrity should be implemented to improve the traffic data collection program and its resulting data**.** ***However, the implementation of such principles requires commitments of more resources than are currently made available.***

2) **The second major recommendation of this study concerns the need for greater centralization of all data collection, processing, storage, and reporting activities, possibly within one group.** At a minimum, there needs to be centralized coordination of these activities.

In addition to the Data Team, there currently are other groups within ADOT and their contractors that conduct traffic data collection activities, including Transportation Planning, Traffic Engineering, Transportation Technology Group, ATRC, and others. Given this distributed institutional structure, overall coordination is difficult, and implementation of consistent standards is a challenge. At a minimum, this requires much greater coordination among these groups, and greater consideration of the methods by which ADOT disseminates information. A central focal point should be established to schedule, administer, and process traffic counts, to assist data users with technical questions, send requested information, and service all information requests from staff, engineering consultants, and the general public.

3) **The third major recommendation is that ADOT pursue a more integrated traffic data solution t**o provide a traffic monitoring system that more readily supports data sharing throughout ADOT, provides efficient processing, flexible reporting, and a map-based interface. It is recommended that ADOT consider specifying and implementing a more integrated solution. This solution should include a more open and optimized database, count scheduling and work order monitoring functionality, spatial content, and a map-based user interface for query, display and reporting. ADOT's existing system, known as TRADAS (Traffic Data System) does not currently meet the agencies' needs in these areas. The spatial data by any such system should be based upon ADOT's ATIS Roads street centerline standard from the Arizona Transportation Information System.

Currently, a Data Team staff member manually plans traffic counts as well as maintenance without benefit of a formal scheduling or tracking system. This is less than efficient, and important experience and information will be lost when this knowledge worker leaves ADOT. A number of other states have implemented integrated systems that schedule and monitor these activities, as well as store, process and report information about traffic data. ***We strongly suggest that ADOT investigate the implementation of a more centralized, and integrated solution for the scheduling, collection, monitoring, reporting and distribution of traffic data.***

4) **Fourth, it is recommended that a Working Group made up of representatives from all ADOT groups and sections that use traffic data, other agencies, and a traffic data collection contractor (as suggested by the project TAC) be convened on a regular basis to share information, identify base data needs, issues and opportunities, and better coordinate collection activities to reduce redundancy and maximize the usefulness and use of all collected data.** ***(Please see the Traffic Working Group section of the Chapter VII Implementation Plan.)***

Traffic data is collected and utilized by a number of sections throughout ADOT. Many of the problems experienced and reported by ADOT can be ameliorated by enhanced communication and coordination between and among the various Divisions, Groups, and Sections that are involved in either collecting, processing, using or distributing such data. A Traffic Data Working Group can facilitate this communication.

The working group will initially focus its efforts internally within ADOT, and when appropriate, will bring in other agencies in the state. The Working Group will develop a policy framework regarding traffic data including:

- Strategic Assessment of data needs.
- Identification of base data for continuous collection.
- Development of a framework for organizing data.
- Cost-effective collection of data.
- Prioritization of data
- Identification of data integration issues.
- Dissemination of data.
- Identification and administration of funding.
- Building consensus, setting priorities, and monitoring progress.
- Planning, publishing and administering guidelines and standards.

- Management of the design and development of a traffic clearinghouse and data warehouse.

Just as importantly, the Working Group can ensure that the focus of data collection is reoriented to a user driven focus, and that the four previously identified principles of successful traffic monitoring systems are implemented. The suggested composition of the Working Group is included in the more detailed recommendations contained in the project report.

5) Recommendation number five calls for the close, centralized coordination of all data collection and processing efforts at ADOT, along with the implementation of an information system to provide a single point of entry to the storage, management, and dissemination of ADOT's data resources.

The recommended system would function as a Traffic Data Clearinghouse. Currently, traffic data are scattered throughout the organization in the form of studies, reports and other documents, and in computer systems in different formats. This makes it difficult to track and determine what traffic data has been collected and what might be available.

The development of a Traffic Data Clearinghouse will assist ADOT in inventorying and maintaining all traffic data collected on State highways. Additionally, if sufficiently documented, the clearinghouse could include traffic data available from other agencies.

Currently, there is no system in place that inventories all traffic data collected on ADOT facilities. Such a system would benefit users since it would make all traffic data easily accessible. In order to implement such a system, a collaborative effort is needed to develop a standard procedure to report all traffic data collection efforts to a central repository.

The Traffic Data Clearinghouse will store information about the existence of traffic data throughout the State highway system. The Clearinghouse, as an inventory of traffic data resources, would serve as a focal point for traffic data collectors, processors, and users. Such a system is analogous to an index system in a library except that, in this case, the index stores information about traffic data rather than books.

The following provides an example of how the Clearinghouse would benefit data users: An ADOT traffic engineer may want information on turning movement counts for a particular intersection. The intersection might have been part of a recent traffic study for a Design Concept Report (DCR) that collected turning movement volumes. Although traffic data does exist for the intersection, there is no convenient way for the traffic engineer to find this out.

To do so, the traffic engineer would need to know about the DCR and obtain it from the Advance Engineering Division. Once the traffic engineer has received the report, he or she must sift through it to find the turning movement counts. To determine if the counts are usable he or she will also have to locate supplemental data (if any exists at all). The supplemental information includes the times the data was collected, the methods used for collection, and the methods used for data processing. All of these steps are required for the traffic engineer to decide whether there are suitable data available, or if additional data collection is needed. If a system was implemented that cataloged all traffic collection efforts, the traffic engineer could conveniently and quickly determine the existence of traffic for any highway facility.

The Clearinghouse will allow users to quickly and conveniently identify and locate available traffic data resources throughout the State. The clearinghouse should incorporate a geographic information system (GIS) so that traffic data resources are spatially referenced. This will allow a user to query traffic data resources by geographic location. For example, a user can select an intersection from a map display to query the clearinghouse. The results of the query might include information about a recent traffic signal study that collected turning movements as well as approach volumes. The query might also include AADT occurring on the major approaches of the intersection.

6) **The sixth recommendation is the development of a Traffic Data Warehouse to bring together data from a variety of systems and formats, and provide a consistent and optimized interface for accessing large amounts of traffic-related data.** A Traffic Data Mart could also be established as a subset of a larger data warehouse that might contain other data in addition to traffic related data, such as financial, capital improvement projects, inventories of facilities, etc.

Most traffic data is currently published as written reports and tabulations. Some of this data is shared using several standard electronic file formats, for example in Excel (Microsoft) spreadsheets. ADOT is now beginning to take advantage of Intranet and Internet technologies to disseminate information, including traffic data. This data is usually presented in the form of static tables that must be manually changed on the Web site when updated data is available. Through a web browser, anyone can acquire AADT and other parameters for any section of the State highway system. This is the beginning of a user-driven approach to data dissemination, which ADOT should aggressively pursue.

The development of interactive and dynamic Intranet- or Internet-based system, coupled with a centralized, online database of traffic data will provide a mechanism for more easily sharing and accessing consistent traffic data throughout ADOT and other agencies. Any updates to the database would immediately and automatically become available without the need to make changes to the Web site content. Also, a centralized database or Data Warehouse would support user access to historical data and could be accessed by other systems.

Such a system would provide more flexible queries and would not require limited standard (canned) reports, although they could still be provided. By providing a graphic query interface to all the data in a data warehouse, users can begin to look at new information in different ways. Associations in the data will be more apparent and if a map-based (GIS) display of the data is available, spatial and temporal patterns are more easily discovered, understood, and communicated. User interfaces can be designed to simplify interaction, so that casual users also have the data at their fingertips.

7) **As a seventh and final major recommendation, a graphic, map-based user application should be implemented to provide easy-to-use, flexible access to the vast resources of the Data Warehouse. The application interface will provide consistent and flexible access to data resources statewide with browser-based query, display, reporting, and mapping capabilities built around the centralized, online traffic-related database.** Such an interface could be used anywhere within ADOT, by other agencies, and by the public, if access is granted by administrators. Such a system will disseminate up-to-date traffic data to the greatest amount of users possible.

It has been noted at ADOT and elsewhere that managers and executive officials are not always aware of the data available to them to support the decision-making process, communicate real conditions and trends, and justify requests for funding. In general, most needed data exists somewhere within the Department, but accessibility to this data is severely limited. Therefore, data are not as widely used as is possible. A system that organizes traffic data in a centralized database will enhance the decision making process by providing an easy way to locate and access available data from across the agency, and if developed around a GIS-enabled Data Warehouse, by providing visual and easy-to-use tools for querying and analyzing large amounts of data.

This leads to a wider conception of how important data should be managed and accessed within ADOT. In this document, the term Data Warehouse refers to the combination of various data and databases across an enterprise. This collection of a wide variety of data is used to provide a single point of access to large amounts of data. The system is optimized to support efficient and flexible querying and reporting for the purposes of decision support. The data warehouse includes processes and systems to extract various data from their sources, transform and validate the data, and load the data into the database structure. Tools are provided so that users may browse and identify data pertinent to their function and then query and report the data in a variety of ways.

If linked to a geographic information system, the query results can also be mapped and analyzed in a spatial context. For example, the data warehouse could be queried for accidents and pavement condition and the results could be correlated and reported in a tabular format, or mapped to display the relationship between accident locations and pavement quality. Many other types of analyses could be performed. Linking different data across the enterprise allows the data to be looked at in ways not possible before, and adds value to existing data resources.

Such systems have been successfully developed and adopted in other states to integrate data from a variety of sources and provide widespread and flexible access to vast data resources for decision-making purposes. The national trend is toward open, integrated information systems that tie together existing databases and applications into cohesive, agency wide, enterprise architectures.

As confirmed in this report, ADOT is already headed in that direction. With executive management support, the findings and recommendations here can be implemented using a step-by-step process, one building on the previous, in order to enhance and maximize ADOT's traffic data resources.

The establishment of a Traffic Data Working Group, adoption of procedures and guidelines for data collection and documentation, and the development of the traffic data clearinghouse will make possible the implementation of a traffic data warehouse to store and process the various data from across the state in a consistent, well documented manner and will provide needed access to this important resource to users throughout ADOT, local jurisdictions, private businesses, and the communities they all serve.

I. INTRODUCTION

Arizona has experienced growth that is impacting transportation infrastructure and leading to problems of congestion. To mitigate these impacts, ADOT and other jurisdictions rely upon traffic data to respond to increases in traffic and plan future improvements. Many groups within ADOT, as well as other public and private organizations in the state require such data.

Traffic data are important pieces of information that are directly and indirectly used by ADOT to provide technical services, analyses, recommendations for transportation projects, roadway and bridge design, traffic forecasting, project prioritization, federal reporting, congestion management, air quality analysis, and ultimately, to the design of roadway improvements, and other mitigating measures.

Much data is currently collected throughout the state, and it is desirable to coordinate these activities to reduce redundancies, increase data consistencies, and leverage the benefits of the large amounts of current and future data that must be maintained. Agencies, such as ADOT have been prompted to more closely investigate the use and sharing of data as the demand for such data increases and funding availability for collection is reduced.

In order to meet the growing demand for traffic data to assess the need for both operational and capital improvements, many states have begun or are planning to implement traffic-related data systems that bring together comprehensive traffic data from a variety of sources in a consistent manner. Timely access to up-to-date and accurate traffic-related information collected by various agencies, and the ability to report, communicate and share this information is an important aspect of ADOT's business and it is vital if optimal use of resources and provision of services are to be achieved.

PURPOSE

This study was undertaken to assess and inventory ADOT's traffic data needs, review the current practices around the nation, identify statewide sources of traffic data, review ADOT's forecasting methods and other analyses, and review and evaluate the technologies used by ADOT to process, store, manage, and disseminate disparate traffic data across the agency.

OBJECTIVES

Based upon the results of the research and review, this study aimed at identifying issues and impediments to efficiently collecting, managing, and providing access to ADOT's vast traffic data resources. This study makes recommendations for addressing these issues and develops an implementation plan with the objective of bringing together disparate working groups within ADOT, establishing consistent standards and procedures, and the phased development of information solutions to integrate, manage, and disseminate accurate and consistent traffic data across the agency and throughout the state. The last section of each chapter documents the research findings and recommendations related to each area. The final chapter of this report, Chapter VII, presents the major findings and recommendations, and an Implementation Plan for moving forward.

SUMMARY

ADOT is faced with increasing responsibilities in planning, constructing, and maintaining an efficient and safe statewide transportation system. The success of this endeavor relies upon accurate and consistent traffic data. At the same time, ADOT's staffing and financial resources to support traffic data collection, management, and reporting have been substantially reduced.

The Data Team is the primary provider of traffic data within ADOT and has seen its staffing reduced by 62%, from 26 to 10 staff since 1989-90. Only five of these staff members support traffic data acquisition, recorder maintenance, data processing and dissemination. Contractors and consultants supplement in-house capabilities, when feasible. With the current levels of resources dedicated to traffic data, the Data Team can only meet the basic federal reporting requirements, but can not provide critical data that are required for making decisions related to building, operating, and maintaining the State's transportation system, especially given the extraordinary population and employment growth experienced throughout the state.

ADOT has expressed an interest in working with local jurisdictions to share data and reduce redundancies. However, these efforts are in their infancy, are not well coordinated, and participation from these other agencies will need to be developed over time. Aside from a few of the larger cities and planning organizations, efforts to make use of local data collection efforts may not prove useful, for a variety of reasons discussed later in this report.

There is also a lack of coordination internally within ADOT. Various divisions and groups are conducting efforts of general interest and wide applicability without the participation, and sometimes without the knowledge of others in the Department. ***One of the major recommendations of this report is the establishment of a Traffic Data Working Group to facilitate communication and teamwork.*** This is a critical first step toward the other recommendations, which involve developing traffic data standards and procedures, and an agency wide traffic data clearinghouse and data system, such as a traffic data warehouse. Such systems have been successfully developed and adopted in other states to integrate data from a variety of sources and provide widespread and flexible access to vast data resources for decision-making purposes. The national trend is toward open, integrated information systems that tie together existing databases and applications into cohesive, agency wide, enterprise architectures.

As confirmed in this report, ADOT is already headed in that direction. *With executive management support,* the findings and recommendations here can be implemented using a step-by-step process, one building on the previous, in order to enhance and maximizes ADOT's traffic data resources.

II. TRAFFIC DATA COLLECTION, USE AND STORAGE PRACTICES

Accurate and reliable traffic data are essential to a wide variety of transportation applications, including highway, pavement and bridge design and operational analysis. Other important applications are performance evaluation, programming, planning, and budgeting activities, as well as legislative and administrative policy development. Some examples of the use of the data are shown in Table 2.1. The efficient management of the transportation infrastructure requires agencies to collect and analyze data on traffic volume, vehicle classification, and weight data in an integrated manner. The need for traffic data has progressed beyond simply knowing how many vehicles travel a particular roadway throughout the year. The traffic must not only be counted, but also classified into vehicle types and weights. Information reporting and sharing are tasks of increasing importance. Traffic monitoring systems are therefore implemented and used as part of a systematic process to collect, analyze, summarize, retain and distribute traffic data.

Table 2.1. Examples of studies using traffic data

Highway Management Phase	Traffic Counting	Vehicle Classification	Truck Weighing
Engineering	Highway Geometry	Pavement design	Structural design
Engineering Economy	Benefit of Highway Improvements	Cost of Vehicle Operation	Benefit of truck climbing lane
Finance	Estimates of Road Revenue	Highway Cost Allocation	Weight distance taxes
Legislation	Selection of State Highway Routes	Speed limits and oversize Vehicle Policy	Permit policy for overweight vehicles
Planning	Location and design of Highway Systems	Forecast of Travel by Vehicle Type	Resurfacing forecasts & Pavement rehabilitation
Safety	Design of Traffic Control Systems and Accident Rates	Safety Conflicts due to vehicle mix and accident rates	Posting of bridges for load limits
Statistics	Average Daily Traffic	Travel by Vehicle type	Weight distance traveled
Private Sector	Location of Service Areas	Marketing keyed to particular vehicle types	Trends in freight movement.

Source: FHWA Traffic Monitoring guide [1]

The purpose of this chapter is to introduce and evaluate the current business practices, uses, and needs for traffic data within ADOT. The approaches other organizations and entities have taken with respect to traffic data collection, processing, and dissemination will be documented as well.

DATA COLLECTION EFFORTS

The Data Team in the Transportation Planning Division undertakes the majority of ADOT’s data collection efforts. The Data Team is responsible for collecting, producing, and maintaining traffic related data and information about Arizona’s network of public streets and roads. Monitoring traffic on the *6,200-mile state highway system is a time and resource intensive task. The traffic monitoring efforts of the Data Team include three major responsibilities:

- Collection of field dataAssembly and processing of raw data.

- Maintenance, calibration, and repair of data collection equipment.

In addition to the efforts of the Data Team, a large amount of data is collected and used for Design Concept Reports (DCR), Operational Analysis and Signal Needs studies and numerous reports for Valley Project Management, Statewide Project Management, and the Environmental Planning and Roadway groups. The majority of this data is collected by consultants for specific studies and applications.

Collection of Field Data by the Data Team

ADOT now divides the State highway system into 1,400 segments for traffic monitoring purposes. Each of these segments is identified by route and milepost and contains an identified location for a Traffic Counting Station. Throughout the year, field personnel visit these locations to count traffic volumes and to collect other types of data. At approximately 120 sites, data is collected to classify vehicles by type. Vehicle weight, determined by weight in motion (WIM) equipment, is collected at seven sites, when the equipment is operational. The majority of traffic volume counts performed by ADOT consist of either 24-hour or 48-hour counts using pneumatic road tubes or inductive loops. Sections on the National Highway System are counted at least once a year for a duration of 48 hours. These 48-hour counts are scheduled using local knowledge about traffic conditions in the vicinity of the Count Station to avoid "seasonal over-counting." On a statewide level counts start in January in the southern part of the State and move north throughout the year. Low volume sections are counted every three years. In certain instances the Data Team performs counts on off-network facilities for special studies.

The Data Team uses several different mechanisms to collect the traffic data as outlined below.

- *This approximate number of miles is based on the centerlines of all State Highway mainline facilities. This excludes ramps, frontage roads, and other auxiliary facilities. Furthermore, this determination of this number does not double-count for divided highways.

Automatic Traffic Recorders

There are about 74 active automatic traffic recorders (ATRs) in the State that continuously monitor traffic 24 hours a day, each day of the year. The location of the ATRs is listed in Table 2.2. Data from these ATRs are automatically fed into a computer system referred to as “TRADAS,” developed by Chaparral Systems. The information obtained from the ATRs is used to develop seasonal adjustment factors, growth factors, and axle factors for AADT. Traffic data is usually pulled from the ATRs on a daily basis and stored in a database where it can be summarized for daily, monthly, and annual reports.

Weigh in Motion (WIM)

The Long Term Pavement Performance Program (LTPP) requires ADOT to collect Weight in Motion (WIM) and Automatic Vehicle Classification (AVC) data [2]. Currently ADOT has nine AVC sites and 16 WIM sites as part of the LTPP program. Table 2.3 lists these sites. The data collected on these sites includes calculations of the yearly truck volumes by truck classification and trucks as a percentage of the total traffic.

Table 2.2. Automatic Traffic Recorder Locations

#	Route	Location	#	Route	Location
1	I-8	Yuma Spd/Len	38	SR 83	Sonoita Spd/Len
2	I-8	Wellton Spd/Len	39	SR 85	Why
3	I-8	Gila Bend Spd/Len	40	SR 86	Robles Jct. Spd/Len
4	I-10	Ehrenburg Spd/Lcn	41	SR 87	Payson Spd/Len
5	I-10	Tonopah Spd/Len	42	SR 87	Winslow Spd/Len
6	I-10	Tempe Alameda BE	43	SR 89	Prescott Spd/Len
7	I-10	Tempe Alameda WE	44	SR 89	Ash Fork Spd/Len
8	I-10	Bapchule Spd/Len	45	SR 90	Benson WIM 002
9	I-10	Marana WIM Cox	46	SR 95	Quartzite WIM 003
10	I-10	Marana	47	SR 95	Parker Spd/Len
11	I-10	Tucson Grant BE Sp	48	SR 99	Leupp Spd/Len
12	I-10	Tucson Grant WE Sp	49	SR 260	Overgaard Spd/Len
13	I-10	Benson WIM 001	50	SR 260	Eager Spd/Len
14	I-10	Cochise Spd/Len	51	SR 264	Moenkopi
15	I-17	Pioneer WIM	52	SR 264	Ganado Spd/Len
16	I-17	New River	53	SR 277	Snowflake Spd/Len
17	I-17	SR-169/Cherry Rd.	54	SR 286	Robles Jct. Spd/Len
18	I-19	Amado Spd/Len	55	SR 377	Holbrook Spd/Len
19	I-19	Tucson Ajo Way Spd	56	US 60	Aquila Spd/Len
20	I-40	Topock Spd/Len	57	ÚS 60	Glendale EB Spd/Len
21	I-40	Seligman Spd/Len	58	US 60	Glendale WB Spd/Len
22	I-40	Winona Spd/Len/CLs	59	US 60	Tempe Hardy EB
23	I-40	Winslow Spd/Len	60	US 60	Tempe Hardy WB
24	SA 89	Sedona Spd/len	61	US 60	Globe Spd/Len
25	SB 8	Yuma	62	US 60	Show Low Spd/Len
26	SR 51	Phoenix Crittendon	63	US 70	Cutter WIM 005
27	SR 64	Valle Spd/Len	64	US 70	Safford Spd/Len
28	SR 68	Bullhead City/Spd	65	US 89	Flagstaff
29	SR 69	Cordes Jct	66	US 93	Kingman Spd/Len
30	SR 69	Mayer Spd/Len	67	US 93	Wikieup
31	SR 72	Utting Spd/Len	68	US 93	Wickenburg Spd/Len
32	SR 77	Snowflake Spd/Len	69	US 95	Yuma WIM 004
33	SR 79	Oracle Spd/Len	70	US 160	Tuba City Spd/Len
34	SR 80	St David Spd/Len	71	US 180	Flagstaff Spd/Len
35	SR 80	Douglas Spd/Len	72	US 180	St Johns Spd/Len
36	SR 82	Nogales Spd/Len	73	US 180	Springerville Spd/Len
37	SR 82	Sonoita Spd/Len	74	US 191	St Johns Spd/Len

Source: Listing from TPG data team

Table 2.3. Arizona Weigh-in-Motion Sites

Arizona/ATRC Site # and Pavement Type	Site Location Route & MP (KIM)	SHRP ID	WIM/AVC Status	Make	Sensor
025 RIGID	US-93 NB 052	0100	PERM WIM	PAT	BENDING PLATE
026 RIGID	1-10 EB 108	0200	PERM WIM	IRD	BENDING PLATE
009 FLEX	1-8 EB 159	0500	PERM WIM	PAT	PIEZO
202 RIGID	1-40 EB 202	0600	PERM WIM	PAT	BENDING PLATE
204 RIGID	1-40 WB 202	0600	PERM WIM	PAT	BENDING PLATE
020 FLEX	1-40 WB 145	1002	PERM WIM	PAT	PIEZO
012 FLEX	I-I0 WB 110	1006	PERMWIM	PAT	PIEZO
011LFLEX	I-I0 WB 115	1007	PERMWIM	PAT	PIEZO
005 FLEX	1-19 SB (029)	1015	PERM WIM	IRD	PIEZO
018 FLEX	I-40 EB 106	1024	PERM WIM	PAT	PIEZO
010 FLEX	SR-85 SB 141	6055	PERM WIM	PAT	PIEZO
006 FLEX	1-19 NB (023)	6060	PERM WIM	PAT	PIEZO
021 RIGID	SR-I0 INB 011	7079	PERMWIM	PAT	PIEZO
024 RIGID	US-60 WB 179	7613	PERM WIM	PAT	PIEZO
019 FLEX	I-40 WB 113	1025	PERM AVC PORT WIM	PAT	PIEZO
015 FLEX	SR-68 EB 001	1037	PERM AVC PORT WIM	PAT	PIEZO
023 FLEX	I-I0 WB 123	1001	PERM AVC NO WIM	PAT	PIEZO
007 FLEX	1-19 NB (054)	1017	PERM AVC NO WIM	PAT	PIEZO
013 FLEX	R-95 SB 145	1034	PERM AVC NO WIM	PAT	PIEZO
008 FLEX	1-19 SB (084)	6054	PERM AVC NO WIM	PAT	PIEZO
022 RIGID	1-10 WB 130	7614	PERM AVC NO WIM	PAT	PIEZO

Source: Development of New Pavement Design Equivalent Single Axle Load (ESAL). [2]

Data Collection Efforts Other than Those of the Data Team

Because of resource and staffing limitations, the Data Team performs few other special counts. Other groups or divisions within ADOT initiate special collection efforts.

Transportation Planning

The Transportation Planning Division (TPD) receives most of their traffic data needed for corridor studies, access management efforts, and long-range planning from the Data Team. However, contractors collect data for Small Area Transportation Studies (SATS) for TPD. Currently there is no procedure in place for storing the collected data other than in report form, and no linkage exists between the Data Team and the TPD collection efforts. When there is a question about the accuracy of the Data Team's traffic data, separate collection efforts are undertaken.

Traffic Engineering Group

The Traffic Engineering Group has very specialized data needs on a project-by-project basis. For traffic engineering studies for example, turning movement counts, peak period volumes, or percentage of trucks are required for intersection design or signal phasing. For “Warrants for Traffic Signals”, for example, traffic count data on specific localities are needed. For these types of studies, the data provided through the Data Team’s traffic monitoring system does not provide enough accuracy and detail. For example, the traffic monitoring system does not provide turning movement counts or peak hour factors for specific intersections that the traffic group need. As a result, additional data is collected for these studies, such as turning movement counts, peak hour factors, stopped delay or vehicle classification. Currently these special counts are published in the traffic studies themselves and there is no systematic mechanism to electronically store the information for later use.

Freeway Management System

ADOT’s Freeway Management System (FMS) collects real time data at 237 locations throughout the greater Phoenix Metropolitan freeway system. The Transportation Technology Group (TTG) manages the FMS. Collected data includes speed, volume, and occupancy. The recording devices are either inductive loops or acoustic sensors. According to TTG staff, up to 50-percent of the traffic recording devices do not properly report data on a continuous basis. The Data Team has also reported that as much as 40-percent of the loop sets are inoperative in at least one lane at any given time. Loop detectors are difficult to maintain, are often not properly installed, and are often damaged during road maintenance activities. ***These situations preclude the acquisition and utilization of this data for any useful planning, design, operation, or maintenance purposes.***

Other sources for traffic related data collected by TTG include:

- The Road Weather Inventory System (RWIS).
- Variable message signs.
- Highway Condition Reporting System (HCRS).

The main customers of the TTG are the AZTech partners comprised of the agencies and private entities deploying the FMS, the jurisdictions in the greater Phoenix area, and the traveling public. The ADOT Phoenix Maintenance District is responsible for the maintenance of loops and other detector systems, and ramp meter controllers. The Transportation Technology Group is responsible for the collection and dissemination of the traffic data collected through the FMS and the implementation of high technology projects such as variable message signs and the Roadway Weather Information System.

Some traffic data has been exchanged between the FMS and the Data Team. However, because of the inaccuracy of the data (primarily caused by failure of recording devices) this information is of limited use to the Data Team. Because the detectors are embedded in heavily traveled roadways, they are very difficult to maintain in correct working order. A limited subset of detectors could possibly be maintained to a higher level, which might yield data that is suitable for planning purposes. To obtain reliable, useful data for planning and other purposes, detectors that are not imbedded in the roadways should be used –detectors that can be more easily maintained. Otherwise, it is very difficult to maintain the devices and they rapidly become inoperative or produce unacceptably inaccurate results.

Since the overall purpose of the FMS is to provide and disseminate real-time traffic data, the system was not designed to collect, store and archive traffic data. However, collected data is stored on CDs and is available in 15 minute and 1 hour intervals by day and year. Another challenge in using this data lies in facilitating the exchange of data between the various groups and agencies collecting the data. The Regional Archived Data Server (RADS) project initiated by the Maricopa County Department of Transportation (MCDOT) is a step in the direction of data sharing among data users. [3] The RADS project is part of the effort of the Maricopa Association of Governments (MAG) to create a regional ITS infrastructure. [4]

The *User Services Requirements Study* for the RADS targets the enhancement of traffic data availability for planning and operations in the Phoenix Metropolitan area. [3] Responding to the need to capture data available through ITS infrastructure, MCDOT developed the Scalable AZTech Data Server Enhancements for Planning and Operations. The goal is to archive data currently collected through ITS applications and to make this data available to local agencies for planning, modeling, or any other needs. Through the implementation of the Regional Archived ITS Data Server (RADS) this data will be accessed, shared, and utilized by a number of various users. To implement the RADS properly, a User Services Requirements Study was undertaken to determine the need for archived data within Maricopa County. The need for additional data was identified. Through intense communication with stakeholders, working groups, interviews, and surveys, specific data needs were identified. Data currently available from the AZTech Server are:

- ADOT Freeway Management System Data.
- Local Jurisdiction Traffic Signal Data.
- Transit Advanced Automated Vehicle Location Data.

Data not currently available:

- Arterial data.
- Parking Management data.
- Commercial vehicle operation data.

- Weather data.

Results of the study in terms of importance of data elements to be collected are presented in Table 2.4.

Table 2.4. User Services Requirements Study—Highest Scoring Data Categories

CRITERIA	RANK	DATA CATEGORY
Most Desired Data Category, based on total number of stakeholders responding within the category (above the median total of 12.5 stakeholders responding within the category)	1	Arterial Traffic Flow Surveillance
	2	Freeway Traffic Flow Surveillance
	3	Transit Usage
	4	Incident Logs
	5	Construction/Work Zone ID
	6	Traffic Signal Phasing
	7	Parking Management
	8	Transit Schedule Adherence
	9	Freeway Ramp Meters
	10	Weather Data
	11	Arterial VMS
Most Important Data Category, based on the total score of data elements within the category (above the median score of 3.73)	1	Weigh-In-Motion Data
	2	Construction/Work Zone ID
	3	Transit Schedule Adherence
	4	Border Crossings
	5	Arterial Traffic Flow Surveillance
	6	Emergency Veh. Dispatch Records
	7	Transit Usage
	8	Incident Logs
	9	Freeway Ramp Meters
	10	Emergency Veh. Locations
	11	Traffic Signal Phasing
Data Availability from Stakeholders' Jurisdiction (above the median score of 16 votes within a category)	1	Traffic Signal Phasing
	2	Incident Logs
	3	Arterial Traffic Flow Surveillance Data
	4	Freeway Traffic Flow Surveillance Data
	5	Transit Usage
	6	Transit Schedule Adherence
	7	Construction and Work Zone Identification
	8	Freeway Ramp Meters
	9	Freeway Variable Message Sign
	10	Weather Data
	11	Weigh-in-Motion (WIM) Data
Data Most Desired from Other Agencies (above median score of 26 votes within a category)	1	Incident Logs
	2	Freeway Traffic Flow Surveillance Data
	3	Traffic Signal Phasing
	4	Arterial Traffic Flow Surveillance Data
	5	Freeway Ramp Meters
	6	Transit Usage
	7	Freeway Variable Message Sign
	8	Transit Schedule Adherence
	9	Arterial Variable Message Sign
	10	Parking Management
	11	Weigh—in—Motion (WIM) Data

Source: User Services Requirements Study [3]

Other data collection efforts within Arizona are performed by metropolitan planning organizations such as MAG, the Pima Association of Governments (PAG), as well as by individual counties and cities.

Arizona Transportation Research Center

ADOT participates through the ATRC in the Strategic Highway Research Program (SHRP) Long Term Pavement Performance Project (LTPP). [5] As part of the SHRP program, ATRC maintains about 27 WIM stations. The data from these ATRC stations is formatted to LTPP standards and are tabulated for hourly vehicle weights, counts and classifications. The data is exchanged with the Data Team. The main goal of the LTPP is the monitoring and evaluating of traffic data, particularly along test sections for the evaluation of pavement conditions.

Assembly and Processing of Raw Data

The Data Team uses a software application, TRADAS, to manage data for ADOT's traffic monitoring system. The software is intended to collect, edit, summarize, and report a wide range of traffic data. Data from permanent ATR sites as well as short-term/manual counts can be accommodated. Segments of the roadway system are referenced by route and milepost. The software is capable of performing linear regression analysis, and calculating K-factors and D-factors. A user of the system can enter a 48-hour field count for a particular location and it will produce an AADT value.

Since it is impossible to monitor traffic continuously at every point along a roadway, data samples are collected from the traffic stream either through ATRs or short-term counts. These samples are then applied to the roadway in general. There are two distinct sampling needs. First, the need to sample at a specific time during the year and apply the sample to a full year, producing a typical average volume. Second, the need to sample a specific portion of a roadway network and apply it to other points in the network.

Factor Groups

The sample data collected from the permanent ATR sites are used to develop seasonal factors and growth factors. These factors, in turn, are then applied to all highway segments in the vicinity of the ATR. The data collected through the short-term counts is seasonally adjusted based on the factor group and AADT values are derived. These adjustments are made before the traffic volume information is published to ensure that the best approximation of a typical 24-hour traffic volume on a specific roadway segment is released. Peak-hour or K-factors are estimated on the basis of ATR data and 48-hour counts. Directional or D-factors are also established based on ATR information. A listing of factor groups and a corresponding map has been available from the Data Team in the past. However, the factors and factor groups have not been updated on a regular basis.

Maintenance, Calibration, and Repair of Data Collection Equipment

The Data Team is responsible for the routine maintenance, calibration, and repair of data collection equipment. The equipment itself and the devices used to record and transmit the data contain sensitive electronics that are particularly vulnerable to lightning strikes, power surges, and power outages. Technicians from the Data Team's electronics shop are tasked with ensuring that the on-site equipment is functioning properly before and during a count.

Ongoing Efforts

The Data Team is very aware of the need to improve the statistical reliability of its data. Toward this goal, alternative methods for counting traffic in urban areas are being pursued, additional funding sources identified for contract counting services, new counting devices purchased, and more than 30 ATR stations added. Additionally, several efforts are currently underway to improve upon the current data collection practices.

Re-sectioning of ADOT's Highway Traffic Database

ADOT's traffic monitoring system was based on 1200 segments identified 25 years ago. Because of changes to the roadway network and the rapid urbanization throughout Arizona, the Data Team realized a need to resection the network in order to establish a new set of homogeneously defined segments. Re-sectioning efforts have produced 1400 segments.

Evaluation of Urban Traffic Count Figures

The Federal Highway Administration requires the calibration of urban ATR sites in Phoenix and Tucson, which haven't been verified before. The project will examine the automatically tabulated data collected by the mostly embedded inductive loop detector sites. Additionally, 8-hour classification counts will be performed on selected sites to evaluate urban traffic count figures.

Regional Traffic Counting Policy

ADOT seeks to establish a regional traffic counting policy emphasizing the need for a comprehensive count program in rural Arizona. This policy will include a procedure for determining cluster groupings for seasonal traffic analysis, and for periodically modifying these groupings as population growth and new roadway construction change the uses and character of the various clusters. The Department intends to analyze and group ATRs into statistical clusters for factor application.

Determine Cluster Groupings for Seasonal Traffic Analysis

Currently ADOT uses growth factor groups to adjust raw counts seasonally. A new project is underway to use ATRs to establish cluster groups for seasonal traffic analysis. The project will analyze and group the existing ATRs into statistical clusters for factor application. Once the clusters are determined, seasonal adjustment factors can be supplied to transportation planning agencies across the State for the determination of Annualized Average Daily Traffic (AADT) values.

Other Highway Related Data Collection and Management Activities Performed by the Data Team

Photo Highway Inventories and Global Positioning Data

The Data Team also compiles an annual photo log of all state highway facilities. Through the use of a specially adapted vehicle, digital images are taken every 53 feet on each roadway. The images are electronically stored and archived on a route-by-route basis on CD-ROMs. A master set of approximately 160 CDs is distributed to a number of ADOT sections.

Another important function related to photo imaging is the collection of global positioning data. In order to maintain accurate centerline location information for Arizona's state highways, the Data Team collects global positioning system (GPS) information for the highways that are photo-logged. The project will deliver electronic images of Arizona highways and their locations at intervals of $1/100^{th}$ of a mile in each direction. The information will then be used to provide spatially accurate information for the update of the GIS centerline file.

State Highway Log

The Data Team is responsible for the maintenance of an annual State Highway Log. This highway inventory documents all State system facilities including features such as geometrics, projects, and other information in route mile order. The information is derived for each State highway as a result of completed construction projects or any resolutions passed by the ADOT Transportation Board. The State Highway Log is currently available for download as a PDF file, as hardcopy, or on CD.

The Administration of the Federal Highway Administration's Highway Performance Monitoring System (HPMS) Program

The Data Team also administers the FHWA's Highway Performance Monitoring System. The HPMS is an integrated database required by the FHWA covering all public mileage within a state. The State delivers the data to FHWA by June 15 of each year. This submittal includes ADOT's certified mileage for the year, roadway extent, use, condition, and performance data. HPMS data is collected, maintained, and described by the Data Team in a standard, coded fashion. The FHWA requires that a number of reporting guidelines, policies and procedures are followed under its HPMS Program.

ADOT queries all jurisdictions each year to obtain the their latest mileage information. Because it is impracticable to collect all data items on all roadway segments of the system, the HPMS contains samples. These samples are picked for segments of the various functional classes to represent all of Arizona's roadway system. Currently 82 data items are required by the FHWA for the samples and include ownership, location information, geometrics, operational, environmental, condition, and performance measurements, together with other supplementary data.

In recent years, ADOT has developed a GIS based information system to enable jurisdictions to maintain, update, or correct the information contained in the HPMS dataset. Additionally, the established GIS allows jurisdictions to correlate other geocoded information with the HPMS data.

Dissemination of Traffic Volume Data

The Data Team is responsible for disseminating traffic data to end-users. Traffic data printouts can be downloaded from ADOT's web site in PDF format. Table 2.5 summarizes the information available at ADOT's Data Team Reports Internet site during the summer season of year 2000. [6] The information and reports available on this Web site may now be different.

Table 2.5. Data Team Reports (On Internet Web site, Summer 2000)

Available Traffic Reports	
Current AADT	
	Average Annual Daily Traffic
K D & T Factors	
	1997 KD & T Factors
	1998 KD & T Factors
Future Traffic Reports	
	TRADAS ATR Station Reports
	Historical AADT
	Season Adjustment Factors
	Forecasted AADT
	Ramp & Crossover Counts
HPMS Reports:	
State Highway System Travel, Route and Lane Mileage	
	1997 by County and Federal Aid Category
	1998 by county and Federal Aid Category
Vehicle miles of travel estimates for State and non-State highway systems for State and Counties by year, includes population estimates	
	CY 1990
	CY 1991
	CY 1992
	CY 1993
	CY 1994
	CY 1995
	CY 1996
	CY 1997
Composite, multi-year statewide Arizona travel statistics (expressed in both annual and daily vehicle-miles of travel) between 1976 and 1998 with forecasts for 2010 and 2015	
Future Reports	
Area-wide Length & Travel Templates	
	Template 1,2 and 3
	Template 6 (7)
	Vehicle Classification Data
	Length & Travel Tables with Demographics

Source: http://205.164.199.86/datateam/reports/index.html

DATA USES AND USERS

ADOT in its function of constructing, operating, and maintaining the State highway system in Arizona must constantly evaluate the performance of the system. A

Through a series of meetings and interviews, ADOT's internal data needs were identified. (See Appendix A for a listing of individuals interviewed). Focusing on traffic related data, a listing of traffic information used throughout the Department was compiled. Overall the data needs can be categorized in five major groups:

1. Volume

- Average Annual daily Traffic (AADT).
- Design Hourly Volume (DHV).
- Peak-hour Traffic Percentage (K).
- Directional Split (D).
- Peak-hour volume turning movement.
- Vehicle Miles of Travel (VMT).
- Hourly Approach Volumes

2. Vehicle Classification

- Average Daily Truck Traffic (ADTT).
- Percentage Trucks in Peak.
- Percentage of Vehicle Class.

3. Truck Weight

- Truck weights
- Equivalent single axle loads (ESAL)

4. Speed data

5. Accident data

Annual Average Daily Traffic (AADT) estimates are the most frequently requested information throughout ADOT and are used for a variety of purposes. Vehicle classification is the second most often-required data item—most users request this in the form of percent-truck figures. Other requested information includes seasonal, daily, and hourly variation of traffic volumes, turning movements, vehicle weights, speeds, and traffic by direction and lane. ADOT processes requiring traffic data are listed in Table 2.6.

Table 2.6. ADOT Processes Requiring Traffic Data

Process/Function	Information Needed	Traffic Data Needs
Planning		
Statewide Needs	Level of Use	AADT, hourly distribution
Corridor Profiles	Level of service	AADT, K, D, percent-trucks
	Estimated Accident Rates	AADT
	Estimate of Goods/Commercial Vehicles	Truck weight, percent-trucks, weight distribution
	Mode split	HOV Count, Transit Vehicle Count, Vehicle Occupancies
HPMS	Level of Use	AADT, percent-trucks
Programming		
Identification of Needs	Level of Service	AADT, K, D, percent-trucks
Five-year program development	Estimated accident rates	AADT
	Truck usage	Percent-trucks
Advance Engineering (Scoping)		
	Level of Service	AADT, K, D, percent-trucks
	Estimated Accident Rates	AADT
Pavement Design		
	Traffic loading	AADT, K, D, percent-trucks, weight distribution
Bridge Design		
	Traffic loading	AADT, K, D, percent-trucks, weight distribution
Pavement Management		
	Traffic loading	AADT, K, D, percent-trucks weight distribution
Bridge Operation		
	Traffic loading	AADT, K, D, percent-trucks, weight distribution
Safety Management		
Candidate Projects	Accident rates	AADT
Spot Experience	Accident rates	AADT
Annual Accident Report	Accident rates	AADT
Traffic Operations		
Determine Lane Configuration	Hourly Volume by Lane	DHV (counted or derived)
Design Traffic Signals	Hourly Volume by Lane	Hourly Volumes (counted or derived)
Determine Speed Zoning	Vehicle Speed Distribution	Vehicle speeds
Maintenance		
	Does not have immediate traffic data needs	
Traffic Operations Center		
	Traffic conditions	Hourly volumes
		15 min volumes
		Traffic Densities
Potential Uses		
Historical traffic growth	Traffic Growth Rates	AADT, percent-trucks
Determine Detour Routing	Level of Usage	AADT, K, D, percent-trucks

Source: Lima & Associates

Planning and Programming

The Transportation Planning Division uses traffic data for a variety of purposes, including corridor studies, access management plans, long-range planning, and Small Area Transportation Studies (SATS). The data elements needed are mainly AADT, type of traffic, such as percent trucks, hourly distribution, K, D, and seasonal factors, and mode split data. Most of this data is provided through the Data Team. For some of the studies, such as SATS, additional data must be collected since SATS address non-system routes, as well as state highways.

Other quasi-legislative efforts such as the Governor’s Vision 21 Transportation Task Force uses system-wide traffic data to identify future needs for Arizona’s transportation infrastructure.

The Planning Division also needs reliable traffic forecasts. Currently, forecasts are produced on study-specific bases within the Transportation Planning Division. For overall system projections, forecasts from the HPMS are used.

The Programming Team within ADOT uses AADT, LOS, percent truck, and accident rates to determine the needs of the transportation system. The same data elements are then used in ranking and prioritizing projects for inclusion in the five-year construction program.

Traffic Engineering Group

The traffic data required by the Traffic Engineering Group go beyond AADT and vehicle classification. Most of the traffic engineering studies require the following additional data elements:

- Speed.
- Peak-hour volumes.
- 100 highest hour volumes.
- Sub-hourly variations.
- Turning movements.
- Approach volumes.
- Stopped time delay.

Because most of these additional data elements are not provided by the Data Team’s collection efforts, they are specifically collected for traffic engineering. In cases where consultants have performed the data collection, it is often unclear which methodologies were used to collect, factor, or adjust the data.

Currently there are no mechanisms in place for coordinating traffic counting activities and avoiding the possible duplication of efforts. There is also an immediate need to establish standards and methodologies for traffic counting procedures as well as the factoring and adjusting of raw data.

Other sources of traffic data such as the Freeway Management System (FMS) and other related Intelligent Transportation Systems should be integrated to make the data available to all potential users, for example in a centralized repository for all traffic related information. A single focal point should be responsible for all of the traffic data collection and dissemination efforts at ADOT.

Advance Engineering (Scoping)

The Advance Engineering Section scopes proposed construction projects. Scoping is a process used by ADOT to determine and document reliable cost estimates for proposed construction projects, and to communicate information about the proposed projects to other concerned groups and individuals. It is in this critical phase that traffic data, such as AADT, design hourly volume, peak hour factor, seasonal factor, etc. are applied. Through capacity and traffic analyses, the design process determines such items as the number of traffic lanes, turning lanes, storage lengths for turn bays, signals, etc. Once this is determined, an appropriate estimate of the project can be calculated. Depending on the complexity of the proposed project, three types of reports are developed: Scoping Letter, Project Assessment (PA), and Design Concept Report (DCR). Traffic data needed for the preparation of these documents are as follows:

- AADT
- Turning movements
- Accidents / volumes

The level of detail in a DCR might require full traffic analysis.

Pavement Design Section

The Pavement Design Section is primarily responsible for the design of pavement structures as part of the project management process for all state highway paving projects including interstate, non-interstate, and the MAG Freeway system. The main products of the section are Pavement Designs and a Materials Design Report for all assigned projects. The traffic data related inputs for the completion of these studies are:

- Traffic loading.
- AADT.
- K-factor.
- D-factor.

- Percent Trucks.

- Equivalent Single Axle Loads (ESALs).

The basic traffic data retrieved from the Data Team are used to calculate future year projections using linear regression analysis. Models are applied to estimate traffic loadings. The Pavement Design Section urgently needs vehicle weight information to further enhance the computation.

Pavement Management

The purpose of ADOT's Pavement Management System is to evaluate the condition of roadway pavement, to identify pavement condition deficiencies, and to identify pavement project needs. The Pavement Management Section is responsible for providing:

- A Statewide Pavement Preservation Program.

- A Statewide highway condition survey that tests for cracking, roughness, rutting, flushing, and friction for use by various design and management functions.

- Site specific testing for smoothness and deflections to support ADOT design and construction functions.

- Expertise in the area of pavement safety and pavement condition.

- All forms of non-destructive pavement tests to support research needs.

The districts, the Maintenance Division and the Planning Division, use the output of the Pavement Management System. The traffic related data elements that the Pavement Management Section need to perform these responsibilities are AADT, ADL (Average daily load), growth factors and projections, and historical trends.

Currently the Pavement Management System is comprised of about 7,500 1-mile segment records. Each segment is assigned to one of three traffic volume groups -low, medium or high- that categorizes the volume of traffic on each segment.

Life cycle analysis for each segment is performed based on the assignment of the segment to one of these groups. Strong variations of traffic volume data for specific segments might lead to change in the assigned traffic volume group from year to year. If traffic volumes change considerably on a particular segment the assignment of that section to the low, medium, or high traffic group might change as well. Continuous changes make it difficult for the Pavement Management Section to determine the life cycle of individual segments.

Bridge Design and Bridge Management Sections

The responsibilities of the Bridge Design Sections are:

- Design and development of construction documents for major highway structures on the Arizona State Highway System.
- Review and approval of all structural plans for state or federally funded highway projects submitted by consultants.
- Publication of Standard Drawings for highway structures and compilation and dissemination of information on bridge design, detailing practice, and structure costs. This information is provided in printed form and also on the Bridge Group's Internet site. [7]

The bridge group mainly uses AADT, projected AADT, forecast years, percent commercial vehicles, and classification data is also extremely important.

A major function of the Bridge Management Section is the inspection of bridges on the State Highway System in accordance with the National Bridge Inspection Standards (NBIS). Additional functions of the section are:

- Maintenance of related bridge inventory records.
- Inspection of bridges on most local government systems.
- Maintenance of records for all publicly owned bridges in the state.

The Bridge Management Section also establishes and maintains a Bridge Management System for all Arizona bridges to evaluate the conditions of bridges, identify deficiencies, and identify bridge project needs. The guiding requirements for bridge inspection are outlined in *Recording and Coding guide for the Structure Inventory and Appraisal of the Nation's Bridges*, FHWA-PD-96-001, which includes the following traffic related data elements: [8]

- Latest Average Daily Traffic.
- Year of Average Daily Traffic.
- Future Average Daily Traffic.
- Year of Future Average Daily Traffic.
- Average Daily Truck Traffic.
- List of Strategic Highway Corridor Network (STRAHNET).
- List of STRAHNET Corridors.

- List of Indian Reservation Roads.
- List of Land Management Highways System (LMHS).
- List of Base Highway Network.
- List of Linear Referencing System.
- Functional Classification.
- List of National Highway System.
- List of Forest Highway System.
- List of Designated National Network.

The Bridge Management section encounters difficulties with the methodology used to store traffic data on the State system. Collection and storage is not consistent with bridge design and management needs since the data is stored and referenced by route and milepost. It is difficult to extract the needed information by a point location representing an individual bridge or bridge structure. For example, traffic volume data is usually provided on the main lines of two intersecting freeways. A traffic interchange however may be comprised of numerous ramps, which usually do not have any specific traffic data associated with them. The bridge group and bridge management section must also devise a means of determining traffic data in instances where the State owns and maintains the underlying structure but the roadway itself is owned and operated by a local jurisdiction.

IMPLEMENTATION OF TRAFFIC DATA SYSTEMS BY OTHER STATES

This section introduces literature relevant to the data collection efforts of other states and entities. The summarized literature represents examples of best practices and highlights strategies for possible implementation at ADOT.

Many organizations tasked with the collection of traffic data are faced with some of the same issues. The demand for comprehensive traffic data and associated results continuously increases while resources and staffing are reduced. Many agencies have begun or are planning to implement traffic monitoring programs to meet the growing demand for traffic data. *The Case Studies of Traffic Monitoring Programs in Large Urban Areas* introduces a list of common issues in regard to traffic management system. [9] The main issues center on the following topics:

- Institutional Arrangements:
  - Interagency contracting
  - Interagency coordination/cooperation

  - Single agency data collection

- Use of Automatic Traffic Management Systems/Traffic Management Center Data for Planning Data Use:

    - Input in models
    - Input to HPMS
    - Support of Congestion Management Systems
    - State DOT needs
    - Local agency needs

- How various data needs fit together in the context of the overall data collection efforts.

- Funding sources/mechanisms.

The project examined four case studies of traffic monitoring data operations within urban areas to support the development of traffic monitoring databases and to promote the upgrading of traffic monitoring programs. Information for the study was collected through interviews with individuals responsible for traffic data collection at various levels of government. The following major findings of the study summarize the current issues in regard to traffic management systems.

"There are no unusual or innovative funding sources for traffic data collection in widespread use at the present time."

In most cases federal funds are used to pay for data collection efforts and most state and local agencies did not have other independent and dedicated funding sources for traffic data collection. On the State DOT level, it appears that staff levels for the data collection programs are determined more by political decisions than by budget objectives.

> "Automatic Traffic Monitoring System (ATMS) type systems can be used to collect planning data, but a well conceived ATMS implementation plan is necessary if the ATMS is to provide data useful in planning."

Traffic control devices, ramp metering systems and other components of ITS infrastructure are being used by agencies to collect traffic data. However, many of the ITS components were developed and implemented with a secondary focus on collecting planning data and the systems were not necessarily designed to collect meaningful data. Another challenge is to maintain the data collection equipment so that reliable data is obtained over time. These systems, as well as the increase in ATRs, are often regarded as solutions to the problem of declining staff levels and increasing data needs.

> “There is no magic ingredient in the success of coordinated collection programs.”

Successful coordinated data collection programs usually have one lead agency advocating and coordinating the program. All participants have to share a spirit of cooperation and professionalism.

> “While current programs generally provide the data that is needed, data quality and accessibility are major concerns.”

Most data requirements seem adequately served by the current data collection programs, however the data users often question the data validity, and quality control. The loss of trained permanent staff devoted to data collection appears to have had an adverse impact on the quality of the data. The reliability of automated traffic data collection equipment, such as AVC, is often questioned as well as the consistency of data formats from various agencies.

> “All new ATMS should be designed and built with the capability of collecting traffic monitoring data”.

A vast amount of data is generated through ATMS but not in all cases is this source of information properly utilized or appropriate for many planning, design, and monitoring purposes.

> “The concept of a central clearinghouse for the evaluation of data collection equipment, and the widespread dissemination of the resultant information to data collection agencies, including those below the state level, should be vigorously pursued”.

Because of the concerns in the data validity and quality of data collected through automated collection equipment every effort should be undertaken to establish commonly accepted standards regarding the calibration, maintenance and usage of such equipment.

A good example for a well thought out traffic monitoring system was developed and implemented by the Manitoba Highways and Transportation. Principles identified early in the process guided the system through development and implementation. [10]

Manitoba Highway Traffic Information System Development

In the Canadian province of Manitoba, the Manitoba Highway Traffic Information System (MHTIS) was developed as a partnership between the Manitoba Highways and Transportation (MHT) and the University of Manitoba Transport Information Group for the collection, analysis, and dissemination of information about traffic movement on Manitoba highways. The majority of Manitoba’s population of approximately one million lives in or near the City of Winnipeg. The 17,400 km (10,700 mi.) roadway network is generally made up of provincial trunk highways and provincial roads, most of which are low volume roads.

The system was developed based on the *Information Delivery Principle* meaning that the most critical component of the system is the information delivery to the users—the system is user driven. [10/11] For example the content of all reports produced by the MHTIS must meet the user's information requirements, be easily accessible to all users, be in an easy to use format, and be available in a timely manner. All reports follow the principles of responsiveness to need, truth in data, and consistent practice while maintaining base data integrity, as shown in Table 2.7.

Several means of communication and reporting are used to disseminate the traffic data collected. A help desk is established assisting data users in technical questions, sending requested information by mail or fax, and in servicing all information requests from MHT staff, engineering consultants, and the general public. An annual publication, "Traffic on Manitoba Highways," provides historical statistics and analysis for the entire province and presents data for all permanent count stations. Traffic information can also be accessed through the Internet using MHTIS Online Traffic Report System. [12] This application allows the retrieval of detailed traffic statistics for each count station. Additionally, traffic information is provided through Geographic Information Systems that allow the production of customized traffic flow maps for the data users.

Table 2.7. Information Delivery Principles

Responsive to need	Provide information required by users; Follow convenient, easy to use format that meets users' needs; Handle request for information quickly; Provide timely information.
Truth in data	Document and disclose methods used for data sampling and expansion; Describe the methods used to collect and process the information presented; Provide estimates of the accuracy of all statistics.
Consistent Practice	Adopt standard methods or press for standards to be established; Conform to standard practice (AASHTO, ASTM, FHWA).
Base date integrity	Screen data for errors and anomalies; Data must be accepted or rejected but not adjusted.

Source: *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation: A Case Study* [10]

AADT Estimation

AADT is estimated at about 2000 locations on the highway network using a variety of equipment. With the exception of 57 sites equipped with ATRs, the locations are counted with mechanical counters twice a year for 48 hours producing short-term samples for the estimation of AADT. AADT at short-term counts is determined using a "factorless expansion method" that directly compares the short-term observed volume with the hourly data from the station's volume control station or Traffic Pattern Group. This method is an extension of the "operational analysis" concept proposed in the AASHTO guidelines.

Traffic Pattern Group Definition

A new methodology of assigning and defining Traffic Pattern Groups (TPG) was developed. To solve the problem of TPGs not reflecting the actual traffic pattern and therefore producing inaccurate estimates on the assigned short-term count locations, new Traffic Pattern Groups were established. The data from each permanent counter were summarized into seasonal and average hourly traffic variations. The new TPGs were developed based on the seasonal variations and then further subdivided. Once the new TPGs were developed, a new process was used to assign the TPG to both the ATRs and short-term count locations. During the annual estimation process, if AADT estimates seem unreasonable, the TPG assignments are re-evaluated and changes are properly documented.

Quality Control of AADT Estimates

A major objective of the MHTIS is the quality control of its data and especially its AADT estimates. In a previous methodology, data input was evaluated through human-intervention. The raw data was screened and verified before being accepted into the database. In 1997 a new method was developed to evaluate AADT estimates systematically. Using a GIS application, an "intersection-balancing technique" is used to identify potential errors. This method is based on the principle of evaluating the conservation of flow at intersections while treating AADT point estimates as traffic flow along continuous links.

Truck Traffic Information System

Past, present, and future truck traffic volumes and characteristics are of great importance to planning, engineering and management issues. [13] Using nine AVC and eight WIM sites as permanent count sites, a new Truck Traffic Information System is being developed to monitor and classify truck traffic flows on low volume highways.

The New England Data Quality Partnership

Faced with budget cuts that force reductions in staff, and an increasing need for quality data for decision making, the New England States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont have been working together to support each other in collecting and sharing transportation data. This cooperative effort is focused on inventory, travel monitoring, and performance data used by the States and reported to the FHWA. The newly developed "data partnership" is based on past informal working relationships that have been institutionalized over the last several years through a series of consultant studies

These activities have resulted in improved working relationships, expanded and open lines of communication, and excellent rapport. The New England states jointly sponsored three major consultant studies: the "New England Vehicle Classification and Truck Weight Program Study," the subsequent "Analysis of Vehicle Classification and Truck Weight Data of the New England States," and the " New England Traffic

Monitoring System." The latest study is a regional pool-funded effort for the development of a comprehensive traffic monitoring system for each state in the New England Region. The main outcomes anticipated are:

- Further sharing of traffic data among the States.
- Access by each State to sufficient data to develop statistically reliable products and applications.
- Combined training.
- Timely and coordinated development and implementation of a uniform system.

The establishment of traffic monitoring systems for each state will be uniform in its data formatting, editing, and storage functionality. However, each state will have the ability to analyze and produce custom reports that fulfill the requirements of the individual state.

The close coordination among the states was built and is continued through a series of activities including conferences and workshops for the FHWA Region One States. A long standing Transportation Coordinating Committee provides a forum for the participating states to discuss the latest efforts on a variety of data collection activities including HPMS, GIS/GPS, accident data, management systems, staffing, and budget problems. A Review Team concept is also used to provide technical assistance to States in regard to technical information.

The success of the New England Data Quality Partnership is attributed to several factors:

- The close proximity of the states.
- The FHWA Regional Office Involvement and proactive participation.
- Visible results of the benefits through realization of the partnership.
- Funding through Federal-aid Statewide Planning and Research (SP&R) funds.
- Active participation by all involved states.
- Ongoing exchange of information.

Maryland State Highway Administration Traffic Monitoring System

The Maryland Department of Transportation (MSHA) developed an automated Traffic Monitoring System (ATMDS) to collect, analyze, and distribute State highway traffic volume data to the State Highway Administration, external agencies, and other users. [15] The system was designed to automate three major processes related to traffic data collection, processing, and reporting:

- Submission of data requests and scheduling of count activities. Requests by central and district offices are handled in a consistent manner. Once input, requests and counts are tracked and monitored throughout the process and reports and maps generated to reveal status and progress.

- Facilitation of automated and manual data input. Incoming data are validated according to federal guidelines and anomalous or incomplete data are identified. User intervention and override are supported. Data is available for query and display in both tabular and map formats.

- Maintenance tracking and reporting. Provides a mechanism for identifying non-operational or malfunctioning equipment and for requesting and scheduling maintenance activities. Tools are provided for tracking problem equipment and for obtaining failure and maintenance reports.

The system provides centralized count requests and contractor scheduling. Users generate count requests through an on-line data entry form that allows the centralized management and administration of the requests. Similarly, the scheduling process is centralized through an on-line application that allows system operators to specify which request is to be assigned to particular contractors. Standard and ad-hoc reports can be obtained.

This state-of-the-art system is GIS-enabled and accessible by many departments within the Administration. Reports available include Group factors, Annual Average Daily Traffic (AADT) calculations, Monthly Average Daily Traffic (MADT) calculations, traffic volume variations year-to-year and month-to-month, traffic distribution information and reports on individual counts. The system maintains, on-line, 10 years of 70+ permanent counters, 700+ program counts per year, and 2,000+ special counts per year.

Maine Department of Transportation: Transportation Information for Decision Enhancements (TIDE) Project

GIS/Trans is currently involved in Phase II of a project for the Maine Department of Transportation (MeDOT). The project is entitled *Transportation Information for Decision Enhancements (TIDE).* Having provided MeDOT with a TIDE Phase I Data Warehouse that equips the Department with an enterprise view of its transportation data, the project is currently in its second phase. A *Requirements Specification Document* outlines the functional and operational requirements of the TIDE data warehouse. [16] The scope of work for the second phase of the project outlines the challenges the Department is facing and includes recommended solutions for overcoming these obstacles. [17] The TIDE development has followed and phased, incremental approach that has demonstrated early successes and benefits. Subsequent enhancements to the system build upon the already established framework.

For the last 30 years MeDOT relied on TINIS, a legacy traffic monitoring system. This system provided:

- Analysis of traffic counts, speed zones, high accident locations.
- Development of accident rates.
- Management of HPMS.

Over time, the information processing environment has changed considerably and new business processes have evolved. In particular, traffic data users and decision-makers are requiring more control and flexibility in regard to the available data. As a result, data managed and stored outside the TINIS system has grown substantially to include project information, management systems, traffic monitoring system, and travel demand modeling data, to name a few. Due to the obstacles to integrating these data sets into TINIS, many desired types of analyses cannot be performed Examples of such limitations include the inability to:

- Track locations of active or proposed projects.
- Determine signing and signaling at high accident locations.
- Relate maintenance and inventory data with project information.
- Relate turning movement and vehicle classifications data with other data sets.
- Easily map transportation data.

The technology used in the TINIS system, primarily from the 1960s and ‘70s limits the usage of the data. Concepts such as a common referencing system for the various data items are difficult to implement. Therefore one of the principal solutions recommended in the TIDE project is the development of an independent location referencing management system to integrate the separate databases and synchronize the locational referencing of the data. To further improve the data management system, the TIDE data warehouse established under Phase 1 is being enhanced to support additional analyses and reports. Eventually, the old TINIS system will be migrated to a new enterprise transportation information system based around the data warehouse.

Texas STARS Project Feasibility Study

Based on the increased demand for traffic data and related products from the Transportation Planning and Programming Division of the Texas Department of Transportation, the Department sponsored a feasibility study to reengineer the existing traffic data collection, analysis and reporting system. The system is referred to as the Statewide Traffic Analysis and Reporting System (STARS). [18] The study addressed:

- Federal requirements regarding the audit of traffic analysis results.

- Increased federal requirements regarding TxDOT's off-state transportation system.
- Agency business retooling initiatives for establishing standards regarding information technology.
- Agency partnering initiatives that support increased data sharing and interaction with internal and external entities.
- The development of new technologies such as GIS, ITS, and Internet/Intranet usage.
- Increased demand for statistics and reports from internal and external customers.

TxDOT Objectives and Goals

The feasibility study concluded that TxDOT was unable to fully address the internal and external requirements pertaining to the collection, analysis, and reporting of traffic data, given staffing and financial constraints. The identified requirements were:

- Federal Highway Administration mandates.
- Legislative requests for data and reports.
- Truth-In-Data strategies.
- Internal audit.
- Results for transportation planning and maintenance.

Currently, an enterprise wide system is being designed and developed to bring together traffic data from various sources and to make this data and its products available across the agency from a single, consistent system. The system will utilize client-server technologies and will employ a modern relational database.

The Use of Data Generated Through ITS Applications

Advanced Transportation Management Systems (ATMS) and Freeway Management Systems (FMS) have been set up in several major urban areas and are being initiated in a few rural or statewide applications. [19] These systems can generate a significant stream of data within their surveillance area monitoring the real-time system performance. The data collection processes function mainly to provide real time information for incident management or traveler information. However there are a number of planning and programming activities that could benefit from the adaptation of such ITS data including:

- Improving the monitoring of transportation system performance.
- Improving the validation of regional travel demand models.
- Researching and developing improved modeling structures.
- Using ITS-derived visualization to communicate the nature of congestion
- Conducting assessments of local traffic and parking impacts using ITS data.

There are strong institutional differences and perspectives between ITS operations and transportation planning. The main differences include the time frame for data collection, the level of geographic aggregation, and communicating with decision-makers and users. While ITS operators deal with minute-to-minute conditions, planners usually deal with long-term trends and forecasts of five to twenty years in the future. However, if collected and archived properly, the ITS-data could provide the needed information for planning purposes, or could support other established planning activities such as HPMS or the determination of factor groups. In particular, the visualization of seasonal and other short-term variations can be derived from ITS data.

Another difference lies within the geographic aggregation of the data. While planners and programmers are concerned with the overall travel and traffic patterns of the system, the ITS operator is focused on specific locations along facilities. To overcome these differences and perspectives in operations and planning, several issues need to be resolved including institutional issues, privacy concerns, development costs, data quality and editing, data manipulation, and coverage. In most cases, separate agencies or departments are responsible for ITS operations and transportation planning. To link ITS operations and planning, personnel from both groups must work closely together and keep communications open. Also, the data quality of the ITS-data has to be monitored against necessary data standards. Standards and common methodologies must be established for the processing, manipulation, and transformation of the ITS-data into information useful for planning and other purposes.

ITS as a Data Resource summarizes the results of a workshop that was conducted to identify ITS data resources for transportation planning. [20] One of the main objectives of the workshop was to bring transportation planners and operators together with the ITS community to:

- Discuss common data needs and concerns.
- Identify currently available ITS data that can meet the data needs of transportation planners.
- Identify opportunities for expanding ITS data collection to meet additional data needs for planning and operations.

TRAFFIC DATA STANDARDS

Several publications offer general guidance in regard to traffic data collection and implementation of comprehensive traffic management systems. The report *Statewide Data Collection and Management Systems* from 1986 evaluates the Washington State Department of Transportation data development and analysis activities. [21] The document provides recommendations for streamlining the data collection program, addresses data quality issues, identifies needed data elements, and recommends statistically valid methodologies to assemble the needed traffic information. In particular, the study recommends implementing a two-tiered data collection approach consisting of a project-specific data collection effort and statistically based statewide sampling.

The *Annual Book of ASTM Standards* defines *Standard Practice for Highway-Traffic Monitoring* including the collection, summary, and reporting of traffic volumes, vehicle classification, and vehicle weight data. [22] The standards are based on three overriding principles. The first is the truth-in-data principle, which requires the provision of supplemental information required for the appropriate use of the traffic data. The second is the principle of unedited base-data integrity, meaning that missing or inaccurate data shall not be completed, filled-in, or replaced for any type of traffic measurement. The third principle is the recognition that traffic-data summaries are representations of traffic at certain times and places, and under conditions that can not always be applied to other locations at other times.

FHWA's Traffic Monitoring Guide has two major objectives: to relate the intensity of the monitoring effort to the quality of the data gathered, and to change the perception that the individual traffic collection efforts are unrelated activities. [1] Traffic counting, vehicle classification, and truck weighing are all part of a related set of traffic characteristic monitoring functions. The components of a traffic monitoring system—counting, classification, and weighing—are discussed in great detail.

Another document, the *Guidance Manual for Managing Transportation Planning Data* views traffic related and transportation data in light of the provisions of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 (CAAA). [26] The manual recognizes the need for data availability to support and keep pace with the development of new multi-modal transportation planning methods. The *Manual* provides guidance for the implementation of a system of Transportation Planning Data through:

- Establishment of a data task force.

- Strategic assessment of data needs.
- Development of a framework for organizing data.
- Cost-effective collection of data.
- Prioritization of data.
- Identification of data integration issues.
- Dissemination of data.

FINDINGS AND RECOMMENDATIONS

Accurate and reliable traffic data are essential to a variety of transportation applications, including pavement and bridge design performance evaluation, and, programming, planning, and budgeting activities, as well as legislative and administrative policy development. Traffic data is one major component in the decision-making processes for administering the State's highway system. Based on available traffic data, the agency does not currently have adequate information to determine the transportation needs with confidence.

While the demand for statewide traffic data collection is continuously increasing, the personnel resources available to collect, analyze, and disseminate the data are not, and have even been reduced. Data collection efforts remain close to the minimum level necessary to meet the basic, immediate data needs of the Department and to address state, local, and federal requirements. ***The ADOT Data Team's ten staff members cannot adequately administer critical data collection, processing, and dissemination programs given their current levels of budget and staff resources. This data is crucial across the entire Department.***

With limited resources available, only a minimal data collection and dissemination program can be undertaken. While this minimalist data collection approach may save money in the short term, it leads to data deficiencies that result in long-term costs greater than any apparent savings. The availability of data is not so great a concern to the users as is the quality and validity of the data provided. The distrust of the data provided leads to redundant data collection efforts by various user groups. These different collection efforts may employ different methodologies for collecting, factoring and projecting the data, which in turn lead to data inconsistencies throughout ADOT.

It must be recognized that traffic data is a major input for planning and conducting the design, construction, maintenance, and operation of the State Highway System and as such, has implications for the efficiency and safety of the system. The latest construction program allocates $2.7 billion to the preservation, improvement, and management of the system over the next five years. The selection of individual projects is often based on available traffic data. The impacts of insufficient traffic data on the long-term administration of the State Highway System must be recognized and resources allocated to provide adequate and accurate traffic data, upon which to base these important decisions.

The literature review reveals that these challenges are not unique to ADOT. Throughout many transportation agencies similar problems and shortfalls are encountered. As previously discussed, a set of well-defined principles can improve data collection efforts. Responsiveness to user needs, the principle of Truth-in-Data, consistent practice, and base data integrity should be implemented to improve the traffic data collection program and its resulting data. ***The implementation of such principles requires the commitments of more staff resources than are currently made available.***

The validity and quality of traffic data is crucial to the success and overall performance of ADOT. In addition to funding, communication and coordination of data collection, the dissemination and accessibility of traffic data is of utmost importance. The formation of a standing working group on traffic data issues could be a means of facilitating such communication and coordination, and could aid in the implementation of the aforementioned information delivery principles. In addition, a focal point or clearinghouse should be established as a central repository of traffic information throughout ADOT.

The Traffic Monitoring System for Manitoba Highways and Transportation is available for guidance in improvements of ADOT's traffic data collection process. There should be great emphasis placed on the Information Delivery Principle. This principle means that the most critical component of the system is the information delivery to the users—the whole system must be user driven. This entails that all reports produced by the Data Team must meet the user's needs and requirements, be easily accessible to all users, be in an easy to use format, and be available in a timely manner. All reports have to conform to the following principles:

Be responsive to user needs:

- Provide information required by users.
- Follow convenient, easy to use format that meets users' needs.
- Handle request for information quickly.
- Provide timely information.

Truth in data:

- Document and disclose methods used for data sampling and expansion.
- Describe the methods used to collect and process the information presented.
- Provide estimates of the accuracy of all statistics.

Consistent Practice:

- Adopt standard methods.
- Conform to standard practice (AASHTO, ASTM, and FHWA).

Base data integrity:

- Screen data for errors and anomalies.
- Data must be accepted or rejected, but not adjusted.

The Arizona Department of Transportation should expand on the methods in how they disseminate traffic data. A central focal point should be established assisting data users in technical questions, sending requested information, and in servicing all information requests from staff, engineering consultants, and the general public. Such a focal point should also maintain a central depository of all available traffic data. Standardized reports, when publicized, should be in various levels of detail.

To enhance ADOT's traffic resources and to implement the information delivery principles, a working group should be formed and be charged with improving the ADOT's data program. Such a group would include the Data Team, essential people in other parts of ADOT and agencies, and District Engineers, and should develop a policy framework regarding traffic data including:

- Strategic assessment of data needs.
- Identification of base data for continuous collection.
- Development of a framework for organizing data.
- Cost-effective collection of data.
- Prioritization of data.
- Identification of data integration issues.
- Dissemination of data.
- Coordination and notification of construction, maintenance, and other activities that affect Traffic Count Station (TCS) sites.

Specific Issues that have to be resolved include:

- Most Data Team activities are geared toward fulfilling federal reporting requirements. The scope of data collection efforts needs expanding in order to be responsive to user needs.

- Reliability of count equipment and automatic traffic recorders needs to be improved. There should be the incorporation of other data collection mechanisms, such as the Weight in Motion stations.

- Centralization of all data collection, processing, storage, and reporting activities within one group.

- Consolidation of all forecasting activities throughout ADOT within one group.

- Evaluation of the currently used traffic data processing software TRADAS.

- Development of statistically based factor groups and adjustment factors and publish such statistics.

- Additional funding sources and mechanisms. Education about the impacts insufficient traffic data has on the long-term administration of the State Highway System.

- Funding and acquisition of additional traffic data collection devices and equipment.

III. NEEDED TRAFFIC DATA ELEMENTS

The objectives of this chapter are to identify traffic data elements that are used throughout ADOT, and to provide a standard data dictionary describing the needed data elements. The list of needed data elements was constructed after gathering information from various divisions and groups within ADOT. Each group was asked the following questions:

- What traffic data do you need for your business processes?
- How often do you use traffic data?
- Which data formats or standards do you require?
- How are the traffic data applied to support your needs?

Many of these questions were outlined in the chapter entitled "Traffic Data Collection and Storage Practices".

LIST OF NEEDED TRAFFIC DATA ELEMENTS

A list of traffic data elements that are used by various users within ADOT and consultants are summarized in Table 3.1.

Table 3.1. List of Traffic Data Elements

	Name of Data Element	**Description**
1	Average Annual Daily Traffic (AADT)	The average 24-hour traffic volume at a given location over a full 365-day year – that is, the total number of vehicles passing a site in a year divided by 365. AADT is counted or estimated for all sections of the State highway system.
2	Annual Daily Traffic (ADT)	The average 24-hour traffic volume at a given location for some period of time less than a year. While an AADT is for a full year, an ADT may be measured for six months, a season, a month, a week, or as little as two days. An ADT is a valid number only for the period over which it was measured.
3	K – Factor	The proportion of daily traffic occurring during the peak hour. K is often computed by determining the proportion of AADT occurring during the thirtieth highest peak hour of the year. The thirtieth highest peak hour is often the criterion for rural design and analysis. Others, such as the fiftieth, are sometimes used in urban situations. K factors are determined for all sections of the State highway system.
4	D – Factor	The proportion of peak-hour traffic traveling in the peak direction. D factors are determined for all sections of the State highway system.
5	T – Factor (percentage of trucks)	The percentage of trucks on a given highway section. These include trucks in the groups 5 through 13 in the FHWA Vehicle Classification Scheme. T factors are determined for all sections of the State highway system.
6	Vehicle Classification	Vehicle classification data describes the types of vehicles that

		are using the facility. The data is grouped into 13 classes based on the FHWA Vehicle Classification Scheme.
7	Vehicle Weight	Vehicle weight data taken at weigh-in-motion (WIM) stations. A weight data record should exist for each truck and include gross vehicle weight and the load delivered by each axle.
8	Percentile Vehicle Speed (Based on a speed study)	Vehicle speed data are collected for a variety of design, operational and enforcement purposes. The specific speed parameters that are used vary widely based on their purpose. A speed study performed by a traffic engineer will generate a distribution of observed speeds. Usually traffic engineers are interested in the 85^{th}-percentile speed generated from a speed study, which is often used as a measure of the maximum reasonable speed for the traffic stream. The 85^{th}-percentile speed means that 85% of the vehicles in the traffic stream travel at or below this speed. Sometimes traffic engineers are interested in determining the 15^{th} and 50^{th} percentile speeds.
9	Advisory Speed	The speed posted on the highway to indicate that speed which is reasonable for the given condition, as on a horizontal curve.
10	Travel Time	The total time for a vehicle to travel a specified section of road. Travel time studies are generally performed to evaluate the extent and causes of congestion or delay along a route.
11	Equivalent Single Axle Loads (ESALs)	The total number of repetitions of a standard 18,000 axle load during a design period.
12	Directional Design Hourly Volume (DDHV)	The peak hour directional volume usually expressed as vehicles per hour. The derivation of DDHV is as follows: DDHV = AADT x K x D. Usually DDHV is derived from a projected (future) AADT. This element is of greatest interest to traffic engineers in design or operational analysis.
13	Adjustment Factors (for monthly and daily variations)	These are used to convert AADT to ADT for a specific month and day.
14	Hourly, weekly and yearly distribution	These data types are usually in the form of graphs. The show how traffic volume varies over time.
15	Forecasted AADT	Projected AADT values for a specific planning horizon. These are derived from linear regression analysis of historical data and/or traffic forecasting models.
16	Traffic Growth Rates	The growth rates based analysis of historical traffic data.
17	Turning Movements	These include turning movement counts for intersections and interchanges.
18	Sub-hourly Flow	The equivalent hourly rate at which vehicles pass over a given point or section of roadway during a given time interval less than 1 hr (usually 15 min). Flow is mostly used by traffic engineers for design or operational analyses. *Note: Flow and volume are often used interchangeably. According to several traffic engineering textbooks, flow generally indicates an hourly rate, whereas volume indicates a rate for a duration of greater than an hour such as average daily traffic (veh/day).*

Table 3.1. List of Traffic Data Elements (continued)

19	Density (veh/mi/ln)	The number of vehicles occupying a given length of a lane or highway at a particular instant. This is often used for analyzing freeway operations.
20	Intersection Approach Volume	This is defined as the total number of vehicles entering an intersection from a specified approach during a given time interval. This element is usually required for analyzing the operational characteristics of intersections.
21	Peak Hour Factor (PHF)	The hourly volume divided by the peak flow rate within the hour. Once determined, the PHF is often used to convert the peak hour volume to a peak rate of flow.
22	Delay	There are many types of delay but "stopped-time" delay is most useful for a traffic analysis. Stopped-time delay is the time an individual vehicle spends stopped in a queue while waiting to enter a signalized intersection.
23	Vehicle Miles of Travel (VMT)	VMT is usually defined for a specified network or the entire State Highway System. It is calculated by summarizing the produce of traffic volume and link length for all links in a network.
24	Pedestrian Volume	Pedestrian volumes are most often used for traffic signal warrant studies in areas of high pedestrian activity.
25	Automatic Traffic Recorder (ATR) Station Reports	These reports provide status of ATRs. These reports are required for the HPMS.
26	Historical AADT	AADT values for previous years.

The list includes some elements that are not frequently used, but are required for specialized analyses and studies.

Data Needs by User Group

For the chapter entitled "Traffic Data Collection and Storage Practices" various data users were asked which traffic data were most useful for their business processes. The following divisions or groups were interviewed:

- Transportation Planning Division
- Traffic Engineering Group
- Programming Team
- Advance Engineering (Scoping)
- Pavement Design Section
- Pavement Management
- Bridge Group

A summary of traffic data needs for the functions of each group are presented in Table 2.6, which shows that the most widely required data elements within ADOT are:

- AADT
- K and D factors
- Percent trucks (or T factor)
- Vehicle weight

Additional Traffic Data Elements

Based on discussions with the users of traffic data, there was only one request for the collection of additional data elements. The Bridge Group made this request. They indicated a desire to have traffic data (particularly AADT and percent trucks) for all non-ADOT roads that cross ADOT structures. All other traffic data users request that improvements be made to the collection and management efforts of existing data to achieve greater levels of accuracy and integrity.

DATA DICTIONARY

Traffic data elements pertinent to ADOT's efforts and responsibilities have been determined and organized into three categories as shown in Table 3.2. The first category includes all data elements that are currently available on a continuous basis since they are maintained by either the Data Team or another section responsible for maintaining traffic data. The second category includes the data elements that are only collected on an "as needed" basis. An example would be turning movements. The third category includes only the subset of elements that are listed in the Traffic Monitoring Guide for federal reporting. These data descriptions from the Traffic Monitoring Guide are provided for reference.

Each data element needs to have supplemental data associated with it, which makes the data values more useful. For example, an AADT value should be associated with a location and the time the count was taken. Another example might be information about how the count was taken and the agency that performed the collection. This section also describes any supplemental data associated with each data element.

Additionally, all highway data should be spatially referenced by route number and milepost, or by another means. Route-milepost is a uniform standard regardless if the data is for traffic, geometrics, projects, signage or accidents.

The following data dictionary presents ADOT's needed data elements by category, lists supplementary data, and defines data fields that are not self-explanatory.

Table 3.2. Categories of Traffic Data Elements

CATEGORY I: DATA ELEMENTS CONTINUOUSLY COLLECTED AND MAINTAINED	AADT
	K – Factor
	D – Factor
	T – Factor
	Vehicle Classification
	Vehicle Weight
	ESAL
	DDHV
	Monthly and Daily Adjustment Factors
	Hourly, weekly and yearly distribution
	Forecasted AADT
	Traffic Growth Rates
	Historical AADT
	Vehicle Miles Traveled (VMT)
CATEGORY II: DATA ELEMENTS COLLECTED AND MAINTAINED AS NEEDED	Vehicle Speeds
	ADT
	Turning Movements
	Sub-hourly Volume/Flow
	Density
	Intersection Approach Volume
	Peak Hour Factor
	Delay
	Pedestrian Volume
CATEGORY III: DATA ELEMENTS REQUESTED FOR FEDERAL REPORTING IN SECTION 6 OF THE TRAFFIC MONITORING GUIDE (May include elements from Categories I or II)	Traffic Monitoring Stations
	ATR Stations
	Traffic Volume
	Vehicle Classification
	Vehicle Weight

Category I: Data Elements Continuously Collected and Maintained

Average Annual Daily Traffic (AADT)

Each data record represents an AADT value for a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
AADT Value	The AADT value in vehicles per day.
Validated by Data Team	Indicates whether the ADOT Data Team has validated the data.
Year of Data	The year that the data represents.
Estimated or Counted	Indicates whether the data element was estimated or actual
Begin Time of Collection	The starting date and time of data collection.
End Time of Collection	The finish date and time of data collection.
Traffic Monitoring Station Identification	An identifier that specifies from which station the data was gathered.
ATR Station Identification	An identifier that specifies the nearest ATR Station.

Memo	A memo field for storing descriptive text.

K – Factor

Each data record represents a K-Factor for a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
K-Factor Value	The K-Factor value as a percentage.
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
Memo	A memo field for storing descriptive text.

D – Factor

Each data record represents a D-Factor for a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
D-Factor Value	The D-Factor value as a percentage.
D-Factor Direction (NB, SB, EB, WB)	The direction of the flow of traffic that the D-Factor represents.
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
Memo	A memo field for storing descriptive text.

T – Factor

Each data record represents a T-Factor for a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
T-Factor Value	The T-Factor value as a percentage.
Classification Count Station Identification	An identifier that specifies from which station the data was gathered..
Memo	A memo field for storing descriptive text.

Vehicle Classification

Each data record represents classification data for a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.

% of FHWA Class 1	Percent of AADT that is of FHWA Class 1
% of FHWA Class 2	Percent of AADT that is of FHWA Class 2
% of FHWA Class 3	Percent of AADT that is of FHWA Class 3
% of FHWA Class 4	Percent of AADT that is of FHWA Class 4
% of FHWA Class 5	Percent of AADT that is of FHWA Class 5
% of FHWA Class 6	Percent of AADT that is of FHWA Class 6
% of FHWA Class 7	Percent of AADT that is of FHWA Class 7
% of FHWA Class 8	Percent of AADT that is of FHWA Class 8
% of FHWA Class 9	Percent of AADT that is of FHWA Class 9
% of FHWA Class 10	Percent of AADT that is of FHWA Class 10
% of FHWA Class 11	Percent of AADT that is of FHWA Class 11
% of FHWA Class 12	Percent of AADT that is of FHWA Class 12
% of FHWA Class 13	Percent of AADT that is of FHWA Class 13
Classification Count Station Identification	An identifier that specifies from which station the data was gathered.
Memo	A memo field for storing descriptive text.

Vehicle Weight

Each data record represents a single truck passing a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Total Weight	Total weight of vehicle.
Number of Axles	Number of axles on vehicle.
A-axle Weight	Weight of axle.
A-B Axle Spacing	Spacing between axles.
B-axle Weight	Weight of axle.
B-C Axle Spacing	Spacing between axles.
C-axle Weight	Weight of axle.
C-D Axle Spacing	Spacing between axles.
D-axle Weight	Weight of axle.
D-E Axle Spacing	Spacing between axles.
E-axle Weight	Weight of axle.
E-F Axle Spacing	Spacing between axles.
F-axle Weight	Weight of axle.
F-G Axle Spacing	Spacing between axles.
G-axle Weight	Weight of axle.
G-H Axle Spacing	Spacing between axles.
H-axle Weight	Weight of axle.
H-I Axle Spacing	Spacing between axles.
I-axle Weight	Weight of axle.
Classification Count Station Identification	An identifier that specifies from which station the data was gathered.
Memo	A memo field for storing descriptive text.

ESAL

Each data record represents ESAL data for a specific highway section.

Data Component	**Comments**

Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Current ESAL for Flexible Pavement	ESAL values for specified timeframe.
10 yr ESAL for Flexible Pavement	
20 yr ESAL for Flexible Pavement	
Current ESAL for Rigid Pavement	
10 yr ESAL for Rigid Pavement	
20 yr ESAL for Rigid Pavement	
Memo	A memo field for storing descriptive text.

Directional Design Hour Volume

Each data record represents a DDHV record for a specific highway section.

Data Component	**Comments**
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
DDHV Value	The directional design hourly volume.
Validated by Data Team	Indicates whether the ADOT Data Team has validated the data element or not.
Year of Data	The year that the data represents.
Derived or Counted	Indicates whether the data element was derived or actually collected.
Begin Time of Collection	The starting date and time of data collection.
End Time of Collection	The finish date and time of data collection.
AADT Value*	The AADT value from which the data was derived.
K-Factor*	The K value from which the data was derived.
D-Factor*	The D value from which the data was derived.
D-Factor Direction (NB, SB, EB, WB)	The direction of the flow of traffic that the D-Factor represents.
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
Memo	A memo field for storing descriptive text.

* Note: DDHV = AADT * K * D

Monthly Adjustment Factor

Each data record represents a set of monthly adjustment factors for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
January Adjustment Factor	Adjustment factors for each month.
February Adjustment Factor	
March Adjustment Factor	
April Adjustment Factor	
May Adjustment Factor	
June Adjustment Factor	
July Adjustment Factor	
August Adjustment Factor	
September Adjustment Factor	
October Adjustment Factor	
November Adjustment Factor	
December Adjustment Factor	
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
Memo	A memo field for storing descriptive text.

Daily Adjustment Factor

Each data record represents a set of daily adjustment factors for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Saturday Adjustment Factor	Adjustment factors for each day.
Sunday Adjustment Factor	
Monday Adjustment Factor	
Tuesday Adjustment Factor	
Wednesday Adjustment Factor	
Thursday Adjustment Factor	
Friday Adjustment Factor	
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
Memo	A memo field for storing descriptive text.

Hourly Variation

Each data record represents a set of hourly variation values for a specific ATR station.

Data Component	Comments
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
% of Daily Traffic 24- 01	Percent of daily traffic traveling between 12:00 am to 1:00 am
% of Daily Traffic 01 – 02	Percent of daily traffic traveling between 1:00 am to 2:00 am
% of Daily Traffic 02 – 03	Percent of daily traffic traveling between 2:00 am to 3:00 am
% of Daily Traffic 03 – 04	Percent of daily traffic traveling between 3:00 am to 4:00 am
% of Daily Traffic 04 – 05	Percent of daily traffic traveling between 4:00 am to 5:00 am
% of Daily Traffic 05 – 06	Percent of daily traffic traveling between 5:00 am to 6:00 am
% of Daily Traffic 06 – 07	Percent of daily traffic traveling between 6:00 am to 7:00 am
% of Daily Traffic 07 – 08	Percent of daily traffic traveling between 7:00 am to 8:00 am
% of Daily Traffic 08 – 09	Percent of daily traffic traveling between 8:00 am to 9:00 am
% of Daily Traffic 09 – 10	Percent of daily traffic traveling between 9:00 am to 10:00 am
% of Daily Traffic 10 – 11	Percent of daily traffic traveling between 10:00 am to 11:00 am
% of Daily Traffic 11 – 12	Percent of daily traffic traveling between 11:00 am to 12:00 pm
% of Daily Traffic 12 – 13	Percent of daily traffic traveling between 12:00 pm to 1:00 pm
% of Daily Traffic 13 – 14	Percent of daily traffic traveling between 1:00 pm to 2:00 pm
% of Daily Traffic 14 – 15	Percent of daily traffic traveling between 2:00 pm to 3:00 pm
% of Daily Traffic 15 – 16	Percent of daily traffic traveling between 3:00 pm to 4:00 pm
% of Daily Traffic 16 - 17	Percent of daily traffic traveling between 4:00 pm to 5:00 pm
% of Daily Traffic 17 – 18	Percent of daily traffic traveling between 5:00 pm to 6:00 pm
% of Daily Traffic 18 – 19	Percent of daily traffic traveling between 6:00 pm to 7:00 pm
% of Daily Traffic 19 – 20	Percent of daily traffic traveling between 7:00 pm to 8:00 pm
% of Daily Traffic 20 – 21	Percent of daily traffic traveling between 8:00 pm to 9:00 pm
% of Daily Traffic 21 – 22	Percent of daily traffic traveling between 9:00 pm to 10:00 pm
% of Daily Traffic 22 – 23	Percent of daily traffic traveling between 10:00 pm to 11:00 pm
% of Daily Traffic 23 – 24	Percent of daily traffic traveling between 11:00 pm to 12:00 am
Memo	A memo field for storing descriptive text.

Weekly Variation

Each data record represents a set of weekly variation values for a specific ATR station.

Data Component	Comments
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
% of Weekly Traffic Saturday	Percent of weekly traffic occurring on Saturday.
% of Weekly Traffic Sunday	Percent of weekly traffic occurring on Sunday.
% of Weekly Traffic Monday	Percent of weekly traffic occurring on Monday.
% of Weekly Traffic Tuesday	Percent of weekly traffic occurring on Tuesday.
% of Weekly Traffic Wednesday	Percent of weekly traffic occurring on Wednesday.
% of Weekly Traffic Thursday	Percent of weekly traffic occurring on Thursday.
% of Weekly Traffic Friday	Percent of weekly traffic occurring on Friday.
Memo	A memo field for storing descriptive text.

Yearly Variation

Each data record represents a set of yearly variation values for a specific ATR station.

Data Component	Comments
ATR Station Identification	An identifier that specifies the ATR Station from which the factor was derived.
% of Yearly Traffic January	Percent of yearly traffic occurring in January.
% of Yearly Traffic February	Percent of yearly traffic occurring in February.
% of Yearly Traffic March	Percent of yearly traffic occurring in March.
% of Yearly Traffic April	Percent of yearly traffic occurring in April.
% of Yearly Traffic May	Percent of yearly traffic occurring in May.
% of Yearly Traffic June	Percent of yearly traffic occurring in June.
% of Yearly Traffic July	Percent of yearly traffic occurring in July.
% of Yearly Traffic August	Percent of yearly traffic occurring in August.
% of Yearly Traffic September	Percent of yearly traffic occurring in September.
% of Yearly Traffic October	Percent of yearly traffic occurring in October.
% of Yearly Traffic November	Percent of yearly traffic occurring in November.
% of Yearly Traffic December	Percent of yearly traffic occurring in December.
Memo	A memo field for storing descriptive text.

Forecasted AADT

Each data record represents a forecasted AADT value for a specific year and highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Forecasted AADT Value	The forecasted AADT value in vehicles per day.
Forecast Year	The forecast horizon year.
Memo	A memo field for storing descriptive text.

Traffic Growth Rates

Each data record represents an annual growth rate for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Annual Growth Rate	Annual growth rate value.
Validated by Data Team	Indicates whether the ADOT Data Team has validated the data element or not.

Traffic Monitoring Station Identification	An identifier that specifies from which station the data was gathered.
ATR Station Identification	An identifier that specifies the nearest ATR Station.
Memo	A memo field for storing descriptive text.

Historical AADT

Each data record represents an historical AADT value for a specific year and highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Historical AADT Value	The historical AADT value in vehicles per day.
Year	The year of which the AADT value applies.
Memo	A memo field for storing descriptive text.

Vehicle Miles Traveled

Each data record represents a vehicle miles traveled value for a specific geographic area.

Data Component	Comments
Geographic Scope	A lookup code for geographic scope (Statewide, by County, by District, etc.)
VMT Value	The vehicles miles traveled value.
Year	The year that the data represents.
Validated by Data Team	Indicates whether the ADOT Data Team has validated the data element or not.
Memo	A memo field for storing descriptive text.

Category II: Data Elements Collected and Maintained as Needed

Vehicle Speed

Each data record represents speed data for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Mean Speed	Average speed from the sample.
85^{th} Percentile Speed	85^{th} percentile speed from the sample.
Begin Time of Data Collection	The starting date and time of data collection.
End Time of Data Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

Turning Movement

Each data record represents data for a specific intersection.

Data Component	Comments
Route	The highway route number.
Milepost	The begin milepost of the highway section.
Cross Street Route	The end milepost of the highway section.
Intersection Name	Name of intersection as indicated by cross streets.
Location of Raw Turning Movement Data Files	Text description of the location of raw data.
Begin Time of Data Collection	The starting date and time of data collection.
End Time of Data Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

Sub-hourly Flow

Each data record represents volume/flow data for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Flow	Flow value.
Unit of Time	Unit of time for flow (seconds, minutes, hour, day)
Begin Time of Collection	The starting date and time of data collection.
End Time of Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

Density

Each data record represents traffic density for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Density	Density value as vehicles per mile.
Time of Data Collection	Time and date of data collection.
Memo	A memo field for storing descriptive text.

Intersection Approach Volume

Each data record represents intersection approach volume for a specific intersection.

Data Component	Comments
Route	The highway route number.
Milepost	The begin milepost of the highway section.
Cross Street or Route	The end milepost of the highway section.
Approach Direction	Approach direction (NB, SB, EB, WB)
Volume	The volume for the approach.
Begin Time of Data Collection	The starting date and time of data collection.
End Time of Data Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

Peak Hour Factor (PHF)

Each data record represents the peak hour factor for a specific highway section.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
PHF Value*	Peak hour value.
Peak Hour Volume*	Volume for the peak hour (vehicles per hour)
15 Minute Peak Flow*	Highest rate of flow during the peak hour.
Direction	Direction of traffic.
Begin Time of Data Collection	The starting date and time of data collection.
End Time of Data Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

* Note: PHF = V/(4 * V15)

Delay

Each data record represents travel delay information for a section of highway.

Data Component	Comments
Route	The highway route number.
Begin Milepost	The begin milepost of the highway section.
End Milepost	The end milepost of the highway section.
Direction	Direction of traffic.
Delay	Delay value (in seconds).
Location of Data Files	Text description of location of raw data.
Begin Time of Collection	The starting date and time of data collection.
End Time of Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

Pedestrian Volume

Each data record represents pedestrian volume for a specific pedestrian crossing on a highway.

Data Component	Comments
Route	The highway route number.
Milepost	The milepost of the location of where the data was collected.
Pedestrian Volume	The pedestrian volume crossing the highway at the specified milepost.
Begin Time of Data Collection	The starting date and time of data collection.
End Time of Data Collection	The finish date and time of data collection.
Memo	A memo field for storing descriptive text.

Category III: Data Elements Requested For Federal Reporting In Section 6 Of The Traffic Monitoring Guide

The data elements listed below are mentioned for federal reporting to the FHWA in Section 6 of the Traffic Monitoring Guide. The description record for each is provided below in Table 3.3.

Table 3.3. Data Elements Requested for Federal Reporting

Data Element	Description	Representation of Data Record
Traffic Monitoring Stations	A table of all traffic monitoring stations throughout the Statewide traffic monitoring system.	Single traffic monitoring station.
ATR Stations	A table of all automatic traffic recording stations throughout the Statewide traffic monitoring system.	Single ATR station.
Traffic Volume	A table of 24-hour counts at all traffic monitoring stations.	Single day of traffic data collection.
Vehicle Classification	A table of hourly vehicle classification counts. Vehicles are classified according to the 13 FHWA vehicle classes.	Single hour of traffic data collection.
Truck Weight Data	A table of vehicle weights taken at WIM sites.	Single truck.

Traffic Monitoring Stations

Each record of a Traffic Monitoring Station table (or file) represents a single traffic monitoring station.

Station Description Record:

Columns	Width	Description
1	1	Record Type
2-3	2	FIPS State Code
4-9	6	Station ID
10	1	Direction of Travel Code
11	1	Lane of Travel
12-13	2	Year of Data
14-15	2	Functional Classification Code
16	1	Number of Lanes in Direction Indicated
17	1	Sample Type for Traffic Volume
18	1	Number of Lanes Monitored for Traffic Volume
19	1	Method of Traffic Volume Counting
20	1	Sample Type for Vehicle Classification
21	1	Number of Lanes Monitored for Vehicle Classification
22	1	Method of Vehicle Classification
23	1	Algorithm for Vehicle Classification
24-25	2	Classification System for Vehicle Classification
26	1	Sample Type for Truck Weight
27	1	Number of Lanes Monitored for Truck Weight
28	1	Method of Truck Weighing
29	1	Calibration of Weighing System
30	1	Method of Data Retrieval
31	1	Type of Sensor
32	1	Second Type of Sensor
33-34	2	Equipment Make
35-49	15	Equipment Model
50-51	2	Second Equipment Make
52-66	15	Second Equipment Model
67-72	6	Current Directional AADT
73-78	6	Matching Station ID for Previous Data
79-80	2	Year Station Established
81-82	2	Year Station Discontinued
83-85	3	FIPS County Code
86	1	HPMS Sample Type
87-98	12	HPMS Sample Number or Kilometer points
99	1	HPMS Subdivision Number
100	1	Posted Route Signing
101-108	8	Posted Signed Route Number
109	1	Concurrent Route Signing
110-117	8	Concurrent Signed Route Number
118-167	50	Station

ATR Stations

Each record of an ATR Station table (or file) represents a single ATR station.

ATR Station Description Record:

Column	**Length**	**Description**
1	1	Record Type: 1 = ATR Station
2-3	2	FIPS State Code
4-5	2	Functional Classification Code
6-11	6	Station Identification
12	1	Direction of Travel
13	1	Lane of Travel
14	1	Posted Route Signing
15-20	6	Posted Signed Route Number
21	1	Concurrent Route Signing
22-27	6	Concurrent Signed Route Number
28-30	3	FIPS County Code
31-42	12	HPMS Sample Number or Kilometer points
43	1	HPMS Subdivision Number
44-45	2	Year Station Established
46-47	2	Year Station Discontinued
48	1	Method of Data Retrieval
49-50	2	Equipment Make
51-100	50	Location of Station

Traffic Volume

Each traffic volume record of the Traffic Volume table represents a single day of traffic data collection.

Hourly Traffic Volume Record:

Column	**Length**	**Description**
1	1	Record Type
2-3	2	FIPS State Code
4-5	2	Functional Classification
6-11	6	Station Identification
12	1	Direction of Travel
13	1	Lane of Travel
14-15	2	Year of Data
16-17	2	Month of Data
18-19	2	Day of Data
20	1	Day of Week
21-25	5	Traffic Volume Counted, 00:01 - 01:00
26-30	5	Traffic Volume Counted, 01:01 - 02:00
31-35	5	Traffic Volume Counted, 02:01 - 03:00
36-40	5	Traffic Volume Counted, 03:01 - 04:00
41-45	5	Traffic Volume Counted, 04:01 - 05:00
46-50	5	Traffic Volume Counted, 05:01 - 06:00
51-55	5	Traffic Volume Counted, 06:01 - 07:00

56-60	5	Traffic Volume Counted, 07:01 - 08:00
61-65	5	Traffic Volume Counted, 08:01 - 09:00
66-70	5	Traffic Volume Counted, 09:01 - 10:00
71-75	5	Traffic Volume Counted, 10:01 - 11:00
76-80	5	Traffic Volume Counted, 11:01 - 12:00
81-85	5	Traffic Volume Counted, 12:01 - 13:00
86-90	5	Traffic Volume Counted, 13:01 - 14:00
91-95	5	Traffic Volume Counted, 14:01 - 15:00
96-100	5	Traffic Volume Counted, 15:01 - 16:00
101-105	5	Traffic Volume Counted, 16:01 - 17:00
106-110	5	Traffic Volume Counted, 17:01 - 18:00
111-115	5	Traffic Volume Counted, 18:01 - 19:00
116-120	5	Traffic Volume Counted, 19:01 - 20:00
121-125	5	Traffic Volume Counted, 20:01 - 21:00
126-130	5	Traffic Volume Counted, 21:01 - 22:00
131-135	5	Traffic Volume Counted, 22:01 - 23:00
136-140	5	Traffic Volume Counted, 23:01 - 24:00
141	1	Footnotes

Vehicle Classification

Each vehicle classification record of the Vehicle Classification table represents a single hour of traffic data collection.

Vehicle Classification Record:

Columns	**Length**	**Description**
1	1	Record Type
2-3	2	FIPS State Code
4-9	6	Station ID
10	1	Direction of Travel Code
11	1	Lane of Travel
12-13	2	Year of Data
14-15	2	Month of Data
16-17	2	Day of Data
18-19	2	Hour of Data
20-24	5	Total Volume
25-29	5	Class 1 Count
30-34	5	Class 2 Count
35-39	5	Class 3 Count
40-44	5	Class 4 Count
45-49	5	Class 5 Count
50-54	5	Class 6 Count
55-59	5	Class 7 Count
60-64	5	Class 8 Count
65-69	5	Class 9 Count
70-74	5	Class 10 Count
75-79	5	Class 11 Count
80-84	5	Class 12 Count
85-89	5	Class 13 Count
90-94	5	Class 14 Count
95-99	5	Class 15 Count

Truck Weight Data

Each truck weight record of the Truck Weight table represents a single truck weighed during traffic data collection.

Truck Weight Record:

Columns	**Width**	**Description**
1	1	Record Type
2-3	2	FIPS State Code
4-9	6	Station ID
10	1	Direction of Travel Code
11	1	Lane of Travel
12-13	2	Year of Data
14-15	2	Month of Data
16-17	2	Day of Data
18-19	2	Hour of Data
20-21	2	Vehicle Class
22-24	3	Open
25-28	4	Total Weight of Vehicle
29-30	2	Number of Axles
31-33	3	A-axle Weight
34-36	3	A-B Axle Spacing
37-39	3	B-axle Weight
40-42	3	B-C Axle Spacing
43-45	3	C-axle Weight
46-48	3	C-D Axle Spacing
49-51	3	D-axle Weight
52-54	3	D-E Axle Spacing
55-57	3	E-axle Weight
58-60	3	E-F Axle Spacing
61-63	3	F-axle Weight
64-66	3	F-G Axle Spacing
67-69	3	G-axle Weight
70-72	3	G-H Axle Spacing
73-75	3	H-axle Weight
76-78	3	H-I Axle Spacing
79-81	3	I-axle Weight
82-84	3	I-J Axle Spacing
85-87	3	J-axle Weight
88-90	3	J-K Axle Spacing
91-93	3	K-axle Weight
94-96	3	K-L Axle Spacing
97-99	3	L-axle Weight
100-102	3	L-M Axle Spacing
103-105	3	M-axle Weight... *Additional fields if needed*

FINDINGS AND RECOMMENDATIONS

Based on discussions with ADOT traffic data users, no additional traffic data elements were identified as needed to support current business processes. All necessary traffic data elements are collected within ADOT. The Bridge Group requested and would benefit from increasing the scope of ADOT's current data to include AADT and Percent-Trucks on all roads that cross ADOT structures, including local and county roads. AADT and Percent-Trucks are already available, but not for non-ADOT facilities.

Although all of the needed data is collected by ADOT, much of it is not conveniently accessible. The most prominent request was for "more and better existing data". This request means that users wish to have data collected more frequently, from more locations, with higher accuracy. For example, the Materials Group wishes to add several more WIM sites throughout the State system and they would like to use technology that achieves the highest level of accuracy. A coordinated, agency-wide WIM site and data collection plan needs to be developed.

Another request is for more frequent data collection. For example, the Bridge Group wishes to have ramps (highway connectors) counted more frequently than the current three-year rotation. Counts are conducted on the highway main lines on a yearly basis. From these annual counts it may be apparent to engineers that traffic volumes have substantially increased on a particular highway, but they still must use out-of-date counts for the connectors. To account for an increase on the main line, an engineer may factor the connector counts, based on the trend on the mainline. If the main line and connector traffic volumes are not directly related, this type of factor may not be accurate. More frequent counts on highway connectors would help ensure that accurate data is used for decision-making and reporting.

The set of data elements described in this chapter may change over time. There are possibilities that ADOT will need to manage additional data elements. It was noted that project numbers that are assigned and used consistently across ADOT would be useful and should be included as a necessary traffic data element. Also, changes in data collection, storage, and processing may be recommended by AASHTO for the implementation of new pavement design and monitoring methodologies.

The task of maintaining a data dictionary for all traffic data elements should be assigned to a working group responsible for traffic data issues. The working group, comprised of ADOT representatives from all groups that collect or utilize traffic data, should enforce standards for the provision of metadata and determine whether there is a need to add new data elements to the dictionary. The maintenance of a data dictionary will be a requirement for a system to manage all traffic data.

In summary, regarding needed traffic data elements, ADOT should:

- Maintain a data dictionary for all needed traffic data elements and add any new elements as needed;

- Investigate ways of acquiring AADT for non-State roads that pass over ADOT structures; and

- Focus on improving the quality of the most needed data elements. This involves installing more automated devices (ATR, AVC/WIM), better maintaining these devices, and the development and adoption of collection, processing, and documentation standards.

These items will require more staff and budget resources than are currently devoted to these efforts.

IV. STATEWIDE TRAFFIC DATA SOURCES

This chapter identifies and reviews the traffic data sources of the Arizona Department of Transportation (ADOT) and other agencies that relate to ADOT's overall data collection activities. The following text identifies the sources, responsible agencies and contacts, the geographical scope of data collection activities, specific information about collected data, and any related issues.

Information for this report was obtained by interviewing ADOT staff and representatives from other agencies. Because ADOT's Data Team collects and processes a substantial amount of traffic data, additional efforts were spent with the Data Team's staff and management. Interviews were intended to focus around the following:

- Current sources of traffic count data.
- The types of traffic data collected.
- Data is collection and storage mechanisms.
- The geographic scope of data collection activities.
- Frequency and intervals of traffic counts.

In addition to interviews, surveys were forwarded to 30 other personnel at 28 agencies. See Appendix A for a listing of survey recipients. Some recipients were also contacted by e-mail and telephone to obtain needed information.

ADOT'S COLLECTION EFFORTS

The main group responsible for collecting traffic data is the Data Team. Several other ADOT divisions collect data for their own specific needs, including the Traffic Engineering Group, Traffic Operations Center, Arizona Transportation Research Center, and Transportation Planning Division.

Traffic Monitoring System

The Data Team is also responsible for measuring vehicular traffic on the Statewide Highway System. Most traffic data users contact the Data Team for up-to-date traffic data for all State highways. The Data Team performs all of the necessary functions for the ADOT's traffic monitoring program. These functions include:

- Data Collection
- Data Processing
- Maintenance of Data Collection Equipment

Each of these functions is described below.

Data Collection

Traffic Volumes

The Data Team collects traffic volumes on all Interstate, U.S. or State highways at approximately 1400 "Traffic Counting Stations" (TCS). The raw traffic counts taken at these stations are used to determine Average Annual Daily Traffic (AADT) values for the highway segments associated with the TCS. Data collectors make periodic field visits each year to the stations, which are mainly in rural areas. Some off system/low order rural roads, with a designations less than local collector, are counted once every three years. Traffic counts performed in urban areas are contracted to consultants specializing in traffic data collection.

Statewide, there are 70 sites with automatic traffic recorders (ATR's), which count traffic volumes continuously 24 hours a day, 365 days a year, when operational. A list of the Statewide ATR's was provided in Table 2.2.

Vehicle Classification

There are two types of vehicle classification collection efforts: 6-hour manual counts and 48-hour machine counts. Both types of collection efforts occur on a 3-year rotation and are used to determine axle correction factors for the traffic volume counts taken by pneumatic tubes and the percentage of AADT that is generated by commercial trucks—also known as the "T" factor.

The 48-hour counts utilize portable programmable classification equipment. Like the 6-hour counts, the 48-hour counts supply axle correction factors and T factors. The classification equipment used in the 48-hour counts classifies vehicles according to the FHWA vehicle classification system. This data is manually post-processed to derive T Factors. The 13 FHWA vehicle classes are described in Table 4.1.

Table 4.1. FHWA Vehicle Classification Scheme

Number	Type Name	Description
1	Motorcycles	All two-or three-wheeled motorized vehicles. Includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.
2	Passenger Cars	All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.
3	Other Two-Axle, Four-Tire Single Unit Vehicles	All two-axle, four tire, vehicles, other than passenger cars. Includes pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Also includes two-axle, four-tire single unit vehicles pulling recreational or other light trailers. Because automatic vehicle classifiers have difficulty distinguishing class 3 from class 2, these two classes may be combined into class 2.
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles.
5	Two-Axle Six-Tire, Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.
6	Three-Axle Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.
7	Four or More Axle Single Unit Trucks	All trucks on a single frame with four or more axles.
8	Four or Less Axle Single Trailer Trucks	All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.
9	Five-Axle Single Trailer Trucks	All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.
10	Six or More Axle Single Trailer Trucks	All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
11	Five or Less Axle Multi-Trailer Trucks	All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.
12	Six-Axle Multi-Trailer Trucks	All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
13	Seven or More Axle Multi-Trailer Trucks	All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Source: FHWA Traffic Monitoring Guide.

Vehicle Weights

The Data Team collects vehicle weight information at seven sites using weight-in-motion (WIM) equipment. This information is collected for the Materials Group on an infrequent basis. Many of these WIM devices are currently not functioning and several may require complete re-installation. Two of the WIM sites equipment also has automatic vehicle classification (AVC) devices. These installations, like other ATRs capable of true vehicle classification, are difficult to keep in proper working order for prolonged and sustained periods of time

Factor Groups

ADOT's Data Team uses a system of growth factors to seasonally adjust traffic volumes based on ATR information. Three main geographical areas are distinguished: 1) the metropolitan areas of Phoenix, Tucson, and Yuma; 2) interstate corridors; and 3) rural portions of the state. Table 4.2 reveals the 1998 growth factors by factor group.

Table 4.2. ADOT Growth Factors by Factor Group for 1998 Traffic Year

Growth Factor Group		Included Sites 97-98	AADT Growth Factor	Included Sites 98	AAWDT Conversion Factor	AAWET Conversion Factor
0	Yuma Metro	1	1.05	1	1.00	0.90
1	I-8	2	1.06	2	0.92	1.06
2	I-10 West of PEW	2	1.08	2	0.95	1.01
3	Phoenix Metro	4	1.05	4	1.09	0.75
4	I-10 PHX-TUC	2	1.08	2	0.92	1.07
5	Tucson Metro	2	1.10	2	1.04	0.88
6	I-10 East of TUC		1.09	1	0.95	1.09
7	I-17		1.09	2	0.84	1.23
8	1-19		1.00		0.91	1.09
9	I-40 West of FLAG	2	1.09	2	0.95	1.07
10	I-40 East of FLAG	2	1.10	2	0.95	1.07
11	Southwest	3	1.04	3	0.93	1.08
12	West Central	7	1.04	7	0.96	1.01
13	East Central	12	1.03	12	0.93	1.03
14	North of 1-40	6	0.99	6	0.98	0.97
15	Extreme SE Corner	5	1.06	5	0.97	1.01
18	I-15		1.00		1.00	1.00
99	Other Sites		1.00		1.00	

AADT – annual average daily traffic
AAWDT – conversion factor: annual average weekday traffic
AAWET – conversion factor: annual average weekend traffic

Data Processing

All traffic data collected in the field by portable and ATR equipment must be processed. The data processing tasks include:

1. Validating raw data;
2. Generating monthly and weekly adjustment factors;
3. Applying axle correction factors; and
4. Generating AADT values.

The Data Team uses a software package called TRADAS -developed by Chaparral Systems, Inc.- to perform most of the traffic data processing.

Maintenance of Data Collection Equipment

Several members of the Data Team perform the ongoing job of maintaining traffic monitoring equipment. The equipment includes traffic sensing devices, such as pneumatic tubes, traffic counters, ATR equipment and WIM devices. ATR's are particularly vulnerable to lightning strikes, power outages, road construction projects and acts of vandalism. It is the responsibility of the Data Team to ensure that all of the ATRs are in good working order. ***This takes substantial effort and is made particularly problematic when construction and maintenance activities affect the location or operation of ATRs and not communicated to the Data Team***

Traffic Engineering Group

Whenever possible, the Traffic Engineering Group uses the traffic data generated by the Data Team. However, studies performed by the Group may require additional traffic data elements that are not supplied by the Data Team. These elements include:

- Speed
- Peak-hour volumes and factors
- 100 highest hour volumes
- Sub-hourly traffic flow
- Turning movements
- Intersection approach volumes

The Traffic Engineering Group collects these data elements as needed to support specific projects and studies.

Transportation Planning Division

The Transportation Planning Division (TPD) also uses data generated by the Data Team. The data elements used by the Division are AADT, K-Factors, D-Factors and T-Factors. Sometimes special data collection efforts are required for small area transportation studies (SATS), corridor profile studies, traffic impact studies, and other special studies. The collection of data for these studies is usually performed by TPD using consultants who specialize in traffic data collection.

The Transportation Planning Division uses AADT values from the Data Team to generate projected AADT for specific planning horizons. These projections are generated using linear regression techniques applied to historical AADT values.

Advance Engineering Section

The Advance Engineering Section obtains traffic data from the Data Team as well. However, some additional data such as turning movements, sub-hourly flow rates and peak hour factors must be collected or derived for Design Concept Reports. Data collection for the Advance Engineering Section is usually contracted to a consultant.

Long-Term Pavement Performance Project

ADOT is an active participant of the Long Term Pavement Performance Project (LTPP), which is sponsored by the Strategic Highway Research Program (SHRP). The Arizona Transportation Research Center (ATRC) runs ADOT's LTPP. The LTPP program requires the collection of the following traffic data elements:

- Vehicle weight
- Vehicle classification

The WIM and AVC sites used by the LTPP program are listed in Table 2.3.

Traffic Data from the Freeway Management System

ADOT's Freeway Management System (FMS) collects real time traffic counts at 237 locations throughout the greater Phoenix Metropolitan freeway system. Some of this data is archived and sent to the Data Team for use in the Traffic Monitoring Program. The data is used for determining AADT on freeway sections. ***Up to 50 percent of the traffic recording devices do not properly report data because of equipment failures. The recording devices, which are induction loops embedded in the pavement, wear out due to heavy traffic loading on the freeways. Obtaining raw data measured from deteriorating equipment greatly impacts the validity of statistics derived from the raw data.*** Some traffic recording devices use sonic detection technology. However, the Data Team has indicated that they will not use any traffic data from these devices since they have been know to produce large variations in traffic volume measurements.

COLLECTION BY OTHER AGENCIES

Other agencies throughout Arizona collect and maintain traffic data. Several of these agencies collect data on State highways and share their data with ADOT. ADOT receives data on an annual basis from Yuma Metropolitan Planning Organization, (Yuma and Yuma County), Maricopa Association of Governments (Maricopa County and Cities including Phoenix, Mesa and Glendale), and Pima Association of Governments (Pima County and Cities including Tucson).

Other sources of data supplied to ADOT come infrequently from the Bureau of Indian Affairs, Bureau of Land Management, National Forest Service, National Park Service, and various Tribal Governments. Only traffic count data is supplied to ADOT from outside agencies. The following section provides examples of traffic count activities throughout the state.

Special Studies

Since 1994, ADOT's Transportation Planning Division has undertaken a program of annual counts for acquiring data on the National Highway System (NHS) and one-third of the remaining State highways. The program requires that local governments obtain traffic counts on roads within their jurisdiction. However, no significant assistance has been given local governments in order to obtain the required annual data. ADOT has recognized that counts on State highways and NHS in rural and small urban areas are too infrequent and that local governments need assistance in obtaining traffic data on their road networks. In 1999, ADOT initiated the *Special Counts for Air Quality and Rural HPMS* project to obtain 48-hour traffic counts at approximately 1,200 locations throughout the State, with the assistance of a consultant. Table 4.3 lists the number of traffic counts for each county throughout the State. The project required:

1) Establishment of count locations.

2) Provision of schedule and sample count data.

3) Data specification including location and hour formatted in both hardcopy and comma delineated ASCII.

4) Maintenance of a master file with separation of the state highway data and data from local roads.

5) A final report summarizing the activity on State and counting activity on local roads by county.

Table 4.3. Traffic Counts by County

County	Number of Counts
Apache	44
Cochise	170
Coconino	150
Gila	64
Graham	68
Greenlee	10
LaPaz	40
Maricopa	-
Mohave	160
Navajo	95
Pima	-
Pinal	110
Santa Cruz	30
Yavapai	70
Yuma	25 (rural only)
Unassigned	164
Total	1,200

Additionally, in 1999, ADOT initiated the *Urban Traffic Counting* project to expand its traffic data collection efforts in the Phoenix and Tucson Metropolitan areas through the collection of 24-hour counts on urban highways, ramps, and frontage roads. To obtain valid traffic volume information for urban sites, traffic counts were taken on established locations based on the 1999 Urban Traffic Counting Study. Count data was collected in 15-minute increments and submitted both in electronic and hard copy formats together with interchange diagram forms. A database was established listing count locations, identifiers, beginning and ending times of counts, and comments. Field data were collected utilizing tube and loop machines, excluding those of the Freeway Management System. Ramp and crossover counts at approximately 548 sites in the Phoenix Metropolitan area and at approximately 23 sites in the Tucson urban area were taken. In addition, approximately 88 mainline counts were taken on State highways in the Phoenix urban area. The counts were taken for continuous periods of 24 hours or more, between midnight Tuesday and midnight Thursday.

To enhance ADOT's information on vehicle classification, the Department initiated a *Long Term Vehicle Classification* project to improve vehicle classification data at approximately 65 statewide locations through 168-hour (1-week) classification counts on the major sites (See Table 4.5). The intent of the study was to determine the magnitude of variation between 6-hour manual classifications and those of week long durations, especially to identify the implications for axle factors and percent truck estimates. Preliminary results revealed essentially no differences between the 6- and 168-hour counts.

Table 4.4. ADOT Long-Term Vehicle Classification 2000

Group	ADOT C#	Highway Description	LEG	No. of Lanes	No of machines	Nearby Town
I	15	I-8 & SB8	E	4	4	GILA BEND
I	16	I-8 & SB8	W	4	4	GILA BEND
I	17	I-8& SB8	N	4	4	GILA BEND
I	127	SR85 & MC85	N	2	2	BUCKEYE
I	128	SR85 & MC85	S	2	2	BUCKEYE
I	129	SR85 & MC85	B	2	2	BUCKEYE
II	12	US7O&SR77	W	2	2	GLOBE
II	13	US70 & SR77	E	2	2	GLOBE
II	14	US7O & SR77	S	2	2	GLOBE
III	84	SR260 & SS260	W	2	2	EAGAR
III	85	SR260 & SR260	N	2	2	EAGAR
III	86	US180 & 5R260	E	2	2	EAGAR
III	87	SR260 & 5R277	SW	4	4	HEBER
III	88	SR260 & SR277	E	2	2	HEBER
III	89	SR260 & SR277	NE	4	4	HEBER
III	92	I-40 & SR77	NE	4	4	HOLBROOK
III	93	I-40 & 5R77	SW	4	4	HOLBROOK
III	94	I-40 & SR77	N	2	2	HOLBROOK
III	107	I-40 & USI80	B	4	4	HOLBROOK
III	108	SB40 & US180	W	4	4	HOLBROOK
III	109	S840 & US180	N	2	2	HOLBROOK
III	90	SR87 & SR99	N	2	2	WINSLOW
III	91	SR87 & 5R99	SE	2	2	WINSLOW
IV	19	I-10 & SR95	W	4	4	OUARTSITE
IV	20	I-10 & SR96	E	4	4	QUARTSITE
IV	21	I-10 & SR95	N	2	2	OUARTSITE
IV	22	I-10 & SR95	S	2	2	OUARTSITE
V	23	US89 & US93	NW	2	2	WICKENBURG
V	24	US89 & US93	SE	2	2	WICKENBURG
V	25	US9 & US93	N	2	2	WICKENBURO
VI	26	I-10 & US95	W	4	4	HAVASU
VI	27	1-40 & US95	E	4	4	HAVASU
VI	28	1-40 & US95	S	2	2	HAVASU
VI	29	SB40 & 1-40	SW	4	2	KING MAN
VI	30	US66 & 1-40	NE	4	2	KINGMAN
VI	31	US66 & 1-40	B	4	2	KINGMAN
VI	52	US93 & 5R68	SE			KINGMAN
VI	53	US93 & SR88	NW	4	4	KINGMAN
VI	54	US93 & SR68	W	2	2	KINGMAN
VII	38	SR89 & SR69	N	4	4	PRESCOTT
VII	39	SR89 & SR69	SW	4	4	PRESCOTT
VII	40	SR89 & SR69	E	4	4	PRESCOTT
VIII	42	I-8&5B8	NW	4	4	YUMA
VIII	43	l-8&5B8	W	4	4	YUMA
VIII	58	US95&C014	S	2	2	YUMA
IX	44	SR82 & B19	NE	2	2	NOGALES

X	62	I-8 & I-10	W	4	4	CASA GRANDE
X	63	I-8 & I-10	N	4	4	CASA GRANDE
X	64	I-8 & -10	SE	4	4	CASA GRANDE
X	65	SR84 & SR387	W	2	2	CASA GRANDE
X	66	SR84 & SR387	E	2	2	CASA GRANDE
X	67	SR84 & SR387	N	2	2	CASA GRANDE
XI	95	SR264 & SR87	E	2	2	SECOND MESA
XI	96	SR264 & SR87	W	2	2	SECOND MESA
XI	97	SR264 & SR87	S	2	2	SECOND MESA
XI	98	US16O & US163	NE	2	2	KAYENTA
XI	99	US160 & US163	SW	2	2	KAYENTA
XI	100	US160&US163	N	2	2	KAYENTA
XI	101	US160 & SR264	W	2	2	TUBA CITY
XI	102	US160 & SR264	NE	2	2	TUBA CITY
XI	103	US160 & SR264	SE	2	2	TUBA CITY
XI	104	US89 & SR64	S	2	2	CAMERON
XI	105	US89 & SR64	N	2	2	CAMERON
XI	106	US89 & SR64	W	2	2	CAMERON
XI	122	SR264 & US191	E	2	2	GANADA
XI	123	SR264 & US191	W	2	2	GANADA
XI	124	SR264&US191	N	2	2	GANADA
XII	113	SR64 & US160	S	2	2	GRAND CANYON
XII	114	SR64 & US180	N	2	2	GRAND CANYON
XII	115	SR64&US180	SE	2	2	GRAND CANYON
XII	116	SR67 & US89A	SE	2	2	JACOBS LAKE
XII	117	SR67 & US89A	NW	2	2	JACOBS LAKE
XII	118	SR67 & US89A	S	2	2	JACOBS LAKE

Maricopa Association of Governments Congestion Study

The Maricopa Association of Governments (MAG) conducted a *Regional Congestion Study* in 1999. The main purpose of the study was to provide objective traffic congestion data for the MAG planning process and aimed to:

- Help ensure that the MAG transportation models are accurately representing congestion.
- Provide input to regional transportation planning studies.
- Provide information for traffic studies and road design.

Machine traffic counts were taken for 48 consecutive hours at approximately 250 intersections. The data was collected between midday Monday and midday Friday and tabulated in 15- minute and hour intervals. Additionally, Freeway counts were obtained from ADOT. Classification counts were also taken on freeway locations and the Maricopa County Department of Transportation Traffic Engineering Division provided arterial classification counts. The classifications were based on the FHWA Guidelines and included the following classes:

- Motorcycles
- Passenger Cars
- Other Two-Axle, Four-Tire Single Unit Vehicles
- Buses
- Two-Axle, Six-Tire, Single-Unit Trucks
- Three-Axle or more Axle Single Unit Trucks
- Four or Less Axle Single Trailer Trucks
- Five or More Axle Single Trailer Trucks
- Multi-Trailer Trucks

Turning movement counts were taken at initially identified locations for the AM and PM peak hours and between midday Monday and midday Friday. Aerial photographs were also taken of freeway traffic and major intersection traffic. The data gathered in the effort was then used to prepare MAG's *Congestion Study*, updating an existing 1991 study.

Pima Association of Governments

The Pima Association of Governments conducted a large-scale traffic data collection effort in spring of 2000. The efforts included 48-hour continuous intersection traffic and turning movement counts on approximately 35 intersections. Roadway segment traffic counts on 270 locations in the Tucson Metropolitan area were conducted as well. In conjunction with the traffic counts, a vehicle occupancy study was undertaken to report the following categories:

- Driver only
- Driver with one passenger
- Driver with two or more passengers

In addition, a visual vehicle classification study was used to identify the following vehicle types:

- Bicycles
- Motorcycles
- Light Truck Category 1: Small pickup, minivan, small/medium SUV

- Light Truck Category 2: Full size pickup, full size van, large SUV
- School Bus
- Transit Bus
- Heavy Duty Truck Category 1: Single unit, 6 tire, 2 axle
- Heavy Duty Truck Category 2: Single unit, 3 axles or more
- Heavy Duty Truck Category 3: Two or more units (trailer), 3 axles or more
- Large Recreational Vehicle: Self-powered, single unit

Local Jurisdictions

Throughout the State, counties and local jurisdictions conduct traffic count programs to various degrees of intensity. Generally, the larger cities and counties implement the more accurate traffic counting programs because they are equipped with better resources. Counties with well established count programs include Maricopa County, Pima County, Yavapai, Mohavi, Chochise, and Coconino Counties. ADOT works through its MPOs/COGs Team with the Council of Governments and Metropolitan Planning Organizationss to aid in the establishment of local traffic count programs.

The agencies shown in Table 4.5 collect traffic data on a scheduled basis. Other agencies have collected traffic data in the past, on an as-needed basis, and are not included in the listing.

Table 4.5. Local Agencies collecting traffic data

Rural Council of Governments	Local Agencies
Western Arizona Council of Governments	La Paz County
	Mohave County
Central Arizona Association of Governments	Case Grande
Southeastern Arizona Governments Organization	Graham County
	Cochise County
	Sierra Vista
Northern Arizona Council of Governments	Navajo DOT
	Chino Valley
	Navajo County
	Yavapai County
	Town of Prescott
	Town of Prescott Valley
	Apache County
	Coconino County

Transportation Management Areas

Transportation Management Areas (TMA) in the State collect substantial amounts of traffic data. The Maricopa Association of Governments for example collects and maintains the following data types:

- Traffic volumes (daily, hourly, and sub-hourly volumes are maintained)
- Turning movements at major intersections
- Vehicle classification
- Other (vehicle speed, queue length, density, intersection geometry, aerial photos of intersections, peak hour factors)

Traffic volume data is collected about once every two to three years. MAG does not have a stand-alone count program that is consistent with the Traffic Monitoring Guide and relies on the local jurisdictions to provide the data. The agency maintains data for facilities of all the member jurisdictions. Data is stored for ADOT highways, city arterials, county roads and freeways. Other data include:

- Traffic data from the FMS.
- Forty-eight hour counts from consultants. (Generally, counts are taken for 15-minute intervals.)
- Vehicle classification data from the FMS video cameras.

MAG uses the data for a variety of purposes including: 1) as input for the travel demand model for projections, 2) creating traffic volume maps, and 3) for special studies, such as the recent congestion study. The data is also distributed to interested parties and is of particular use to consultants involved in design work. The data is available on a CD as well as through MAG's web site (www.mag.maricopa.com), which displays a map of traffic volumes for the region. Overall the depository of turning movement counts is a valuable source of information for general transportation engineering and planning purposes.

Ongoing Efforts

ADOT is currently conducting the *Statewide Regional Traffic Data Collection Program*. Through this study, a regional traffic data collection methodology is being developed to enhance traffic data collection efforts throughout the State on a regional level. Overall, the efforts aim at combining the currently available tools such as ATIS, HPMS, and the Data Teams count efforts with the local governments traffic data collection programs. The study is currently being finalized and is expected to be available at the end of September 2000.

Survey of Traffic Data Collection Efforts of Other Agencies

A survey was conducted to understand the traffic data collection programs of other agencies. These agencies included municipalities, counties, metropolitan planning organizations (MPO's), council of governments (COG's), and other government entities. A list of survey recipients is in Appendix A and the actual survey is presented in Appendix B. Responses were obtained from 32 percent of the agencies surveyed. Respondents were:

- City of Mesa
- Pima Association of Governments
- City of Glendale
- Flagstaff Metropolitan Planning Organization
- Yuma Metropolitan Planning Organization
- Maricopa Association of Governments
- Pima County
- US Forest Service
- City of Phoenix

Review of Survey

All of the respondents indicated that they collect traffic volumes on facilities within their jurisdiction. Two of the nine respondents specifically indicated that they collect volumes annually. All respondents but the US Forest Service and the City of Phoenix indicated that they share traffic data with ADOT. However, none of them specified the data shared. Five of the nine respondents collect traffic data on ADOT facilities, but three of them specifically indicated that they only collected data on freeway ramps. Table 4.6 summarizes those respondents who collect traffic data on ADOT facilities.

Table 4.6 Survey Respondents that Collect Traffic Data on ADOT Facilities

Agency Name	Types of ADOT Facilities Included in Data Collection
City of Mesa	Ramps only
Pima Association of Governments (PAG)	Freeways, collectors and Frontage roads.
City of Glendale	Ramps only
Flagstaff Metropolitan Planning Organization	Freeways and some ramps.
Maricopa Association of Governments (MAG)	Ramps

The majority of the respondents use pneumatic tubes for collecting traffic volume and only the City of Glendale indicated that they use the Traffic Monitoring Guide. Six respondents collect vehicle classification data and none of the respondents collect vehicle weight.

FINDINGS AND RECOMMENDATIONS

This chapter presented an overview of traffic data collected both internally by ADOT or its contractors and externally by other agencies. ADOT's internal sources provide the data needed for ADOT's business processes. This is clearly illustrated in Table 2.6, which lists business processes and traffic data needs by division. The traffic data elements that are most needed are: AADT, K-factor, D-factor, percent trucks, and vehicle weights. These data elements are continuously collected and maintained internally by the Data Team and ATRC (for LTPP purposes).

Other internal sources of traffic data are the Transportation Planning Division, Traffic Engineering Group, and the Advance Engineering Section. These are considered internal sources because they do occasionally sponsor the collection of data for specialized purposes –for data that are not provided by the Data Team. These specialized purposes include traffic studies, design concept reports, capacity studies and others. Since they do not have the staff or equipment to collect data, these other divisions usually contract collection to consultants. Due to their specialized content and format, these data are usable to only a minimal range of users and applications. For example, a Traffic Control Signal Needs study for a particular intersection may produce vehicle-delay data. This data can probably not be used for planning purposes, pavement design, or programming. However, a few months later this information might be useful for the design of a turning lane or a capacity study for the same intersection.

The data that are produced for special purposes should be leveraged and made available for future, potential uses by all ADOT traffic data users. Potential users need a way of identifying existing data that may be available, evaluating the data against their needs, and acquiring the data if appropriate. To accomplish this, all data collection efforts should be centrally coordinated, cataloged in a database, the data should be documented in a standard way, and the data should be provided in some standard format to the greatest degree possible. Please see the Implementation Plan in Chapter VII for more details.

Agencies other than ADOT generally collect and maintain traffic data for facilities under their own jurisdiction. The survey in this chapter indicated that five agencies collect traffic data on ADOT facilities. However, the data that is collected for these facilities may not be usable for ADOT applications since the standards for their collection and processing may be lacking or inconsistent with ADOT’s data collection. For example, the City of Mesa may collect traffic data on ADOT Freeway ramps, but only for 24-hour periods. ADOT requires collection for 48 hours. Like ADOT, these other agencies have limited data collection and maintenance resources and tend to concentrate on meeting their particular needs, rather than developing data resources that can be shared across agencies for multiple purposes. ***If ADOT is to benefit from and***

share data efforts with other agencies, ADOT should first improve their internal data quality, availability and credibility, so that both internal users and those of other agencies will have more confidence in ADOT's capabilities and data, and therefore be more willing to participate. Also, more formal relationships will need to be fostered with these other agencies. The initial stages of evaluating such relationships is currently underway, headed by the Data Team. Other ADOT groups would also benefit and should be included in these efforts.

Based on a review of external traffic data sources, there does not seem to be a lot of usable traffic data available from local and other agencies. Some traffic data collected by these agencies does exist, but it is generally not documented or maintained in a readily useable format. If such local collection activities could be coordinated with ADOT, including collection and validation standards, documentation standards, and storage standards, some of this data may be available for shared use. One particular potential source of traffic-related data may be gained from ongoing ITS projects.

Significant Issues

Much traffic-related data is collected by ADOT and other agencies throughout the state. However, many traffic data users are disadvantaged in that this data is either inaccessible or unsuitable for their needs. The reasons for this vary, but several major issues have been identified:

- Data availability is unknown or known data is undocumented
- All data is not collected to the same standards
- Data collection and storage is not coordinated and there are no mechanisms for sharing data

These issues are briefly described below.

Unknown and Undocumented Data and Sources

Frequently, data generated by specific data collection efforts are not published or disseminated to all possible users. The data may be presented in a report, but is unknown to most traffic data users. Aside from the data provided by the Data Team, there is a general lack of awareness of what data is available. This condition leads to duplication of traffic data collection efforts. One important step to promote the awareness of available traffic data is to develop and maintain an inventory of all traffic data as a master catalog of traffic data resources. This inventory should include a geographic element so that users can spatially locate and determine the scope of available statewide traffic data sources

Lack of Standards

There is some distrust of available traffic data. This distrust usually results from a disapproval of, or lack of knowledge about the methods applied to obtain or adjust the data. Hence, some traffic data users feel compelled to collect their own data. A set of standards for collection methodologies and data documentation will help build confidence and ensure consistency in the data used throughout ADOT. This, in turn, will help make each data element usable to a wider range of traffic data users. Standards in methodologies include the use of competent and experienced data collection services, well calibrated, maintained, and properly applied equipment, and full documentation of the procedures used and any adjustments made to the raw data.

The implementation of such standards will require extra effort in administering data collection activities, which will be offset with more useful, more accurate, and more widely accessible data resource. For example, newly established standards may force the collector to spend more time checking that the equipment is working properly throughout the entire collection period to ensure an optimal level of completeness. Another potential drawback to implementing such standards is that collectors will need to prepare more documentation. However, it is necessary and beneficial that this documentation be available to the user so that the data can be evaluated and appropriately applied in support of capital-intensive improvement projects. Implementing standards for collection methodologies and documentation will ultimately add value to the data and thus the planning and decision-making processes. However, some effort should be made to help ensure that these standards do not hinder the efficiency and convenience of data collection strategies.

Internal/External Coordination and Data Sharing

As mentioned in this chapter, ADOT does share data with local agencies. However, the acquisition of data from local agencies, for use at ADOT, occurs only for special studies and reports, including HPMS and ATIS. All traffic data sources outside of ADOT could be identified and catalogued for future use, and entered into a centralized traffic database. When the outside agency updates their data, a process could be initiated to incorporate new data into ADOT’s centralized traffic database. This will require direct communication between a central traffic data group and the local agency. ADOT should promote a formal line of communication with some of the larger agencies that collect substantial amounts of traffic-related data throughout the state. ***Addressing all these issues will require staff and budget resources that are not currently provided.***

Standards, documentation, and coordination will promote an awareness of available data and help users determine appropriate uses of particular data. Lacking such items and procedures, people may tend to recollect data to suit their needs, which results in some duplication of effort and depletes scarce resources and manpower that have been allocated for data collection programs. By pursuing communication and understanding, more data will be shared by a larger number of users, thus maximizing the return on ADOT's investment in its data resources.

V. TRAFFIC DATA FORECASTING, AND OTHER POTENTIAL ANALYSIS

The following chapter has three major sections. The first documents the types of data needed for applications used by ADOT, the second provides an evaluation of traffic demand forecasting techniques, including those used by the Metropolitan Planning Organizations (MPO) in the State and the transportation models used for rural areas. In the third section, ADOT's traffic forecasting practices are described, along with those of other states.

USES FOR TRAFFIC DATA

As introduced in the previous chapter, ADOT most business functions require combinations of five basic types of traffic data, which are listed below:

- Average Annual daily Traffic (AADT).
- Design Hourly Volume (DHV).
- Peak-hour Traffic Percentage (K).
- Directional Split (D).
- Peak-hour volume turning movement (PEAK TM).
- Vehicle Miles of Travel (VMT).

Vehicle Classification:

- Average Daily Truck Traffic (ADTT).
- Percentage Trucks in Peak (PEAK %Truck).
- Percentage of Vehicle Class (% Veh. Class).

Truck Weight:

- Truck weights.
- Equivalent single axle loads (ESAL).

Speed data.

Accident data.

Table 5.1 presents a listing of the ADOT business functions in need of traffic data. In summary, the following ADOT business processes require traffic data: the Highway Performance Monitoring System (HPMS) data collection, Management Systems, Planning and Programming, Pre-design/Design, and Special Studies.

Table 5.1. Uses for Traffic Data

Functions Using Traffic Data	AADT	Future AADT	DHV	K	D	Peak TM	VMT	PEAK %Truck	% Veh. Class	Truck Weights	ESAL	Operating Speed	Design speed	Accidents	Data Source
Management Systems															
Pavement Management System (PMS)	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		1
Bridge Management System (BMS)	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	1
Congestion Management System (CMS)*	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓		1
Safety Management System (SMS)	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	1
Planning and Programming															
HPMS	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓		1
Statewide Transportation Planning	✓	✓					✓		✓					✓	1
Corridor Profile Studies	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	1,2
Small Area Transportation Studies	✓	✓	✓	✓	✓				✓			✓		✓	1,2
Project selection	✓	✓							✓					✓	1
Pre-design/Design															
Design Concept Reports & Project Assessment	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	1,2
Highway Design	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓		1
Bridge Design	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		1
Pavement Design	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		1
Traffic															
Traffic Engineering studies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	1,2
Highway Capacity Analysis	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		1,2
Safety Studies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	1,2
Special Research Studies															
Traffic Forecasting	✓	✓	✓	✓	✓	✓		✓	✓			✓			1
Historical Trends Analysis	✓	✓	✓				✓	✓	✓	✓		✓		✓	1
Special Studies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1,2

Data Collection Efforts

TRADAS

The TRADAS software system is designed to accommodate ADOT's internal traffic data programs and to provide a single system for processing various types of traffic data. The TRADAS server is set up to:

- Receive and manage raw data files.
- Process analyze, and validate raw data.
- Convert incoming raw data into consistent traffic measurements.
- Aggregate and summarize these measurements.
- Generate consistent and managed views of detailed measurements.

Two major tasks are preformed by the system: 1) automatic data polling activities/ manual data submission of counts; and, 2) the analysis and output of various types of traffic data. TRADAS uses a Data Collection Management System (DCMS), which is a stand-alone Windows-based program to perform data collection and routing. Data can be read as binary files and are written to ASCII files by the DCMS. The application itself uses an Oracle Relational Database Management System (RDBMS) to process and analyze the collected data. About 30 different reports are produced by the system to summarize the gathered count information. Even though TRADAS utilizes an "open" RDBMS, it is designed and implemented as a standalone application. Dynamic linkage to other databases or ADOT's GIS has not been implemented.

HPMS

One major component of ADOT's data collection effort is the annual HPMS data collection. The HPMS, developed in 1978, is a national highway transportation system data base and includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and summary information for urbanized, small urban and rural areas. Each State collects and submits HPMS data to the Federal Highway Administration (FHWA). The HPMS data is stored in a Microsoft Access table that is exported to a comma-delimited, ASCII file for submission to the FHWA. The layout for this file is defined by the HPMS Field Manual. [26]

ATIS

The Arizona Transportation Information System (ATIS) utilizes a spatially referenced data layer of all Arizona roads and streets, known as ATIS Roads. In an effort to simplify the data collection efforts for the annual HPMS data collection, ADOT developed HPMS data collection software which links HPMS data with ATIS. This tool allows not only the storage of traffic related data items in a spatially referenced database, but also the display of the data in map format. Another provision supports factoring raw counts to generate AADT volumes.

Management Systems

ADOT's Management Systems are programs to provide for the preservation of the statewide transportation system through the implementation of reconstruction or repair. These management programs are designed to inventory and address problems that are often statewide in scope, and that tend to recur year after year. All of these systems require traffic data.

Pavement Preservation

The Pavement Management System (PMS) inventories the statewide highway system and assesses the degree of work required to maintain pavement conditions and to prevent the system from deteriorating. Currently the PMS is a standalone software application using FoxPro and MS Access.

Safety Management

The goals for the statewide Safety Management System (SMS) include the reduction in highway related accidents and the improvement of safety on transportation facilities. The SMS is a collection of numerous existing, multi-disciplinary safety programs. Except for the Candidate Location for the Operational and Safety Evaluation (CLOSE) Program, all of the other safety programs are relatively small in terms of funding. These smaller safety programs address a variety of safety issues, including the Railroad Crossings Program, Interstate Signing, and Traffic Signal Program.

Bridge Management

The ADOT Bridge Management System (BMS) is a unified system of bridge status information and project identification. The BMS inventory contains inspection information about every public bridge in Arizona. The overall goal of the BMS is to ensure that Arizona's bridges are safe and managed in a cost-effective manner. One major component of the BMS is the Arizona Bridge Inventory Storage System (ABISS).

Congestion Management System

A Congestion Management System has been defined by ADOT as a systematic approach for identifying congestion and mobility problems, recommending strategies to alleviate them, and forwarding solutions to the programming process. The identified design of the Congestion Management System has yet to be implemented and the CMS is currently not operational.

Planning and Programming

The Priority Programming Team maintains the Five-Year construction program as well as candidate projects in an MS Access database. For other major business functions such as Statewide Transportation Planning, Corridor Profile Studies, and Small Area Transportation Studies (SATS), traffic data is collected and stored on a project specific basis. In the case of SATS, traffic data are used as inputs to travel demand models developed for these studies.

Pre-Design/Design

There is no unified software application for the various business processes in Pre-design and Design groups. However, for various aspects of the design work, specific applications, such as Highway Capacity Software are used. Pavement Design uses data provided by the PMS and additionally uses spreadsheet models to forecast future traffic loadings and ESALs.

Traffic

Various aspects of traffic engineering, traffic safety, and traffic design use traffic related data elements. In addition to the Safety Management System, there are various software applications for the analysis of accidents, travel speeds, and roadway conditions. Other applications aid in design activities, signal phasing, and the operation of facilities.

Special Studies

In regard to special studies, traffic data is used, analyzed, and stored on a project basis. The Transportation Planning Division requires traffic data as inputs to travel-demand models used in a variety of applications throughout the State. TransCAD and TRANPLAN are used to develop travel demand models for SATS. EMME/2 is the preferred software for regional models such as the one used by the Maricopa Association of Governments (MAG).

Table 5.2 summarizes ADOT business functions and supporting applications mentioned above.

Table 5.2. Summary of Major Applications and Software Used

Functions Using Traffic Data	Application	Software
MANAGEMENT SYSTEMS		
Pavement Management System	PMS application	FoxPro, MS Access
Bridge Management System	BMS application (ABISS)	MS Access/ Visual Basic
	PONTIS	C++ / SQL Server / Informaker
Congestion Management System	Not currently operational	
Safety Management System	SMS applications	
PLANNING AND PROGRAMMING		
HPMS	FHWA: HPMS data collection software	MS Access
ATIS/HPMS Tool	AZ base road GIS/HPMS data collection tool	ArcInfo/ArcView extensions
Statewide Transportation Planning	Various applications	MS Access, MS Excel
Corridor Profile Studies	Various applications	
Small Area Transportation Studies	Travel demand Models. GIS, spreadsheet, database	TRANPLAN, TransCAD
Project selection	Programming database	MS Access
PRE-DESIGN/DESIGN		
Design Concept Reports & Project Assessment	Highway Capacity software	FHWA Highway capacity software
Highway Design	Highway Capacity software	FHWA Highway capacity software
Pavement Design	Pavement Design models	Excel spreadsheet models
TRAFFIC ENGINEERING		
Highway Capacity Analysis	Highway Capacity software	FHWA Highway capacity software
Safety Studies	Accident analysis	
SPECIAL RESEARCH		
Traffic Forecasting	Travel Demand Models	EMME/2, TransCAD, TRANPLAN
Historical Trends Analysis	No specific application	
Special Studies	No specific application	

Source: Lima & Associates

FORECASTING TECHNIQUES

Traffic forecasting techniques range from simple growth factor methods to comprehensive traffic forecasting models. Various techniques are used to forecast traffic on highway segments, within corridors, and across entire regional street networks. This section describes various traffic forecasting techniques, reviews the traffic forecasting practices of the Arizona Department of Transportation (ADOT), and discusses the traffic forecasting practices of other states. Table 5.3 summarizes the advantages and disadvantages of simple trend models and four-step forecasting models discussed below.

Mathematical methods of developing these models are not discussed here. However, additional information on the details of specific traffic forecasting models are available in the literature annotated in the bibliography.

Table 5.3. Advantages and Disadvantages of Traffic Forecasting Methods

Method	Advantage	Disadvantage
Simple Trend Models	Straight forward to use	Not reliable in areas that are growing more rapidly than historical trends.
	Easy to understand	Not sensitive to demographic changes.
	Good for areas where trends have been constant	
4-Step Forecasting Model	Based on a rational travel demand process.	Must have significant traffic volume data for calibration.
	Develops specific travel demand relationships for a given area.	Special education and training are required to develop traffic forecasting model.
	Describes relationship between traffic volume and demographic data.	Requires significant time to develop traffic forecasting model.
		Must be maintained on a regular basis.

Growth-Factor Methods

Growth-factor methods forecast traffic by multiplying base traffic volumes by some factor to obtain a value for future traffic volumes. The growth factor is generally based on historical traffic volumes increases, or decreases. A growth factor could also be developed based on population data.

Linear Regression

Regression techniques estimate the “best” linear relationship between the dependent variable—traffic volume—and independent variables. Linear regression models include: 1) simple trend models; 2) moving average models, and 3) ARIMA techniques.

Simple Trend Models

A common approach using linear regression is to estimate a linear relationship between historical traffic volumes as the dependent variable and years as the independent variable. Future traffic volumes are then estimated by extrapolating to future years. Simple trend models can be extended by adding causal variables. Causal variables include population and employment.

Moving Average Models

Moving Average models eliminate bumpiness within a data series by averaging several values that are close together in time. These models are often used to eliminate seasonal, weekly, and diurnal fluctuations in data.

ARIMA Techniques, or Box-Jenkins Models

ARIMA techniques, or Box-Jenkins models determine the best fit using complex time series, particularly those with seasonal fluctuations.

Four-Step Forecasting Method

The traditional four-step forecasting method is used to develop traffic forecasting models in urban areas, sub-state regions, and even entire states using the following steps: trip generation, trip distribution, modal split, and traffic assignment. A street and highway network is defined first consisting of nodes and links representing intersections and streets. Characteristics are then assigned to the links such as distance, speed, and capacity. In addition, the study area is divided into geographical zones, called Traffic Analysis Zones (TAZs) that represent homogenous geographical areas such as residential and commercial areas. For each TAZ, land uses are identified and demographic data are defined including population and employment.

The trip generation phase estimates the number of trips produced in and attracted to each TAZ based on its population and employment characteristics. The trip distribution phase then allocates those trips between each zone and the other zones generally as a function of travel time. A trip table is produced that is a matrix of the trip interchanges between all the zones. The modal split phase apportions the trip interchanges between zones to various modes such as single automobiles, carpools, and transit. This phase produces modal trip tables that show the number of trips between zones for each mode. The automobile trip tables are then assigned to a street and highway network based on travel time and congestion on the routes resulting in the assigned daily traffic volumes for each street in the model’s network. Some traffic forecasting models also estimate hourly volumes.

Traffic forecasting models developed by the four-step method are calibrated by comparing the traffic volumes assigned by the model to actual traffic counts. The various relationships are adjusted until the actual traffic volumes are reproduced within a specified limit.

Although the four-step forecasting method has been used to develop traffic forecasting models primarily in urban areas, similar models have been developed for larger sub-state regions and for entire states.

Hybrid Technique

A pivot method uses output from a travel forecasting model and from a time-series model to provide precise forecasts on one or more highway segments.

Total Corridor Demand

This method estimates travel demand within a corridor modeled as a function of socioeconomic data.

ARIZONA PRACTICE

There are numerous agencies in Arizona that conduct travel demand modeling activities at different geographic scales. All of these efforts should be based on consistent model inputs.

Arizona Department of Transportation

Transportation Planning Division

The ADOT Transportation Planning Division (TPD) uses regression analysis to forecast daily traffic volumes on state highways on a route-by-route, as needed basis. Historical traffic volumes are “regressed” against a span of years using traffic data from a table of historical traffic volumes from a MS ACCESS database. The “best” linear fit between the historical traffic volumes and years is determined by finding the linear coefficients that produced the best coefficient of determination. Given the “best” fit, future daily traffic volumes are determined by extrapolating to future years.

The TPD is currently sponsoring a research study to investigate traffic forecasting techniques to forecast future traffic volumes on state highways. The study has investigated various linear and non-linear techniques to estimate future traffic volumes using the ADOT traffic count database. The study is still underway and the final results should be available by summer, 2001.

The Arizona Data Team within the TPD uses regression analysis for segments of the HPMS or forecasts developed using four-step models and provided by MPOs.

Metropolitan Planning Organizations

Arizona has four Metropolitan Planning Organizations (MPOs) that have transportation planning responsibility for urbanized areas of 50,000 or more persons. These four MPOs are Maricopa Association of Governments (MAG) MPO, Pima Association of Governments (PAG) MPO, Yuma MPO, and Flagstaff MPO. Both MAG and PAG are also designated as Transportation Management Areas (TMAs) for urbanized areas over 200,000. The MPOs use the traditional four-step traffic forecasting methods to produce 20-year traffic forecasts. However, the forecasting processes for the two TMAs include more sophisticated techniques for distribution, modal split, and traffic assignment in order to better represent traffic patterns in these more complex urban areas. The traffic forecasting used by the MPOs produce future traffic volumes on the streets and highways that are on the regional networks. MAG also produces hourly traffic volumes.

Small Urban Areas/Sub-area Regions

Traffic forecasting models have been developed in various small urban areas and sub-area regions throughout Arizona. Most of these models have been developed as a product of Small Area Transportation Studies (SATS) cosponsored by ADOT. Table 5.4 summarizes the urban traffic forecasting models that have been developed in MPO regions and other urban areas in Arizona. All of these traffic forecasting models were developed using the four-step process. In general, the areas outside the MPOs use 3-step methods that forecast automobile traffic only and do not include a separate (fourth) modal split process. Since most of the areas outside of MPOs do not have professional staff dedicated to transportation modeling and planning, models developed in these areas are not maintained on a regular basis.

Table 5.4. Traffic Forecasting Models in Arizona

Area	Software	Year Developed
Metropolitan Planning Organizations		
MAG	EMME/2	Maintained Currently
PAG	EMME/2	Maintained Currently
YMPO	TransCAD	Maintained Currently
FMPO	TransCAD	Maintained Currently
Small Urban Area/Rural Regions		
Colorado River Region, Including Bullhead City and Golden Valley	TRANPLAN	1997
Casa Grande	TransCAD	Will be updated in 2000
Cottonwood	TRANPLAN	1999
Globe	TRANPLAN	1998
Graham County	TRANPLAN	1998
Kingman	TRANPLAN	1998
Lake Havasu	TRANPLAN	Updated 1997
Nogales		Upcoming
Page		Upcoming
Parker?		Upcoming
Payson	TRANPLAN	1998
Pinal County	TRANPLAN	Updated 2000
Central Yavapai County (Prescott, Prescott Valley, Chino Valley)	TRANPLAN	Updated 1998 Maintained Currently
Verde Valley, Yavapai County	TRANPLAN	1999
White Mountain Region	TRANPLAN	1998

Source: Lima & Associates

PRACTICES OF OTHER STATES

Other states use various methods to forecast traffic ranging from simple trend models to comprehensive statewide passenger and freight models. Table 5.5 summarizes forecasting methods used by the states that were identified by a 1991 report. [27] The following describes a few methods used by various states. In addition, a summary of statewide forecasting methods is also presented.

Forecasting Traffic for Highways and Corridors

Indiana

Both aggregate and disaggregate models were developed to forecast traffic on Indiana's state highways. [27] The aggregate models are based on the functional classification of a highway and the disaggregate models are location-specific. These models use traffic data from continuous count stations in rural locations, and data for various county, state, and national level demographic and economic predictor variables. The aggregate models forecast future year Average Annual Daily Traffic (AADT) as a function of base year AADT modified by various predictor variables.

Kentucky

A two-stage modeling process was used to forecast traffic volumes on Kentucky highways. [28] The process uses growth factors representative of Kentucky highways and accounting for the effects of socioeconomic and demographic variables. The first stage of the model used linear regression to relate average daily travel on Kentucky roadways to personal income, price of fuel, and total miles of streets and highways. The second stage used cross-tabulation to relate growth in traffic volume at a specific site to highway functional classification, rural/urban location, county population growth, SMSA/non-SMSA designation, and volume level.

New Mexico

A linear regression model was created to forecast heavy commercial vehicle traffic on a single road in New Mexico. The model included a trend term, years, and three causal variables: US disposable income, US gasoline cost, and New Mexico's cost of residential construction. The overall fit of the model was good (R-square of approximately 0.8).

Table 5.5. Summary of Traffic Forecasting Procedures Used by State Agencies

State	Urban	Rural
Alabama	Traffic derived from modeling process then smoothed as needed and compared with existing counts.	Growth-factor procedure.
Arizona	Four-step urban modeling process.	Traffic count trend lining along with linear regression model.
Arkansas	Use four-step UTPS exclusively. Microcomputer software allows multiple runs of distribution and/or assignment process until volumes are adjusted and calibrated growth.	Factor procedure.
California	Traditional four-step UTPS process using both mainframe and microcomputers.	Same four-step UTPS process where data are available for model calibration. Otherwise growth factors based on population and registered vehicle trends. State is divided into 1500 zones and a network of principal arterials.
Colorado	The traffic forecasts coming out of the MPO are reviewed in the context of existing levels and compared with a trend line estimate. If the estimate from the MPO is not dramatically different, the MPO estimate is used. If there is a major difference, a final trend line set s developed and sent to the MPO for concurrence.	
Connecticut	Statewide traditional four-step UTPS model with manual adjustments of traffic assignments.	
Delaware	Four step UTPS modeling process.	Four step UTPS modeling process. Entire state is modeled down to the collector system in many instances. State is divided into 410 traffic analysis zones.
Florida	Comprehensive network traffic assignment.	Combination of trend lining and growth factor procedure, with historic growth projections modified for changes n land use or other factors that change the traffic patterns in the area.
Hawaii	MPO and planning committees. Use policy technical and citizen advisory committee. Use land use files and general development plans to prepare forecasts.	Use process and committees modeled after MPO and UTPS.
Illinois	An increase-factor method based on trend line data adjusted for the forecast period for changes in the highway network, socioeconomic population.	An increase-factor method based on trend line data adjusted for the forecast period for changes in the highway network, socioeconomic population.
Indiana	Request latest traffic data from MPOs. Take necessary steps to use MPO data. Prepare detailed forecasts required by project.	Most recent traffic data are summarized from files. Traffic is forecasted based on factors. Detailed forecasts are prepared as required.

Table 5.5. Summary of Traffic Forecasting Procedures Used by State Agencies (Continued)

State	Urban	Rural
Iowa	Four-step UTPS modeling process along with growth-factor extrapolation to design-year volumes.	Use growth factors developed for three vehicle types-autos/pickups, single-unit trucks, and tractor-trailers. Growth factors consider socioeconomic data and data from permanent ATRs.
Kansas	Examine model outputs, past traffic in area, changes in land use, and socioeconomic information. Review previous studies, project traffic, and refine projections.	Trend line traffic counts and refined using professional judgment and knowledge.
Louisiana	UTPS. QRSII. TRANPLAN.	Trend line projections augmented by future development.
Maine	Urban models or historical counts.	Trend lining of traffic counts.
Maryland	MPO mainframe forecasts.	Historic growth state planning projections at employment and population growth. Research on rezoning or large developments with manual assignments to/from these sites.
Michigan	Urban models along with additional use at turning movements and manual techniques for refining model output.	Four-step UTPS statewide modeling system plus manual tine tuning.
Minnesota	Model volume loadings are analyzed using mainframe programs, and zone boundary analysis with trips reassigned manually.	Historic trend analysis on route corridors, area, county population trends.
Mississippi	Ten-year and 20-year forecasts are mode based on current traffic and past trends.	Traffic trend lining.
Missouri	Urban plan target-year travel forecasts are modified by latest traffic data, socioeconomic data, and traffic impact studies.	Determine current volumes and characteristics at travel. Review historical and proposed socioeconomic of study area.
Nebraska	Use data from computer assignments with adjustments.	Historic growth trends.
Nevada	Mainframe UTPS.	QRSII and regression analysis on past 10 years of ADT counts.
New Hampshire	Trend lining.	Trend lining.
New Jersey	Trend lining. Four-step UTPS modeling.	Trend lining, growth factors four-step UTPS modeling.
New Mexico	Gravity model simulating of base case, use of Delphi technique for design- year population and employment.	Multiple regression analysis with historical traffic data.
New York	Use regional travel forecasting model results and step down to project- specific area using manual adjustment techniques; microcomputer models focused on project-specific area, manual methods only.	Elasticity-based models and traffic trend lining.

Table 5.5. Summary of Traffic Forecasting Procedures Used by State Agencies (Continued)

State	Urban	Rural
North Carolina	If model is available it is used for the prediction of future travel, If no model is available, historic trend data are used.	Growth rates are applied based on historic trends. New traffic generators are considered along with diversion curves.
North Dakota	Trend lining, growth factors, and four-step UTPS modeling.	Trend lining and growth factor techniques.
Ohio	MPOs provide coded network, and state reviews model runs.	Growth factors based on socioeconomic data.
Oklahoma	Conduct corridor analysis study (4 to 6 mi wide) to determine potential growth.	Straight line or compound-growth curves.
Oregon	Four-step urban modeling process.	Trend lining of traffic counts.
Pennsylvania	Traffic counts factored by growth trends by functional class and socioeconomic trend.	Traffic growth trends by functional class adjusted for major land use changes.
South Carolina	Develop traffic from recent traffic assignment. Check against recent count data for reasonableness.	Check count data, determine growth factor based on area type and functional class.
South Dakota	Historical data are used plus land use in the area and communications with local officials.	Traffic forecasting model that uses historical, as well as socioeconomic data.
Tennessee	Urban modeling process and manual adjustments.	Traffic trend lining plus manual adjustments.
Texas	Long-range modeling performed by highway department and adjusted as needed.	Trend line of traffic counts.
Utah	Long-range urban modeling.	Growth factors applied to traffic counts.
Vermont	Traffic growth factors.	Traffic growth factors.
West Virginia	Four-step UTPS modeling process with manual adjustments.	Linear regression model using vehicle miles of travel and motor vehicle registrations.
Wisconsin	Urban modeling process combined with regression analysis	Statewide model; regression analysis and growth factors.
Wyoming	Urban modeling process.	Linear regression to develop growth factors.

Source: "Traffic Forecasting on State and Provincial Highway Segments," *ITE Journal, Volume 61, Issue 12,* Institute of Transportation Engineers, December 1991.

New York

The New York State Department of Transportation developed the Rural Forecast Methodology (RFM) to forecast traffic on rural state highways in New York. The methodology uses quick response procedures to forecast rural traffic. [29]

Florida

A method was developed for forecasting traffic along 300 miles of rural and urban, existing and proposed sections of Florida's turnpikes. The method combines traffic count and population trends with turnpike usage data and existing urban area transportation planning models in order to produce a consistent set of forecasts. [30]

Statewide Transportation Models

Statewide transportation models have been developed in various states for forecasting passengers and freight. These models have been developed using the four-step traffic forecasting method. Table 5.6 lists statewide passenger forecasting models that have been developed in various states.

Statewide forecasting models are useful to examine the following:

- Transportation needs for non-metropolitan areas.
- Connectivity between metropolitan areas.
- Recreational travel and tourism.
- Preservation of rights-of-way for future projects.
- Long-range needs of the state transportation system.
- Methods to enhance the efficient movement of commercial goods.

Most of the statewide forecasting models have been developed using the techniques applied to develop urban travel demand models. The urban models have been developed based upon well understood theories about travel choices. In addition, commercial travel forecasting packages developed for urban areas are readily available including many refined algorithms. However, the convenience of the software may deter implementation of better methods. Urban models may be overly complex for many intercity applications. Also, data requirements for these models can be burdensome at a statewide level. Lack of data in sufficient quantities has limited the development of statewide models.

A comprehensive report on statewide travel demand forecasting makes the following recommendations for developing statewide models:

- Use a statewide model for analysis of statewide effects of transportation system or socioeconomic changes or for statewide corridor planning only.
- Build the statewide model in a form consistent with available data.
- Examine, simultaneously, alternative methods of modeling.
- Re-examine the structure of any “traditional’ urban transportation methods used.
- Make use of existing government and commercial databases.
- Make use of existing statewide traffic monitoring programs.

- Plan for future data collections that will enhance an existing model.
- Make use of expert panels in the modeling process.
- At future dates, assess the performance of the model(s) used.

Table 5.6. Current Statewide Passenger Models

State	TAZs	Modes	Purposes	Comments
Connecticut	1300 total	1. SOV 2. HOV 3. Bus 4. Rail	1. HBW 2. HBNW 3. NHB	Mode split based on LOS information. Iterative-equilibrium assignment for highways.
Florida	440 internal 32 external	Highway Vehicles Only	1. HBW 2. HB Shop 3. HB Soc./Rec. 4. HB Misc. 5. NHG 6. Truck/Taxi	All trips are modeled to maximize use of MPO models. Gravity friction factors based on MPO urban models. Mode split is auto occupancy only based on production zone. Extensive use of K-factors.
Indiana	500 internal 50-60 external	1. Auto 2. Truck 3. Transit	1. HBW 2. Other Business 3. HB Other 4. NHB 5. Recreational 6. Truck	Under development. Internal TAZs at the township level. Aggregate mode choice.
Kentucky	756 internal 706 external	Auto only	1. HBW 2. HBO 3. NHB	Model includes a large portion of surrounding states. NPTS national average data used for trip generation.
Michigan	2392 total	Auto only	1. HB Work/Biz. 2. HB Soc./ Rec./Vac. 3. HB Other 4. NHB Work/Biz. 5. NHB Other	All trips modeled – previous models did not consider local trips. Two possible mode split models: (1) Simple cross-classification; and (2) LOS-based. LOS-based mode split model still under development. NTPS data used for calibration; CTPP data used for validation. Extensive use of K-factors.

Table 5.6. Current Statewide Passenger Models (Continued)

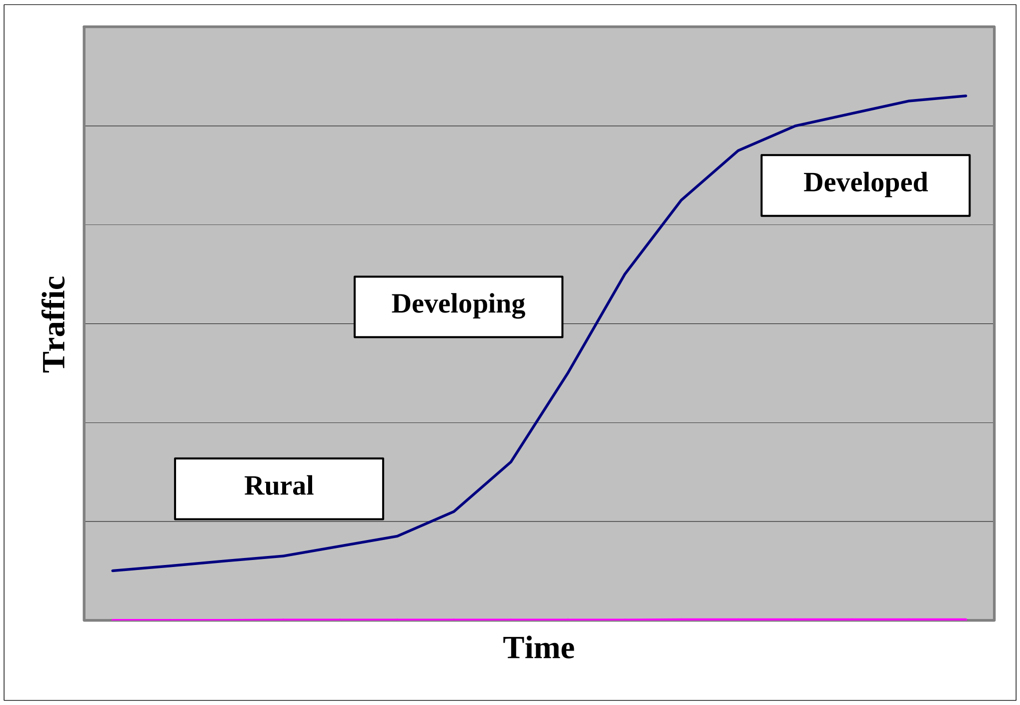
New Hampshire	1 per 5000 pop.	1. SOV 2. HOV2 3. HOV3 4. Bus 5. Rail	1. HBW 2. Business related 3. Personal 4. Shopping 5. Recreational 6. Other	Under development. Logit trip generation and distribution. Time of day and seasonal factors.
New Jersey	2762 internal 51 external	---	---	Model created by merging 5 MPO models.
Vermont	622 internal 70 external	Highway Vehicles Only	1. HBW 2. HB Shop 3. HB School 4. HB Other 5. NHB 6. Truck	Based on extensive statewide survey.
Wisconsin	112 internal 45 external	1. Auto 2. Air 3. Rail 4. Bus	1. Business 2. Other	Under development. No external trips considered. Network used only to develop impedances for mode share calculations.
Wyoming	5 internal 5 external	1. Auto 2. Truck	---	Model created mostly to demonstrate techniques. Summer weekend travel is modeled. Full trip table estimated using entropy maximization technique.

Source: *Guidebook on Statewide Travel Forecasting*, U. S. Department of Transportation, Federal Highway Administration, March 1999.

DISCUSSION OF TRAFFIC FORECASTING ISSUES

Currently, the ADOT TPD and other ADOT Divisions use simple linear trend models to forecast traffic on highway segments outside of MPO regions. Simple trend models assume that future growth will replicate historical patterns. However, this assumption breaks down in developing areas. Figure 5.1 illustrates how traffic volumes might increase over time in rural, developing, and developed areas. Simple trend models are suitable for segments of rural roads where traffic volumes will not be affected by more growth than experienced in the past. Moreover, simple trend models are more reliable for forecasting traffic for shorter rather than longer time periods. Simple trend models also do not include causal variables such as population and employment that are needed to explain traffic growth in developing and developed areas. Several states have developed extensions to trend models by including socioeconomic variables in the models.

Figure 5.1. Relationship of Traffic Growth to Development



Research is currently underway to develop simple trend models for ADOT with the intent to improve the overall accuracy of the modeling results. The development of accurate simple trend models depends significantly on the quality of the historical traffic count data. Some users believe there are deficiencies in the currently available historical data, which is available in an electronic format for each year as far back as 1974.

In using simple trend models, the segment lengths that are analyzed must be carefully defined, examining where traffic volumes might break from the normal trend. In addition, a major issue is how to "smooth" the traffic forecasts where major volume breaks occur, such as at the boundaries between rural and urban areas.

Traffic forecasting models developed in urban areas using the four-step method generally produce good estimates of traffic volumes. The ability of a model to replicate current traffic volumes depends on the model process, modeling techniques, and on the quality of the available demographic and traffic count information. The importance of accurate demographic and traffic count information for developing an accurate traffic forecasting model cannot be overstated. Of course, the accuracy of the traffic forecasts is greatly dependent on the quality of demographic forecasts.

Currently, the various ADOT divisions do not coordinate on the methods of forecasting traffic on state highways. Better coordination between the Divisions would improve the consistency in estimating traffic on Arizona's state highways. Moreover, ***consolidating all forecasting functions in one section within ADOT to forecast traffic***

would be highly beneficial for developing solid forecasting methods and forecasting traffic in a consistent manner throughout the state.

FINDINGS AND RECOMMENDATIONS

ADOT's business processes, including HPMS Data Collection, Management Systems, Planning and Programming, Pre-design/Design, Traffic, and Special Studies all utilize traffic data. The types of necessary data can be categorized in five groups; Volume, Vehicle Classification, Truck Weight, Speed, and Accident. Depending on the business process, various levels of accurate data are needed and a variety of applications throughout ADOT are used to manipulate and analyze the traffic data. ***The multitude of applications used to manage, process, and analyze traffic data can be seen as an indicator for the need to further centralize traffic data processing and distribution.*** While users will always have the need for specific applications to analyze traffic data, the availability of standardized base data should be increased to reduce the need for data processing and manipulation.

Forecasting

An area of special concern is the forecasting of future year traffic volumes. ADOT's Transportation Planning Division (TPD) uses regression analysis to forecast daily traffic volumes on state highways on a route-by-route basis, as needed. Historical traffic volumes are "regressed" against a span of years using traffic data stored in a MS ACCESS database table of AADT volumes. The "best" linear fit between the historical traffic volumes and years is determined by finding the linear coefficients that produced the best coefficient of determination. Given the "best" fit, future daily traffic volumes are determined by extrapolating to upcoming years using the formula derived by the regression technique.

Other groups within ADOT, such as the Pavement Design section and the Data Team also use regression analyses to forecast traffic volumes. However, there is no standardized methodology in place guiding these forecasting procedures. Currently, the various ADOT Divisions do not coordinate on the methods of forecasting traffic on state highways. ***Better coordination between the Divisions would improve the consistency in estimating traffic on Arizona's state highways. Moreover, the designation of one section within ADOT to forecast traffic would be highly beneficial for developing solid forecasting methods. Besides the lack of a standardized procedure, the simple linear trend models in use have limitations.***

Simple linear trend models assume that the future growth will replicate the historical patterns. In developing areas, however, this assumption breaks down, so these methods are reportedly not used for Phoenix, Tucson, Yuma, and Flagstaff. Simple linear trend models are suitable for segments of rural roads where traffic volumes will not be affected by more growth than experienced in the past. When forecasting traffic for shorter rather than longer time periods, simple linear trend models are more reliable. Also, simple trend models do not include causal variables such as population and employment needed to explain traffic growth in developing and developed areas. Several states have developed extensions to trend models by including socioeconomic variables.

The development of accurate simple trend models depend significantly on the quality of the historical traffic count data. In addition, a major issue is how to "smooth" the traffic forecasts where major volume breaks occur, such as at the boundaries between rural and urban areas. ADOT uses these methods for forecast traffic volumes in some areas, so should make efforts to improve traffic data quality and quantity.

Traffic forecasting models developed in urban areas using the four-step method generally produce good estimates of traffic volumes. The ability of a model to replicate current traffic volumes depends on the model process, modeling techniques, and on the quality of the current demographic and traffic count data. The importance of accurate demographic and traffic count information for developing an accurate traffic forecasting model cannot be overstated. Of course, the accuracy of the traffic forecasts is greatly dependent on the quality of the data input to the process.

In summary, regarding traffic forecasting, ADOT should:

- Improve the accuracy of its traffic counts, in part by providing additional staff, new count devices and equipment, and through better coordination and cooperation among ADOT divisions and groups;
- Coordinate forecasting process between divisions, perhaps by designating one group to provide forecasting services for all ADOT efforts;
- Develop standard forecasting methodologies;
- Expand forecasting techniques by incorporating socioeconomic variables; and
- Explore the possibility of 4-step modeling process on a statewide level or on a corridor level.

VI. TRAFFIC DATA COLLECTION, PROCESSING AND DISSMENATION TECHNOLOGIES

The objective of this chapter is to report all existing technologies that ADOT employs to collect, process, store and disseminate traffic data. Such technologies include but are not limited to:

- Devices to sense vehicles and their weight,
- Field equipment for traffic data recording,
- Devices or hardware for transmitting traffic data from collection devices to a computer,
- Software for converting, compiling, or processing raw traffic count data,
- Software or relational database management system (RDBMS) for storing traffic data,
- Software or system used to determine locations and frequency of collection efforts,
- Software or system for reporting, graphing or mapping traffic data,
- Software, format, standards, and the medium for disseminating traffic data to interested parties.

To report on traffic data technologies, information was gathered from various groups within ADOT. All these groups, to a certain extent, collect and/or maintain traffic data either for their own purposes or for others within ADOT. The following groups collect and/or maintain traffic data:

- Transportation Planning Group
- Arizona Transportation Research Center
- Freeway Management System
- Materials Group
- Traffic Engineering Group
- Bridge Group

Each group was contacted to determine what technologies they use to collect, maintain, report and/or disseminate traffic data. A list of individuals interviewed is provided in Appendix A.

COLLECTED TRAFFIC DATA

ADOT collects a wide assortment of traffic data for various needs. Each data element that ADOT collects is briefly described below.

Traffic Volume

ADOT collects and maintains traffic volumes for all highways at specific collection sites. Traffic volume is defined as the number of vehicles that pass a point on a highway, or a given lane or direction, during a specified time interval. Some sites record traffic volumes continuously throughout the year while most sites are only counted for 48 hours once a year. The results of the collection effort are used to compile or compute average annual daily traffic (AADT) values for every section of the state highway system.

AADT is the average 24-hour traffic volume at a given location over a full 365-day year – that is, the total number of vehicles passing a site in a year divided by 365. About 70 collection sites are equipped with automatic traffic recorders (ATRs), which can record traffic continuously throughout the year. The other sites need to have the AADT estimated by factoring the 48-hour count by seasonal, monthly and day-of-week factors.

Truck Weight

ADOT collects vehicle weight information for commercial trucks to determine the loading on statewide highways. This information is valuable for pavement design and maintenance, and vehicle weight enforcement.

Vehicle Classification

Vehicle classification data describes the types of vehicles that are using a particular facility. The FHWA has developed a classification scheme shown in Table 4.1, which is used by ADOT.

Other Data

ADOT collects other types of traffic data, but not on a continuous basis. These data elements are listed in Table 6.1.

Table 6.1. Other types of data that ADOT collects on an infrequent basis

Data Element	**Description**	**Reason for Collection**
Vehicle Speeds	Vehicular speeds on highway segments. Analysts usually collect speed data to determine average, standard deviation, and 85th-percentile speed.	Speed data is useful for accident studies, design studies, enforcement recommendations and signal timing studies. *Note: During the 1970's and 1980's, the ADOT Data Team was required to collect vehicle speed information for FHWA reporting purposes. This was during the enforcement of the national 55 mile per hour speed limit which was a result of the oil embargo of the 1970's. However, speed collection requirements have been suspended for the last 10 years.*
Turning Movement Volumes	Traffic volumes for each possible turning movement at an intersection during a specified period.	Turning movements are useful for signal timing/phasing studies, capacity analyses and design studies.
Travel Delay/Stopped Delay	Travel delay measures the time vehicles are stopped while traveling between a specified origin and destination. Stopped delay measures the number of vehicles that stop at an intersection during a given time period.	Travel/stopped delay studies are useful for evaluating level of service for highway sections. They also identify problem locations on facilities.

TRAFFIC VOLUME COLLECTION TECHNOLOGY

Obtaining traffic volume involves counting the number of vehicles that pass a point along a highway or street for a specified time period. There are several techniques for accomplishing this. The simplest approach involves a person manually counting the number of vehicles passing a point along a highway during a given time period. However, several technologies have been developed for automating this. The two key components for automatic vehicle counting are the detector and counter (often called recorder).

Traffic Detectors

Traffic detectors are designed to indicate the presence of a vehicle. ADOT uses one of several types of detectors. The most common are the pneumatic road tubes. These are hollow rubber tubes, which are placed across the road perpendicular to the direction of travel. The tubes are filled with air to a pressure equal to the atmosphere. When the tire of a vehicle passes over the tube, it causes a sudden pulse in pressure. This event is known as an "axle strike". An axle strike triggers a counting device, which electronically records the event. The major disadvantage of road tubes is that they really sense axles and not the actual vehicles. As a result, axle strike factors must be developed to properly convert the number of axles counted to the number of vehicles. Axle strike factors are developed after collecting vehicle classification data. Another disadvantage is due to Arizona's hot, arid climate, these detectors have a relatively short lifespan.

A second type of a traffic detector is the induction loop detector. An induction loop detector consists of an electronic detector module and the inductive loop coil. The coils are embedded into the pavement about 2 inches deep. The electronic detector module drives an electric current through the inductive loop coil creating an electromagnetic field. When a metallic object (such as a vehicle) passes through the field a decrease in inductance in the coil occurs. This sudden change of inductance is sensed by the detector, which actuates electronic output to a traffic counter or recorder. Inductive loops have the advantage of actually sensing individual vehicles so that axle factors are not needed. However, inductive loop detectors are more expensive than road tubes and, because they are embedded into the pavement, are permanent. Also, they tend to fail when subjected to heavy traffic loads, even over relatively short time frames.

Several new technologies have been developed to sense traffic. These devices include sonar, video and radar detectors. These devices have been mostly implemented to sense traffic for real-time monitoring. Real-time monitoring is required for traffic signal operations, ramp meters, freeway monitoring systems, and incident detection. Detectors used for real-time monitoring are usually not intended for counting or recording traffic volumes. They are mostly used to detect the presence of vehicles or determine vehicle speeds. This information is useful for indicating incidents or unusual traffic slowing. As a result, such devices are not maintained or calibrated to a level required for valid traffic data collection.

Traffic Counters

The hardware used to convert the signals from the detectors and record them electronically are the traffic counters. Data can be extracted from traffic counters to a laptop computer or can be sent remotely to a computer through a modem. The counter exports the data as a binary file. The exported data is converted to ASCII format with software provided by the vendor.

AUTOMATIC TRAFFIC RECORDERS (ATR'S)

While it is too costly to collect continuous traffic volumes from all sections of ADOT's highway system, it is still necessary to at least designate several sites for continuous traffic counting using automatic traffic recorders (ATR). ADOT operates about 70 ATRs throughout the state. ATRs are permanent sites designed to collect traffic data continuously, 365 days a year. ATR data is extremely important since it is used to determine seasonal and other factors for converting 48-hour counts into AADT values. Some ATRs collect additional information—vehicle classification and weight.

A typical ATR consists of the following elements:

- Sensing equipment which are usually inductive loop detectors;

- Traffic counting hardware which processes signals from the sensing equipment;

- Solar panels for generating electric power;

- Low power modem for transmitting data to the Data Team via cellular telephone devices (some locations only).

Data collected from ATRs are downloaded every night, through a modem, to a central computer at the ADOT Data Team office. Since ATRs are located in remote areas, they must by equipped with solar panels for electric power and some utilize cellular devices for communication. Some ATRs are not equipped with telecommunication devices and must be visited in the field to manually download the collected data onto a laptop computer.

VEHICLE CLASSIFICATION DATA

The simplest and most straightforward approach to obtaining classification data is visual observation and recording techniques. However, automated vehicle classification (AVC) devices can collect data continuously or for longer durations at a lower cost than visual procedures. The accuracy of AVC technology has rapidly improved. The Traffic Monitoring Guide reports that AVC systems have been found to be 90 to 95 percent accurate. Conversely, visually obtained vehicle classification data have been known to have a ten percent error on total vehicle flows with errors above 30 percent for certain vehicle types. As a result, automation of the collection of vehicle classification data should be considered for a system-wide traffic monitoring program.

It is impractical for ADOT to collect vehicle classification data on every section of every highway. Therefore, specific sites have been established to represent all highway sections within a specified area. Two separate groups within ADOT collect vehicle classification data. One is the Arizona Transportation Research Center, which collects traffic data for the Long Term Pavement Performance Program (LTPP) and the other is the Data Team.

6-Hour Manual Traffic Counts for Vehicle Classification

Although it is labor intensive, ADOT does perform manual vehicle classification counts at a few sites. Devices have been created to assist in the manual counting process. These devices include a panel with several tally buttons. The user presses the buttons based on what type of vehicle is passing the observation point. The results are later transferred to paper forms.

48-Hour Counts for Vehicle Classification

Several sites are established for 48-hour vehicle classification counts. This collection effort can utilize the same detection devices that are used for collecting traffic volumes. The only difference is the counting device that records the data. The devices use sophisticated algorithms to determine the type of vehicle that passes over the detectors. After the collection process, the data can be downloaded from the recorder to a laptop computer.

Automatic Vehicle Classification

Several sites have devices for the continuous collection of vehicle classification counts. As a result, they are called automatic vehicle classification (AVC) sites. These sites work in the same manner as the ATR sites. Some AVC sites transmit data into a computer via modem, while others must be connected to a laptop computer on site. All AVC sites use axle sensors and induction loops for vehicle detection/classification.

VEHICLE WEIGHT DATA COLLECTION

The Motor Vehicles Division (MVD), the Materials Group, and the Arizona Transportation Research Center (ATRC) all collect vehicle weight data. The MVD collects truck weights for enforcement purposes only while the Materials Group and the ATRC collect vehicle weight for pavement management and research purposes. The MVD uses static scales at point-of-entry (POE) stations throughout the state. When a truck enters a POE station, it makes it stops on a static scale so that its gross weight can be measured. Static scales have high accuracy but they are impractical for collecting large samples of data since they require that each truck be motionless while being weighed. POE stations do not have the technical resources for truck weight data collection. This is because the MVD only needs the information for a short while to determine if a truck, currently under inspection, is compliant. These stations would need to be outfitted with data collection and storage equipment if they were to gather and share truck weight data with the Materials Group and the ATRC.

WIM Sensors

Weigh-in-motion (WIM) technology has been developed to weigh vehicles while they are traveling at normal speeds. The Data Team and ATRC utilize two types of WIM sensors at designated collection sites: bending-plates and piezoelectric cables.

Bending-Plate Sensors

Bending-plate sensors consist of steel plates, which are embedded in concrete pavement. As a vehicle passes over the bending-plate it deflects. The amount of deflection is proportional to the load. The amount of deflection is sent to a data recorder, which computes the load. Bending-plate sensors typically last longer and are believed to be more accurate than piezoelectric sensors. Bending-plate sensors must be inspected and maintained on a regular basis since worn-out steel plates may be suddenly ejected from the pavement when ran over by a vehicle. For longer life and improved performance, bending plate sensors should be installed only in rigid (concrete) pavements. Therefore, any WIM site located on a roadway with flexible (asphalt) pavement should have a short section of rigid pavement if bending plate sensors are to be used. The technology and installation requirements of bending plate sensors make them more expensive than piezoelectric sensors.

Piezoelectric Sensors

A piezoelectric WIM sensor consists of a casing that contains a piezoelectric material. Materials that have piezoelectric properties generate electric charges when subjected to mechanical stress. Therefore, when a vehicle passes over the sensor the load generates an electric charge. The charge is proportional to the load. The charge is measured and a load is computed and saved on a data recorder. The sensors can be metal cased, bare, or in a composite channel. Rubber cased units are typically used only for temporary installations. Although piezoelectric sensors are not as reliable as bending plates, they are less expensive.

When WIM data collection is required for a short duration or the site is for temporary collection only, piezoelectric sensors offer a cost-effective solution. However, if a permanent collection site is required to collect WIM data continuously for a long period (for several months), the cost of installing a bending plate installation could be justified. Parameters such as cost, maintenance, duration of collection, reliability and accuracy must be considered when choosing a WIM technology.

WIM Recorders

WIM recorders convert signals from the sensors into load values. It is important to note that the accuracy of WIM is affected by many factors and it must be calibrated on a frequent basis. The WIM recorders at some ADOT collection sites have hardware for remote communication. WIM data can be downloaded remotely to a computer through a phone line. However, some sites that use WIM do not have remote communication capabilities and therefore field crews must visit them to download data onto laptop computers. Furthermore, the sites that continuously collect WIM data must be visited frequently since the recorders have a limit on how much data they can store.

DATA PROCESSING, REPORTING, AND STORAGE TECHNOLOGIES

Conventional Technologies

During the interview process, several questions were asked regarding any technologies used to store and analyze traffic data. With the exception of the Data Team and the LTPP, all traffic data is stored in ASCII files, Excel spreadsheets or small-scale databases using Microsoft Access or FoxPro. Most ADOT groups appreciate the flexibility of using spreadsheet software such as Excel. In a spreadsheet, data can be stored, viewed and printed in tabular format. Since ADOT's AADT, vehicle classification and vehicle weight database isn't very big (the AADT table only has 1,200 records) a spreadsheet can store these data. A spreadsheet allows analysts to perform computations on the data for their own business processes and personal needs without the need for much application development. For example, the Materials Group uses Excel to store traffic data and uses the standard spreadsheet functions to compute equivalent single axle load (ESAL) values. Furthermore, spreadsheet files are easily shared across different groups in ADOT and outside agencies. The Data Team often distributes its traffic data in Excel format to interested parties.

TRADAS: ADOT's Traffic Monitoring System

ADOT's traffic data collection program, which is performed by the Data Team, generates large amounts of data. All of it must be properly analyzed and processed to determine valid AADT, vehicle classification and weight values for the 1,200 highway segments throughout the state. ADOT uses a software package called TRADAS for inputting, compiling, analyzing and reporting traffic data. TRADAS was specifically designed for agencies who must implement traffic monitoring systems according to the requirements outlined in the following documents:

- FHWA Traffic Monitoring Guide
- AASHTO Guidelines for Traffic Data Programs
- Highway Performance Monitoring System (HPMS) Field Manual
- STM E-1442, Standard Practice for Highway-Traffic Monitoring

TRADAS is a product of Chaparral Systems and is in its second version. Written in C++, it is a client/server system, which meets the data processing requirements for a traffic monitoring system and stores traffic data in an Oracle database. The front-end of TRADAS is a client software program called Roadrunner. Roadrunner gives a user all of the functionality of TRADAS through a Windows-based graphical user interface (GUI). The TRADAS server must be installed on a computer running Windows NT. The client software can run on computer with a Windows 95/98 or NT operating system.

TRADAS can process the following data types:

- Traffic volume
- Vehicle classification
- Vehicle weight
- Vehicle speeds
- Intersection turning movements
- Vehicle length
- Vehicle headways

ADOT uses TRADAS for calculating AADT, determining and applying adjustment factors, K factors, and axle factors. However, some vehicle classification and weight data is processed and stored on the system. Some of the most important features of TRADAS include:

- Reading data from a variety of traffic collection devices from multiple vendors

- Performing data quality control by employing a versatile set of data checking capabilities

- Generating a wide variety of standard reports based on daily, weekly, monthly and annual summaries

According to Chaparral Systems, TRADAS was designed to be scalable so that it serves the traffic data processing needs of an agency of any size. The Data Team staff stated that uploading, and processing takes an inordinately long period of time to complete, and that maintenance of the system and database is cumbersome and complex.

Data Input Functionality

There are a great number of types of traffic collection devices. TRADAS has been developed to accept raw data from many traffic data collection devices. Chaparral is familiar with traffic detection technology and develops "format readers" so that TRADAS can read data from existing and newly developed devices. TRADAS reads data from ADOT's ATRs using a software module called Data Collection Management System (DCMS). DCMS is a data polling service software that runs on Windows and performs data collection and routing for TRADAS. A user can also enter data manually or submit an ASCII file that was created by a portable traffic counter.

Data Storage and Processing Functionality

TRADAS has the processing functionality to validate data, associate raw data with count sites, and compute various traffic parameters required for reports. It also has the ability to assist a user in maintaining data integrity by determining and eliminating data that may contain errors. When traffic data from an ATR is automatically polled into TRADAS, the system looks for any data outliers that appear to contain errors. These errors are mostly due to counter or traffic detector failures. Any traffic data that is erroneous is automatically filtered out.

TRADAS performs the necessary calculations for developing seasonal adjustment factors. ATR data are used to develop these factors. Once they have been computed, they are used to convert the short-term counts into AADT. TRADAS can compute equivalent single axle loads (ESALs) from vehicle classification and weight data, however ADOT doesn't use this functionality. TRADAS can also develop traffic projections using linear regression, but ADOT doesn't use this functionality.

Within the TRADAS environment, raw and processed data can be bound to data records that represent highway count sites and sections. As a result, TRADAS has the ability to manage multiple traffic counts for a single site. The system can compare multiple counts and determine if any fall within normal ranges.

The back-end storage system for TRADAS is an Oracle database, which stores traffic and site data. The user may store meta-data along with traffic and site data as additional descriptive information about the traffic and site data elements.

Data Reporting and Viewing Functionality

Many reporting and viewing functions are provided with TRADAS. Users can create and view raw or processed data, in tabular or chart format in a GUI environment. The chart types that can be created are bar, column, stack, point series, line, area, and ribbon. However, it does not provide the ability to prepare geographical map-based reports such as traffic count maps. ADOT mostly uses TRADAS reporting functions for preparing traffic volume reports that summarize AADT along with adjustment factors. TRADAS can also report on system processes such as raw data conversion, quality control checks and errors. The time frame of TRADAS reports can be daily, weekly, monthly or yearly. TRADAS can automatically prepare reports using formats required by:

- FHWA's continuous count program
- Long-Term Pavement Performance (LTPP) project
- Highway Performance Monitoring System (HPMS)

The annual reports that TRADAS can create include ATR summaries, annual count audit, and system-level vehicle distance traveled summaries. All reports can be exported as ASCII files.

ADOT's Experience with TRADAS

The users of TRADAS at ADOT were interviewed to review the software's functionality for monitoring traffic on State highways. The TRADAS User's Guide and product Web site (www.chapsys.com/tradas.html) were also reviewed to gain a better understanding of the product's functionality and claims. The functionality of TRADAS is very comprehensive and appears to accomplish much of an agency's computing needs for a traffic monitoring system. ADOT has had its share of problems with the system, however. The Data Team staff has reported that it is slow, complicated, cumbersome, unstable, and has an over-abundance of graphical interfaces. Nevertheless, the department has used TRADAS for more than six years. Whether using TRADAS or another product, the Data Team has expressed interest in having a map component integrated with their traffic monitoring software.

Analysis and Storage of Vehicle Weight and Classification Data

While ADOT uses TRADAS to process and store traffic count data, it is also used to store some vehicle classification and weight data from ATRs. However, other data is gathered from devices that do not have a link to the TRADAS server. Since weight and classification data come from a variety sources, not all of this data is kept in one central location.

Once vehicle classification and weight data have been collected, it needs to be extracted from the collection devices and imported into a computer. Sometimes this process is automated, if there is a connection between the collection equipment and the computer. This connection is established through a modem. If the data input procedures are not automated, the data is usually passed manually to the computer in binary format. The vendors who make vehicle classification detectors and WIM equipment provide software for importing the data into a computer and for converting, analyzing and reporting the data. The software converts the data into ASCII files, which can be used for reporting or for further conversion into a database, or spreadsheet software such as Excel. The data that is stored in TRADAS is converted and loaded using the DCMS software module mentioned previously in the Data Input Functionality section.

The analysts who perform data collection and processing for the LTPP use software provided by their traffic monitoring equipment vendor for converting and reporting raw data. The software product is called REPORTER and is provided by the PAT Traffic Control Corporation, which also provides equipment for collecting the data. REPORTER will convert raw data into ASCII format and can create tables necessary for reporting in the traffic monitoring guide (TMG) format. LTPP also uses spreadsheet software, such as Excel, for further analysis and validation of their vehicle classification and weight data. LTPP analysts have developed several customized macros for some calculations. Once the data has been processed and analyzed, LTPP keeps it in a Microsoft Access database.

Geographic Information Systems

A geographic information system (GIS) provides the ability to link traffic data with spatial data. Like other geographic data, traffic data can be spatially referenced by route number and milepost, or using a number of other methods, including x-y coordinates, such as longitude and latitude. A traffic volume record for a highway section that is spatially referenced as Interstate 10 Milepost 10.5 to 25.2 can be shown on a digital map. The only other data source required is a spatial map layer that contains a highway network with milepost data embedded into the spatial features. This highway network acts as a linear referencing system (LRS) for data that is spatially referenced by route and milepost values. Through this dynamic link, traffic data can efficiently be shown on a digital map.

ADOT maintains a highway network coverage called the Arizona Transportation Information System (ATIS). ATIS contains linear features that represent road centerlines for all of Arizona’s highways and streets. A Linear Referencing System has been developed for the ATIS coverage. ADOT’s GIS analysts link traffic data with ATIS and create maps that show traffic data throughout the state. The data can be represented in various ways. For example, a map can be created with annotated traffic volumes along major highways. Another example is a color-coded map showing percentage of commercial vehicles on ADOT highways. ADOT's GIS analysts have developed applications that automate the process of linking traffic data with ATIS and "painting" traffic data along highway features on a digital map.

ADOT also maintains a highway network spatial layer for the HPMS. This layer is a subset of the ATIS network in that it only contains Interstate and other principal highways. The HPMS data layer stores several types of information including roadway geometry and traffic data. The traffic data includes current, historical, and projected AADT as well as percent trucks.

GIS technology is currently being used to re-section ADOT's traffic database. The 1,200 highway sections for the traffic database were developed 25 years ago. The increase of population in Arizona has drastically changed the pattern of the homogenous traffic count sections statewide. As a result, GIS will be used to establish new segment breaks where major traffic generators have been located.

TECHNOLOGIES USED FOR DATA DISSEMINATION

Conventional Technologies

ADOT's Data Team is the main source of most traffic data within the organization. The Data Team prepares hardcopy reports of statewide historical, current, and projected AADT, as well as adjustment factors, and vehicle classification data. These reports are available upon request. Many data users request data in electronic format. The digital data is usually provided as ASCII files, Excel spreadsheets, and Adobe PDF files.

ADOT's Data Section Web Site

The Transportation Planning Division, maintains Web pages (map.azfms.com/datateam/trafmon.html) that provide access to various traffic data and traffic-related reports. Most of the traffic data has been compiled, tabulated, and exported into Adobe PDF format. Users must have the Adobe Reader to view the data. The Web pages provide public relations information about the Data Section (Data Team), its objectives, function, and responsibilities. Two pages of the Web site provide traffic data. One gives general traffic-related data such as AADT and adjustment factors and the other gives information related to the HPMS.

Data Elements in the Traffic Reports and Data Web Page

Data elements in the Traffic Reports and Data Web page are listed in Table 6.2.

Table 6.2. Data elements available on the Traffic Reports and Data Web page

Data Element	Description
Current AADT	A statewide, tabular listing of current average annual daily traffic values by roadway section.
K, D & T Factors	Factors used for converting an AADT value into directional design hourly volume (DDHV). K is the proportion of daily traffic occurring during the peak hour. D is the proportion of peak-hour traffic traveling in the peak direction. Each set of factors is determined by the data from the ATRs and are applied to specified highway segments. (WHAT IS THE "T" FACTOR call mark or bob pike).

At the time of this writing, the Data Section Web pages indicated that the data elements shown in Table 6.3 will be available online.

Table 6.3. Data elements that will soon be available on the Traffic Reports and Data Web page

Data Element	Description
ATR Station Reports	Reports from the 70 continuous traffic recording stations statewide.
Historical AADT	Statewide AADT values by year from the past 20 years.
Season Adjustment Factors	Adjustment factors used to convert AADT to ADT for a particular season.
Forecasted AADT's	Statewide AADT values that have been projected for several planning horizons.
Axle Correction Factors	Factors used to convert axle strikes on axle sensors to vehicles.
Ramp and Crossover Counts	Traffic counts on interchange ramps, which are collected every three years.

Data Elements in the HPMS Reports Web Page

The data elements from the HPMS Web page are listed below.

- Daily vehicle mile traveled (DVMT) Estimates for State and Non-State roads with population estimates, 1990-1997
- Route mileage, lane mileage by county and functional class, and DVMT, 1997-1998
- Composite, multi-year statewide annual vehicle miles traveled (AVMT) and DVMT 1976-1998 and 2010, 2015 forecasts

At the time of this writing, the Data Section web pages indicated that the following data elements will be available online (Table 6.4).

Table 6.4. Additional data elements that will soon be available on the Traffic Reports and Data web page

Data Element	Description
Area wide Length and Travel Templates	Unknown
Vehicle Classification Data	Information that describes the types of vehicles, which are on the highways (i.e. passenger cars, commercial trucks, etc.).
Length and Travel Tables with Demographics	Unknown

FINDINGS AND RECOMMENDATIONS

Traffic-related data are used to make important and costly transportation decisions about capital investments and operating expenditures. To provide timely data of sufficient accuracy, ADOT must ensure that appropriate traffic collection equipment is available, continuously maintained in good working order, and calibrated to provide accurate results. Transportation Technology Group staff have reported that roughly only 50% of the Freeway Monitoring System traffic sensors are operational at a given time. As another example provided by the Data Team, about 90% of the automatic traffic recorders (ATRs) used to collect data for the HPMS fail at least once each year. On November 13, 2000, only 55 (74%) of the total of 74 ATRs transmitted any data. This failure rate is, in part, attributed to the lack resources for ongoing maintenance. Due to this lack of resources, no maintenance schedule has been established. Maintenance is conducted in a reactive mode –as sites fail, they are visited, fixed, and maintenance is performed at that time.

Traffic Data Collection Technologies

ADOT uses proven, current methods and technologies in their traffic data collection efforts. ADOT's need for accurate and timely data is balanced against available resources and the cost-effectiveness of the methods and technologies employed. The ability to utilize the most accurate data collection technologies is impacted by limited funding for capital items and for maintenance activities. Sensing devices must be periodically replaced and there are ongoing maintenance costs. For example, piezoelectric sensors need to be replaced about every three years and, to ensure accuracy, they need to be calibrated once or twice a year, at a cost of $3,000 to $5,000 per calibration. Efforts to collect adequate and accurate data are further impacted by a lack of spare parts and a long-cycle procurement process. The process of specifying, procuring, and acquiring such equipment can require up to a period of 12 months. Since the collection system is growing old, and it is inadequately maintained, maintenance requirements are increasing.

To enhance current data collection infrastructure, it is recommended that some group within ADOT be given agency-wide responsibility for maintaining collection and

related equipment and systems, and that additional budget be allocated for maintenance activities.

As judged from discussions with ADOT staff, there has not been much luck in using technologies, such as bending-plates, for capturing Weight-In-Motion (WIM) data. It was reported that particular bending-plate installations have only operated for a 3-month period before being rendered unusable by excessive traffic volumes. Some ADOT staff believe that WIM data is not frequently used, and therefore its collection is not given priority. However, such data is useful, if not essential for activities, such as pavement design management, bridge design and operation, and enforcement of weight limits on State highways.

One potential, yet untapped source of truck weight data may be static scales that do not rely upon the aforementioned technologies. Vehicle weights are measured at these locations and recorded in a written record. If this data could be entered and stored in a persistent medium, such as a database, it may be used for these other purposes, especially if information about which routes are used by the vehicle could also be obtained. The funding of such an effort is an ongoing, open issue.

To investigate and develop a way of obtaining and providing adequate WIM data, it is recommended that ADOT assign the responsibility of developing a coordinated, agency-wide WIM data plan. To be successful, and not fall short as past efforts have, this plan will require management support and funding.

Traffic Data Storage and Processing Technologies

As mentioned previously, the Data Team uses TRADAS for traffic data storage, processing, reporting, and monitoring purposes. TRADAS seems to satisfactorily perform operations needed by the Data Team and does provide a number of fixed, standard reports. However, the system is reportedly very slow, requiring extended periods of time to process data, is complicated to use, and has no map-based interface. ADOT's upgrade to a version of the TRADAS software for Microsoft's Windows operating systems has not gone smoothly and some disruptions to ADOT's daily activities have been experienced.

Although the system and its performance were not reviewed here in depth, TRADAS seems to offer much functionality that is either not needed or not used at ADOT. The TRADAS system utilizes an undocumented Oracle database, so it is very difficult to use the data stored in TRADAS for other purposes, without exporting the data in another format (i.e. ASCII). TRADAS does not provide an open environment for the input, storage, maintenance, reporting, and dissemination of comprehensive traffic-related data. As implemented at ADOT, it is a narrowly focused application.

It has been noted that TRADAS does not support scheduling and monitoring count and maintenance activities. Currently, a staff member manually plans traffic count and maintenance, "in his head". Some important experience and information will be lost when this knowledge worker leaves ADOT. A number of other states have implemented integrated systems that schedule and monitoring these activities, as well as store, process, and report information about traffic data.

To fulfill the need for a traffic monitoring system that more readily supports data sharing throughout ADOT, provides efficient processing, flexible reporting, and a map-based interface, it is recommended that ADOT consider specifying and implementing a more integrated solution. This solution should include a more open and optimized database, count scheduling and work order monitoring functionality, spatial content, and a map-based user-interface for query, display, and reporting. The spatial data should be based upon ADOT's ATIS Roads street centerline standard.

Other ADOT groups use small-scale database programs, such as MS ACCESS, and spreadsheets for traffic data storage and analysis. These solutions are affordable, easy-to-learn, and reliable, but do not provide an integrated solution nor support widespread access to the data in its current format. ADOT should aggressively pursue the development of a centralized traffic database solution that will inventory, and eventually store traffic data from all the various sources. This is not a trivial task, and several technical, organizational, and financial issues will need to be addressed. However, other agencies, such as Maine DOT have discovered that the design, development and implementation of an enterprise traffic data system have been crucial in providing access and supporting the management of their traffic data resources in a useful and efficient manner.

To provide a statewide source of traffic-related data for planning, management, and operations across ADOT, the Department should design and develop a centralized information system that will allow all users to locate, evaluate, and acquire data from available, existing, and future sources. Such a system will serve as a clearinghouse of traffic data and will help coordinate activities, maximize the use of data resources, and provide consistent data across the agency. For example, any number of users will be able to obtain the same values for queries such as: what is the fatality rate statewide or for a particular segment of highway; how many lane-miles comprise the state highway system; or what is the traffic volume at any particular intersection each month of the year.

Data Dissemination Technologies

Most traffic data are currently published as written reports and tabulations, and some information is shared using several standard electronic file formats, for example in Excel (Microsoft) spreadsheets. ADOT is now beginning to take advantage of Intranet and Internet technologies to disseminate information, including traffic data. This data is usually presented in the form of static tables that must be manually changed on the Web site when updated data is available. Through a web browser, anyone can acquire AADT and other parameters for any section of the State highway system. This is the beginning of a user-driven approach to data dissemination, which ADOT should aggressively pursue. The development of interactive and dynamic Intranet- or Internet-based system, coupled with a centralized, online database of traffic data will provide a mechanism for sharing and accessing consistent traffic data throughout ADOT and other agencies in an automated way. Any updates to the database would immediately and automatically become available without the need to make changes to the Web site content. Also, a centralized database, or Data Warehouse would support user access to historical data. Such a system would provide more flexible queries and would not require limited standard (canned) reports, although they could still be provided.

To provide consistent and flexible access to data resources statewide, ADOT should develop a browser-based query, display, reporting, and mapping interface that utilizes a centralized, online traffic-related database. Such an interface could be used anywhere within ADOT, by other agencies, and by the public, if their access is granted by administrators. Such a system will disseminate up-to-date traffic data to the greatest amount of users possible.

It has been noted at ADOT and elsewhere that managers and executive officials are not always aware of the data available to them to support the decision-making process, communicate real conditions and trends, and justify requests for funding. In general, most needed data exists somewhere within the agency, but accessibility to this data is severely limited. Therefore, data are not as widely used as is possible. This lack of access is one reason that redundant data collection does occur. A system that organizes traffic data in a centralized database will enhance the decision making process by providing an easy way to locate and access available data from across the agency, and if developed around a GIS-enabled Data Warehouse, by providing visual and easy-to-use tools for querying and analyzing large amounts of data.

To realize the maximum benefit of ongoing data collection efforts, all data must be made available to all potential users. Users need the ability to identify and located available data, and query, summarize, report, and obtain such data. To ensure that this data is useful, it must conform to accepted standards and must be adequately documented, so that users can assess the suitability of all data for their particular use.

VII. IMPLEMENTATION PLAN FOR ENHANCING ADOT'S TRAFFIC DATA RESOURCES

A research effort was undertaken to review current traffic data collection, storage, and analytical practices, identify statewide sources of traffic data, and develop a plan for maximizing the use and accessibility of this data, while minimizing redundant systems or activities. ADOT's traffic data collection, storage and analysis practices have been reviewed and documented, and traffic data needs and issues have been identified. This implementation plan presents recommendations for ADOT to address the current needs and issues associated with its traffic data resources.

OBJECTIVES

This plan first provides a brief summary of the research findings before describing actions recommended to meet needs and resolve issues identified thus far. The main objectives of the recommendations are to:

- Foster cooperation between and among and between those collecting and using traffic data;
- Maximize the usability and accessibility of the various data that are collected and processed;
- Minimize redundant collection and processing efforts; and
- Establish common procedures and standards to support such goals.

This Implementation Plan was constructed with information gained from evaluating ADOT's current traffic data resources and associated business processes, including relevant activities at other agencies. The main recommendations are the:

- Establishment of a Traffic Data Working Group;
- Drafting and publishing of procedures, standards and guidelines for data collection, processing, Metadata, and data documentation;
- Development of a Traffic Data Clearinghouse; and
- Development of a Traffic Data Warehouse.

Other recommendations dealing with specific issues within ADOT's groups or sections are provided under the appropriate chapters of this report.

SUMMARY OF ISSUES IDENTIFIED

As a result of the research effort, a number of critical issues have been identified as having a substantial impact on traffic data collection, processing, storage, and utilization at ADOT. The main issues fall into one or more of the following areas:

- Coordination of collection efforts;
- Collection procedures, standards, and data documentation;
- Data quality and validity; and
- Data access and availability

Below, issues are described and put into context as background for understanding the challenges and recommendations made for addressing each.

Coordination of Collection Efforts

Various groups and agencies collect traffic data that are used for many purposes at ADOT. For example, the Data Team collects statewide traffic volumes, the Traffic Engineering Group and others in the Transportation Planning Division often collect traffic volumes on State highways for special studies, and other ADOT groups, MPOs, counties, and municipalities also perform collection efforts for state highways.

Currently, these efforts do not seem to be coordinated, although a study is reportedly underway to explore this issue. Because these efforts are not always coordinated, there is potential for redundant data collection and processing efforts.

Collection Procedures, Standards and Documentation

Many traffic data users would like to have information available about methods used to collect and process data and the conditions under which the collection was performed. Such information will facilitate the user's determination of whether particular data is appropriate and suited for a specific need or purpose. In the absence of such information, the tendency is to recollect data to help ensure its suitability. The concept of providing information about the data has been referred to as *truth in data*.

Much of the traffic data used at ADOT is collected and processed by the Data Team, whose efforts conform to the Traffic Monitoring Guide and other standards. However, other efforts, especially those for special studies, do not necessarily follow any standard guidelines. As a result, the data produced from these efforts may not be seen as usable to the Data Team or other groups, which may have a need for the same data. This issue is related to the documentation of the data source. If data is documented as meeting certain standards, there may be more willingness and ability to use such data.

Data Quality and Validity

Users of the traffic data require complete and accurate raw data representing typical conditions on facilities of interest. Equipment failures or malfunctions can cause erroneous data values that are not always screened and removed from the data product provided to the end user. In addition to these errors, data can be recorded during activities that are impacted by accidents, weather, special events, construction activities, etc.

When reflected in data products, this can cause skepticism among users. If a user doesn't trust data that is provided by another source, he or she may be tempted to perform additional, redundant data collection at additional cost. Errors due to equipment failures will continue as a problem until additional staff and financial resources are available to support adequate maintenance.

Data Access and Availability

Various data are collected by a variety of ADOT groups and other agencies for a multitude of purposes. Some data are widely used, while others are used only for specific purposes. Many of these collection and processing efforts are not coordinated between the various departments. As a result, many potential data users are unaware of the various collection activities and are not able to identify all existing sources of available data. This can lead to redundant collection efforts and does not promote the use of existing data resources, even when they might be suited to the particular purpose.

OUTLINE OF RECOMMENDATIONS

The main issues discussed in previous sections were identified after an extensive literature review and comprehensive interviews of stakeholders from all concerned ADOT groups and some other agencies. To address these main issues (reduce redundancy, ensure data quality, and maximize access and use of data resources) a number of actions are proposed below. The main recommendations as a result of this effort are to:

- Establish a Traffic Data Working Group;
- Adopt and Publish Traffic Data Collection, Processing, and Dissemination Standards and Guidelines;
- Develop a Statewide Traffic Data Clearinghouse and Traffic Data Warehouse.

Other issues are discussed in previous chapters of this report.

Traffic Data Working Group

Many of the problems experienced and reported by ADOT can be ameliorated by enhanced communication and coordination between and among the various Divisions, Groups, and Sections that are involved in either collecting, processing, using, or distributing traffic data.

The establishment of a Working Group will facilitate communication and coordination and serve as a forum for identifying agency-wide data needs and priorities for both ongoing, continuous collection and for ad-hoc collection activities to meet specific project needs. It is recommended that a Working Group made up of representatives from all concerned ADOT Divisions and other agencies be convened on a regular basis to share information, identify issues and opportunities, and better coordinate collection activities to minimize redundancy and maximize the usefulness and use of all collected data. The Working Group should be comprised of members from the following:

- Planning and Programming;
- Traffic Forecasting;
- Advance Engineering;
- Highway Design;
- Pavement Design;
- Bridge Design;
- Traffic Engineering;
- Pavement Management;
- Bridge Operations;
- Safety Management;
- Traffic Operations;
- Metropolitan and Local Planning Organizations;
- County, City, and Federal Government
- Arizona Transportation Research Center; and
- Traffic Data Collection Contractors (as requested by the project TAC)

Each representative could report information back to management and other staff in their areas. Some of the other responsibilities of the Working Group could be to:

- Identify and administer funding;

- Build consensus, set priorities, and monitor progress;
- Plan, publish, and administer guidelines and standards; and
- Manage the design and development of the traffic clearinghouse and data warehouse.

As other, more specific needs are determined, it may be that specialized subgroups, or ad-hoc groups could be formed to address them as needed, without requiring participation by each representative. Initially, an individual, or group will be needed to sponsor, host, organize, and administer the Working Group.

Guidelines, Procedures, and Standards

There is an overall need to establish a common set of standards for all traffic data collection efforts for ADOT. Standards can be developed and published to guide collection and processing practices. The goal being to enhance the usefulness of data collected. Such standards and guidelines will allow the data to be more widely used in appropriate ways.

Currently there are no uniform standards across ADOT for traffic counting, factoring, and adjusting raw data. The Data Team's collection efforts conform to standards set forth in the FHWA Traffic Monitoring Guide (TMG) for the statewide traffic monitoring program. However, ADOT uses no uniform standards for special collection efforts that occur for Small Area Transportation Studies, Corridor Analyses, and Design Concept Reports.

Data from special collection efforts have been used in conjunction with data from the traffic monitoring program. This can create a situation where dissimilar data are combined. Traffic data meant to represent uniform conditions across a broad area are sometimes derived from specific studies that may have employed different standards and procedures. Although tolerated, this problem has been a concern among those who use traffic data for decision support. Developing and encouraging standard practices in traffic data collection and processing will lead to improved consistency and facilitate the proper use of data for multiple purposes across the agency.

Additionally, data users often need to judge the suitability of data for their application, and relate the sensitivity of decisions to the quality of the data. To meet these needs, users must have access to pertinent information about the data. This information might include a description of the equipment used to collect the data, the time period over which the data were collected, the analysis methods used, and the accuracy of the estimate, and any adjustments made, if any. The provision of such information is known as "truth-in-data". Truth-in-data should be a standard requirement for every data collection effort sponsored by ADOT. Although not all data users wish to be bothered with such detailed information, such data and standards should always be accessible to them and required of them.

Primary Standards for Traffic Data Collection and Processing

To address the need for standards and guidelines, several items should be evaluated. Some examples are outlined in Table 7.1. Actual guidelines and standards can only be developed after the formation of the Traffic Data Working Group, which will provide a forum for discussion to build consensus of the important elements, their priority, and feasibility. Several resources are available to explore predefined standards for traffic monitoring. These resources include the Federal Highway Administrations' (FHWA) Traffic Monitoring Guide, American Society of Testing and Materials Standard Practice for Highway Monitoring, and American Association of State Highway and Transportation Officials' (AASHTO) Guidelines for Traffic Data Programs. Once adopted, standards and guidelines should be published and distributed to affected parties.

Table 7.1 List of Example Standards for Traffic Data Collection and Processing

	Required Standard	**Description**
Standards for Traffic Data Collection	Time of day and day of week	Guidelines should be set for defining the appropriate times for data collection. For example, all traffic counts for AADT should only occur Monday through Thursday.
	Duration of traffic data collection	A standard duration should be defined based on the data being collected. For example, all traffic counts that are used for determining ADT should cover 48 continuous hours.
	Data requirements to support factoring	Standard requirements for continuous data collection; counts and vehicle classification
	Equipment	Standard procedures should be followed for equipment setup, maintenance, testing and calibration.
Standards for Traffic Data Processing	Traffic data verification	A standard procedure should be established for screening and verifying data. These have already been defined in ASTM standards.
	Data format for submittal	A standard format should be defined for data storage and transmittal.
	Factoring raw data	Standards for documenting adjustments and the factoring process, including the data used in factoring.
Standards for the Provision of Truth-in-data	Traffic data information	All traffic data collection efforts should implement the truth-in-data principle. Standards should be set for reporting supplementary information about the data.
Standards for Reporting Traffic Data to Central Repository	Registration of traffic data	A standard procedure should be defined for reporting the collection or derivation of traffic data to a central repository. For example, every data collection effort, performed by any division, must be reported to the repository along with supplemental information. Supplemental information must include location, time of collection, data type, method of collection, etc.

Traffic Data Clearinghouse and Data Warehouse

The various traffic data collected, processed, analyzed, and reported throughout ADOT are not currently stored and maintained as an integrated resource. Traffic data are scattered throughout the organization in the form of studies, reports and other documents, and in computer systems in different formats. This makes it difficult to track and determine what traffic data has been collected and what might be available, let alone share the data. For example, an ADOT traffic engineer may want information on turning movement counts for a particular intersection. The intersection might have been part of a recent traffic study for a Design Concept Report (DCR) that collected turning movement volumes. Although traffic data does exist for the intersection, there is no convenient way for the traffic engineer to find this out.

To do so, the traffic engineer would need know about the DCR and obtain it from the Advance Engineering Division. Once the traffic engineer has received the report, he or she must sift through it to find the turning movement counts. To determine if the counts are usable he or she will also have to locate supplemental data (if any exists at all). The supplemental information includes the times the data was collected, the methods used for collection, and the methods used for data processing. All of these steps are required for the traffic engineer to decide whether there are suitable data available, or if additional data collection is needed. If a system was implemented that cataloged all traffic collection efforts, the traffic engineer could conveniently and quickly determine the existence of traffic for any highway facility.

The development of a Traffic Data Clearinghouse and Traffic Data Warehouse will assist ADOT in inventorying and maintaining all traffic data collected on State highways. The clearinghouse could include traffic data available from other agencies. Currently, there is no system in place that inventories all traffic data that is collected on ADOT facilities. Such a system would benefit users since it would make all traffic data easily accessible. In order to implement such a system, a collaborative effort is needed to develop a standard procedure to report all traffic data collection efforts to a central repository. As a second phase, actual traffic data could be extracted form the different sources and loaded into a Traffic Data Warehouse for use throughout the agency.

Traffic Data Clearinghouse

The Traffic Data Clearinghouse will store information about the existence of traffic data throughout the State highway system. The Clearinghouse, as an inventory of traffic data resources, would serve as a focal point for traffic data collectors, processors, and users. Such a system is analogous to an index system in a library except that, in this case, the index stores information about traffic data rather than books.

The Clearinghouse will allow users to quickly and conveniently identify and locate available traffic data resources throughout the State. The clearinghouse should incorporate a geographic information system (GIS) so that traffic data resources are spatially referenced. This will allow a user to query traffic data resources by geographic location. For example, a user can select an intersection from a map display to query the clearinghouse. The results of the query might include information about a recent traffic signal study which collected turning movements as well as approach volumes. The query might also include AADT occurring on the major approaches of the intersection.

The actual traffic data is not stored in the Clearinghouse. This more resource intensive role would be served by a data warehouse. The data warehouse would serve to bring together data from a variety of systems and formats, and provide a consistent and optimized interface for accessing large amounts of traffic-related data.

Traffic Data Warehouse

In this document, the term data warehouse refers to the combination of various data from databases across an enterprise. This collection of a wide variety of data is used to provide a single point of access to large amounts of data. The system is optimized to support efficient and flexible querying and reporting for the purposes of decision support. The data warehouse includes processes and systems to extract various data from their sources, transform and validate the data, and load the data into the database structure. Tools are provided so that users may browse and identify data pertinent to their function and then query and report the data in a variety of ways.

If linked to a geographic information system, the query results can also be mapped and analyzed in a spatial context. For example, the data warehouse house could be queried for accidents and pavement condition and the results could be correlated and reported in a tabular format, or mapped to display the relationship between accident locations and pavement quality. Many other types of analyses could be performed. Linking different data across the enterprise allows the data to be looked at in ways not possible before, and adds value to existing data resources.

The establishment of a Traffic Data Working Group, adoption of procedures and guidelines for data collection and documentation, and the development of the traffic data clearinghouse will make possible the implementation of a traffic data warehouse to store and process the various data from across the state in a consistent, well documented manner, and will provide needed access to this important resource to users throughout ADOT, local jurisdictions, private businesses, and the communities they all serve.

CONCEPTUAL IMPLEMENTATION PLAN

The main purpose of the Traffic Data Clearinghouse and the Traffic Data Warehouse is to establish a platform for providing statewide access to the multitude of traffic-related data collected and used throughout ADOT and other agencies. The Clearinghouse will enable the identification of available data and facilitate its evaluation for particular uses. The Data Warehouse will provide a common interface to the various data and provide for the dissemination of this data in variety of useful formats. Each of these proposed systems provides for maximizing the utility and use of statewide traffic data resources. Once established, the data warehouse can be used by any number of applications.

Because the use of various traffic data is widespread throughout ADOT for different purposes by a number of different sections, groups, and divisions, it is critical that the Traffic Data Working Group is established to guide its design and implementation to ensure that all critical needs are met in a way to serve all potential users. These systems will only be successful if some basic collection and documentation guidelines and standards are adopted to allow the storage and management of diverse data within a single system.

As conceptualized, the Traffic Data Clearinghouse and Data Warehouse would eventually be incorporated into one seamless system after a phased development approach. The Clearinghouse would be designed, developed, and implemented first. Based on the outcome of that process, which would be largely data driven, and the priorities established by the Working Group, the Data Warehouse could then be designed and developed. The Clearinghouse project could, in part, serve as a prototype for the actual data warehouse. The data dictionaries and physical data model would be documented and developed at that time. The Clearinghouse database would be designed so that additional data could be added at a later date.

High Level Architecture

It is proposed that the Traffic Data Clearinghouse and Data Warehouse be developed as a modern, open and scalable, *n*-tier client-server system for a distributed computing environment. Intranet, Internet, and Web technologies will be implemented in order to provide distributed access to the centralized data repository. A diagram of the proposed system is revealed in Figure 7.1. There are a number of components to the system:

- Client tools for data input and spatial referencing;
- Web application services;
- Clearinghouse database;
- Map and spatial processing services;
- Client tools for query, display, and reporting.

Data collection guidelines and documentation standards are also important aspects of the system. Any new data collected for use at ADOT would be collected according to some set of standards and guidelines. This will help ensure that the data is appropriate for use as a statewide resource, and that it meets the requirements for listing in the Clearinghouse, particularly the documentation requirements.

Client Tools For Data Input and Spatial Referencing

For the first phase of the system, the Clearinghouse, Metadata for all traffic data collected will be entered into the Clearinghouse database. This Metadata, or “data about data," is a description of the data. It lists the source of the data (who it was collected by), data owner (who maintains or keeps the data), currency of the data (when it was collected), collection methods, the scale of the data (especially for spatial data), the history of the data, for example any processing or summarizing that has been performed, the format of the data, and any other information that would help a user determine its suitability for particular uses.

The information about the data will include a listing of all the data field names, a description of each, allowable value ranges, how the data is coded, and a data definition for each field specifying the data type (whether it is alpha or numeric, etc.) and how wide the data field is. This information is referred to as the data dictionary.

The Metadata and data dictionary for all traffic data will be entered into the system with input forms through a standard Web browser interface. Pull down menus will be used where possible, mandatory fields will be clearly identified, and data values will be validated on input. To spatially enable the Clearinghouse, the data input tools will allow the each data set to be spatially referenced as appropriate—given a location on the digital network of ADOT's state highways (ATIS Roads). The spatial referencing function will include a map-based display and allow referencing by route-milepost, street address, cross-streets, traffic count station, highway section, etc., or by the users point-and-click on the map display.

To subsequently extend the system as a Data Warehouse, the data input tools will also need to allow an administrative user to import and load the actual data into the system. This can also be accomplished through a Web browser-based interface. For the import of large data files, the actual upload may need to be invoked after hours so that network performance is not degraded during normal business.

Web and Application Services

The Web server will host the Intranet / Internet Web site pages and will manage interaction with other system components. The Web services manage system traffic and pass requests and information between the user and appropriate system components. The Application services contain all of the business logic that comprises the system. For example the actual programs that perform data loading, attribute or spatial queries, or spatial referencing will reside on the Application server. Figure 7.1 shows Web and Application services as one physical computer. These services could be distributed across two or more machines in order to meet performance goals, depending upon the size of the database, number of concurrent users, and processing required by the applications.

Clearinghouse Database

The Clearinghouse database will be designed around a commercial, client-server, relational database management system, such as Oracle or MS SQL Server. The relational data structure will provide for the efficient storage of large amounts of data, and will allow additional data tables and elements to be added as the system transitions from a Clearinghouse (index of available traffic data) to a Traffic Data Warehouse containing and providing access to the data resources across the agency.

During the Clearinghouse phase, the Metadata and data dictionaries will be stored and managed in the database. This data will facilitate users in identifying data that is available and in evaluating whether it meets their particular needs. If users wish to acquire any data, they will contact the data owner listed in the database.

In the Data Warehouse phase, the actual traffic data will be stored and maintained in the database. This will require the expansion of the database to include additional tables to hold the traffic data, and other database objects to manage relationships between the data, Metadata, and data dictionaries. After the actual traffic data is stored in the systems database, users will be able locate, evaluate and acquire needed traffic data through a single interface.

Map and Spatial Processing Services

The map-based services will provide geographic information system (GIS) functionality to both the Clearinghouse and the subsequent Data Warehouse. The GIS functionality will make use of existing GIS data at ADOT, namely ATIS Roads, ADOT's georeferenced road centerline file developed and maintained by the Transportation Planning Division's GIS Team. GIS functionality will be used for three main purposes: location referencing of traffic data, spatial queries, and map-based display.

When Metadata is input to the Clearinghouse system, a required data element will be the geographic location applicable to the traffic data. For example, when Metadata for continuous counts are entered, users will specify a location, perhaps by traffic count station, highway section, or by route-milepost. A GIS function will then reference the traffic data to the ATIS road centerline file and create a feature in a GIS layer to represent the count location. If a user enters data about turning movements at a particular intersection, that user might enter in the cross-streets and then the same GIS process would be used to reference the intersection against the road centerline file and create a spatial feature representing the turning movement data.

With a spatial feature available to represent each traffic data record in the Clearinghouse, users will be able to query the database by location. For example, a user could ask the system for a list of all available data for a section of highway, maybe between two mileposts, or the could query the system to determine if any recent turning movements have been collected for a particular intersection(s), etc. They could also specify a location and have the system generate a list of data available within some distance of the location, for example to find all traffic data collected within the last 12 months, within 1,000 feet of a proposed housing development.

The map display will be available to support location referencing and to display the results of queries in the form of a map. For instance, using the last example above, a map could be presented on the screen showing all streets in ATIS, the potential housing development, and the location of any traffic data meeting the query criteria. All of this functionality would be available in the Data Warehouse as well the ability to perform more complex spatial queries, overlays, spatial analysis, and the ability to map all results. On screen maps could also be printed as hardcopy, if desired

Client Tools For Query, Display, and Reporting

Some examples of queries were described in the previous section. In addition to those, the database can be queried by any variable contained in the database, as appropriate. So, in addition to spatial queries, traffic data could be identified based on the type of traffic data, date and time of collection, data source, data owner, etc. In principle, any Metadata could be used to query for available traffic data. Like the data input tools, the user interface will be presented in a standard Web browser. Input forms, pull-down lists, menus, and buttons provided to the user to simplify the interaction with the system. Query results in tabular and map-based form would be available on-screen, for printing, and as an exported file, as appropriate.

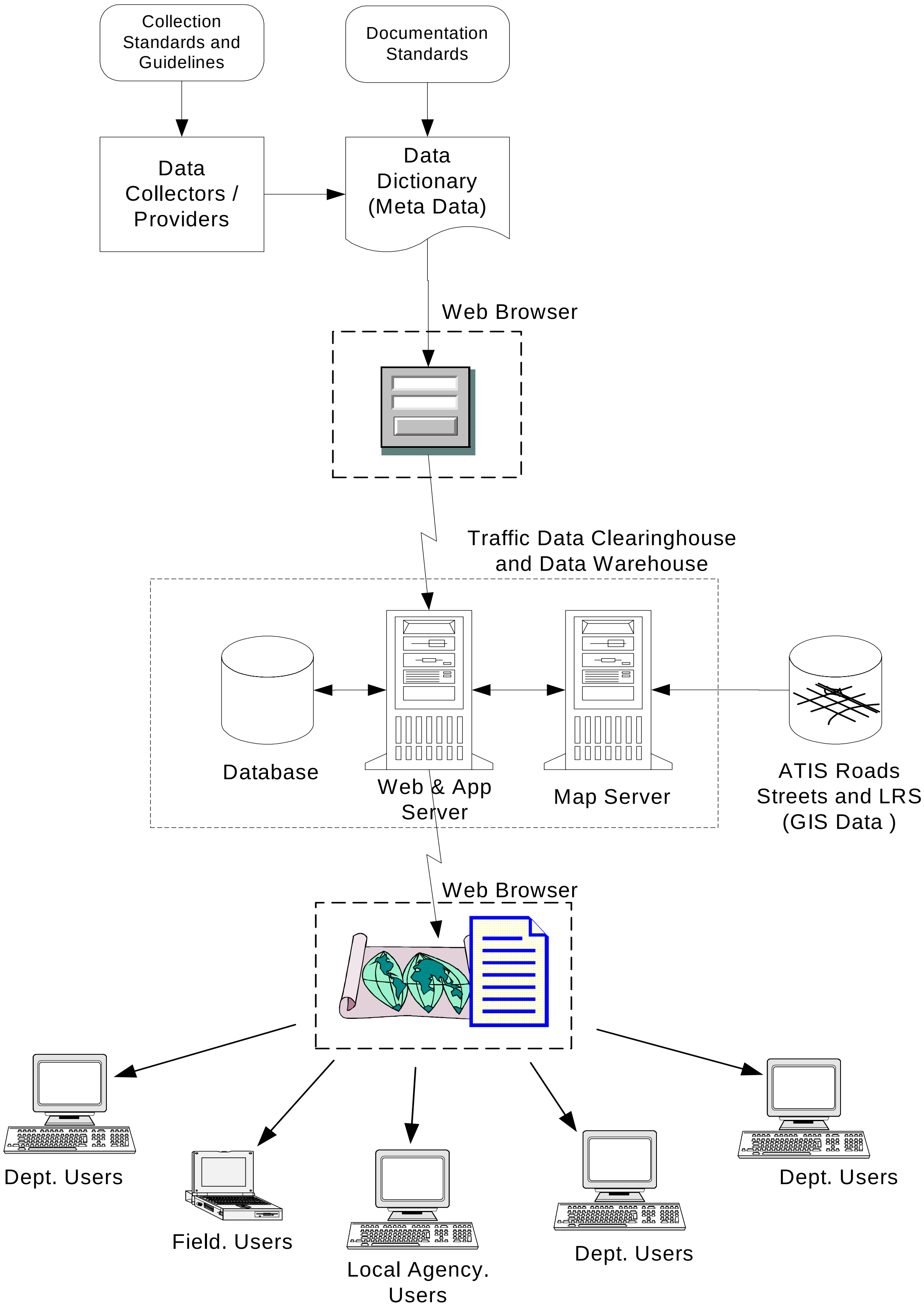


Figure 7.1 Traffic Data Clearinghouse and Data Warehouse System Overview

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APPENDIX A – LIST OF CONTACTS

Table A-1. List of Contacts

Name	TAC Member	Title	Date of Meeting	Division/Group
Jim Dorre	No	State Maintenance Engineer	6/19/2000	Maintenance Group
Tom Parlante	Yes	Traffic Engineer	6/19/2000	Traffic Group
George Way	Yes	Pavement Section Engineer	6/19/2000	Materials Group
Sarath Joshua	Yes	ITS Program Manager	6/19/2000	Maricopa Association of Governments
Bob Pike	Yes	Manager	6/20/2000	Data Team/Transportation Planning Division
Tony Gonzales	No	GIS Project Leader	6/20/2000	Transportation Planning Division
Jean Nehme	No	Bridge Management Leader	6/20/2000	Bridge Group
Sunil E. Athalye	No	Bridge Management Engineer	6/20/2000	Bridge Group
Jim Delton	No	Pavement Management Engineer	6/20/2000	Materials Group
Herman Mozart	No	Manager	6/21/2000	Predesign Program Management Section A
Brian Kenny	No	Manager	6/21/2000	Predesign Program Management Section B
Tom Wolfe	No	Assistant State Engineer	7/06/2000	Transportation Technology Group
Glenn Jonas	No	Senior System Engineering Specialist	7/06/2000	Intermodal Transportation Division
John Pein	No	Manager	6/23/2000	Transportation Planning Division
Estomih M. Kombe	No	Transportation Research Engineer	7/13/2000	ATRC
Larry Scofield	No	Transportation Research Engineer	7/13/2000	ATRC
Joe Flaherty	No	Senior Transportation Planner	6/22/2000	Transportation Planning Division
Mark Catchpole	No	Sr. Transportation Planner	7/13/2000	TPD Data Team
Jerome Breyer	No	Works Consulting	7/13/2000	Principle

APPENDIX B – LIST OF SURVEY RECIPIENTS

Name	**Title**	**Organization**	**Address**	**Phone Number**	**Email**
Davide Wessell	Transportation Planner	Flagstaff Metropolitan Planning Organization	2111 W. Aspen Ave., Flagstaff, Az. 86001	520-779-7685	
Chris Fetzer		Northern Arizona Council of Governments	119 E. Aspen Ave.,Flagstaff, AZ 86001	520-774-1895	
Charles Hodges	Transportation Model Manager	Pima Association of Governments	177 North Church, Suite 405Tucson, Az. 85701	520-628-5313	
Rick Garr		Western Arizona Councils of Governments	118 Bisbee St., Bisbee, Az. 85603	520-432-5858	
Dave Barber		Southeast Arizona Government Organization	208 N. 4th. St., Kingman, Az. 86401	520-753-6247	
Anthony Araza		City of Mesa	P.O. Box 1466, Mesa, Az. 85211	480-644-3402	
Steve Tate		Maricopa Association of Governments	302 N. 1st. Ave., Suite 301Phoenix, Az. 85003	602-452-5010	
Mark Schlappi	Systems Analysis Program Manager	Maricopa Association of Governments	302 N. 1st. Avenue, Phx. Az. 85003	602-254-6300	
Paul Anderson		US Forest Service	517 Gold Ave., SW, Albuquerque NM 87102	505-842-3852	
Bill Woodward		US Forest Service	517 Gold Ave., SW, Albuquerque, NM 87102	505-842-3852	
Duane Collier	Supervisor	National Park Service	3115 N. 3rd.Ave., # 101, Phoenix, Az. 85013	602-640-5256	
Rick Tewa		The Hopi Tribe	P.O. Box 123, Kykotsmovi Az. 86039	520-734-3244	
Brent Billingsley		Central Arizona Association of Governments	271 Main St., Superior Az. 85273	520-689-5020	
Steve Mathein		City of Phoenix	200 W. Washington, 5th. Floor, Phoenix, Az. 85003	602-262-6284 Ext. 6559	
Larry Vasselin		City of Glendale	5850 W. Glendale Ave., 3rd. Floor, Glendale, Az.	602-931-5545	

Name	**Title**	**Organization**	**Address**	**Phone Number**	**Email**
Larry Hunt/Christina Hawkins	Transportation Planner	Yuma Metropolitan Planning Organization	200 W. First St., Yuma, Az. 85364	520-783-8911	
Delwin T. Wengert	Engineer		P.O. Box 238, St. Johns, Az. 85936	520-337-4364	
Allan Owen	Highway Flood Plan Director	Cochise County	1415 W. Melody Lane, Bisbee, Az. 85603	520-432-9420	
Jim Stalnaker	Public Works Director	Coconino County	5800 E. Commerce, Flagstaff, Az. 86004	520-779-6630	
John Trejoullo	Engineer	Gila County	1400 E. Ash St., Globe, Az. 85501	520-425-3231 - Ext. 501	
Currently Vacant	Engineer	Graham County	921 Thatcher Blvd., Safford, Az. 85546	520-428-3924	
Philip A. Ronnerud	Engineer	Greenlee County	P.O. Box 908, Clifton, Az. 85533	520-8654762	
Michael Tomlenson	Public Works Director	La Paz County	1112 Joshua Ave., #207, Parker, Az. 85344	520-669-6407	
Tom Buick		Maricopa County	2901 W. Durango, Phx., Az. 85009	602-506-4622	
Richard Skalicky	Engineer	Mohave County	3675 Highway 66, Kingman, Az. 86401	520-757-0910	
William Cox	Engineer	Navajo County	P.O. Box 668, Holbrook, Az. 86025	520-524-4100	
Currently Vacant	Public Works	Pima County	201 N. Store, Tucson, Az. 85701	520-740-6410	
Garry Jaggers	Engineer	Pinal County	P.O. Box 727, Florence, Az. 85232	520-868-6411	
Ken Zehentner	Public Works Director	Santa Cruz County	Congress Drive, Nogales, Az. 85621	520-761-7800 - Ext. 3071	
Richard Straub	Engineer	Yavapai County	Prescott, Az. 86301	520-771-3183	

APPENDIX C – SURVEY QUESTIONS AND RESPONSES

Survey Questions

What traffic data does your organization collect and how often do you collect it?

TYPE OF TRAFFIC DATA	YES/NO	HOW OFTEN
Traffic Volumes		
Turning Movements		
Vehicle Classification		
Vehicle Weight		
Vehicle Speeds		
Other		
Other		

Q2. What is the geographic scope of the traffic data collection?

- What areas or jurisdictions?
- What kinds of facilities? Freeways? Arterials? Collectors? Local/Residential Streets?
- Do you collect any type of traffic data on ADOT facilities?

Q3. How do you collect and store the traffic data?

- How do you utilize any automated equipment?
- Do you contract out the collection effort?
- What collection equipment do you use? Pneumatic tubes? Loop detectors? Piezoelectric plates? Manual labor?
- What technologies do you use to process, store, and report traffic data? Database software? Spreadsheets? ASCII files? GIS or CAD software? Off-shelf traffic monitoring software packages?

Q4. Do you maintain AADT data for your street/highway facilities?

- Do you use the Traffic Monitoring Guide?

Q5. How is your traffic data used?

- For general traffic monitoring and planning purposes?
- For traffic studies only? Signal and stop sign warrants?
- For planning/design purposes?
- Is any of the collected traffic data an input into the Highway Capacity software/calculations, travel demand models, or a traffic (signal timing) simulation software.

Q6. Are you aware of the Arizona Transportation Information or the ADOT Data Team's traffic monitoring system?

Q7. Do you use ADOT traffic data?

Q8. Do you share traffic data with ADOT?]

Survey Responses

Agency	Question 1: What traffic data do you collect and how often do you collect it?
City of Mesa	**Traffic Volumes:** Annually - Map ½ of City
	Turning Movements: Rarely
	Vehicle Classification: Rarely
	Vehicle Weight: No
	Vehicle Speeds: Yes
	Other: No Response
PAG	**Traffic Volumes:** Yes
	Turning Movements: Yes
	Vehicle Classification: Yes, every 3-5 years
	Vehicle Weight: No
	Vehicle Speeds: Yes, in house, on going annually
	Other: No Response
City of Glendale	**Traffic Volumes:** Yes, Arterial streets
	Turning Movements: Yes - 10 ±
	Vehicle Classification: No
	Vehicle Weight: No
	Vehicle Speeds: Yes - as needed - 20± per year
	Other: No Response
FMPO	**Traffic Volumes:** Yes - annually
	Turning Movements: No Response
	Vehicle Classification: Yes
	Vehicle Weight: No
	Vehicle Speeds: Occasionally
	Other: No Response
YMPO	**Traffic Volumes:** Yes
	Turning Movements: No Response
	Vehicle Classification: No
	Vehicle Weight: No
	Vehicle Speeds: No
	Other: No Response
MAG	**Traffic Volumes:** Yes - once every 2/3 years
	Turning Movements: Yes at major intersections
	Vehicle Classification: Yes - county wide
	Vehicle Weight: No
	Vehicle Speeds: Yes
	Other: Queue length, intersection geometry, density, aerial photos and peak hour
PIMA County	**Traffic Volumes:** Yes - 480 defined segments on county roads every 18-24 months
	Turning Movements: Yes
	Vehicle Classification: No
	Vehicle Weight: No
	Vehicle Speeds: No
	Other: Accident statistics

US Forest Service	**Traffic Volumes:** Yes, but only seasonal ADT since most of the roads are lightly used in the winter.
	Turning Movements: No Response
	Vehicle Classification: Yes
	Vehicle Weight: No Response
	Vehicle Speeds: No Response
	Other: Trip purpose and length.
City of Phoenix	**Traffic Volumes:** Yes
	Turning Movements: No Response
	Vehicle Classification: No Response
	Vehicle Weight: No Response
	Vehicle Speeds: No Response
	Other: No Response

Agency	**Question 2: What is the geographic scope of the traffic data collection?**
City of Mesa	**What areas or jurisdictions?** City wide
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? Citywide, Arterials, Collectors and Local
	Do you collect any type of traffic data on ADOT facilities? Ramps
PAG	**What areas or jurisdictions?** Eastern Pima County, (non reservation)
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? Freeways, collectors and frontage roads, State routes and Interstates.
	Do you collect any type of traffic data on ADOT facilities? Yes
City of Glendale	**What areas or jurisdictions?** City Wide
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? Citywide, Arterials, collectors, Local and some ramps. Arterials, collectors, local streets and some freeway ramps.
	Do you collect any type of traffic data on ADOT facilities? Ramps
FMPO	**What areas or jurisdictions?** 525 sq. mile area Coconino County, Belmont to Winona, Kachina Village to N. of San Francisco Peaks
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? Citywide, Arterials, collectors, Local and some ramps. Freeway, arterials and collectors.
	Do you collect any type of traffic data on ADOT facilities? Yes
YMPO	**What areas or jurisdictions?** County Wide
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? Citywide, Arterials, collectors, Local and some ramps.
	Do you collect any type of traffic data on ADOT facilities? No Response
MAG	**What areas or jurisdictions?** Urban areas of Maricopa County
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? Citywide, Arterials, collectors, Local and some ramps.
	Do you collect any type of traffic data on ADOT facilities? Ramps
PIMA County	**What areas or jurisdictions?** County wide and county roads only
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? County roads
	Do you collect any type of traffic data on ADOT facilities? No

US Forest Service	**What areas or jurisdictions?** All US Forest Service roads in the Southwest Region (includes Arizona, New Mexico, Texas and Oklahoma)
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? No response
	Do you collect any type of traffic data on ADOT facilities? No response.
City of Phoenix	**What areas or jurisdictions?** No Response
	What kinds of facilities? Freeways, Arterials, Collectors? Local/Residential Streets? No response
	Do you collect any type of traffic data on ADOT facilities? No response.

Agency	**Question 3: How do you collect and store the traffic data?**
City of Mesa	**How do you utilize any automated equipment?**
	Do you contract out the collection effort? Yes
	What collection equipment do you use? ATR's
	Pneumatic tubes? Yes
	Loop detectors? No
	Piezoelectric plates? No
	Manual labor? For Turning movement counts (TMC's).
	What technologies do you use to process, store and report traffic data?
	Database software? No
	Spreadsheet? Excel spreadsheets and hard copy
	ASCII Files? No
	GIS or CAD software? No
	Off-shelf traffic monitoring software packages? No
PAG	**How do you utilize any automated equipment?** For Volume and Speed Counts
	Do you contract out the collection effort? Yes
	What collection equipment do you use?
	Pneumatic tubes? Yes
	Loop detectors? No
	Piezoelectric plates? No
	Manual labor? Yes for Turning movement counts (TMC's)
	What technologies do you use to process, store and report traffic data?
	Database software? No
	Spreadsheet? Yes
	ASCII Files? Yes
	GIS or CAD software? No
	Off-shelf traffic monitoring software packages? No
City of Glendale	**How do you utilize any automated equipment?**
	Do you contract out the collection effort? Yes
	What collection equipment do you use?
	Pneumatic tubes? Yes
	Loop detectors? One permanent ATR
	Piezoelectric plates? No
	Manual labor? Turning movement counts (TMC's)
	What technologies do you use to process, store and report traffic data?
	Database software? In Excel
	Spreadsheet? Excel spreadsheet and hard copy
	ASCII Files? No
	GIS or CAD software? No
	Off-shelf traffic monitoring software packages? No
FMPO	**How do you utilize any automated equipment?**

	Do you contract out the collection effort? Yes
	What collection equipment do you use?
	Pneumatic tubes? Yes
	Loop detectors? **No**
	Piezoelectric plates? No
	Manual labor? Yes Turning movement counts (TMC's)
	What technologies do you use to process, store and report traffic data?
	Database software? Yes
	Spreadsheet? Hard copy
	ASCII Files? **Yes**
	GIS or CAD software? **No**
	Off-shelf traffic monitoring software packages? **No**
YMPO	**How do you utilize any automated equipment?** Yes
	Do you contract out the collection effort? No
	What collection equipment do you use?
	Pneumatic tubes? Yes
	Loop detectors? **No**
	Piezoelectric plates? No
	Manual labor? No Response
	What technologies do you use to process, store and report traffic data?
	Database software? Access/manual entry/hard copy
	Spreadsheet? No Response
	ASCII Files? **No**
	GIS or CAD software? **Yes**
	Off-shelf traffic monitoring software packages? No
MAG	**How do you utilize any automated equipment?**
	Do you contract out the collection effort? Yes
	What collection equipment do you use?
	Pneumatic tubes? No Response
	Loop detectors? Yes
	Piezoelectric plates? No
	Manual labor? At some locations for Turning movement counts (TMC's)
	What technologies do you use to process, store and report traffic data?
	Database software? Uses Paradox database
	Spreadsheet? No Response
	ASCII Files? **No Response**
	GIS or CAD software? **ArcView GIS for creating traffic volume maps**
	Off-shelf traffic monitoring software packages? **No Response**
Pima County	**How do you utilize any automated equipment?**
	Do you contract out the collection effort? No
	What collection equipment do you use?
	Pneumatic tubes? Yes
	Loop detectors? 3 permanent counters
	Piezoelectric plates? No
	Manual labor? Yes
	What technologies do you use to process, store and report traffic data?
	Database software? Since 1999 Jamar program/sofware
	Spreadsheet? Bid Files/Hard copy
	ASCII Files? No Response
	GIS or CAD software? No
	Off-shelf traffic monitoring software packages? Jamar

US Forest Service	**How do you utilize any automated equipment?** No response
	Do you contract out the collection effort? No response
	What collection equipment do you use?
	Pneumatic tubes? Yes
	Loop detectors? No response
	Piezoelectric plates? No response
	Manual labor? Yes
	What technologies do you use to process, store and report traffic data?
	Database software? No response
	Spreadsheet? No response
	ASCII Files? No Response
	GIS or CAD software? No response
	Off-shelf traffic monitoring software packages? No response
City of Phoenix	**How do you utilize any automated equipment?** No response
	Do you contract out the collection effort? No response
	What collection equipment do you use? No response
	Pneumatic tubes? No response s
	Loop detectors? No response
	Piezoelectric plates? No response
	Manual labor? No response
	What technologies do you use to process, store and report traffic data?
	Database software? No response
	Spreadsheet? No response
	ASCII Files? No Response
	GIS or CAD software? No response
	Off-shelf traffic monitoring software packages? No response

Agency	**Question 4: Do you maintain AADT data for:**
City of Mesa	**Street/highway facilities?** No
	Do you use the Traffic Monitoring Guide? No
PAG	**Street/highway facilities?** No - deliver to ADOT for AADT
	Do you use the Traffic Monitoring Guide? No
City of Glendale	**Street/highway facilities?** Yes
	Do you use the Traffic Monitoring Guide? Yes
FMPO	**Street/highway facilities?** No
	Do you use the Traffic Monitoring Guide? No
YMPO	**Street/highway facilities?** No
	Do you use the Traffic Monitoring Guide? No
MAG	**Street/highway facilities?** No
	Do you use the Traffic Monitoring Guide? No
Pima County	**Street/highway facilities?** No
	Do you use the Traffic Monitoring Guide? No
US Forest Service	**Street/highway facilities?** No response
	Do you use the Traffic Monitoring Guide? No response
City of Phoenix	**Street/highway facilities?** No response
	Do you use the Traffic Monitoring Guide? No response

Agency	Question 5: How is your traffic data used?
City of Mesa	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? Yes
	Signal and stop sign warrants? Yes
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No
	Travel demand models? Yes
	Traffic (signal timing) simulation software? Yes
PAG	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? Yes
	Signal and stop sign warrants? No
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? Yes
	Travel demand models? Yes
	Traffic (signal timing) simulation software? Yes
City of Glendale	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? Yes
	Signal and stop sign warrants? Yes
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? Yes
	Travel demand models? Yes
	Traffic (signal timing) simulation software? Yes
FMPO	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? Model Calculations for Traffic
	Signal and stop sign warrants? No Response
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No Response
	Travel demand models? Yes
	Traffic (signal timing) simulation software? No Response
YMPO	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? No
	Signal and stop sign warrants? Yes
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No Response
	Travel demand models? Yes
	Traffic (signal timing) simulation software? No Response
MAG	For general traffic monitoring & planning purposes? Yes
	For traffic studies only? No
	Signal and stop sign warrants? No Response
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No Response
	Travel demand models? No Response
	Traffic (signal timing) simulation software?

Pima County	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? No
	Signal and stop sign warrants? No Response
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No Response
	Travel demand models? No
	Traffic (signal timing) simulation software? Yes (used PAG's)
US Forest Service	**For general traffic monitoring & planning purposes?** Yes
	For traffic studies only? No response
	Signal and stop sign warrants? No Response
	For planning/design purposes? Yes
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No Response
	Travel demand models? No response
	Traffic (signal timing) simulation software? No response
City of Phoenix	**For general traffic monitoring & planning purposes?** No response
	For traffic studies only? No response
	Signal and stop sign warrants? No response
	For planning/design purposes? No response
	Is any of the collected traffic data input into the Highway Capacity software/calculations? No Response
	Travel demand models? No response
	Traffic (signal timing) simulation software? No response

Agency	**Question 6: Are you aware of the Arizona Transportation information or the ADOT Data Team's traffic monitoring system?**
City of Mesa	No by name ATIS but Yes as to Data Team collection efforts
PAG	Yes / Yes
City of Glendale	Yes / Yes
FMPO	Yes / Yes
YMPO	No Response
MAG	Yes / Yes
Pima County	No Response
US Forest Service	No Response
City of Phoenix	No Response

Agency	**Question 7**: **Do you use ADOT traffic data?**
City of Mesa	Yes for freeway counts
PAG	Yes
City of Glendale	Yes on Grand Ave.
FMPO	No Response
YMPO	No Response
MAG	No Response
Pima County	No Response
US Forest Service	No Response
City of Phoenix	No Response

Agency	**Question 8**: **Do you share traffic data with ADOT?**
City of Mesa	No unless asked
PAG	Yes
City of Glendale	Yes through MAG
FMPO	Yes for 2000
YMPO	Yes
MAG	Yes
Pima County	Yes - through PAG
US Forest Service	No Response
City of Phoenix	No Response