FHWA Study Tour for European Traffic Monitoring Programs and Technologies

INTERNATIONAL
TECHNOLOGY

FHWA's Scanning Program

U.S. Department of Transportation
Federal Highway Administration

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European Traffic-Monitoring Programs and Technologies

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European Traffic-Monitoring Programs and Technologies

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Thanks also go to the FHWA, Office of International Programs, for technical assistance and funding of this effort.

Particular acknowledgment is also due to American Trade Initiatives, Inc., for arranging the meetings, planning the travel, escorting the team, and producing this report.

EXECUTIVE SUMMARY

In many areas in the United States, government expenditures on transportation have not kept pace with the increase in travel. It is, therefore, becoming particularly important that States and the Federal Government act to ensure accurate and cost-effective collection of the data necessary to manage the Nation's highway system.

In Europe, many countries are facing similar constraints. To learn how European countries perform traffic monitoring, the Federal Highway Administration (FHWA) sponsored a scanning tour of the Netherlands, Switzerland, Germany, France, and the United Kingdom.[1] The review was conducted in June 1996, and the scanning team was specifically interested in the following areas of study:

- Types of data collected.
- Methods for data collection.
- Organizational arrangements for data collection.
- Equipment used and experience with that equipment.
- Data validation efforts to ensure quality and accuracy.
- Purposes for which data are used.
- Innovative reporting procedures.

[1]Information obtained from the Department of Transport in the United Kingdom pertained almost exclusively to England. Roads in Scotland, Wales, and Northern Ireland are operated and maintained by separate agencies.

The executive summary of this report includes the findings of the investigation, first by highlighting innovative ideas that warrant followup or special consideration, then by listing other significant findings from the trip. The main body of the report is divided by country and by primary subject area.

Best or Most Interesting Practices

The following points describe practices and discoveries observed by the scanning team that appear to have the most practical benefit for State Departments of Transportation (DOTs) and other traffic data collection entities in the United States.

Equipment Reliability

The four continental countries that the scanning team visited indicated that their inductance loop detection systems work very reliably. Reported numbers of failures are low compared to failure rates usually found in the United States. One finding common among the countries visited was that transport experts have determined that purchasing high-quality components for data collection equipment results in significantly better system reliability and lower long-term costs, even though those components have higher initial prices than "comparable" components. Specifications for loop installation and electronic loop monitoring equipment from the countries visited have been obtained and are stored at the FHWA Office of Highway Information Management. (See the report bibliography.) States interested in these documents should contact that office.

Use of Control Systems for Data Collection

The European countries have realized substantial cost savings and data improvements through the use of intelligent transportation systems (ITS). Traffic control systems and intelligent driver information systems collect, store, and supply traffic information for general operational decisions, planning, and engineering functions. All the traffic control systems that the scanning team observed included a data collection and storage component. These data are used for less-than-real-time analysis and are made available outside the operation divisions of individual highway agencies. In most cases, approval of an ITS traffic control system was contingent on the system's ability to supply these data. Application of the same principle in the United States would greatly reduce data collection costs and improve performance-monitoring capabilities on the roads that are most in need of such monitoring.

Ensuring Cooperation in Data Collection

The team observed two innovative systems that are intended to ensure that automated data collection systems meet the needs of users. Either system could be implemented or adapted in the United States.

In the Netherlands, data processing and application development functions have been separated from engineering functions. An account manager is responsible for ensuring that systems are built and maintained to meet the users' needs, because it is the users who fund the operation of the data processing group. In the United Kingdom, the Department of Transport (DOT) created "liaison groups" within the organizations responsible for data collection and analysis at different levels of government. These groups are responsible for maintaining an understanding of each other's data collection programs and needs to better coordinate data collection efforts and to share data among operating groups and agencies.

Purchase of Data Collection Services

The Europeans often "purchase" data rather than fund general collection programs. For example, in England, the regional offices of the Highways Agency (HA) contract with county governments to supply traffic count data on national roads within those counties. The HA determines a location to be counted and the data required, and the county determines the method of collection and cost. The HA funds the county's expenditures. Private companies or temporary staff are hired by counties to perform the actual data collection.

Similar contracts between federal agencies and provincial or local government agencies were described in Germany and France. German agencies also contract with private companies for traffic data collection.

Truck Data Collection

Although all five countries visited are interested in the number of, and loads on, heavy trucks, fewer data are collected on trucks than in the United States. Also, most of the data collected are much less detailed. All of the countries visited typically use double-loop detectors to collect simple, length-based vehicle classification data. Although these length classes differ from country to country, they are generally used to differentiate between "light" and "heavy" vehicles. Only in England and France are axle-detection devices routinely used to classify vehicles into multiple axle-based categories. Adoption vehicle-length classification schemes based on loop detection in the United States might significantly reduce the cost of vehicle classification data collection. It might be particularly useful in heavily traveled urban areas, where axle sensors wear out quickly and are difficult and expensive to replace.

Standardization

The Europeans are working toward standardization and its benefits are apparent in some areas. In Germany, the Netherlands, and France, national standards for data collection equipment have been developed; all equipment purchased for national traffic data collection will use the same formats and protocols to communicate. Although the initial equipment cost may be higher than that for purchasing nonstandard equipment, the process appears to reduce maintenance costs, increase reliability of field equipment, increase the quality and accuracy of data collected, and decrease the effort needed to transfer data between agencies or offices. The use of common data storage and interchange standards also allows common data analysis and validation programs to be developed, further reducing the overall cost of collection and analysis.

Weigh-in-motion (WIM) equipment is a part of the standardization effort. Through a combination of three initiatives, the Europeans are working to coordinate WIM research and development to produce better, more reliable WIM devices. The DIVINE, COST 323, and WAVE initiatives have produced great interest in sharing resources to reduce the cost of system development and promote compatibility among countries. DIVINE is the Dynamic Interaction of Vehicles and Infrastructure Experiment; COST 323 is the European Cooperative for Scientific and Technical Research; and WAVE is the WIM of Axles and Vehicles for Europe.

WIM Calibration

In Germany, tests have determined that calibration of WIM systems can be maintained by monitoring the axle-load distribution for each site, although the distribution varies from site to site. In addition, WIM systems require calibration visits at least twice per year. Research in the United Kingdom has determined that it is not possible to use front-axle loads on specific vehicle types to perform accurate WIM calibration. As a result, the selected calibration procedure uses three test trucks of different configurations and weights.

Data Validation

Europeans are progressing quickly in automated validation of traffic data, and further investigation of these systems is recommended by the scanning team. (See sections on the Netherlands and the United Kingdom.) All the ITS that were observed perform some type of automated data validation, usually by comparing current data from a particular site with historical data from that same site during the same period. If data are identified as questionable, operators use graphic displays to review data and determine acceptability.

Performance Information

All the European countries are working to collect performance information, primarily about speeds and travel times. There is little concern about counting vehicle occupancy, because none of the countries visited have high-occupancy vehicle (HOV) facilities similar to those found in the United States. In England, the city of London conducts a number of routine travel time studies to detect changes in congestion levels over time. In Switzerland, travel times are also measured to compare the door-to-door travel times of different modes.

Other Findings

The following paragraphs highlight findings that the scanning team considered to have either less practical application or benefit to U.S. transportation data collection agencies or a less significant impact on traffic monitoring in the United States. Overall, the European countries visited do not have counting or monitoring programs that are as extensive or sophisticated as those usually found in the United States.

National Data Collection Systems

The national data collection role in all five countries visited differs markedly from that of the FHWA. National highway authorities have operational responsibility for specific road networks and are, therefore, directly responsible for data collection on that network. In addition, with the exception of the United Kingdom, funding is not distributed to lower levels of government (e.g., regions, provinces, counties) on the basis of vehicle distance or vehicle miles traveled (VDT or VMT). This removes the need to monitor travel with the degree of statistical precision required in the United States, where travel data are used in computing apportionments to the States. Consequently, the European Federal Governments are less prescriptive about how traffic data should be collected at lower levels of government. The United Kingdom is the only country visited that applies a fund distribution system similar to that used in the United States, but the British DOT collects its own statistical sample of road volumes to estimate VDT.

Cooperation Among Transportation Agencies and Manufacturers

The level of cooperation among various national transportation agencies and electronics and signal manufacturers seems to be higher in European countries than in the United States. Most of the national agencies have created equipment specifications for permanent data collection equipment. Equipment can be purchased from several manufacturers in each country, and the components from different manufacturers are usually interchangeable. These systems appeared to be more reliable than similar systems used in the United States. Transportation agency personnel indicated that, in most cases, they have purchased similar equipment from private suppliers but have not been satisfied with the reliability of that equipment. It is also interesting to note that, England excepted, each country visited uses its own equipment and specifications. The United Kingdom is also the only country in which the scanning team was informed of equipment problems similar to those found in the United States. Neither the United Kingdom nor Switzerland is using equipment purchased to meet some national standard.

Manual Data Collection

In all five countries, large quantities of traffic data are still collected manually. Data collected manually include information about pedestrian and bicycle volumes, vehicle classification, and country/county of origin; the last is used to determine the amount of international travel on a roadway or within a region. Manual traffic volume and classification counts are routinely performed every 5 years, several times during the year, but for a limited number of hours each day during which data are collected.

WIM Installations

Only France and the United Kingdom have extensive WIM system installations. The most common French system is based on a single piezo cable and two loops. The electronic equipment is the same basic station used for conventional data collection with additional electronic boards that allow it to compute vehicle weights. The British are using three different systems. Staff members from the other three countries expressed significant interest in the purchase and installation of WIM equipment, although none is convinced that available systems will meet their countries' needs in terms of cost, accuracy, and reliability. The European response to this problem has been the development of pan-European WIM testing efforts through a combination of agencies and coordinating groups. These efforts include the DIVINE project, the COST 323 effort, and the WAVE project.

Coordination Among Operating Agencies

In the four continental countries, coordination among different operating agencies is better than what is often found in the United States. Several agencies and/or operating divisions are often responsible for equipment that transmits data to a central data collection station. In almost all cases, the central national organization specifies the type of equipment to be selected, but regional operating agencies purchase (and are reimbursed for) the equipment, and install and operate it. Regional offices then collect data automatically and transmit copies to the federal level. The data transfer usually takes place automatically via telephone or high-speed communication line. In most cases, regional data are also used for operational decisions at the regional level.

Data Aggregation and Reporting

Another feature common among the countries visited is that data collected for traffic control purposes (i.e., incident and/or congestion detection, variable speed limit control, and motorist information) are aggregated, stored, and used centrally for other purposes. The processes of data aggregation and reporting are integral parts of system designs.

Multiple Purposes for Data Collection

Most permanent data collection locations serve multiple purposes, one of which is often collection of traffic performance data used for providing motorist information. The British are creating similar systems for sharing data but are not at the level of the other four countries visited.

Reliability

Another similarity among the systems observed outside the United Kingdom is in their high degree of reliability. The organizations visited generally agreed that, in order to maintain credibility with the public, the systems that supply data to advanced traffic management systems (ATMS) and advanced traveler information systems (ATIS) should operate reliably. That is, the data have to be accurate and the collection equipment must survive for a certain period of time to be cost-effective. None of the countries expressed concerns about the service life of their loop detection systems, although the British expressed concern about the reliability of their data collection electronics. Each of the countries visited is conducting research into new detection systems, but none is seeking to replace inductance loops as the primary means of traffic data collection.

Several of the countries have fairly extensive data validation systems, although all of the systems require some manual input. In almost all cases, validation methods are based on the development of "rules" for individual sites, based on historical patterns by lane, time of day, and day of week for that site. Flagged data—data that fail the validation routines—are brought to the attention of system operators, who decide whether the data are correct or invalid. Invalid data are marked and replaced, either with data from previous time periods at that site or with data that have been collected earlier at that site, then factored with growth estimates taken from nearby counters that worked correctly during the period being reviewed. In Germany and the United Kingdom, existing validation systems were developed by consultants under contract to national agencies and are considered proprietary.

Equipment Maintenance

In several cases, maintenance of the data collection equipment has been contracted out to private companies. In the Netherlands and Germany, equipment is purchased by a national agency but installed and operated by a private contractor. Contracts are written for the collection and submission of specific amounts of data, rather than for specific amounts of labor. The Germans go further and require the contractor to test and guarantee the equipment, giving additional responsibility to the vendor.

Submission of information is not audited routinely, with the exception of that for toll roads, where the data collection system has an impact on either the revenue collection or the revenue control function of the toll authority. Note that even in the United Kingdom, where the Government pays private companies a fee per vehicle for building, operating, and maintaining roads, a toll authority is responsible for data collection on the toll road.

Technology Transfer

Despite many efforts to improve the international communication of research efforts, there is still a significant lack of communication between U.S. and European researchers. The Europeans are duplicating much of the U.S. research of the last 10 years. It was not possible, however, to determine how much duplication has resulted from a need to repeat tests under different conditions and how much is the result of the fact that U.S. research is unavailable in the appropriate languages. Conversely, it is likely that research has been conducted in the United States that duplicates work performed earlier in Europe.

Alternative Data Collection Methods

Because the Europeans are satisfied with loop detection systems and the use of length data collected with dual loop systems, they are less interested than U.S. agencies are in alternative data collection devices, such as video, radar, and microwave. The scanning team did, however, observe an impressive demonstration of a French video surveillance system, which probably warrants additional investigation.

It was not clear from the demonstration whether the French system develops problems with accuracy in severe weather conditions similar to ones that occur in current U.S. systems.

Research Budgets

The scanning team did not routinely obtain budget information on the research programs in the respective countries, but in the Netherlands, it was apparent that a higher proportion of funding is set aside for research and development than is budgeted in the United States.

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1.0 INTRODUCTION

1.1 Study Background and Objectives

In many areas of the United States, government expenditures on transportation have not kept pace with the increase in travel. Increasing pressure is being placed on highway agencies to improve the ability to monitor the use of roadway facilities, while simultaneously reducing the cost of monitoring activities.

European countries are facing similar constraints, and a scanning review was undertaken to learn how the Netherlands, Switzerland, Germany, France, and the United Kingdom conduct traffic monitoring. A series of specific questions was transmitted to the hosting agencies before the meetings (see Appendix A). The scanning team was interested in the following topics:

- Types of data collected.
- Methods for data collected.
- Organizational arrangements for data collection.
- Equipment used and experience with that equipment.
- Data validation efforts undertaken to ensure quality and accuracy of the data.
- Purposes for which the data are used.
- Innovative reporting procedures.

The findings presented in this report must also be considered in the context of the relative sizes and population densities of the countries visited, as well as the differing roles each agency visited plays in the general transportation scheme of those countries.

For example, the extent of the national road networks in some countries can be compared with those operated and maintained by some States in our country, as shown in Table 1. Table 2 shows that the populations and numbers of vehicles registered are also similar among some States and the countries visited. The striking difference is the density of population; States in this country have much lower population densities (see Table 3).[2]

1.2 Scanning Trip Personnel

The scanning team was composed of the following FHWA, State, and university representatives:

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[2]Sources: *World Road Statistics, 1990-1994*, International Road Federation, Washington, DC, 1995; *1994 Highway Statistics*, FHWA, Washington, DC, 1995; *International Comparisons of Transport Statistics, 1970-1993*, United Kingdom DOT, 1996.

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1.3 European Contacts

During its tour, the scanning team met with the organizations mentioned below. A list of individuals contacted is in Appendix B.

Meetings in the Netherlands were hosted by the Transport Research Centre (AVV), of the Ministry of Transport, Public Works and Water Management, Directorate-General of Public Works and Water Management.

Meetings in Germany were hosted by the Bundesanstalt für Straßenwesen (BASt), in Bergische-Gladbach, and by the Hessisches Landesamt für Straßen und Verkehrswesen, the Road Traffic Authority of Hessen, in Russelsheim.

In Switzerland, the scanning team met with the Institute of Transport Planning, Traffic Engineering, Road and Railway Engineering (IVT) at the Federal Institute of Technology in Zurich (ETH). The team also met with the Swiss Federal Highways Office, in Bern; with Kistler Instrumente, AG; and with officials of the Cantons of Bern and Zurich.

Meetings in France were hosted by Service d'Études Techniques des Routes et Autoroutes (SETRA), Cofiroute, and the Laboratoire Regional de L'Ouest Parisien in Trappes.

Meetings in the United Kingdom were hosted by the Transport Research Laboratory (TRL), the Department of Transport, and the Highways Agency.

Table 1. Road Network Sizes (km)

Country or State	Interstates or Equivalent	National Highway System or Equivalent	All Roads
France	9,000	29,00	813,000
Germany	11,140	42,000	640,000
United Kingdom	3,140	12,200	366,000
Netherlands	2,170	2,100	104,000
Switzerland	1,540	18,300	71,000
California	3,900	22,100	272,000
North Carolina	1,560	7,700	155,000
Texas	5,200	25,200	474,000

Table 2. Vehicles in Use

Country or State	Passenger Cars	Buses	Lorries and Vans	Tractors
France	24,900,000	78,000	4,881,000	181,000
Germany	39,918,000	87,400	2,168,000	1,899,000
United Kingdom	20,102,000	107,000	2,600,000	318,000
Netherlands	5,884,000	12,000	650,000	38,000
Switzerland	3,268,000	14,600	263,000	123,000
California	14,743,000	42,300	7,554,000	110,000
North Carolina	3,525,000	34,100	5,443,000	53,000
Texas	8,699,000	68,500	4,859,000	133,000

Table 3. Population Densities

Country or State	Population	Land Area (km^2)	Population Density (persons/km^2)
France	57,800,000	570,000	101
Germany	81,338,000	356,900	228
United Kingdom	56,559,000	229,900	246
Netherlands	15,400,000	40,800	377
Switzerland	6,938,000	41,300	168
California	31,408,000	403,970	78
North Carolina	7,070,000	126,200	44
Texas	18,413,000	678,400	27

2.0 THE NETHERLANDS

2.1 Summary Points

The Dutch report an unusually reliable inductance loop detector system. The system is based on specifications developed in the Netherlands after it was determined that commercially available systems did not meet the needs for reliable, and long-term operation. The reported loop failure rate, the number of loops inoperable at any given time, is 1 per 1,500. Three companies in the Netherlands make the system.

The Dutch have also developed a data validation, storage, analysis, and reporting system called Intensiteiten (INTENS), meaning "traffic flows." INTENS is used to process, store, and retrieve all traffic data collected by the National Government. These include data that are collected by the ATMS/ATIS; from the conventional, permanent traffic-recorder stations; and from short-duration counts taken at fixed points across the nation. An ATMS/ATIS variable speed limit system that operates in the Amsterdam urban area uses dual loop detectors and supplies data on motorway traffic volume, speed, and lane occupancy to the INTENS system.

All vehicle classification data are collected by dual loop detectors and categorized in three length-based classifications.

In the Netherlands, investigations into WIM technology are just beginning. The Netherlands is participating in the various European WIM standard-setting efforts, including the COST 323 and WAVE projects. COST 323 is a data-sharing effort on WIM equipment, sponsored by the European Commission DG VII group. WAVE is a series of WIM research projects and tests that is also sponsored by DG VII. More complete discussions of these tests appear later in this report, as part of the findings from the team's visit to France.

In the Netherlands, an unusual organizational decision was made to separate the system management function from the applications group. The system management group is responsible for collecting and making data available to users, who are responsible for creating and operating their own applications. This ensures that each effort receives the appropriate level of attention and that all groups have access to the same data.

Portions of the data collection effort have been privatized, particularly the collection of data outside of the traffic control system and the maintenance of many locations. This effort is viewed as successful. For the most part, contracts are written for the submittal of valid data, and audits of the contracts consist mainly of reviewing data within the INTENS system.

2.2 Introduction

The Netherlands is a small country located on the Atlantic coast with a flat terrain, moderate weather, and a high population density. The country has roughly 15 million people, 106,000 km of roads, and 6 million cars. The population generates about 130 million vehicle kilometers of travel (VKT) by car, 25,800 million VKT by public transport, and 14,300 million VKT by bicycle.

Because of its location on the Atlantic coast and its excellent harbors, the Netherlands is a center for shipping; the Port of Rotterdam is one of the busiest in the world. However, the small size of the country relative to other Western European countries means that the majority of freight traffic moves through the Netherlands, rather than being destined for it.

2.3 Organizational Responsibilities

In the Netherlands the road network is divided into three organizational levels:

- National
- Provincial
- Municipal

The national road network is constructed, operated, and maintained by the National Government through the daily operation of eight regional administrations. All the road miles within the national road system are freeways (motorways), and funding for the system is provided by the National Government. Provincial and municipal roads are the responsibility of the provincial and municipal governments, and funding is provided by those respective governments. The National Government does not allocate funds to local governments for construction, repair, and maintenance of roads.

Technical assistance to the national regional administrations is provided by the Ministry of Transport, Public Works and Water Management's Transport Research Center, the AVV. Much of the technical assistance for traffic-counting equipment, data collection and analysis, and reporting is provided by AVV. It is charged with supporting the research and policy of the Ministry and operates across the full transportation spectrum (road, water, rail, and air). AVV's duties include providing policy recommendations, acting as a knowledge transfer point, and providing information and basic data on traffic and transport to the Ministry.

The Netherlands Government has two major sets of traffic data collection responsibilities. It collects and publishes general statistics for all roads in the country and collects the data needed to plan, build, maintain, and operate the national road system. Traffic counts are developed for all segments of the Dutch national roadway network each year. Total national road system distance traveled is then computed by aggregating the section-specific VKT estimates.

In the United States, distribution of funds to the States is based partly on the VMT in each State. Conversely, in the Netherlands, it is the National Government that operates the roadways, and VMT in particular areas is not necessarily a basis for funding. The traffic data that the Dutch National Government collects are similar to those collected by our States, but there is no need to collect sophisticated, sample-based data sets, such as those gathered by the Highway Performance Monitoring System (HPMS).

The primary focus of the data collection effort in the Netherlands is to obtain reliable average annual daily travel (AADT) estimates for all sections of the national roadway system and to provide information on temporal distribution and vehicle classification composition. These data are used for a variety of purposes, including the following:

- Input for legislation, policy, and development and preparation of projects.

- Compilation by national and international bureaus of statistics.

- Use by various regional agencies to implement projects and plan maintenance.

- Dissemination to the media and public.

While the National Government does not operate or fund road transportation at the provincial and municipal levels, it is responsible for collecting and reporting statistics on travel for all modes and all facilities within the country. This is accomplished by requesting basic statistics, such as VDT or lane miles of roads, from the provinces and municipalities. Because these data are used primarily for reporting trends and not for disbursing funds, precision of estimates is not a concern. Generally, the National Government accepts the numbers submitted by the provinces and municipalities without review.

Although the national government has provided the provinces and municipalities with basic guidance on collecting and manipu-lating traffic data, there are no formal program guidelines similar to the U.S. Traffic-Monitoring Guide. Consequently, the provincial and municipal counting programs tend to be reasonably small and based on the operational needs of individual provinces or cities.

In the Netherlands, an interesting organizational decision was made to separate the system management function from the applications group. The system management group is responsible for collecting the data and making them available to users, who are then responsible for creating and operating their own applications. This ensures that each effort receives the appropriate level of ttention and that all groups have access to the same data. In addition, the Dutch have created the position of "account manager" to act as a liaison between the data collection/ management group, the application developers, and the end users.

Portions of the data collection effort have been privatized, particularly site maintenance and data collection outside of the traffic control system. Privatization is viewed as successful. For the most part, contracts are written for the submittal of valid data, and auditing consists mainly of reviewing data within the INTENS system.

2.4 Counting Program

2.4.1 Road Traffic

The majority of traffic data in the Netherlands are collected from permanently installed loop detectors. The loop detectors can be characterized into three systems, although these separate systems are evolving toward a single system. In fact, the basic aggregation program is the same for each of the data collection systems. It includes hourly data, annual statistics, and the data validation process.

The three components of the data collection program are as follows:

- Traffic-signaling real-time traffic control systems (about 400 sites).

- Permanent traffic-monitoring locations at which data are continuously collected (about 110 sites).

- Traffic-monitoring sites at which data are periodically collected (about 300 sites).

The traffic-signal control system is an ATMS. Its primary purpose is to collect real-time traffic volume and performance information for traffic control purposes on the national motorway system. Traffic control purposes include operating variable speed limit signs (i.e., speeds are changed to reflect dangerous conditions ahead) and providing automated lane closure information. ATIS will soon be available.

As part of the traffic monitoring data base developed by AVV, traffic data from the ATMS are collected periodically from the local controllers, aggregated as 1-minute volumes, and processed by the INTENS system. All ATMS data collection sites are dual inductance-loop locations.

The traffic monitoring devices for permanent locations at which data are continuously collected are equivalent to what most State DOTs call annual traffic recorders (ATRs). These devices are also dual-loop-based and transmit data to the central processing site each hour in 1-minute increments. The data collected include volumes, speeds, lane occupancy, vehicle gaps, and vehicle classifications. Vehicles are sorted into three categories that are based on length: cars, which are less than 5.4 m; delivery trucks, which are 5.4 to 11.5 m; and heavy trucks, which are larger than 11.5 m. Average speed and standard deviation of the speed are computed for each of the three vehicle classes.

The counters for sites at which data are collected periodically provide the same data as the counters discussed above. The differences are that these counters are not connected by modem to the central office, are not interrogated frequently by the central office, or have data collected by contract staff that physically visit the site to retrieve the stored data. These sites collect data for roughly one month at a time (or are set up in the field to collect data only periodically) and transmit data to the central office monthly. All data points use permanent loop detectors, and short-duration counts are conducted by temporarily hooking electronics to the permanent loops. As a result of these efforts, rural roads are counted fairly well. Roads in urban areas where detectors are not routinely placed are counted less effectively.

Provinces and municipalities do not have complex data collection and analysis systems, but they do collect some traffic data to meet both project-related and reporting requirements. For example, the city of Rotterdam has 40 permanent sites and 60 semipermanent sites.

2.4.2 Bicycles

For the most part, the National Government does not count bicycle traffic directly. The extensive network of bicycle paths is not located on the national road system but is, instead, part of the provincial and municipal systems. Provinces and municipalities collect some usage data with either inductive loops, tube counters, or manual counts. Inductive loops must be tuned very carefully to detect bicycles, but they are used to detect the presence of bicycles for traffic signal actuation.

Direct bicycle counts are supplemented by information available from the national transportation survey (NTS). The NTS obtains 10,000 responses per month and provides information on mode choice (all modes of travel), average trip length, origin/destination of trips, and various other statistics.

2.4.3 Transit Counts

Transit counts are performed by the transit authorities with a combination of automated passenger counters and manual counts.

2.4.4 Pedestrian Counts

Pedestrian counts, like bicycle counts, are not conducted by the National Government because of the nature of the roads that the Government operates. As with bikes, aggregate statistics on pedestrian travel are obtained from data collected as part of the larger NTS, but more specific pedestrian information is collected by municipalities and provincial agencies as part of special studies. That is, the data are collected by special arrangement, with a data collection plan designed expressly to meet the needs of the intended use.

2.4.5 Vehicle Occupancy Counts

The National Government does not routinely collect vehicle occupancy information. Vehicle occupancy can be estimated from the NTS responses, but otherwise it is collected only for special cases.

2.4.6 Travel-Time Determination

Travel times are computed from loop detector data, using a "platoon" tracking system. The platoon-based travel-time computation only works over moderate distances (5 to 8 km) and only when traffic flow has not broken down. When flow breaks down, travel times must be estimated from in- and out-counts.

2.5 Equipment

2.5.1 Data Collection Systems

In the Netherlands, inductance loop detectors are used for data collection. Under contract with the University of Minnesota, experiments are being conducted using Autoscope to supply the same data collected by the existing loop system. Autoscope is being investigated for use in areas where lane lines are changed periodically (such as during road work), making it impractical to have loops cut in the lanes. To date, AVV is not satisfied with Autoscope's performance, although it is anticipated that future software upgrades will allow the system to meet data accuracy requirements.

An important aspect of AVV's loop inductor system is that its failure rate is claimed to be only 1 per 1,500. Loop-detector failure is a major problem in the United States, and AVV staff indicated that loop failure has also been a problem in the Netherlands. The Dutch were originally unable to purchase loop detector systems (loops, associated electronics, and telecommunications) that worked reliably over time from commercial vendors. Consequently, AVV created its own loop detector specifications. According to AVV staff, the specifications include all hardware and software components and are responsible for the high level of reliability of the detectors. There are three manufacturers in the Netherlands that can make and sell the systems.

The Dutch also stressed the need for fail-safe design in equipment specifications. The devices follow standard U.S. traffic signal system design, which includes battery back-up, hierarchical control, and progressive failure levels. In other words, when communications fail, the system has sufficient local intelligence to operate as intended and is capable of storing large quantities of data. This allows the system to maintain all collected data (and control functions) until central communications can be reestablished.

In the urban area freeway control section of the national network, loop spacing is typically 500 m, never less than 175 m. Plans are to implement travel-time computations that use license plate matching but do not actually read the plates. Instead, digital images of the plates taken at two different locations will be matched. This will avoid the privacy problem of trying to read different plates and should increase the match rate. On the other hand, it will also increase the computer processing time and storage needed to match images.

2.5.2 WIM Systems

In the Netherlands, exploration of WIM systems is just beginning. There are currently no operational WIM systems, although several sensors have been purchased from different vendors for testing. Current plans are for the installation of 40 to 60 WIM sites; installation is intended to start in 1997 with about 5 systems.

The Dutch are currently working on the development of purchasing and acceptance specifications. They are working with the COST committee on WIM and will probably produce a specification that combines the preliminary findings of the COST effort with material from the ASTM 1318 specification.

Dutch officials expressed concern about the cost of installing concrete pads for WIM systems and about the "bump" that would result from soil settlement at the joint between concrete and asphalt. They also expressed optimism that the sensors selected would be able to work with acceptable accuracy in Dutch asphalt pavements.

It is important to note that WIM systems in the Netherlands only began to generate significant interest when groups other than the pavement design/maintenance community became interested in the information available from these systems. Current plans call for close cooperation among the pavement design group that is leading the effort, enforcement personnel (police), and economic analysts interested in the movement of freight through the Netherlands. Economists are interested in the effects of different weight regulations on the Dutch infrastructure as a result of changes agreed to as part of the European Union (EU) regulations. Even with current EU regulations, weight laws are not consistent among countries. For example, the Dutch allow a gross vehicle weight (GVW) of 50 tons, with a maximum of 11.5 tons on any one axle, while the French allow only 38 tons of GVW, but up to 13 tons per axle. Further study of the actual weights being carried, the number of over-loads, and the types of vehicles operating on the roadway will be needed if standardization of vehicle weights and dimensions will be accomplished in the EU.

Cooperation among groups interested in WIM data is apparent in the selection process for the new WIM sites. Based on the need for national monitoring information, AVV will designate the basic geographic locations; that is, roads on which the devices are to be located. Local weight enforcement staff and municipalities will have significant input into the actual locations selected for WIM installation, as long as they are within the general boundaries set by the National Government. This arrangement will allow the national agency to obtain the representative data required while meeting the local needs of the provinces and municipalities. The system will also provide a way to obtain local support for the WIM installation effort and local knowledge necessary for optimum site selection and construction. In return, the regions will benefit from having the data, a single central information source, and systems compatible with those purchased by other regions.

AVV is considering privatizing the collection of WIM data because of a lack of staff time. A primary concern is that the available consultants in the Netherlands may not have expertise in the installation, operation, or maintenance of WIM sites.

2.6 Data Analysis and Validation

Much of the data analysis and validation conducted in the Netherlands is contained in the INTENS software system. INTENS collects traffic data from the various traffic-monitoring sites, conducts automated validation checks, allows manual review of data flagged by the checks, and produces a variety of summary statistics and graphics. Both the validation routines and the graphic output are worth considerable review by U.S. DOTs. The system runs on a Sun 20 workstation that is networked to and accessible from conventional Windows-based PCs; the soft-ware package is written in a combination of ORACLE and ARCINFO.

The data validation process consists of a series of parameter checks that compares the data submitted for each site with confidence limits set specifically for that site. Although specific rules and parameters were not explained in detail to the scanning team, the validation process is roughly outlined below.

The INTENS validation process consists of checks for errors that occur during the transmission and labeling of data sets and for errors in the actual data (e.g., inaccurate counts). Validation routines cover all the data types collected and are performed on lane-specific data.

Initial data checks ensure that data are labeled correctly (i.e., belong to a site for which data are expected), have the appropriate number of lanes for that site, and pass other site identification checks. These checks are referred to as "planning activities." Software routines that allow the central processing operator to add new sites and make other necessary changes to the data base are also part of the planning activities in the INTENS software.

The second checks are called the "primary control" checks. These are a series of maximum and minimum allowable data ranges for specific variables that are based on historical data for each site. In addition to being checked against a series of other data validity rules, previously collected data are analyzed to create the expected bounds for hourly traffic statistics. The software checks the percentage of traffic allocated to each hour of the day, by lane and direction, and compares traffic volumes across lanes and directions. Absolute and percentage traffic volumes are checked. The system is sensitive to expected day-of-week, month-of-year, and seasonal effects and tracks and accounts for holidays and other "calendar-related" traffic events. Checks are performed by vehicle classification, and "questionable data" flags can be produced by unexpected volumes in any vehicle classification or by the total volume count.

Data flagged as questionable are forwarded to an operator. The operator has a variety of tools available to display the questionable data and the expected volume bounds. If, on the basis of this review, an operator believes that the data are valid, questionable data flags may be removed and comments inserted to indicate why the data are valid; INTENS will then use these data to calculate annual and daily statistics.

INTENS is also able to estimate traffic volumes when no data are available. Essentially, the software uses a "smart" linear interpolation process between locations from which data are available. Although the process was not explained in detail, it appears that where knowledge of major volume changes is available (i.e., known increases/decreases in volume at road interchanges), these data are used to supplement the linear interpolation process.

INTENS is run in batch mode approximately once a month. Although the process could be run more often, data from many of the sites are not collected daily via telemetry but are submitted on computer-readable format from contractors that visit the sites to collect the data and conduct necessary site maintenance.

INTENS requires approximately 3 to 4 hours of CPU time to process monthly data from 800 sites. Another 3 to 4 hours of staff time is required to review the data flagged as questionable. The time required for manual review is very low because of the high degree of reliability of the loop sensors. Relatively few data points are flagged as questionable, so little time is required to review those data points. It has been found that 2 to 3 percent of the data are not valid, a decrease from the 5-percent rejection rate experienced when INTENS was initiated.

One limitation of the INTENS data review process is that the data reviewer does not have complete access to incident information or other information that could be used to quantify valid but abnormal traffic conditions. It is difficult to track incident effects, partly because processing is conducted monthly for the entire country and partly because the data processing is centralized, rather than conducted at a local freeway operation center. Speed data are available for many of the data collection sites, making it possible to determine when congestion is present over the loops. It is, however, not possible to determine directly from the volume and speed data when a blockage upstream of a loop has prevented traffic from reaching that loop. Similarly, operators may not always have construction-related closure information that would indicate when a lane closure was limiting access to a loop.

2.7 ITS

The Netherlands is very involved in the Eurodelta test site. This project is a combination ATMS/ATIS for the intermodal movement of people and goods from the country's ports. The system includes the collection, use, and dissemination of data on weather conditions, tides, highway volumes and performance, ship movement, and other factors that affect management of the transportation network that serves the ports. An integral part of the Eurodelta test site is expansion of the national motorway monitoring system, which will, in turn, lead to more traffic information being collected and fed into the INTENS system.

3.0 GERMANY

3.1 Summary Points

The German WIM system's calibration can be maintained by monitoring the axle-load distribution for each site, although the expected distribution can vary from site to site. In addition, German studies show that WIM systems require calibration at least twice per year.

The Germans have determined that they can realize substantial cost savings and data improvements if ATMS and ATIS collect, store, and supply traffic information for general operational decisions and planning and engineering functions. This data collection function is a part of all of the funded ATMS/ATIS.

The German Government relies heavily on nonfederal agencies and private companies for traffic data collection. For permanent sites, the Federal Government specifies the equipment to be purchased and reimburses state highway agencies for purchasing and operating that equipment. Installation and operation is usually implemented by private contractors working for the states.

For some data collection efforts, contracts with private firms are based on collection and submittal of specific amounts of data, rather than specific amounts of labor. Contractors test and guarantee the equipment that will be used. This gives additional work to the contractors, which, in the United States, has traditionally been performed by State DOTs. Audits of the collected information are not routinely conducted.

3.2 Introduction

The Federal Republic of Germany covers a surface area of 375,000 km^2 and, including the new Federal states of the former East Germany, has a population of about 80 million people. The roadway system is categorized as follows:

- Federal autobahns
- Nonurban Federal highways
- Laënder (state) highways
- District roads
- Local jurisdiction (municipal) roads

Roughly 2 percent (11,000 km) of the approximately 550,000-km road system consists of Federal autobahns. Another 42,000 km of roadway are Federal non-autobahn roads, and laënder (or Bundes-lande) roads consist of about 88,000 km. Approximately 50 percent of the VKT are on the two Federal road classifications.

3.3 Organizational Responsibilities

The Federal Government is responsible for financing the autobahn and national road networks. It is also in charge of designing and planning these roads and for providing legal and technical supervision of construction and operation. However, the actual construction, operation, and administration of these roads are performed by the Bundes-lande on behalf of, and with funding from, the Federal Government.

National oversight is performed by six regional divisions of the Federal Ministry of

Transport, the Bundesministerium für Verkehr. In addition, technical support, research, and analysis are provided by the BASt, a national research institute that is similar in function to the FHWA Turner-Fairbank Highway Research Center. The Bundeslande roads are constructed, maintained, and operated by the Bundeslande, and the district and local roads are constructed, maintained, and operated by those authorities.

Nonfederal agencies are not required to collect and submit traffic data to the Federal Government. The German Federal Government does not require the same levels of accuracy and precision that the U.S. Government requires from the States. Federal road funds are not distributed to the Bundeslande, except for work done on the national road system. That is, funds from the Federal Government are not provided to the Bundeslande based on VDT; hence, accuracy of VDT estimates is not a significant concern of the Government. Because the Federal Government has no financial stake in the amount of traffic using local and Bundeslan-de roads, local authorities are free to collect data in the manner best suited to their needs.

Traffic data collection responsibilities in Germany are similar to those in the other European countries visited. The Federal Government provides operational support to the Bundeslande for the national road network and is responsible for collecting the data necessary for the planning, design, and maintenance of that road system. The data collection design is performed by BASt, and funding for the effort comes directly from the Federal roads budget. Once the national data have been collected, copies of the data are sent to BASt, which is responsible for producing national traffic statistics.

To collect data, the Federal Government specifies the data collection points and equipment, then contracts with the individual Bundeslande for data collection. The Bundeslande hire temporary workers or contract with private companies to conduct data collection.

For data collection, storage, and processing for their own purposes, the Bundeslande may hire staff or contract with private firms. A private contractor that provides data collection, processing, and analysis services to both the Bundeslande and BASt made a presentation to the scanning team.

3.4 Counting Program

The basic Federal traffic data collection effort has four separate components:

1. Data collected by real-time ITS traffic control systems (usually variable-speed control).

2. Data collected by permanently operating dual-loop traffic counters.

3. A manual count program performed every 5 years for the United Nations and used to produce national travel statistics (referred to as "UNO" in Switzerland and the Netherlands).

4. Summary statistics provided by the local road authorities.

3.4.1 Permanent Count Program

The traffic signal system is a combination of variable speed-limit and motorist information systems that provide congestion detection and driver information, such as congestion warnings and possible alternate routes. This system was implemented in response to concerns about safety that arose from increasing congestion and the lack of a speed limit on the autobahn. While the system's primary function is roadway management, it also collects and stores a wide range of summary statistics, such as volumes, speeds, and basic vehicle classifications, that are used for planning, forecasting, and other data-intensive tasks.

The permanent count program, which is separate from the ITS, covers 1,128 points; the counters are distributed as follows:

Type of Road	*Permanent Counters*
Autobahns	450
Other Federal highways	520
Bundeslande highways	142
District roads	16

The initial plan for the count locations called for instrumentation of the entire national road network, but this proved to be too expensive. Consequently, the Federal Government created a four-tiered system that assigns each road segment a priority rating based on incident probabilities at that site.

The four categories range from locations that are highly incident prone to not very incident prone. For each category of road, an instrumentation level is specified. These levels are as follows:

1.	High incident	1 unit per km
2.	Moderately high	1 unit per 3 km
3.	Moderately low	1 unit per 6 km
4.	Low incident	1 unit per 18 km

Data from the locations are sent to regional operation centers in each Bundeslande. (Two of the Bundeslande have two operation centers, the rest have one each.) At the centers, data are used to make operational decisions, such as operating variable speed-limit signs, activating alternative route plans, and identifying and responding to incidents and accidents. The data are also stored for later use and transferred to BASt for use at the Federal level.

Operational control is maintained at the regional center level and includes input from the local police and traffic authorities. Variable message signs are activated at the local and regional levels, not by the BASt or the central Government. Figure 1 illustrates a typical equipment setup for these systems.

As in the United States, administrative organization of the individual Bundeslande differs throughout the country. Regional centers are operated by the appropriate traffic authority for each Bundeslande, although this is not necessarily the same agency, and each Bundeslande has flexibility in selecting operational procedures for its control center(s).

3.4.2 Manual Short-Count Coverage Program

In addition to the data collection described above, the Federal Government conducts a large, manual traffic count every 5 years as part of a United Nations effort to report inter-European travel. This effort is conducted by the Bundeslande, under contract with the Federal government. The program also provides an update of Federal estimates of total vehicle travel throughout Germany. During years when maual counts are not conducted, estimates are updated annually on the basis of data from the permanent counters.

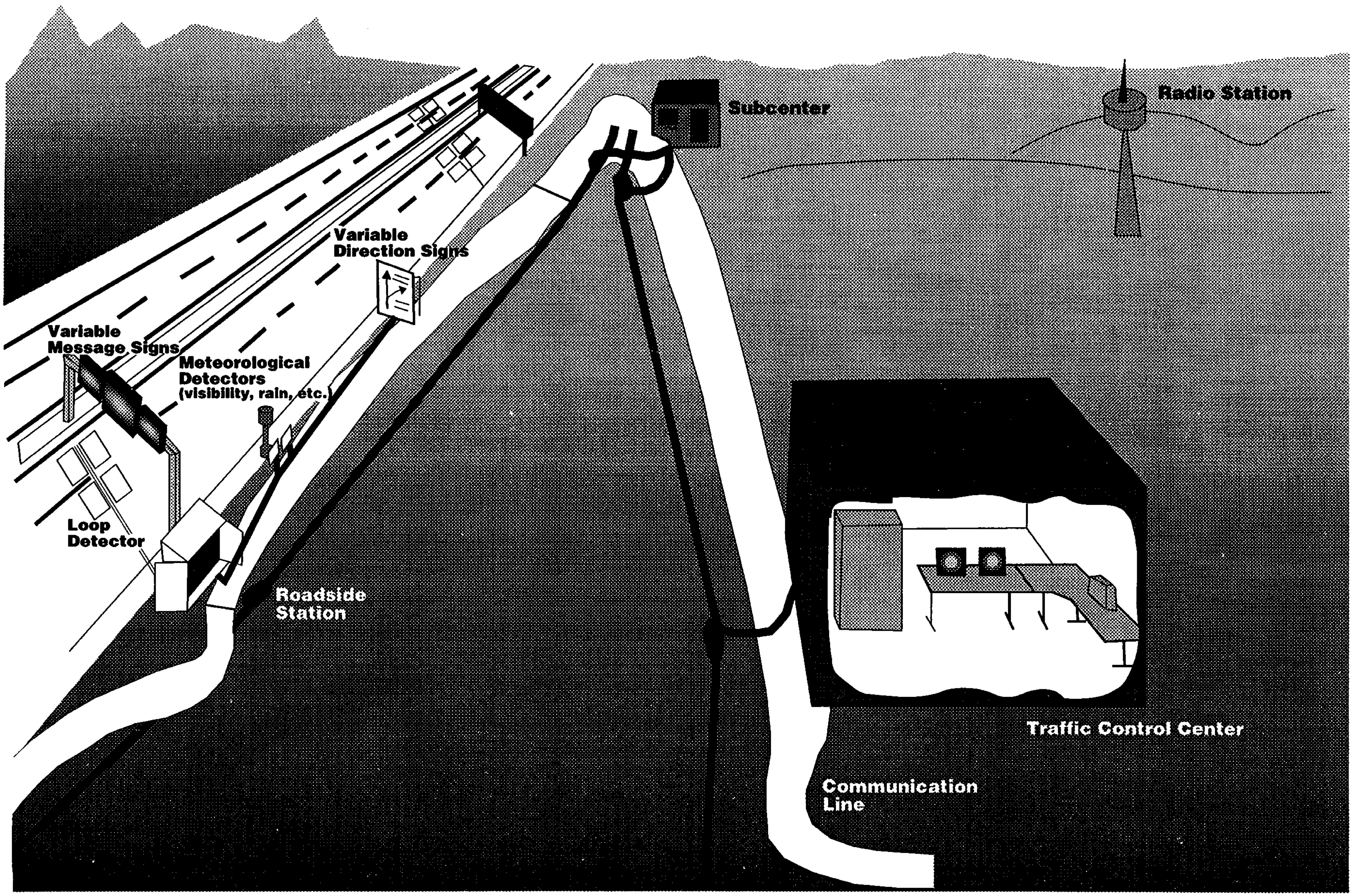

Figure 1. German ATMS/ATIS Configuration

The manual count program covers 48,250 locations, each of which is counted 6 to 8 times during the year. Roads with expected average daily volumes of over 5,000 vehicles are counted 8 times, and smaller roads are counted 6 times. Counts are done manually for 4 hours, in the afternoon of each count day, although vehicles on a limited number of high-volume sites are also counted for 2 hours in the morning. The count days are the same for all sites and include two weekdays, two Sundays, and two holidays. The sites that are counted eight times are also observed on two Fridays. On smaller roads, data are collected without regard to lane or direction of travel. On larger roads, multiperson crews collect data by lane and direction. Table 4 shows the design of the manual count program.

Weekend and holiday traffic are counted to provide data that measure recreational travel. All of the hourly counts are then factored to estimate average annual traffic volumes. More detail about this kind of data analysis is in Section 3.6.

In addition to hourly traffic counts, the manual data collection procedure includes information on the number of cars with foreign license plates and the mix of vehicles within the traffic stream. Currently, the manual count program collects data on 7 modal classes, a reduction from the 11 classes previously studied. The classes currently used are as follows:

- Bicycles
- Motorcycles
- Cars
- Buses
- Small, single-unit trucks (<3.5 tons)
- Large, single-unit trucks (>3.5 tons)
- Combination trucks

Table 4. Time Schedule for Short-Term Manual Data Collection

Census Points		Additional Census Points
AADT>5,000 vehicles/24 hrs	AADT≤5,000 vehicles/24 hrs	
Directional Counting	Nondirectional Counting	Directional Counting
2 Normal Weekdays 2 Fridays 2 Sundays 2 Holiday Weekdays	2 Normal Weekdays 2 Sundays 2 Holiday Weekdays	2 Normal Weekdays 2 Fridays 2 Sundays 2 Holiday Weekdays
Counting Interval: 3-7 pm = 4 hrs (In addition, on normal weekdays: 7-9 am = 2 hrs)	Counting Interval: 3-7 pm = 4 hrs	Counting Interval: 6 am-10 pm = 16 hrs
8 counts/36 hrs	6 counts/24 hrs	8 counts/128 hrs

The Bundeslande and municipal governments also perform separate count programs, but the scanning team did not obtain information on these systems. Federal data are made available to the Bundeslande, so that they are aware of traffic volumes and characteristics on the Federal roads in their jurisdictions.

In addition to the count programs described, special project counts are conducted by all levels of government to meet specific needs, including pavement design, geometric improvements, and special planning studies.

Like most Europeans, Germans rely heavily on more traditional ridesharing modes, such as trains, trams, and buses. The Federal Government does not collect vehicle occupancy or bicycle use information, because neither is important to the national road system, which is primarily oriented toward intercity travel. Carpool formation is not a policy direction of the Government.

3.5 Equipment

3.5.1 Data Collection Systems

Through BASt, the German Federal Government has created a single equipment specification for the dual loop detectors used for the majority of traffic detection and data collection on the national road system. This specification was developed to meet the needs of the Federal monitoring system. The dual loop detectors collect volume and speed information for both cars and trucks, and the equipment is also capable of collecting and reporting loop occupancy and average vehicle gap. Data are reported in 1-minute intervals. The most recent version of the roadside electronics is also capable of differentiating between five to eight vehicle-length categories, but the Germans currently use only the simpler car/truck differentiation in routine data collection. Figure 2 illustrates how the counters interpret wave forms generated by loops to determine vehicle types.

An important aspect of the German specification is that all data collection systems use the same data-transfer protocols. Thus, all data collection equipment is interchangeable at the major component level, regardless of the manufacturer. The same communication standard process also applies to other data collection devices in use, such as precipitation, fog, temperature, and other sensors. The intent is to be able to add any type of data collection device to any site, regardless of the manufacturer of the detector or the local controller. Like the Dutch, the Germans have also ensured that more than one manufacturer can make data collection equipment that meets the specifications.

The Germans seemed satisfied with current equipment performance and are not vigorously exploring infrared or radar-based data collection equipment. However, staff at the regional office in Hesse did comment that the cost of data collection equipment (including the communication costs) is sufficiently high that it significantly limits their ability to place detectors. Lower cost methods for collecting traffic performance information are being investigated.

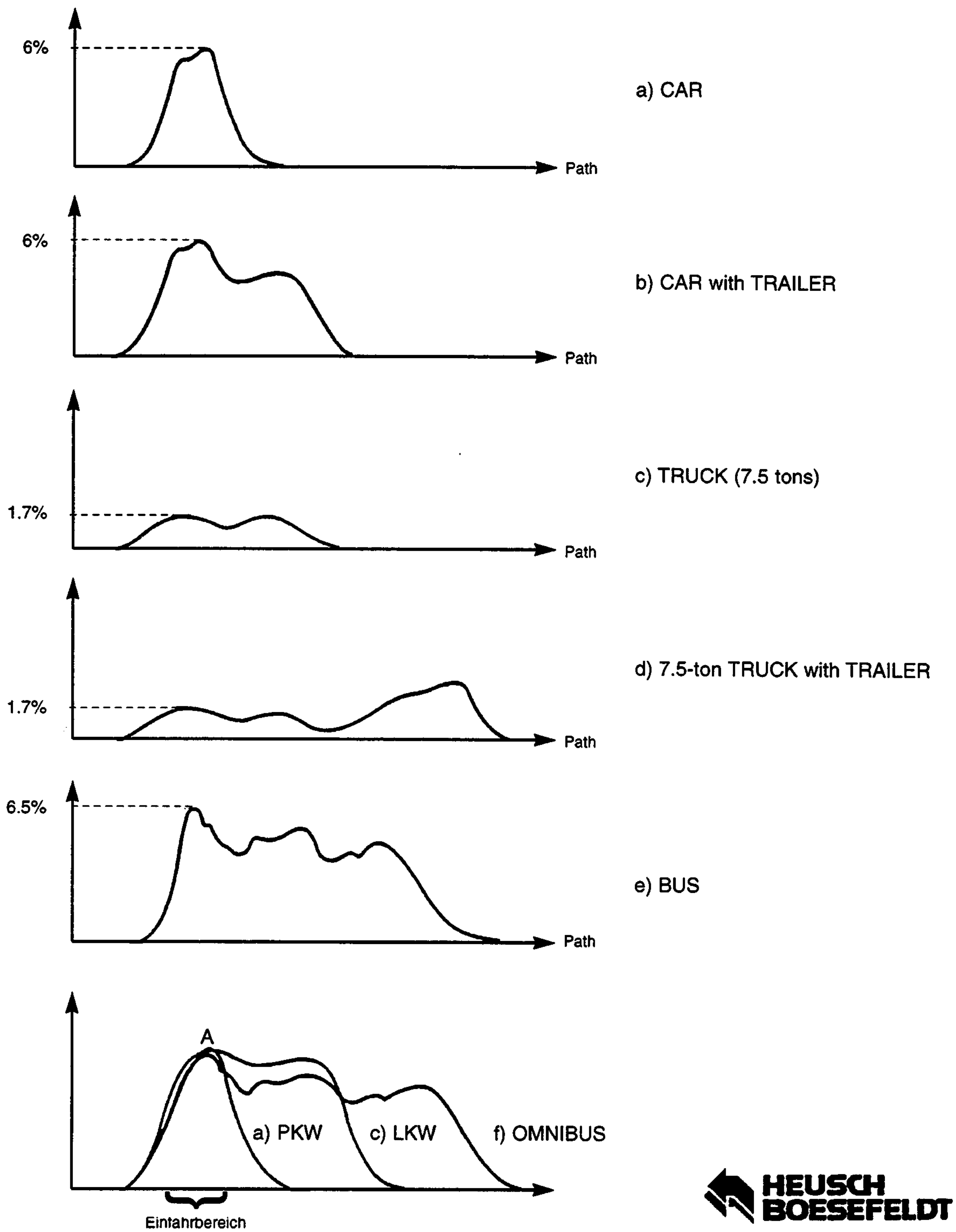

Figure 2. Inductance Loop Wave Forms Used To Perform Vehicle Classification
Reproduced with permission from Heusch Boesfeldt

In Hesse, part of the Bevei-TMC (traffic message channel) field trial involves the use of probe vehicles for collecting real-time highway performance information. Use of Kahlman filtering techniques to reduce the number of detectors required to provide the current level of traffic information and accuracy is also being researched. The Hessen urban freeway control system costs DM15 million (about US$10 million). It includes one central computer; 144 loop locations, with dual loops in all lanes of freeway at each location; 33 gantries; and 174 optical fiber variable speed-limit signs mounted on the gantries.

The Germans are also experimenting with video-based license-plate readers to determine identities of vehicles passing a location. Vehicle license plates are used to determine each vehicle's engine type for use in air pollution modeling.

Finally, equipment in 400 of the permanent data collection sites is capable of collecting axle profile information. The capability is not currently in use, but it is believed that the information will become useful once WIM systems become operational. BASt is developing procedures to test improved vehicle classification devices, but this is just beginning, so details were not available.

3.5.2 WIM Systems

Germany has participated in a number of WIM tests over the last decade. The latest series of tests, performed in 1993, included the Golden River capacitance strip sensor, the ECM piezoelectric sensor, and the PAT bending-plate system. Tests concluded that the bending-plate technology was the best system for German needs, and the Federal Government is currently installing five WIM systems in the Rhein-Main area.

BASt also provided the scanning team with a report on German WIM studies.[3] Researchers concluded that WIM systems, regardless of sensor design, needed periodic independent calibration and recommended calibration at least twice a year. Additional calibration checks are recommendeded whenever axle-weight distributions at a site change.

Nevertheless, the Germans believe that further research into WIM system design and operation is still required, and they are active participants in the COST 323 and WAVE efforts.

3.6 Data Analysis

3.6.1 Short-Count Factoring

In Germany, an extensive factoring process is used to convert manually collected short-count data to estimates of AADT. As shown in Figure 3, the procedure has two factoring steps.

Four-hour counts are initially converted to daily estimates using factors obtained from the extensive permanent count system described above. These multiple daily volume estimates are then combined by a weighted averaging process to estimate average annual conditions.

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[3]H. Kalisch and B. Paatz, *20 Years of Weigh-in-Motion (WIM) in Germany*, BASt, Bergische-Gladbach, Germany. (Publication date not available.)

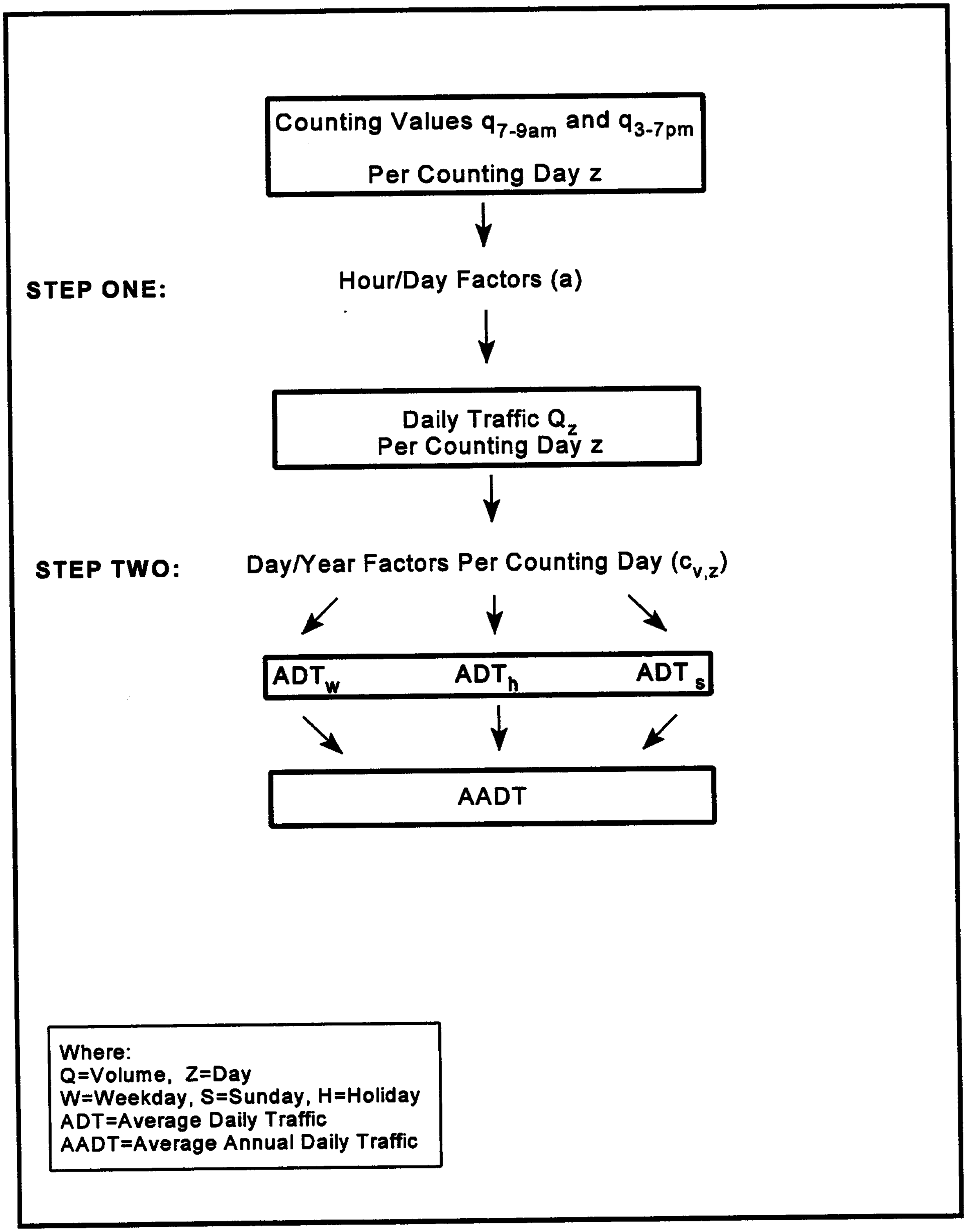


Figure 3. German Short-Count Factoring Procedure

Factors for converting the 4-hour counts to annual estimates are selected for each short-duration count on the basis of the following conditions:

- Road classification
- Day of data collected
- Region of the country
- Vehicle category

For high-volume locations, direction of travel is also used for factor selection. Factors are taken from the same year for which the counts have been taken. For example, only data collected from permanent counters in 1996 are used to factor short counts taken in 1996.

The German system has the following strengths:

- The factors adjust specific days in specific years to annual conditions, which means that the factoring process accounts for unusual conditions, such as weather, that occur during the data collection periods.

- There are numerous permanent counters against which the short counts can be matched, so that the ability to associate a specific short count to a known factor is very high.

- The system explicitly counts "unusual" days (i.e., weekends and holidays), so that not only is information known about special traffic conditions, but conditions can be accounted for in the AADT values.

The relatively short duration of the manual counts improves the quality of the data, because the individuals performing the counting do not lose concentration as much as they would in longer count periods. In addition, use of manual techniques limits the number of equipment-related problems. However, this system is expensive, it provides data only every 5 years, and it also limits knowledge of daily traffic conditions at these data collection points.

To estimate conditions during years when the 5-year census is not taken, the Germans factor these counts by growth estimates obtained from the extensive permanent counter system.

BASt computes annual VKT statistics for both the two Federal road classifications and for the nation as a whole. For the Federal road system, it uses counts, or count estimates, for every road section on the network and then aggregates those values to provide systemwide totals. It was not clear how VKT for nonfederal systems was computed.

In addition to the annual VKT statistic, the Germans calculate an average daily road volume by road type. This "average road volume" appears to be an important trend statistic. It can also be easily computed for all road categories on the basis of the census data; thus, the average road volume can be computed for all roads, regardless of which level of government owns and operates the facility.

In addition to AADT, the Germans are also very interested in vacation travel volumes and are working to forecast volumes to improve facility operations during peak vacation times. Forecast volumes are also used to schedule construction activity and to broadcast information about expected traffic conditions. The scanning team noted that careful timing of construction activity, based on accurate traffic-volume forecasts, could substantially improve the speed of construction, while reducing construction costs. That is, more of the construction could be performed during daylight hours.

3.6.2 Data Validation

The German presentations did not include significant detail on the data validity checks that BASt uses. In response to a question about such procedures, the scanning team was informed that the BASt data processing system includes checks, but that the validity checking process was being revised as part of a major software enhancement effort.

A private consultant described the quality control process applied to Bundeslande data. The system uses maximum/minimum bands for volume information to flag suspicious data. A 2-week analysis period is used, because it is believed that monthly intervals are not stable. The system also accounts for holidays and the starting and ending times of schools, because these days may shift from year to year.

The other data validity checks explained to the scanning team were from an ITS being constructed in Hesse. This system, which is being built by a consultant and is considered proprietary, uses a combined fuzzy logic/ expert system approach for data validation. The system is trained on data that are considered "valid" and then reports invalid data. Invalid data are then reviewed manually. Data that are determined to be acceptable are included in the "training" of the system, so that other data with those characteristics will be considered valid.

3.7 ITS

The German government is investing significant resources in the development and application of ITS for traffic management. Primary areas of emphasis are imposing and controlling variable speed-limits on the autobahn system and providing motorist routing information.

The goal of the variable speed-limit system is to provide smoother transitions from high-speed, free-flow conditions to congested conditions by providing graduated speed reductions and warnings of queues. Initial routing and speed-control systems are in place, and the scanning team observed them in operation. The systems collect volume and speed data by car and truck classifications and make automated decisions on when to impose speed limits and what limits to post. Speeds are reduced incrementally through multiple gantry signs, a process referred to as "speed funneling."

In addition to displaying the new legal speed limit, the variable speed-limit system illuminates signs that restrict trucks to the right lane to reduce the number of incidents caused by large speed differentials between trucks and cars. The variable speed-limit systems have successfully reduced crash rates and severities at high-incident locations. Through these reductions, the Hesse regional office indicated that the variable speed system has paid for itself in 3 years.

Another area of particular interest is routing traffic on the autobahn around congestion. This is accomplished by using one of two systems: substitution or addition. For substitution, rotating signs are used to change the signed route for reaching specific destinations. When congestion occurs, signs are changed to route traffic onto roads that still have capacity. This technique is particularly useful for routing traffic around special events, so that through traffic is routed away from roads leading to the event. The problem with this system is that it causes motorists to take unexpected routes and/or miss intended midtrip destinations.

To resolve the limitations, an additive system was developed. The additive technique uses orange-colored arrows (trailblazer signs) to show the recommended diversion route. Drivers simply follow the arrow signs until they are back on their original routes. In this way, drivers are given a choice of route to take and know that the marked route is both faster and less congested. The additive procedure provides motorists with more control over trip paths and a better understanding that they are being routed around congestion.

In Hesse, the existing ITS are also being expanded to include priority-merging operations. This is achieved by using overhead signing to automatically close selected lanes.

Priority merging will be installed at major motorway interchanges that have the appropriate lane configurations and high-volume differentials on two merging ramps. A lane will be closed under the following conditions:

- Where two freeway-to-freeway ramps share a merge lane.
- When one merging movement is significantly greater than the other.
- Where traffic volumes exceed a specific level.

When these conditions occur, the shared merge lane of the ramp with the lower volume will be closed to reduce the size of the merge conflict, thereby providing greater throughput for the higher volume ramp and reducing congestion at the intersection. Note that both merge ramps may be closed, depending on the time of day and relative size of the merge movements.

Most traffic information is provided to motorists through nonverbal signs, although traffic information is also broadcast over the commercial radio system. Germany is moving toward providing traffic congestion and routing information through the RDS-TMC. RDS-TMC is the Radio Data System-Traffic Message Channel, which transmits digital codes on FM subcarriers broadcast on conventional FM radio signals. Use of RDS-TMC could solve the problem of communicating in multiple European languages and give highway agencies the ability to provide more detailed traffic information without disrupting commercial radio broadcasts.

The RDS-TMC will provide information generated by the automated traffic control systems and based on data entered manually by the regional traffic control centers, most of which are supplied by the highway police. For example, automatic ice formation warning systems already exist in Germany, but a policy has been adopted that only the police may decide when to broadcast ice-warning messages. Decisions regarding operational control of motorist information systems and the organizational responsibilities for system operation are made at the regional level on the basis of local operating policies and regional government systems.

Hesse is currently involved in a large-scale RDS-TMC test as part of the Bevei field trial. The technology will be expanded as the various components become available.

One concern voiced by the BASt staff involved public/private cooperation. It is difficult for German public agencies to implement field-tested equipment because of a "chicken-and-egg" problem with private partners. On the one hand, the public agencies cannot get funding support to build the public infrastructure until the private sector has supplied and marketed the information-receiving devices. On the other hand, the private sector will not market the receiving devices until the public sector has deployed the infrastructure that will supply those devices with useful information. The result has been a much slower movement from field tests to operational systems than anticipated or desired.

4.0 SWITZERLAND

4.1 Summary Points

The geographic and political conditions in Switzerland result in some striking differences from and similarities to the other European countries visited by the team.

With some exceptions, late-night truck travel is prohibited, as part of a noise reduction effort. This reduces the need to count vehicle classifications at night.

Legal truck weights in Switzerland are lower than weight limits found in most of the rest of Europe.

A Swiss company, Kistler Instrumente AG, has developed a quartz-based, piezoelectric sensor that appears to have significant promise as an axle-weighing device. The team believes that it warrants further investigation by companies that sell WIM equipment in the United States and by State DOTs that are experiencing problems with WIM sensors that use piezoelectric cable.

In Switzerland, there is close cooperation among national traffic data collection efforts and those at the canton and municipal levels. The national highways office contracts directly with the canton governments for the collection of nationally required traffic data. This ensures that the canton highway agency knows which data are available from the National Government and that the necessary funding is available for collecting those data.

As in the rest of the continental countries visited, length-based vehicle classifications are used in Switzerland. Classifications are not, however, always consistent between the national and canton governments. The national highways office is currently investigating both equipment and classification schemes that could provide more robust and informative data by vehicle category.

In Bern, the Swiss are deploying an ATMS/ ATIS that stores traffic system performance data used for variable speed-limit control and as input to a variety of traffic information devices. Data supplied by the system will permit incremental improve-ments to system operation and provide long-term planning and evaluation information for all roads covered by the ATMS.

4.2 Introduction

The geographic location and topography of Switzerland, its density of population, and its long history of democratic government combine to provide a unique climate for transportation system development. Development has produced an environment for transportation decision making that is different from the rest of Europe and the United States and that affects the roadway travel data collected in the country.

Switzerland is a small, mountainous country that lies in the middle of Europe. It is both a destination of many European travelers and a thoroughfare for people and goods moving from France and Germany to Italy. The productive areas of Switzerland, 32,500 km^2 of land, are served by 71,000 km of roads and 5,400 km of railway lines. The 7.1 million inhabitants own 3.3 million cars, and 50 percent of Swiss people own bicycles. Each year, 60 million foreign vehicles enter the nation.

National road construction started in 1960 and 1,540 km of national roads have been completed. Another 142 km are under construction, and the planned total is 1,800 km. The majority of these roads (1,480 km) are or will be autobahns; the remainder will be semi-motorways. Roughly 40 percent of the road travel takes place on the national roads or on the 2,200 km of main roads.

The Swiss experience many of the same transport problems that other industrial countries do. Despite the dense development of the country and strong political support for walking, bicycling, and use of public transport, the rate of automobile ownership is growing. Traffic volumes and VDT continue to increase, although, since 1992, they have grown at a slower rate than in the previous 30 years. These factors have led to increased requirements for mitigating environmental problems caused by the existing roadway system, which, in turn, drive some of the changes occurring in the Swiss traffic data collection effort.

For example, some Swiss cities try to reduce the use of cars for commuting to work if a driver lives within a specified distance of public transportation access. This rule is enforced by preventing the traveler from obtaining a parking space within the city. Similarly, a national law states that people who live within 30 minutes of work by public transport may not deduct the cost of their cars (roughly $US0.50/km) from their national income taxes.

Two other political decisions play important roles in shaping the Swiss data collection process: The national road system often does not include bypasses around major cities, and most truck travel is prohibited at night.

In Swiss cities, main roads pass very close to houses, and the noise and pollution generated from traffic are major sources of public concern. The result has been national and local legislation designed to reduce traffic noise and vehicle emissions, an example of which is the nighttime truck-travel ban. New requirements have created a need for more detailed road usage information than is ordinarily required for traditional purposes, including more data on travel by vehicle type.

The national effort to deemphasize road travel is also apparent in the long-term goal to move as much freight and passenger traffic as possible by rail. This outlook has also affected the national planning process, in which, for example, the Swiss are encouraging the piggy backing of heavy vehicles on rail cars for transit through the country.

Trucks moved in this fashion are "through" vehicles carrying loads that are, by Swiss law, too heavy, but are legal outside of Switzerland. Such vehicles are placed on trains to traverse the country and continue their movement by road.

In Switzerland, heavy reliance on traditional forms of public transit, combined with urban population densities and urban designs that are compatible with walking and cycling, make ridesharing an idea that interests engineers. However, it currently attracts little political interest. The Swiss estimate that carpooling would divert riders from public transportation, thus decreasing operating revenues and increasing required subsidies. The Swiss are not, therefore, particularly interested in such data as average car occupancy that are needed to evaluate the success of ridesharing programs.

4.3 Organizational Responsibilities

The Swiss road system is divided into national roads, main roads, and municipal/ local roads. All roads are actually owned and operated by the 26 cantons (equivalent to states) or the 3,300 community government jurisdictions in which a road may lie. Functionally, the national roads are similar to the U.S. interstate system.

The Swiss Office of Federal Highways is part of the Department of Transportation, Communication, and Energy, which is one of seven Federal departments. The Office of Federal Highways is responsible for the Swiss national roadway system; however, the actual owners and operators of the network are the cantons in which the roads are located.

Specific national laws govern funding and operation of the national roads. National laws also govern the Federal contribution to the cantons for main roads. National funding for roads comes from a gasoline tax of about SFR1.00 per liter (slightly under US$4.00 per gallon). In addition, there are "stamp taxes" for cars that use the national road system and heavy-truck taxes. One-half of these funds is set aside for road transportation.

Funds pay for the construction, operation, and maintenance of the national roadways. For example, if a road were to be built, the contract for construction would be obtained from the canton, but the national highway office would have final approval of both technical and financial matters.

At the next lower level of roads in the country (main roads), the national level of responsibility is reduced, as is the national funding. The national share of the cost of main roads is determined through political negotiation that considers the national importance of specific main roads, along with a variety of other factors. At this level, the national highway office may decide only how much subsidy it will provide to the canton for each road. All other decisions are left to the canton.

Roads within the municipal category are funded, built, and operated at the expense of the jurisdiction that constructs the facilities.

Traffic-monitoring responsibilities are shared by national, canton, and municipal governments. The national highway office is responsible for collecting data on the national road system, but the actual data collection effort is conducted primarily with automated counters that are placed and maintained by canton staff or private contractors working for the cantons. Funding for these efforts is supplied by the National Government.

Cantons and municipalities are responsible for data collection on their own road systems. The national highway office does not require any specific traffic statistic reporting from these agencies, although the cantons periodically submit statistical summary reports to the National Government.

It is important to note that the Swiss have laws mandating the collection of data to meet environmental regulations, and the Government encourages the creation of data-collection guidelines produced by the national engineering society. Some laws call for other data collection efforts, such as the UNO counting program, various trans-Alpine traffic studies, and several modal-specific (air and rail) surveys.

Because of the lack of direct national guidance for data collection at the canton and municipal levels, some cantons operate extensive and sophisticated traffic-counting programs, while others collect very little traffic data. A mixture of public and private staff are involved in the data collection efforts. Such differences are not important to the National Government, which is primarily interested in the national roadways and uses its own collection stations to obtain data.

4.4 Counting Program

Travel data are collected at several levels among the Swiss highway agencies. Because, as noted above, the National Government does not provide specific mandates, traffic data collection programs differ by canton and by urban area. This section explains the differences by categorizing the traffic-counting programs by type of government agency.

4.4.1 National Traffic Data Collection

The national highway office performs several routine, ongoing monitoring activities for traffic data. These include the following:

- Operation of permanent traffic data collection sites, called the "Automatische Verkehrszählung"

- Collection of geographically distributed short-duration counts as part of the U.N. travel-monitoring effort (the UNO counts)

- Implementation of special-purpose count programs, such as monitoring of freight traffic through the Alpine tunnels leading to Italy.

In addition, special project counts are conducted, as needed, to meet project-specific data collection needs.

The primary traffic-counting program funded by the National Government includes about 200 permanent counting stations. These data collection sites use loop detectors to provide hourly traffic volume data. Between 30 and 40 of these sites have dual loop detectors that also provide data on vehicle volumes by vehicle category.

The Swiss national highway agency categorizes vehicles into four types, according to length. These categories are as follows:

- <2.7 m
- 2.7–6 m
- 6–12.5 m
- >12.5 m

The first category (<2.7 m) is meant for motorcycles, but does not work very well. Compared to other vehicles, motorcycles have a low metal content, and riders tend to change lanes often. The remaining categories can be associated with cars, delivery vans, trucks, and articulated combination trucks. Although the dual loop detectors can also measure speed, such measurement is not done routinely and must be conducted as a special study.

In Switzerland, it has been determined that limited data collection categories restrict the ability to monitor and predict some important traffic characteristics. Consequently, a consultant has been contracted to examine the data collection categories and the associated equipment. The consultant will recommend whether the categories and equipment should be changed to meet the changing data collection needs.

The national highway office specifies the equipment to be purchased and used at the 200 permanent sites. Cantons are responsible for purchasing and maintaining the equipment. They are reimbursed by the national highway office for those expenses, but installation costs are the responsibility of the canton. This process was implemented to enable the national highways office to maintain a single source (its central PC) for traffic data collection. Data from the national data collection sites are readily available to all national, canton, and municipal agencies.

Reimbursement for equipment costs takes about one month. The law that created the national roads specifies that the National Government and the cantons must set aside funding to pay for the national road network. Cantons are free to purchase and use equipment from other manufacturers for their own count locations, but not at the national data collection sites.

The Swiss Federal Government does have several other permanent traffic-monitoring systems, primarily to provide operation control for such facilities as the trans-Alpine tunnels. These systems currently do not store the traffic data collected and, thus, are not part of the Federal data collection effort. The philosophy that leads to discarding these data is beginning to change because of the desire to reduce costs through resource sharing. The result of this change in attitude can be seen in the design of the Canton of Bern's ATMS system, which is discussed in Section 4.7.

The Swiss participate in the EU program that counts vehicles every 5 years to measure national and international road travel. These counts, the "UNO" counts, are performed manually. Other techniques for collecting the UNO sample have been considered; however, the Swiss are not satisfied with the vehicle classes that other techniques obtain. In Switzerland, it is necessary to distinguish between foreign and internal traffic, so the use of manual techniques is continued.

For the most recent UNO data collection effort, 470 locations were counted on 5 different days in the year. Each day's count consisted of several short-count periods that totaled 6 hours per day on workdays and 4 hours per day on Sundays. This is a reduction from the 17 hours that had been used for previous UNO census efforts. Two thousand people were hired to measure the multiple lanes and directions at these 470 count locations.

To compute AADT values from the collected short-duration counts, the Swiss apply factors based on data from the national permanent count stations. Factors for each site are based on a cluster analysis that uses data from the different short-duration counts and the permanent sites.

Data collected in the UNO effort include vehicle volumes and classifications by hour, as well as the split between foreign- and Swiss-registered vehicles. UNO counts classify vehicles into six categories, which are as follows:

- Motorbikes
- Cars
- Delivery vans (<3.5 tons)
- Single-unit trucks
- Combinations
- Coaches (buses)

About 80 percent of the count locations are the same as those counted in the last UNO census; the remainder are new locations.

Along with the Swiss Federal Government and the participating European governments, the cantons have some input in the sample design for the UNO study. Cantons are also responsible for supplying the field staff and 50 percent of the funding required to collect the UNO data. This results in the use of a variety of different data collection devices, ranging from paper forms to more modern handheld counting devices. Editing and planning of the UNO counts is usually conducted by a private firm.

As an example of a special-project counting effort, the Swiss briefly described to the scanning team the data collection for a recurring trans-Alpine freight study. The data collected are compiled from a series of driver interviews that include the following information:

- Origin/destination
- Border-crossing point
- GVW
- Empty vehicle weight
- Loaded weight
- Type of vehicle
- Commodity

For this study, the Swiss do not actually weigh vehicles but determine loaded weight by reading the bill of lading carried on the vehicle. The national office is trying to decrease the number of trained individuals required to conduct this study. In the future, trained individuals will be moved from site to site and the data collection effort will be extended over a longer period. Previously, many temporary laborers were used, and counting took place on a limited number of days.

The national highway office also operates several real-time traffic-monitoring systems, such as the monitoring system for the trans-Alpine tunnels. These systems collect traffic data, but the information is not currently being stored and used in the national highway office.

4.4.2 Canton Data Collection

Information was obtained by the scanning team on data collection performed in the Cantons of Zurich and Bern. Both cantons contain large cities and conduct relatively extensive traffic-monitoring efforts. In both cases, the canton data collection effort is separate from, but carefully coordinated with, the national data collection effort. This is relatively easy to do, because the cantons physically conduct the national traffic data collection.

4.4.2.1 Zurich

Initial data collection resources are the nationally funded permanent count locations. In Zurich, traffic data are routinely collected at 270 measuring points, 22 of which are nationally funded, permanent count locations. To count the remaining 248 locations, the canton owns 30 sets of electronic data collection equipment. The electronics are moved from site to site and connected to loops embedded in the ground. Counters are left at each location for a minimum of 2 weeks each year, and data are collected all year, because existing loops allow data collection under all weather conditions. Where data are needed for a specific purpose, data collection electronics may be left for up to a full year.

The Zurich data collection devices normally use dual inductance loop sensors to collect data in three vehicle-length categories:

- <5 m
- 5–8 m
- >8 m

These correspond roughly to cars, delivery vehicles, and larger trucks. Note that the vehicle-length classes differ from those used by the National Government, so the two data sets are not truly comparable.

The short-duration counts are adjusted to estimate annual average conditions. Sites at which short-duration counts are taken are assigned to one of the following six factor groups, on the basis of 1 week of hourly traffic counts:

- Long-distance traffic
- Long-distance, with commuter traffic
- Commuter roads
- Local traffic
- Regional traffic
- Recreational traffic

Adjustment factors for each category are obtained from a combination of the canton's and Federal highway office's permanent data collection devices.

Traffic volume data are also obtained from the loop detectors that are used to operate the city's traffic signal system. However, an engineering review of the detectors indicated that they undercounted traffic; consequently, the city installed additional detectors to provide more accurate counts.

Although the national data play an important role in the canton data collection and analysis process, the results of canton-specific traffic collection are not routinely uploaded to the national highway office. That office is not usually concerned with traffic on non-national roads.

The canton supplements the data collection described above with a variety of special-purpose studies, project counts, and traffic-flow predictions from its urban modeling system. Data collected through the counting program are used to calibrate and validate urban traffic models, which are then used to forecast traffic estimates and expand them to other roads and periods.

The canton performs a microcensus every 4 years to provide additional travel details for both modeling efforts and general planning activities. The microcensus includes questions about the number of trips made and the length, timing, and mode of travel. It is also an important source of information for calibrating the model's estimates of travel times for particular trip segments. These segments are as follows:

- Home to expressway/major arterial
- Expressway to city street
- City street to parking
- Parking to office

In Zurich, travel diary information is also being collected to compute the circulation time leading to or from the main roadway system, so that the centroid connector time in its model will be correct. Zurich also performs special studies of bicycle and pedestrian traffic, which are done manually, often in concert with the national railways.

Special effort is made to monitor traffic flowing into and out of the city, as well as the volume of traffic flowing tangentially to the main radial routes to and from downtown Zurich. Numbers of vehicles crossing the river bridges are also monitored. These efforts help legislators and planners determine the success of policies designed to encourage more efficient land use and transportation interaction and to reduce negative environmental impact from transportation sources.

Zurich has experienced the effects of suburbanization, as have most urban areas in modern industrialized nations. The political response has been to adopt policies that encourage the use of public transit and decrease the use of cars. In many respects, these policies have succeeded, although Swiss car ownership has grown faster than the population.

4.4.2.2 Bern

The traffic-counting program in Bern is similar in many ways to that of Zurich. The permanent national count locations are supplemented by count locations that meet specific canton requirements. The canton collects data for annual, 2-week, or shorter periods (depending on specific needs) at a number of fixed count locations. These data are used to both calibrate and validate the EMME II traffic-forecasting model and are supplemented by the output of that model. EMME II is used to predict the effectiveness of various traffic control strategies.

As in Zurich, the staff in Bern conduct many special traffic data collection efforts to provide the data necessary to meet policy needs. Special efforts include the collection of selected bicycle and pedestrian movements (counted by hand), as well as congestion and queue studies.

A major difference between Bern and Zurich is that Bern is developing and implementing an ATMS/ATIS. This system collects traffic performance data, determines where and when speed limits on the monitored facilities should be changed, and makes those changes with visual message signs or signals.

Data from the traffic detection system are stored in a data base for later use by Bern highway agency staff. The system stores traffic volumes (by trucks and cars), speeds, and lane occupancy information. Bern staff can also access some traffic volume information stored by the central traffic control system, which controls between 30 to 40 of Bern's 120 signals.

When asked by the scanning team how congestion was measured, officials indicated that measures varied from study to study to fit the policy goals that a subject system was intended to achieve. For example, the Swiss have adopted the traffic signal policy of "gating" traffic. That is, the signal system is used to maintain traffic flow in some areas by purposely preventing cars from entering the area. This creates longer queues and delays in some geographic areas, while other areas are able to flow freely. In such instances, simple congestion measures, such as queue length, are not satisfactory measures of the true intent of the gating system.

4.5 Equipment

4.5.1 Data Collection Systems

As in much of the rest of Europe, loop detectors are used in Switzerland for most traffic data collection. Although the detector failure rates are higher than those mentioned in Germany, the Netherlands, and France, error rates are still lower than those commonly found in the United States. The exception to this is in Zurich, where a special study recommended specific detector changes and placements to improve the reliability of the data collection equipment. The changes appear to be necessary mainly because of detector placement in an urban traffic-signal environment, rather than because of actual limitations in the detectors themselves.

Because of the low rate of loop detector failure and because the data provided are reliable and meet the needs of users, the Swiss have little need for more sophisticated data collection. They are not strongly motivated to test and adopt new data collection technologies. For example, they are not experimenting with video, radar, or sonic-based vehicle detectors.

The Swiss national highways office reported that typically about 5 of its 200 sites are inoperable at a particular time. The most common causes of failure are related to breakdowns of the telecommunication system. The second biggest problem is clock timing, that is, the system's inability to keep time accurately. The Swiss also reported experiencing loop failures, now that loops have been in the ground for 10 years. It was reported to the scanning team that 75 percent of the counters miss roughly 3 percent of the traffic passing over the detector. Another 15 percent of the equipment has error rates below 9 percent, and the remaining sites have error rates above 9 percent. A copy of the equipment specifications for the Swiss loops has been requested and will be translated into English by FHWA.

Equipment acceptance testing is performed manually by comparing visual observations with reported vehicle counts and classifications and by using video recordings for subsequent analysis and confirmation of equipment performance. The test itself usually lasts 6 to 8 hours, and data are collected over the course of 5 days.

Calibration and maintenance leaflets are given to the cantons by the national highways office for national equipment.

4.5.2 Vehicle Classification Technology

As in the rest of the continental countries that the scanning team visited, in Switzerland, there is interest in improving truck volume and classification information. Little interest was expressed in expanding the existing number of data collection points, but increasing and improving the vehicle classification data that can be obtained from the 200 permanent data collection points is desirable.

To help achieve these goals, the National Government contracted with a consultant to examine the current potential for automated vehicle classification monitoring. The consultant is studying profiles of loop inductance, vehicle, axle, and weight. One of the preliminary findings corroborated the results of a Canadian attempt to create a vehicle classification scheme. That is, too many trucks of different characteristics have similar profiles in terms of pavement damage exerted, acceleration, deceleration, and turning movements. This finding seems to limit the "accuracy" of most of the available classification technologies, but the Swiss have not yet generated final conclusions on this project.

4.5.3 WIM Systems

WIM equipment is not routinely used for data collection at either the national or canton levels. The Swiss do have an old PAT WIM site, but it has not been reliable and is not regularly used. In addition, there are also a number of systems installed at the ETH test facility in Hagenholz, near Zurich.

The Swiss are active participants in the COST 323 effort and are likely to embrace WIM systems once such systems have been demonstrated to operate more effectively. Toward that end, Kistler Instrumente's new quartz-based, piezoelectric sensor is being examined.

According to product information given to the scanning team by Kistler, the sensor has several advantages over the piezoelectric ceramic cable sensors currently marketed in the United States. The advantages of the sensor include the following:

- It is not temperature sensitive. (Significant problems with adjustments for temperature sensitivity have been reported by several States that use piezoelectric ceramic cables.)
- It can be statically calibrated in the field.
- It is directional and, thus, is not affected by horizontal stresses induced in the road surface.
- It is a true pressure sensor, unlike a stress/strain sensor that must either account for differences in strain caused by various pavement conditions or be separated from the roadway through some type of external frame.

Initial results from the Hagenholz test site are shown in Figure 4. The sensor appears to warrant additional review by the U.S. WIM community, but until that takes place, it is not possible to state whether the sensor actually provides better or more cost-effective axle weight information than technologies currently used in the United States.

4.6 Data Analysis and Validation

To factor a short-duration count to estimate average annual conditions, Zurich uses a week of traffic data (with hourly distributions) to help define the road category that is used for selecting the appropriate factor. Selection criteria are based on the day-of-week and hour-of-day patterns observed during the 2-week data collection period. Professional judgment is then used to match the patterns to specific permanent counting locations nearby.

At the national level, two sets of data validation checks are conducted. The first is a simple check to determine whether the telemetry system functioned correctly. The second set examines the submitted records and marks as questionable the records that exhibit any of the following characteristics:

- Zero volumes or other errors in the hourly records.
- Unexpectedly high volumes (by direction) in the hourly records.
- Hourly volumes, by day, that exceed a maximum percentile.
- Variation in the ratio of 14-hour volumes to 24-hour volumes (14 hours from 6 am to 8 pm) for weekdays.

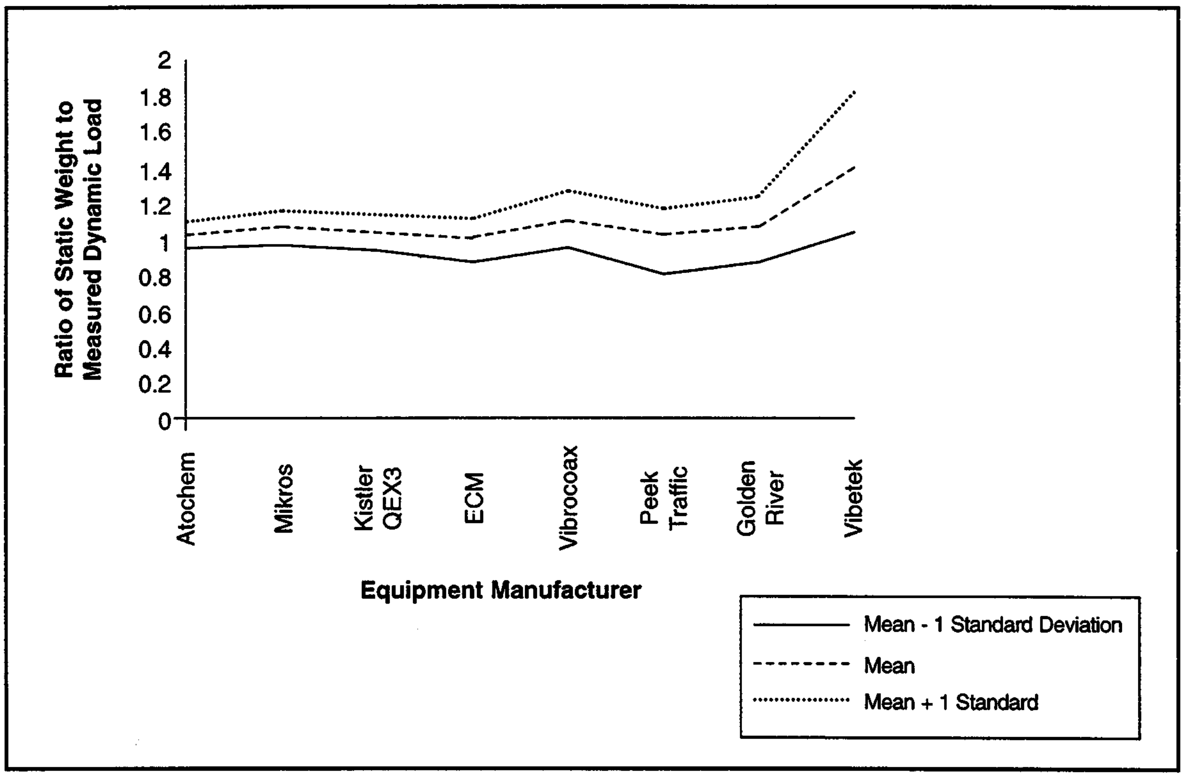


Figure 4. Initial Results of the Hagenholz WIM Tests[4]

- Variation in the ratio of 5-hour volumes to 14-hour volumes (5 hours from 3 pm to 8 pm) per weekday.
- Variation in the directional distribution.

The Zurich data validation effort is based heavily on judgment—when staff members set up the counter, they briefly monitor its performance. Analysts review the data to ensure that the count makes sense, given the location, but there is no formal review algorithm. Note that by using permanent loop installations instead of portable road tubes, the Swiss are much less likely to have a vehicle sensor fail during a short count.

[4]E. Doupal and M. Caprez, "European Test of WIM Systems in Switzerland," post proceedings of the First European Conference on Weigh-in-Motion of Road Vehicles, pp. 189-207, March 1995.

Loop failure is more likely to occur between counts and should be detected when the electronics are initially connected and tested.

The scanning team did not obtain information on Bern's data validation process.

4.7 ITS

The Swiss are also working on an ATMS/ ATIS in Bern that is similar to the one being implemented in Germany. Referred to as "VBS" (VerkehrsBeeinflussungsSystem), the system is operating on the N1 in Grauholz. VBS is a variable-speed and lane-control system that has motorist information and data collection components. Central control of the system is located in the police building of the Canton of Bern, because the police are responsible for con-trolling the roads. In addition, the highway authority is a major partner in the system's design, construction, implementation, and operation.

Although VBS was not scheduled for completion until July 1996, the scanning team was able to observe it in operation, using real-time information. After implementation, a 2-year evaluation period will monitor the performance of the system. If it performs favorably, funding will be sought to expand it. Initial funding has been supplied by the canton, because the system is viewed as primarily local. Canton officials have, however, argued that they cannot manage the street system without being able to manage the national motorway system that is within the city. Furthermore, because a part of this effort is on the national road system, the National Government should assist with costs.

The impetus behind this system has been the desire to increase mobility in the region without new highway construction and with a minimum of negative environmental impact. VBS appears to be an effective means of achieving these goals.

The specific goals of VBS are to:

- Increase capacity.
- Improve safety.
- Reduce environmental problems.
- Give police a modern traffic signal system.
- Provide a more economic means of improving mobility for the region.

VBS includes the following features:

- Real-time traffic data collection.
- Automated decision making for variable speed-limit controls.
- Automated selection of variable speed limits.
- Optional human override of automated speed-limit selection.
- Transmission of both messages and collected data between the roadside and central computers.
- Data analysis tools for planning and operational purposes.

No human interface is required for basic sign control. The system does, however, permit easy observation of current conditions via a number of graphic displays. It also allows operators to override automated control decisions.

VBS collects data on volumes, speeds, and lane occupancy and aggregates the data at

30-second intervals. It also computes segment statistics for routine facility performance reporting. In another interesting application, police are using the system to reconstruct traffic conditions (e.g., volume, speed, legal speed limit) that existed before recorded accidents, as part of the accident investigation process.

Control decisions are based on volume, speed, and occupancy data. Researchers in Bern have developed a graphic that uses color to indicate the appropriate range of operating conditions for each volume, speed, and lane-occupancy condition. Thus, when the operating conditions degenerate to particular levels, a specific set of speed limit and variable messages is posted immediately. The process is dynamic—speed limits may change several times each hour as traffic congestion levels change.

The system architecture follows the traditional architecture of distributed master traffic signal systems. Figure 5 illustrates its basic concepts. The system includes local control and a hierarchical network connection from each site to the central computer. Total investment is SFR8 million (about US$6.6 million).

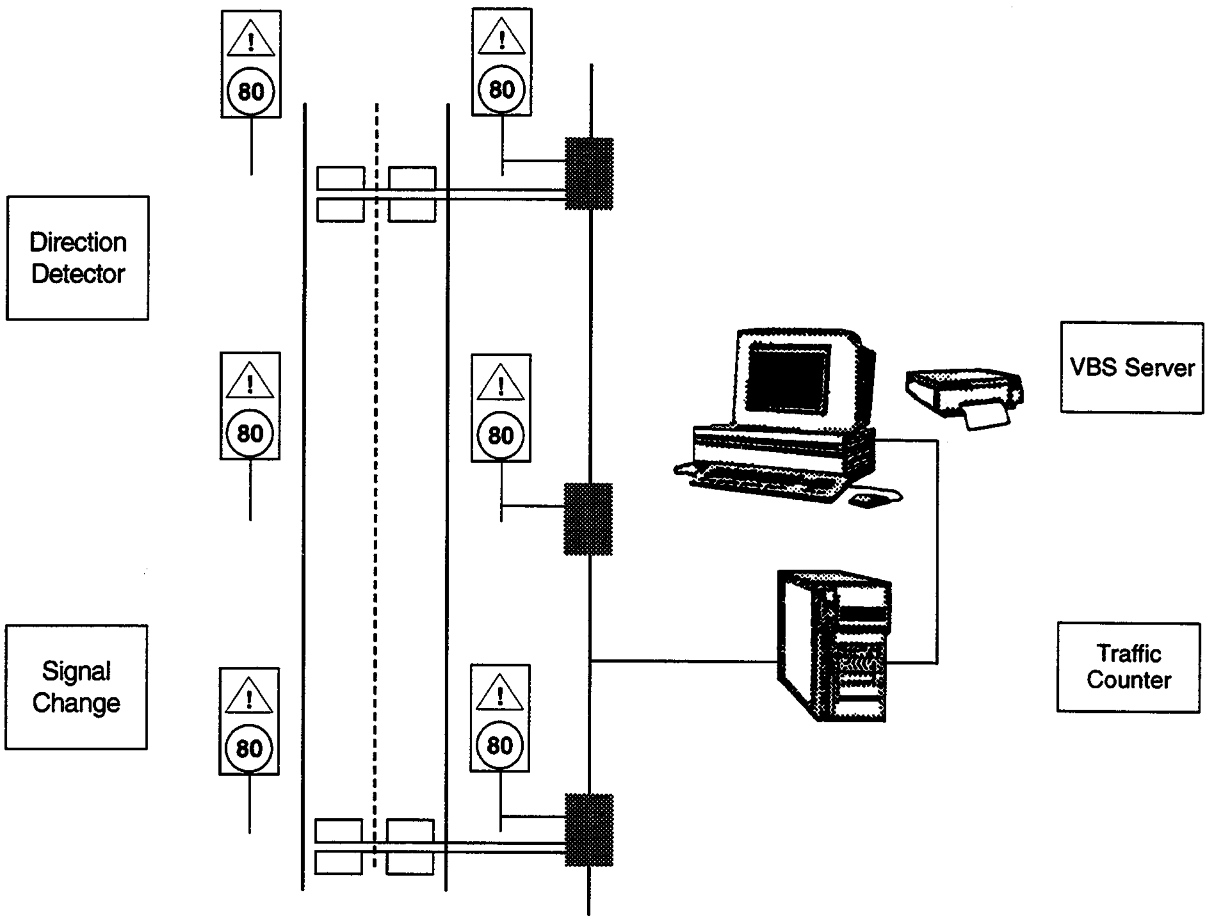


Figure 5. Basic Architecture of the Bern ATMS

5.0 FRANCE

5.1 Summary Points

Organizational responsibilities are strongly split in France. The National Government controls and collects data on the national road system, and the regional and local jurisdictions control and collect data on the remaining roads.

The French have developed a system of electronics to collect data both for real-time traffic monitoring and for lower priority (not real-time) planning. The equipment is known as Systéme Informatisé de Recueil de Données, or SIREDO. Because the same type of equipment collects both kinds of data, the French are able to collect, store, and use most of the data that traffic-monitoring systems collect, thereby significantly reducing the need for more traditional data collection devices.

French national agencies work together to share facilities and data, and cooperate on roadway operations. Much of the cooperation has resulted from the need to manage the very high traffic volumes and congestion that occur during vacation movements at the beginning and end of August.

France is a major influence in the development and conduct of WIM research in Europe. It participates in three separate but related EU research efforts, COST 323, DIVINE, and WAVE.

The French are also particularly active in collecting and using traffic information for motorist information and facility management. Two types of ATMS/ATIS are used: one for routinely congested urban roads and one for rural roads that are subject to extreme recreational loadings. Several systems are in full operation, although enhancements will continue to be made.

5.2 Introduction

France has 58 million people in 551,000 km^2 of land. The road system includes 35,000 km of national roads, 350,000 km of departmental roads, and 560,000 km of other roads. The road system carries 90 percent of all passenger travel and 70 percent of all freight travel in the country. About 50 percent of roadway travel is on the national road system.

The National Government is increasingly concerned about the nation's mobility. This concern is generated by growing urban congestion and increases in international travel. Studies have shown that international traffic is growing much faster than traffic generated from within France. As a result, the French are increasingly concerned with trip origins, destinations, and purposes.

5.3 Organizational Responsibilities

There are four levels of government in France: the National Government, 22 regions (provinces), 100 departments (equivalent to U.S. counties), and 36,400 communities. There are two primary domains of responsibility for traffic monitoring, the National Government and the local governments, which encompass all three lower levels of government. In addition, there are eight tollway authorities, each of which is responsible for the construction, operation, and maintenance of its own facility.

Under the National Government, roadways fall under the jurisdiction of the Ministry of Transport, within which are seven administrations. Three of these, the Highway Administration, the Traffic and Safety Administration, and the Surface Transportation Administration, conduct some form of traffic data collection, although most data are collected by the Highway Administration and the Traffic and Safety Administration. The Surface Administration is primarily concerned with transportation of goods and, therefore, is interested in WIM technology.

The administrations are aided by several technical institutes and laboratories supported by the Government. These include the following:

- Laboratoire Central des Ponts et Chaussées (LCPC), comparable to FHWA's Turner-Fairbank Highway Research Center.
- Service d'Études Techniques des Routes et Autoroutes (SETRA), which conducts applications research.
- Centre d'Études sur les Réseaux et les Transport l'Urbanisme (CERTU), which is focused on public planning.
- Centre d'Étude des Tunnels (CETU), which studies tunnels.
- Seven regional information centers.
- Seventeen laboratories.

In addition to research, these organizations conduct a significant amount of data collection, analysis, and reporting for the National Government, and direct some of the work performed for the Highway and Traffic and Safety Administrations.

The seven regional information centers are unique in that their offices are shared by three different ministries, the Ministry of Transportation, the Ministry of Police, and the Ministry of Defense. The regional centers are the primary operational control points for the annual vacation movement to southern France. The three ministries work together, because limitations of each ministry's authority prevent any one agency from maintaining operational control during the vacation movements. For example, the police may not work outside of towns, and the gendarme (military police) may not work in towns. Similarly, until last year, soldiers could work "off hours," but civil servants could not.

In addition, the Transport Ministry has 22 regional offices and 100 field offices, 1 per department. Unlike the other European countries that the scanning team visited, in France, the regional offices do not operate the national highway system. Instead, their role is to distribute funds to the departments in a manner that helps the departments meet national goals most effectively.

All traffic data for national purposes are collected by these agencies, by a private contractor for one of these agencies, or by one of the lower levels of government, at the National Government's request.

In France, local jurisdictions are not required to collect data for or transmit data to the National Government. This gives local governments the freedom to design and operate data collection efforts in the manner that best meets their needs. A local government may provide data to a national agency if requested, but is not compelled to do so. Local data collection tasks are, therefore, funded by the local jurisdictions, which may conduct their own counts or contract them to the national field offices.

Each toll road company performs its own data collection, both for toll collection and for operation and maintenance purposes.

Each of the three ministries has a different set of primary goals with respect to the roadway system. The Highway Administration is responsible for the following:

- Consistency of the road infrastructure
- Establishment of standards and modernization of the road network
- Coordination of the departments' work on the road network
- Management of toll road concessions.

The Traffic and Safety Administration's three main goals are to:

- Build, monitor, and manage roads so that they operate more safely
- Establish technical specifications for vehicles, such as safety belt and drunk-driving regulations
- Issue licenses for drivers and vehicles.

The Surface Transportation Administration is concerned with freight movement, including the following aspects:

- Hours a driver spends behind the wheel of a truck
- Establishment and enforcement of weight laws
- Other factors that help ensure fair competition among trucking companies and between trucking companies and other modes of freight shipment.

Although the Traffic and Safety Administration is primarily responsible for heavy-vehicle data collection, the Surface Transportation Administration is also interested in WIM data collection, both to improve the efficiency of static scale operations and to provide information on the extent of vehicle weights that are over legal limits.

One significant difference between the Highway Administration and the Traffic and Safety Administration is that the Highway Administration must deal with only the national roads, whereas the Traffic and Safety Administration is responsible for reporting on and appraising the safety of all road networks in France. Not surprisingly, given the lack of incentive to provide the National Government with roadway use data, the safety statistics on the local road net-works are less complete than the national roadway statistics.

5.4 Counting Program

The national counting program involves the collection of data on the national roadway network only. It includes both real-time operational data and summary data for planning, engineering, and other needs. The national effort has three main components:

- National traffic evolution index
- Permanent traffic census
- National traffic composition study

All three use data collected from the same set of permanent data collection locations, although the census counts require additional data. The same permanent locations provide real-time data for motorist information and roadway operational control.

The National Government maintains 1,200 permanent data-collection sites. The sites were selected on the bases of statistical considerations and "homogeneous" situations. Homogeneous sections are bounded by major intersections and/or cities of greater than 10,000 inhabitants.

5.4.1 National Traffic Evolution Index

The national traffic evolution index uses data collected at 265 locations—137 on the national routes, 71 on other freeways, and 57 on toll roads. Equipment at these locations provides daily traffic volumes, which are used in combination with the number of lanes at that location to compute a congestion index. An accident rate for each location is also computed, as are a number of other statistics.

The traffic census collects data on 5,000 road sections. Just over 1,000 of these points are monitored permanently, while the other 4,000 sites are monitored 4 times every 2 years. Each monitoring session covers 1 week and is taken from one of four periods:

- February through April
- May, June, or September
- July through August
- October through December

Random weeks are selected for each counting period, and data are then factored to estimate average annual conditions. Factors are chosen on the basis of a cluster analysis technique in which the patterns observed in the four week-long counts are compared with similar data taken from permanent count locations. French officials indicated that this technique yields annual traffic estimates that are accurate to within 4 to10 percent.

5.4.2 National Traffic Composition Study (National Traffic Sounding)

The national traffic composition study is done every 5 years as part of a U.N. effort to monitor and report European travel. Its primary intent is to estimate heavy vehicle use by origin; that is, French versus non-French trucks. Traditionally, data for this count program have been collected manually. For the latest count effort, however, the French used SIREDO traffic-monitoring stations, supplemented by a limited sample of manual counts, to provide country-of-origin data.

SIREDO stations collect two types of vehicle classification data. For the first, 460 SIREDO sensors connect to axle sensors and classify vehicles into 14 vehicle categories. For this study, the categories are further reduced to seven classes (cars, light trucks, buses, three-axle trucks, four-axle trucks, five-axle trucks, and six-axle or more trucks). Another 550 SIREDO stations collect four length-based classifications. These data are then expanded to the seven reporting categories by using a cluster analysis that correlates length classes to proportions of vehicles within the seven axle classes.

In addition to the SIREDO counts, 270 locations are manually counted for twelve 1-hour periods in both directions to provide information on the number of vehicles by country of origin; i.e., the country that issues the license plate.

5.4.3 Other Planning Data Collection

The French are also interested in the amount of interurban travel. Simple but effective measurement of "out-of-region" travel is conducted by observing vehicle license plates. Each French license plate contains a two-digit code for the department in which that vehicle is registered. Observing the numbers provides a quick and fairly accurate measure of the percentage of traffic at a location that is local and the percentage from outside the region.

5.4.4 Operational Data Collection

For operational purposes, real-time data are required for urban control and driver information systems and for the rural operation and motorist information systems developed to handle the large vacation movements that occur in August. A large proportion of the French population takes summer vacations from 1–28 August. On 1 August, the traffic heading to the south is routinely 2.5 times normal volumes.

Over the years, the French have developed a sophisticated motorist information system for managing this predictable, but massive, traffic flux. The system, called Bison Futé ("Wise Buffalo"), includes a variety of printed materials, such as maps showing alternative route choices and brochures indicating when the heaviest travel days are expected. The system also includes enroute motorist information from variable message signs, media outlets, and special highway radio systems that broadcast traffic information to users of specific roadways.

A large amount of real-time data, primarily volumes and speeds, are collected by the SIREDO systems and transmitted to the seven regional control centers. The centers process the data and make decisions concerning roadway operations. They also provide specialized traffic information broadcasts (e.g., via the French Minitel system and special traffic radio frequencies) and give commercial radio and television stations updates on traffic conditions. To facilitate the broadcasts, radio stations have complete broadcast facilities in the regional centers.

5.5 Equipment

5.5.1 Volume and Classification Equipment

SIREDO is the French standard data collection system, which can accomplish a number of data collection tasks, depending on the sensors and communication facilities to which it is attached. SIREDO stations can operate as real-time data collection devices, much like a U.S. 170-type controller, and can operate as long-term volume counters, similar to ATRs. Central software, called MELODIE, downloads and manages the data collected by SIREDO stations and provides the mechanism for changing the parameters that control how each station operates (i.e., at what level to aggregate data, when and how to report the data).

SIREDO can be attached to loop detectors or axle sensors. Dual loop detectors are required to provide accurate vehicle speed measurements. Installations are also capable of collecting volume information by multiple vehicle-length classifications. Two loops and a single piezo-cable axle sensor are needed for axle-based length classifications. SIREDO stations can also be outfitted with the necessary electronics to perform as WIM stations, by using two piezoelectric-cable sensors as inputs. Each station can be connected to up to eight sensors. Figure 6 illustrates the axle-based classification scheme developed for SIREDO.

SIREDO was developed in the late 1980's, and national implementation started in 1991. Implementation was completed in 1996, at a cost of US$20 million. The cost includes the purchase and installation of 1,200 stations on portions of the national road system, managed by the National Government, and another 800 stations for locations under non-national control. These 2,000 sites have a variety of sensor configurations; the selection configuration for any one site depends on the importance of speed and classification data at that site. Some sites report traffic conditions in near real time (i.e., 10 seconds between transmissions from a location), whereas others report data only when called via modem. The basic SIREDO station now costs about US$12,000 installed.

SIREDO was developed to take the place of the multiple types, styles, and models of data collection electronics used in France before the early 1990's. The Government wanted a system that would be standardized, automatic, capable of providing the necessary information, and available to any jurisdiction in the country.

The system can be powered by alternating current, solar cells, or, for a limited time, batteries. The standard station communicates through three separate ports using conventional telephone, wireless, or computer-to-computer communication via RS-232 ports. Communication types depend on the modems connected to the roadside electronics.

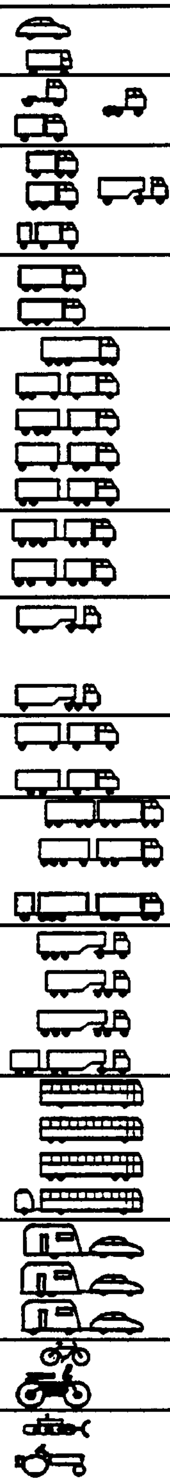
Data can be transmitted in near real time or aggregated and stored on site for later transmission. Standard programs are resident in the station to store data at 1-minute, 6-minute, hourly, and daily levels, depending on the level of data aggregation desired. The daily level requires the least storage but the longest transmission time, and it is often all that is necessary for most days of the year at many locations.

Three French companies, Lacroix Technologie, Sofrela, and Sterela, manufacture SIREDO equipment. Electronic components from one of the manufacturers are interchangeable with the same components from the other two. This arrangement eliminates problems with single-source equipment suppliers and ensures competitive pricing.

Individual SIREDO stations are interrogated by a regional concentrator located at the regional operation office. Each concentrator interrogates more than 100 stations. The concentrators are also interconnected, so that once a user is connected to the system, data can be obtained from any SIREDO site in the country. Users can either extract data directly from the local site or from a concentrator, which can, in turn, extract data from a different concentrator to provide data from a remote site. Figure 7 shows the basic SIREDO system architecture.

SYSTEME INFORMATISE DE RECUEIL DE DONNEES

SIREDO



Configurations Used in the Siredo Classification / Silhouettes Utilisees Dans La Classification Siredo		
1	Light Vehicle or Van	VL our Fourgon
2	2-axle Truck 3-axle Truck	Camion 2 essieux ou Tracteur 3 essieux
3	2-axle Tractor and 1-axle Trailer 3-axle Truck	Tracteur 2 essieux et Remorque 1 essieu Camion 3 essiux
4	4-axle Truck	Camion 4 essiuex
5	5-axle Truck 2- or 3-axle Truck and 2- or 3-axle Trailer	Camion 5 essiuex Camion 2 ou 3 essieux et Remorque 2 ou 3 essieux
6	3-axle Truck and 3-axle Trailer	Camion 3 essieux et Camion 3 essieux
7	2-axle Tractor and 2-axle Trailer 3-axle Tractor and 1-axle Trailer	Tracteur 2 essieux et Remorque 2 essieux Traceur 3 essieux et Remorque 1 essieux
8	2-axle Truck and 2-axle Trailer	Camion 2 essieux et Remorque 2 essieux
9	4-axle Truck 4-axle Trailer 8 axles and up	Camion 4 essieux et Remorque 4 essieux 8 essieux et plus
10	2- or 3-axle Tractor 2- or 3-axle Trailer	Tracteur 2 ou 3 essieux et Remorque 2 ou 3 essieux
11	Bus	Bus
12	Light Vehicle and Trailer	VL et Remorque
13	2 wheelers	2 roues
14	Public Works Vehicle or Farm Vehicle	Engin de chantier our agricle

Figure 6. SIREDO Vehicle Classification Scheme

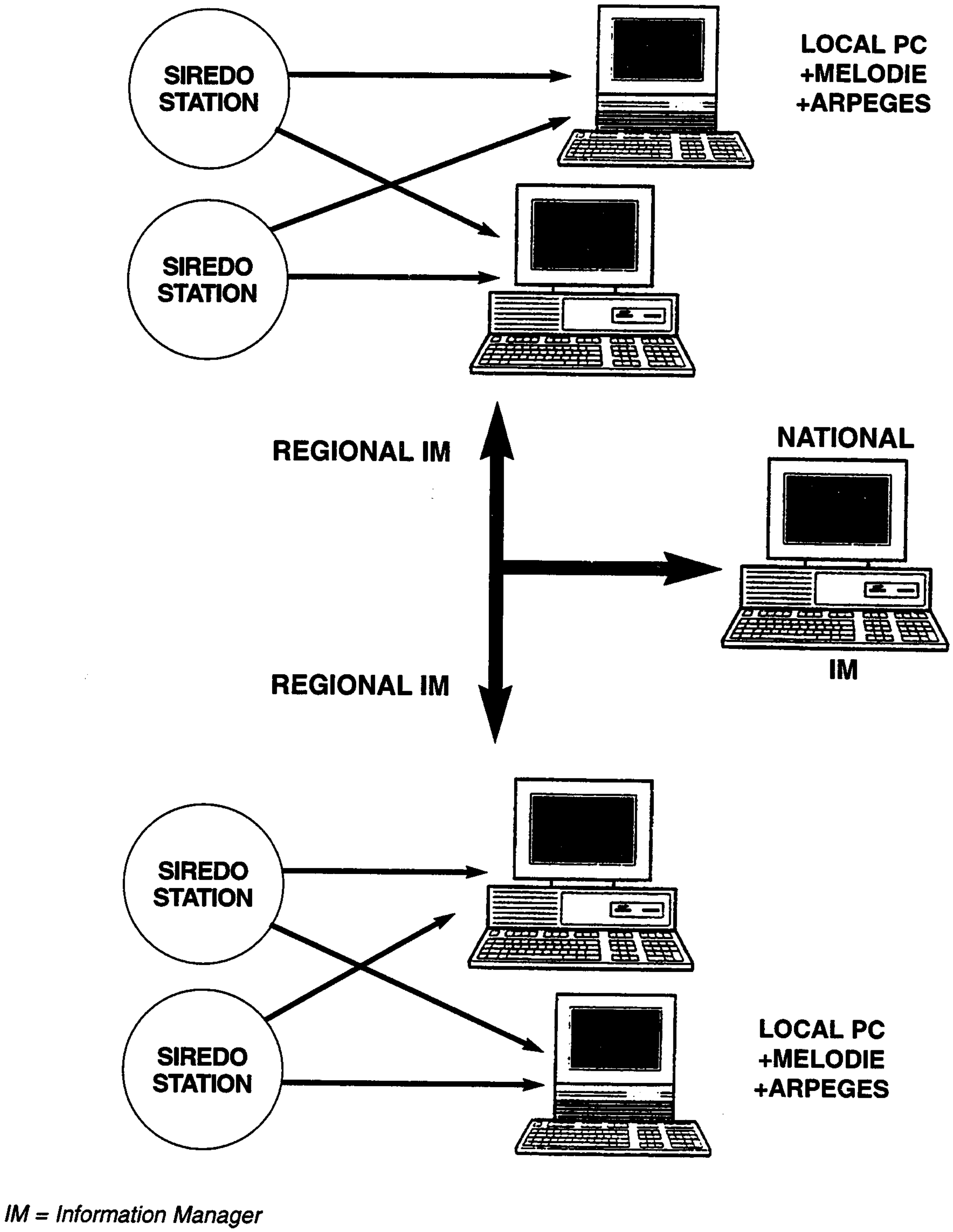


Figure 7. SIREDO System Architecture

5.5.2 WIM Systems

The French are researching WIM equipment and showed the scanning team both the DIVINE project test site and a new, light-weight static scale that can be used for roadside enforcement. In addition, the French are participating in the COST 323 and the WAVE WIM test efforts.

COST 323 is not so much a research program as an organized data-sharing effort, under the European Commission DG VII group. The program also obtains direction from the 18-member body of the Forum of European Highway Research Laboratories.

The objectives of COST 323 are to promote development and implementation of WIM technologies and applications and to facilitate the exchange of information about experiences with WIM equipment among European countries. To date, COST 323 is creating a pan-European WIM purchase specification, building a data base that will list the WIM sites operating in Europe, and publishing a glossary of WIM terms translated into seven languages. (Countries with different native languages that subsequently join COST will be asked to add their translations of the glossary to the COST document.) COST is also creating a report that describes each COST country's WIM requirements. The program sponsored the First European Weigh-in-Motion Conference, at which the Swiss tests of four WIM systems and four new sensors were first presented.

Two WIM tests are scheduled for Europe in the near future. A cold environment test will take place in Sweden, near the Finnish border, starting in 1997, and the continental motorway test will take place on the A31 motorway near Metz. More information on these tests can be obtained from Internet site <http://www/zag.si/wim>.

WAVE (WIM of Axles and Vehicles for Europe) is partially funded by the European Commission DG VII and includes a number of different but related projects. One WAVE project is designed to improve the estimate of static weights from WIM systems by installing multiple-axle sensors and/or by using bridge WIM equipment. A second project within WAVE is designed to create better quality assurance procedures, data base structures, and data formats. The third project will improve WIM system durability, calibration, testing procedures, and operations in cold climates. The last WAVE objective is to test the use of new optical fiber WIM systems.

Sponsored by the Organization for Economic Cooperation and Development, the DIVINE tests (Dynamic Interaction of Vehicles and Infrastructure Experiment) were conducted near Trappes and examined the spatial repeatability of axle weights. For the tests, 18 piezoelectric axle sensors were placed in smooth pavement at nonuniform spacing. This involved more sensors than had originally been planned, because early test results showed that it was important to obtain additional sensor readings to accurately measure the longer wave lengths.

Researchers conducted a spectral analysis of the weights at each of the sensors and drew the following conclusions:

- Individual vehicles follow repeatable loading patterns.
- There is a strong wheel-length component to the WIM measurements;

that is, every turn of the wheel results in the same spike in the impact pattern, especially if the road is smooth and the wheels are not balanced.

- Although two similar vehicles with similar loads do not necessarily have the same spatial impact pattern, a statistical pattern emerges for large numbers of vehicles of a particular load and configuration. This implies that some sections of road are subject to much higher loading forces over time than other nearby sections of the same road.

- Steel suspensions tend to have higher maximum-impact factors than air suspensions.

The Surface Transport Administration is also interested in WIM data collection, both to improve the efficiency of static-scale operations and to provide monitoring information on the extent of vehicle weights that are over legal limits.

The issue of overloaded vehicles is becoming more important in France. The amount of trans-European freight has increased, along with the number of Eastern European and Middle Eastern trucking companies operating in France. It is believed that such trucking companies are more likely to operate illegally. In fact, the pressure to monitor suspected overloads has become so great that the Surface Transportation Administration has requested research to improve the accuracy with which WIM systems estimate static weights. If the accuracy can be improved, the Administration plans to use WIM scales, in combination with photographs, to issue overweight tickets automatically.

Initial plans are to use slow-speed WIM scales (5 to 25 kph) with load cells on a weighing platform that isolates the wheel from the road surface. Researchers have not yet been successful in defining the "accuracy" of these scales to the point that the definition will stand up in court. They are also in the process of determining the legal weight for a vehicle, because factors other than axle configuration are used to determine the allowable load on a vehicle. (For example, the French have three different legal GVWs for a two-axle truck.) Once these issues have been successfully resolved, France will move toward high-speed WIM systems that would most likely use multiple weighing sensors to factor out the dynamic effects caused by the interaction of pavements and suspensions.

5.5.3 Other Equipment Research

The French are developing video detection systems for urban motorways and are attempting to use video imaging to count pedestrians in subway stations. A demonstration for the scanning team illustrated the use of digital video-imaging techniques for incident detection, queue measurement, detection of vehicles traveling the wrong way, and a variety of other functions. Although the demonstration was impressive, it is not clear whether the French have solved the problems encountered in the United States using similar systems in inclement weather.

To circumvent the problem of shadows in urban areas, reference images without traffic are being built at each location to monitor differences between the reference images and the pictures received. The French indicated that the current system detects

90 percent of all incidents, with one false alarm per camera every 5 days.

Low-cost sonic sensors for use in rural areas, particularly the Alps, are also being investigated. The sensors are capable of determining crude speed ranges, i.e., traffic moving quickly, moderately, or slowly. It is hoped that installing the sensors will limit the cost of equipment installation by using solar power and cellular communications in rural areas. The sonic detectors would report when vehicle speeds dropped below specific ranges at the instrumented locations. Detectors would be placed at locations where congestion was first likely to occur and, when it occurred, operational decisions (motorist information broadcasts and implementation of alternative route signing) would be made. The institutional requirements of deploying such a system are substantial.

5.6 Data Analysis and Validation

Preliminary French traffic data analysis work is conducted within the MELODIE software system, which creates many of the basic reporting statistics needed for later analysis. The French have two systems for seasonal factoring. The older system associated short-duration counts with specific permanent counters on the basis of the geographic location of the two counters; that is, both roads carried the same basic traffic movement. The new system relies on cluster analysis to indicate the permanent counter that should be associated with each short-duration count. The cluster analysis is based on four counts during the year at the short-count location.

The French are also researching traffic forecasting for both short-term and 1-year intervals. Toll authorities are particularly interested in the ability to forecast traffic, because forecasts affect the number of toll collectors assigned to work on specific days or during specific periods.

Data validation within the MELODIE system is conducted visually, by the system operator; there are no special algorithms within the system itself. To aid in this process, MELODIE is able to produce graphic output of the data being reviewed. If the operator determines that some data are invalid, the program will use the previous month's data to replace the invalid data. The MELODIE system keeps track of the fact that invalid data have been replaced and indicates this by using different color schemes when replacement data are displayed on the screen. No documentation was available that described the instructions given to operators responsible for this task.

5.7 Traffic-Monitoring Plans

In France plans are to increase both urban and intercity traffic-monitoring capabilities. In urban areas, the primary concerns are congestion and quick detection and removal of incidents. In rural areas, simple systems are desired that will allow operation of rural roadways more effectively during peak travel days (roughly 20 days per year), without having to pay for the infrastructure required for extensive urban monitoring systems.

To achieve this goal, France has adopted a four-tiered plan for prioritizing infrastructure investments to improve roadway management. The tiers are as follows:

1. Urban roadways with major congestion or safety problems, such as spot or area problems.

2. Urban and rural roadways that are part of a corridor-management effort.

3. Other major roads with minor congestion or safety problems.

4. Remainder of the network.

The French are also planning to make route-choice data available, based on collected traffic data, and are investigating the feasibility of providing this information on a European, as well as a national, level. This is important to traffic management, given the amount of cross-border traffic for both passengers and freight.

The basic plan is to create an "implicit contract" with motorists so that, if motorists use a specific level of roadway, they can expect a specific level of information and/or service. For example, on a toll facility, motorists can expect multiple types of real-time traveler information and rapid incident detection and emergency response. On a lower level road, they should expect to receive less precise, less timely information and much slower incident detection and response. Table 5 is an excerpt from the road management master plan and shows the sample levels of roadway and the types of information that are associated with each. The implicit contracts are viewed as a "quality process" rather than as a legal responsibility.

A significant example of this "expectation of performance" is illustrated by the Cofiroute

Table 5. Traffic-Monitoring Density and Motorist Information in France

Main Operating Environments for French Network
Road Traffic Management Master Plan

Level 1: Urban expressways, daily problems
Level 2: Heavy motorways, strategic corridors
Level 3A: Routes with permanent monitoring
Level 3B: Routes with seasonal monitoring (not shown in table)
Level 4: Other roads (not shown in table)

Service Type	Level 1	Level 2	Level 3A
Emergency Post	1/1 km	1/2 km	1/2km
Patrols	1/1 hr	1/2 hr	1/4 hr
Traffic Station	1/1 km	1/10 km	1/20 km
Alert	<10 min	<20 min	<30 min
Emergency	<15 min	<30 min	<45 min
Black Ice (time to return to normal)	2 hrs	3 hrs	4 hrs

toll road system. Cofiroute operates a sophisticated traffic-monitoring center that provides both real-time traffic performance information and historical traffic statistics. Real-time information is broadcast to travelers over special directional FM radio channels. This provides users of the system with up-to-date, localized traffic information, while allowing the same broadcast frequencies to be used in other parts of the country. Historic traffic statistics are used for a variety of purposes, including:

- Forecasting traffic demand to execute labor management (i.e., accurate predictions of traffic volume allow Cofiroute to schedule the optimum number of toll collectors).

- Performing system planning.

- Scheduling pavement maintenance.

- Conducting revenue control audits.

- Providing the necessary traffic input for pavement and geometric designs.

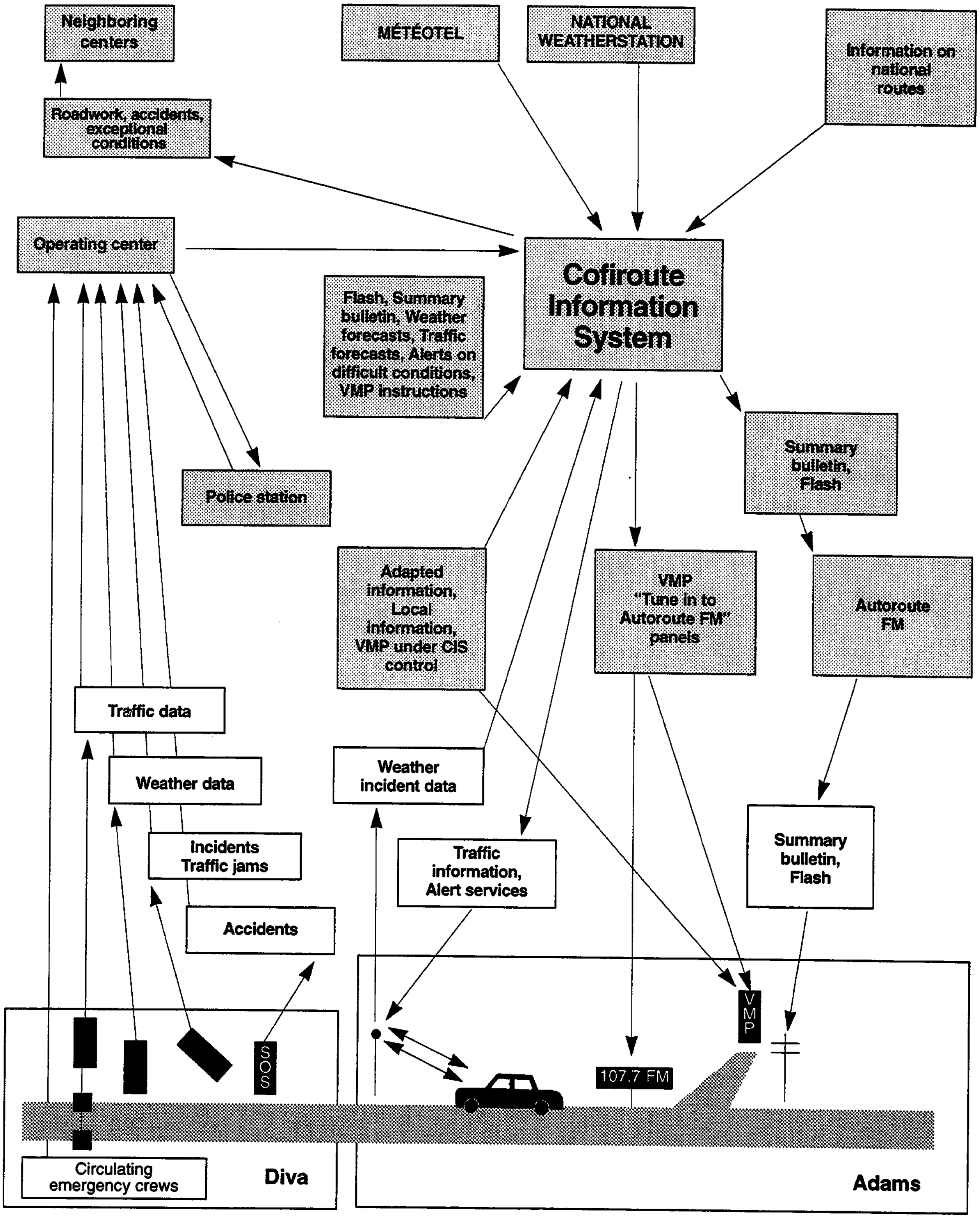
The need for data to perform these functions has encouraged Cofiroute to develop and operate state-of-the-art traffic operation centers.

5.8 ITS

As part of the plans to improve traveler information, the French are conducting RDS-TMC tests for use during the summer vacation period. Private toll-road operators, such as Cofiroute, are also implementing ATIS. Figures 8 and 9 illustrate the overall information chain for the Cofiroute ATMS/ATIS.

It is also interesting to note that, in Paris, variable message signs are used to provide motorists with estimates of journey times to the next two major exits on the peripheral freeway.

Overall Information Chain Diagram



VMP = Variable Message Panel

Figure 8. Information Flow in Cofiroute ATIS

CIS Operating Diagram

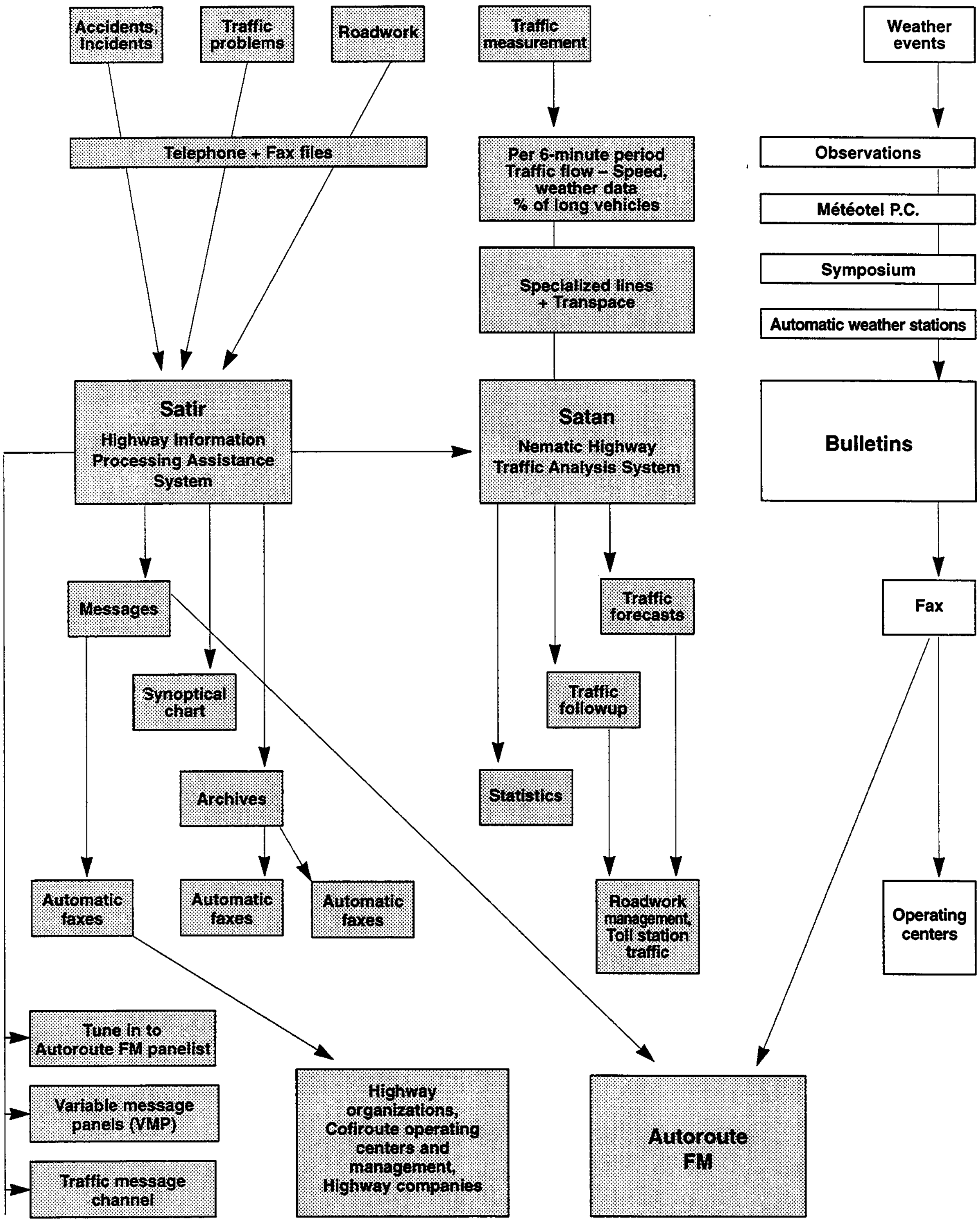


Figure 9. System Architecture for Cofiroute ATMS/ATIS

6.0 UNITED KINGDOM

6.1 Summary Points

The Transport Research Laboratory (TRL) is actively developing an ITS data fusion system for the United Kingdon Highways Agency (HA) that will supply a variety of traffic information to users on a fee-for-service basis. The system is intended to reduce data collection costs by combining data in one central location, while creating revenue that can pay for system maintenance and operation.

The National Government uses VMT as one of the parameters to decide the national funding of English counties. Computation is based on a random sample of roads selected by the DOT. Data collection on these road segments is normally performed by the counties, or by contractors to the counties, but it is funded by the DOT.

Traffic data are collected for different purposes, and it is not always possible to combine all the data into an integrated, structured survey. The DOT, however, has recently set up "liaison groups" to increase the level of cooperation between agencies and ensure the best use of resources.

The need to eliminate duplication of effort and reduce the cost of data collection is also apparent in efforts to obtain traffic count information from existing and planned traffic control systems. Efforts include extracting traffic performance information from all SCOOT systems (Split Cycle and Offset Optimization Technique) and all planned ATMS/ATIS in the country.

The British experience with data collection equipment is similar to that of the United States. The British have experienced a high number of device failures on equipment that uses piezo sensors for detailed vehicle classification. British equipment vendors are being consulted to develop more reliable classification equipment.

Further WIM system installation effort is being deferred while the data collected from the initial WIM installations are further analyzed and advancements are made in the state of the art.

The primary data validation system used by the DOT's permanent vehicle classifiers compares daily volumes by vehicle class, time, and direction with expected values, ±4 standard deviations of those mean values. Data points that fall outside of those ranges are withheld for further review and possible replacement. Statistics used in the validation process must be created site by site.

The regional project selection process includes the preparation of a cost/benefit analysis for each project. An independent panel creates guidelines for calculating estimates and reviews submittals to ensure that projects are analyzed accurately. Before-and-after studies then help confirm the predicted outcome.

6.2 Introduction

The United Kingdom's transportation system is heavily influenced by the country's dense land use and high population. According to British officials, the result of these characteristics is that, despite having national averages in car ownership, miles driven, and other factors similar to those of other European countries, the United

Kingdom experiences a higher level of traffic congestion than the other European countries visited.

At the same time, the British have been reducing the size of their Government and the amount of roadway system expenditures for several years. Reductions include the privatization of some governmental agencies, such as TRL, and the use of design, build, finance, and operate (DBFO) contracts. In a DBFO arrangement, the private sector constructs new roads in return for payments made by the Government, based on the volume and characteristics of traffic that uses the facilities.

The British refer to this kind of payment based on measured volume as "shadow tolling." Shadow tolling does not include the use of toll booths or electronic toll collection. It is simply a fee system by which the Government pays a negotiated fee per vehicle (often by vehicle category) based on volume measurements collected and supplied by the roadway owner.

The DBFO schemes have been introduced to improve the efficiency of the road network by introducing private finance. The arrangements are intended to provide value for money and relieve traffic congestion and improve safety and the environment.

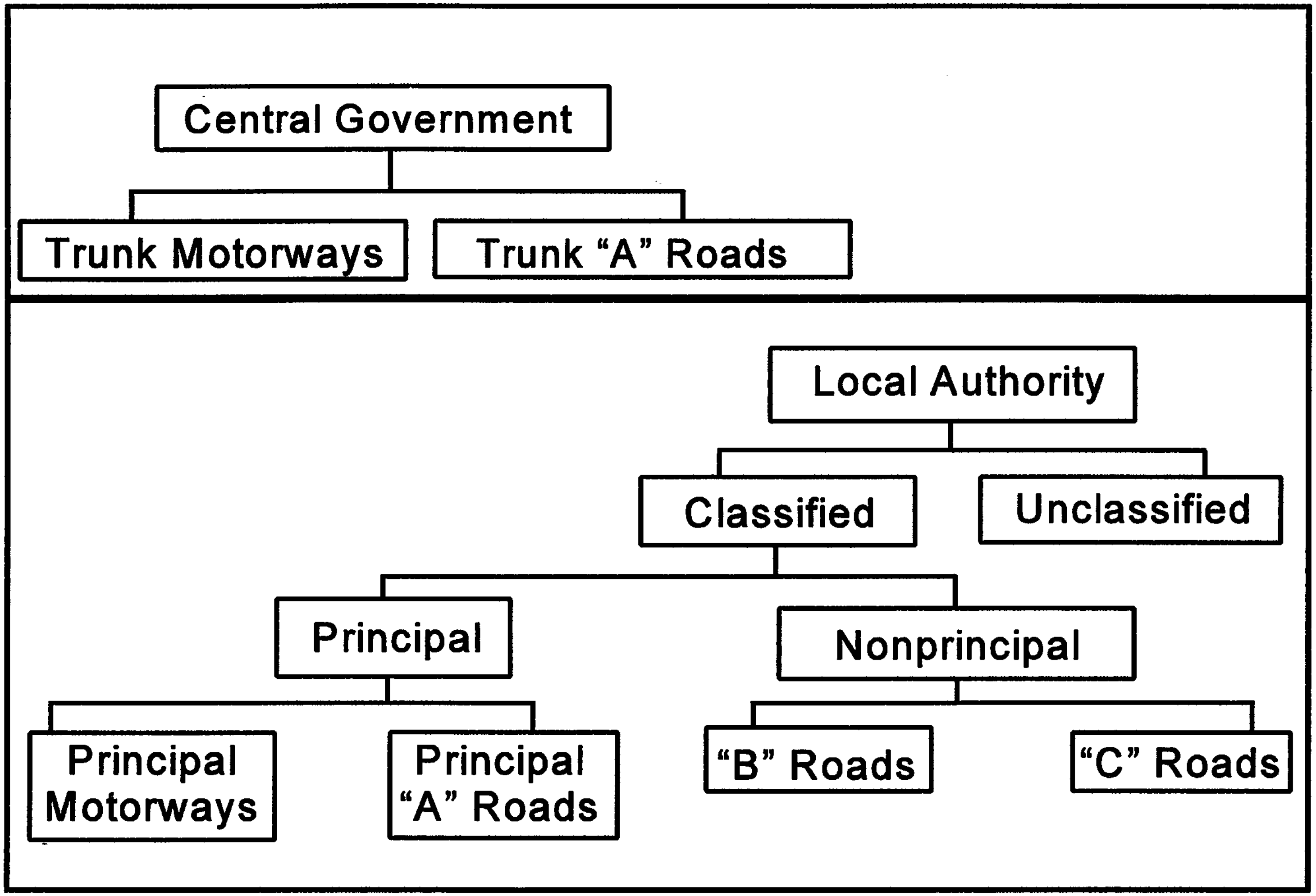
6.3 Organizational Responsibilities

In the United Kingdom, the road systems of Wales, Scotland, and Northern Ireland are managed separately from that of England. The scanning review focused only on data collection on the English road network.

In England, the HA acts on behalf of the Secretary of State for Transport. Through four regional offices, the HA constructs and operates the national roads in England, including motorways (designated with an "M") and some primary highways ("A" roads). Divisional responsibilities are shown in Figure 10. The national roads in Scotland, Wales, and Northern Ireland are managed by separate offices. For example, the Scottish Development Department has this responsibility in Scotland and, in Wales, the Welsh Office has this responsibility. The DOT collects statistics from these agencies and publishes summary statistics for the United Kingdom. The rest of the roads in the country are owned, operated, and maintained by local highway authorities.

Within the DOT, several organizations play roles in traffic data collection. The most important of these are the Central Transport Group (CTG) and the HA. CTG is responsible for policy, strategy, analysis, and administration for the DOT. Part of CTG is the Statistics Division, which helps to better integrate statistical analysis within the DOT. The statisticians are also part of the national Statistical Service, which crosses all departmental lines. This gives CTG some independence in ensuring the accuracy and reliability of its statistical summaries. The HA and CTG each receives its own budget and reports to the Secretary of the DOT.

The statisticians prefer the dual organizational arrangement of being part of both the DOT and the Statistical Service, which enables them to be close to both the data collection and policy staff. This way, they gain a more thorough understanding of the data and can answer ad hoc questions from policy staff more completely.



Note: All trunk roads are major roads.
All principal roads are major roads.
All “B,” “C,” and unclassified roads are minor roads.

Figure 10. Responsibility for Public Roads in the United Kingdom

One important function performed by the DOT is monitoring the VMT on each of the road systems in each of the regions of England. The VMT figures are used as one data source in allocating funds to local authorities, similar to the system used in the United States. The major difference between the British and American systems is that CTG is responsible for designing its own sampling plan and collects its own data. In the United States, FHWA provides guidelines to the States regarding the design of the sampling plan and monitors performance to ensure that the submitted data sets are comparable.

In the last decade, TRL was privatized. TRL still conducts a large portion of the DOT's research, but it is no longer a government agency. The result has been a significant change in how TRL operates and views the work it performs.

Privatization of TRL was achieved by an open competition that was won by the in-house team, and TRL was converted into a private, nonprofit foundation. Initial funding came from loans used to purchase the TRL infrastructure from the Government. Loans were supported by initial research contracts set up between TRL and the DOT. Most of TRL's work is still for the Government, although a portion is conducted for local authorities, the private sector, and developing nations. In the future, TRL hopes to collect some funding from the operation of various data banks that it will build and operate for the Government; a portion of the funds could come from selling data to potential users. For example, TRL could build real-time ITS traffic-monitoring systems and sell the data collected by those systems to ITS information providers.

TRL's intent to "sell" traffic data reflects a number of factors, including the following:

- Belief that a market exists for these data.
- Continued need to explore new funding sources for transportation system improvements.
- Continued effort to privatize work that has traditionally been a public sector activity.
- Acknowledgment that a single data collection effort can serve the needs of many different users, who can share the cost.

TRL's efforts in this area are a natural outgrowth of its previous experience in collecting large quantities of data, its ongoing work in ITS, and its need to generate its own funding sources. Although the concept of "selling" traffic data seems straightforward, discussions that occurred in the presence of the scanning team illustrated that there are many complications in the execution of this idea. The primary complications are that it is difficult to understand which types and forms of data have value to outside users and to manipulate the data in hand to meet those needs.

TRL and CTG personnel are working to ensure that available data can be stored, manipulated, and transmitted in a fashion that reduces costs for all involved. The cooperation between TRL and CTG illustrates an ongoing effort in the country to coordinate the traffic data collection efforts of different agencies.

Actual data collection tasks are divided among automated systems, regional HA personnel, county or municipal personnel, and private contractors that work for either HA or county/municipal agencies. Distribution of tasks among groups varies by application and by region.

6.4 Counting Program

In England, traffic data collection is conducted by three levels of government for three purposes. There is little or no mandatory national data collection at the counties' expense. When the National Government needs data, the DOT usually contracts with the counties to collect data on the sites under county control. For example, when CTG collects data at a large set of randomly selected locations to quantify national traffic, the effort is paid for directly by CTG. In addition, each HA region has its own traffic-counting program, which provides data for its specific regional operational requirements. Each county or municipal government collects data for its own purposes. Until recently, these data collection efforts tended to be totally independent, but initiatives are underway to coordinate activities to reduce the total cost.

6.4.1 CTG Data Collection Program

The CTG counting program consists primarily of two efforts:

- The core survey is a set of 130 permanent count locations that continuously collect data.
- The rotating counts are a set of 12,000 links on major roads and 1,500 locations on the minor road network, on which short-duration counts are collected. (A link is defined as any road segment between major junctions.)

Count locations are selected randomly (the permanent sites are selected only once) to supply a statistically valid estimate of total VMT. Count locations on minor roads are selected by randomly generating grid references and then determining whether the appropriate type of road is present in that grid reference.

The permanent CTG sites have automatic vehicle classification equipment. The system selected for this task uses 2 inductance loop detectors and 2 axle sensors to categorize vehicles into 21 vehicle types, which are then further aggregated to 11 vehicle types that match manually collected data. To collect data at the 130 locations, 157 sets of classifier electronics are needed.

For each of the rotating count locations, data are collected manually for 11 vehicle classes over 12 hours. Estimates are factored to represent average annual statistics based on data taken from the core census and are then converted to a measure of VMT.

The size and scope of the manual data collection is one of the major reasons that CTG is interested in cooperating with the HA regions and county highway agencies to reduce costs. Many roads are already counted for other reasons, and both CTG and the other agencies would like to reduce data collection budgets by having access to other agencies' data.

Problems with this cooperative effort do exist, however, including:

- CTG does not know where the other agency counts are located.

- Other agency counts are not collected at random points, and other agencies' site selections may bias the statistical summaries produced by CTG.

- Data collected for a variety of purposes and under a variety of data collection procedures are not generally comparable.

As a first step toward data sharing, CTG, regions, and counties are examining different methods for describing the type and location of data collection activities. In addition, the HA regions and the counties are exploring the creation of data interchange protocols and the use of either identical data base systems or a mutually acceptable data-reporting format to simplify transfer of data among agencies.

Unlike the other countries visited by the scanning team, the United Kingdom does not conduct extensive manual data collection to determine international versus national travel. Because the United Kingdom has a limited number of entry points, the British rely heavily on statistics from entry points to determine cross-Channel traffic via ferries and the Channel Tunnel. In addition to being less expensive than extensive manual counts, this system also allows the British to determine how many vehicles registered in the United Kingdom travel to and from other European countries. However, one special set of manual counts is aimed specifically at the use of trucks with foreign registrations for commercial travel within the United Kingdom; i.e., foreign commercial vehicles that both pick up and deliver freight in the United Kingdom.

Other information on freight movement can be obtained from a survey of road haulage companies in which details of the movements of vehicles carrying specific goods are collected. Further information can be obtained by examining tachographs (an older style of on-board computer) and bills of lading. These provide basic origin/destination and trip performance information, such as average speeds and percentage of time under specific speeds. A more permanent system under consideration would pay specific trucking companies to provide trip highway performance information for particular travel corridors.

CTG also conducts a limited travel-time data collection program on the national road system. Data collection is performed by a number of private contractors, each covering specific roadway corridors. Each link is surveyed eight times per year, covering four time periods and both directions of travel. Contracts specificy the data to be collected to ensure that data submitted by different contractors are comparable.

The contractors use an instrumented vehicle that collects data every 2 seconds. These data are validated with a basic reasonability check, then used to compute a mean speed for the entire road network. The aggregation process weighs the speed measurements by vehicle volume on a segment. Only the mean speed for the entire network is published, because the small sample size for any one road makes any estimate for a single facility unstable. Data from the instrumented vehicle also allow CTG to determine the amount of time that the data collection vehicle spends in each speed range and the number of acceleration/deceleration cycles.

Both of these data items are extremely useful for vehicle emission computations.

An ongoing effort uses number-plate recognition at multiple locations to measure travel time. The trial of this system will take place on the M62 motorway over a 60-mile route. The National Government is also interested in the data collected by the DBFO facilities, which are responsible for collecting their own traffic data and reporting to the Government. These data are used as the basis for payments to the facility operators. It is interesting to note that, when this process was created, the equipment available for data collection purposes could not provide the levels of traffic data accuracy required by the initial contracts. Requirements have since been lowered to a 5-percent error for total traffic volumes and a 7-percent error for trucks.

The equipment used to provide the count measurements is subject to audits every 90 days; however, a means for conducting audits has not yet been determined. The opinion of the staff that the scanning team met is that the audits will be performed by comparing traffic counts against manual count estimates made from video images taken during daylight hours.

6.4.2 Regional and County/Municipal Data Collection

The regional HA offices operate their own data collection programs, including permanent data collection sites, real-time traffic-monitoring and control systems, and short-duration counts. Short-duration counts are conducted both for coverage count purposes and to supply project information, such as data required for design or operation purposes.

The attitude toward data collection at the regional level is undergoing a significant change. In the past, regions counted traffic to determine vehicle volumes and composition for construction purposes. Now there is a greater emphasis on traffic flow management, which requires knowledge of congestion levels and journey times. Determinations of how to take these measurements are just beginning.

Part of the need for data about congestion levels and journey times arises from the English project selection process. A cost/benefit analysis (COBA) is required for each proposed road project to be eligible for national funds. In addition to predicting the benefits of a project, regions must conduct a before-and-after analysis to confirm that the expected benefits have been obtained.

To ensure that COBAs are not biased, objective reviewers in a formal COBA certification process check the data and techniques for appropriateness and the assumptions for reasonableness.

Much of the data collected by the regions and counties are project related. Regions do not have random-count programs like those used by CTG, because there is no incentive to provide an independent statistical measure of total travel. Consequently, most data collection locations are selected to provide information on specific vehicle movements. The cost of many of these data collection efforts is charged directly to the project budget for which the data are collected, similar to the project-count funding process used by many States in this country.

One advantage of a project-related traffic-counting program is that, when the national transportation budget was cut and fewer projects were funded, the need for traffic data also diminished. Therefore, cuts in data collection were more easily sustained. Still, such budget reductions have led the regions and counties to investigate data sharing to improve the information available for all purposes. As a result, all the regional HA offices have selected and use the same traffic data base software, known as TITAN (see Section 6.6). In addition, regional agencies now want to share data with CTG, because use of CTG data may also reduce their own data collection needs. Although these data are currently available to the regions, they have not been routinely applied, and the data-transfer process is not automated. An effort is underway to create a data base that indicates where each agency has installed permanent loop detectors so that other agencies can be aware of data collection locations.

Another change has been an increase in the desire of the regional HA offices to obtain and use data collected as part of the real-time motorist information systems that operate in the regions. All the motorways maintained by the regional HA offices operate real-time variable message signs, which are connected to traffic-monitoring devices. However, these systems have not traditionally stored the data; thus, the data are not available for later use. Because these systems are now nearly 20 years old, the regions are considering upgrades that would include the ability to store and transmit the monitored traffic data.

Those involved in regional traffic data collection and analysis have some reservations about the use of these systems. Experience has shown that the data collection function is subordinate to other needs at these locations, which has led to delays in receiving information and/or repairing sites that were not supplying data at all. The response to this concern has been that funding for these systems will eventually be contingent on their being used for multiple purposes. A new funding scheme should lead to a higher priority for outside interests in the operational performance of the detectors and better access to the data.

The region that the scanning team visited operates a number of permanent counter locations. Only a few locations operate all year, while the rest serve as semipermanent count locations. At these locations, data are collected for 4 to 6 weeks. These data are manually collected from the on-site electronics, and the electronics are then moved to another site. Each semipermanent site is counted twice each year.

In addition to volume data at these sites, the regional office also collects truck classification data, based on vehicle lengths. The equipment collects data in four length categories, the boundaries of which are set by the region and are not part of a national standard. The categories are primarily intended to distinguish heavy from light vehicles. These counts are supplemented by a limited number of manual counts that provide more specific vehicle information.

To estimate bicycle use, TRL has developed an algorithm that detects bikes on the basis of sensor output from piezo cables. At this time, however, TRL is not satisfied with the results of this system. There is too much noise in the piezoelectric-cable sensor under real traffic loadings, and it is difficult to detect the small bicycle output signal in relation to the cable output caused by passing cars. The lack of data on bike paths is an acknowledged limitation of the mobility-based counting program.

The London region has also undertaken a recurring travel-time survey that is conducted every 3 years. The survey measures door-to-door travel times by different modes and is meant to provide updated estimates of comparative travel times by mode.

6.4.3 TRL Data Collection Efforts

TRL is leading an effort to extract traffic information from the nation's traffic signal system. Most British signal systems include SCOOT, which incorporates vehicle detection capabilities and a central processing facility. For the SCOOT system, detection loops are located just downstream of intersections to serve as upstream detectors for the next signal. This means that vehicles rarely stop on top of the loops (which can cause volume-counting errors); volume estimates obtained over these signal systems are more accurate than those based on stop-bar detection. However, in many of the SCOOT systems, detection loops span more than one lane, reducing the accuracy of the detector data.

Data that can be obtained from SCOOT include:

- Flow (vehicles/hour).
- Delay (vehicle hours/hour).
- Congestion (percentage of lane occupancy over the loops), meaning the time that the queue extends back to the previous intersection plus normal vehicle lane occupancy.
- Detector flow (vehicles/hour).
- Detector occupancy.

The problem with the use of SCOOT is that it does not directly measure all vehicles. TRL staff indicated that it describes conditions and trends very well, but its actual measurements are not "accurate." To increase "accuracy," but not necessarily precision, data are adjusted to account for the limitations in the detection scheme (e.g., one loop covering two lanes).

In addition, the first three data items mentioned above are modeled output from SCOOT rather than measured data. These data are only as accurate as the model, which depends on a variety of assumptions. SCOOT can also produce computations for vehicle delay, journey time, speed, a congestion index, vehicle occupancy, and a link profile unit factor that is an index of estimated travel time divided by expected free-flow time.

Although these data are not perfect, the length, duration, and geographic coverage of the SCOOT data make up for much of the system's limitations. It is also important to remember that these data are already available through the existing SCOOT traffic control system. New data collection efforts do not need to be funded.

At issue, therefore, is not how accurate these data are, but whether they are acceptably accurate for the desired uses, whether the cost of collecting better data could be justified, and whether the value of better data is worth the expenditure of the added resources.

As part of the British ITS effort, TRL is also developing new ATMS and ATIS. The system that the scanning team observed is discussed in Section 6.7; however, a brief review of the data collection portion of the system is included below.

The data required by the ATMS/ATIS being developed include:

- Smoothed speed per lane.
- Vehicle volume.
- Journey times.
- Classification (roughly the number of heavy and light trucks).
- Vehicle headways.
- Lane occupancy.

Because the British do not have an HOV lane system, it is not necessary to collect vehicle-occupancy data to provide HOVs with preferential facility access or other incentives.

To collect data most efficiently, the British are investigating ways to obtain data from all systems operating in the area and "fuse" those data. This means that they are trying to obtain data from the TrafficMaster® infrared devices; the MIDAS (Motorway Incident Detection and Automatic Signaling) loop detector system, built specifically for the ATMS; manual input from police; and any other real-time source operating in the area. In an HA project, TRL is attempting to collect these data at the most disaggregated level, then aggregate to whatever other levels are required for each user. In other words, the system is built to manage the most onerous user task, but provide less complex levels of the data for less data-intensive applications.

TRL also collects data for specific projects that may be used for more general purposes. One example is a series of truck weight measurements being compiled for a study of vehicle "wear" factors. The data include:

- Static weights from roadside surveys.
- Dynamic WIM weights.
- Eisennman factors from roadside surveys.

This data collection process will yield information on axle weights, tire pressures, suspension types, axle configurations, and wheel types. Trucks are sorted into 12 classes, and axle weights within each vehicle category are aggregated into one of 10 bins, by axle position. These data will also be useful in providing a clear snapshot of the characteristics of the truck fleet operating on the nation's roadways.

6.5 Equipment

6.5.1 Volume-Counting Equipment

Unlike the other European countries visited, the United Kingdom has not created its own data collection equipment specification. Instead, equipment has been purchased from existing private suppliers, as is commonly done in the United States. (British suppliers are also found in the U.S. market.)

Not surprisingly, the British also have complaints about equipment failures that are similar to those of many States. CTG representatives commented that, in a normal month, 90 percent of the counters work. During the early implementation of the special classifying-counting system designed for the national traffic census, as many as 20 percent of the counters failed. The British also commented that they had problems in cold weather because of the difficulty of installing or repairing equipment in low temperatures.

6.5.2 WIM Systems

In England, experiments with WIM systems have been conducted for several decades. WIM data have been used for pavement design; pre-selection (sorting) of illegally loaded vehicles; design of very long bridges, when headways for specific types of vehicles were desired (i.e., measuring how many large trucks will be on the bridge at any one time); and enforcement of truck bans. The Briditsh are also investigating the use of WIM systems to protect weak bridges.

Researchers remain unconvinced, however, that system development has reached a stage that warrants large-scale deployment. Tests using WIM to pre-select heavy vehicles for enforcement purposes were not successful. The tests demonstrated that the random variation in axle weights caused by vehicle and roadway interaction resulted in too many errors in the selection of vehicles for static weighing. Researchers concluded that the only ways to improve the success of the systems are to improve the smoothness of the pavement or install multiple weighing sensors.

Until the latest series of WIM tests, CTG had planned on a three-phase installation program of WIM systems. Instead of using sorter scales, the CTG effort was aimed at measuring "average" vehicle weight conditions; thus, the effects of random variations in the axle weights are not as significant as they are for enforcement weighing. Phase I, the installation of three sites, was completed in the winter of 1993-94. In Phase II, 10 additional sites were installed the following year.

Proposals were solicited in which the CTG specified the site locations that would be used, rather than listing the roughness and/or pavement conditions under which the equipment would be expected to operate. For the equipment acceptance tests, accuracy of the system was computed on the basis of the system's ability to weigh three specific calibration vehicles—a two-axle, single-unit truck; a three-axle, single-unit truck; and either a six- or seven-axle, semitractor-trailer.

CTG computed accuracy on the basis of 10 passes for each vehicle and computed a coefficient of variation (COV) of the measured impact factor. The acceptance specification required that the computed impact factor be equal to 1 ± 0.1, with a COV of 18 percent.

Another element of the bid was a provision for the installing vendor to maintain the equipment for 3 years and recalibrate the equipment every 6 months. The initial three systems were divided between two vendors. For the second 10 systems, a third vendor was selected and one of the initial vendors was dropped from the contract. Systems from all three vendors can be interrogated from the same central computer using the same software interface.

The accuracy levels achieved by British WIM systems measuring individual vehicles differs from the statistical confidence intervals prepared for the estimates of national average weights for different types of vehicles. In operation, the British WIM systems achieved error rates of 12 to 32 percent, computed as the average 95-percent confidence limit of the percentage difference between static and WIM GVW measurements. (These values are similar to those found in the United States.) The difference between static and WIM measurement is obtained from calibrated vehicles and is currently yielding COVs of better than 10 percent.

At the meeting with the scanning team, TRL presented other research that has been undertaken in England. One of these efforts examined the effects of different truck characteristics on the accuracy of WIM estimates of static weights. It was demonstrated that the impact factor for trucks is not normally distributed. Research by David Cebon of Cambridge University clarified the reason for this result.[5] Using multiple weight sensors, Cebon found that similar vehicles (as defined by suspension types, axle configurations, and loads) tend to follow similar loading patterns. That is, similar vehicles have axles that follow the same pattern for "bouncing" down the road. Thus, if vehicles at a site tend to be similar in load and type (e.g., mostly loaded, air-suspension, tractor semi-trailers), a WIM scale will tend to see all axles as either "heavy" or "light," depending on where the axle sensors are located relative to the dynamic motion of those vehicles. This will, in turn, cause the weights at that location to be skewed toward that particular weight pattern. Dr. Cebon's results are similar to those found by the French as part of the DIVINE project.

[5]D. Cebon, "Multiple-Sensor WIM: Theory and Experiments," Pre-Print Number 910482, 70th Annual Transportation Research Board Conference, Washington, DC, January 1991.

The British also concluded that calibrating a scale based on front-axle loads of specific vehicles is not effective. The conclusion was that the "correct" front-axle weights vary substantially from site to site.

Other recent British research confirmed the results of early tests of heavy-vehicle electronic license plate systems. Results demonstrated that three axle sensors are the optimum number required to "average out" the effects of random motion of the vehicle load.

The British experience with piezoelectric sensors has also been mixed, as have the most recent experiments with the new capacitance strip sensors.

One final concern of the British when selecting WIM sensors is the manner of failure in the pavement. Early British WIM sensors tended to rip out of the pavement and become road hazards. If they fail, newer systems are required to fail in a manner that will not create a hazard.

6.5.3 Vehicle Classification Equipment

The permanent CTG vehicle classification equipment is based on a TRL design. It uses two inductance loop detectors and two axle sensors to categorize vehicles into 21 vehicle types, which are then further aggregated to 11 vehicle types that match manually collected data.

The regions use much simpler classification equipment that relies on dual inductance loops to classify vehicles into four length categories. However, the length categories vary among jurisdictions, because there is no national standard for this classification scheme.

6.6 Data Analysis and Validation

6.6.1 Data Analysis

One of the interesting data analysis techniques that was described to the scanning team was the random sample taken by CTG for computing VMT by county. Data collection points on minor roads are selected from among random geographic reference points. Counters are subsequently assigned to a segment in that geographic location, if a road is present.

Also of interest in this process is the assumption that all minor road segments have the same length, thereby simplifying the aggregation process. Testing a similar process in the United States might provide an interesting check on local road VMT estimates used in the HPMS reports submitted by the States to FHWA.

Another interesting analysis performed by CTG is the production of a weekly volume summary from the permanent counting stations. The report includes four vehicle classes and is viewed as a quick means of describing the volatility of economic activity in the nation. Although this statistic is not viewed as strongly linked to true economic activity, its relatively unbiased nature and the speed with which the report can be produced make the statistic interesting.

One other advantage of producing a weekly volume summary is that it forces CTG to process its data on time, encourages review of equipment operation in a more timely fashion, and helps ensure that quarterly statistical reports are produced on time and with valid data. CTG views its quarterly report as a more reliable indicator, partly because the quarterly processing schedule allows time to review and edit data as needed.

Other items of interest are two data base systems being constructed for use by government highway agencies. The TITAN data base system has been developed by the Northern Regional HA office and has been selected as the de facto standard for the other regional HA offices. TITAN maintains data in an ASCII format, with some header information, and a suite of programs provides specific summaries for requested time periods. Results from these programs are in tabular format.

Although TITAN is a relatively simple data base, it meets the vast majority of HA needs, particularly the transfer of data between offices. Its simple structure also makes it easy to transfer TITAN files into geographic information system (GIS) formats once a GIS has been selected. This system has been so well accepted that requiring DBFO companies to supply their data in this format, as well, is under consideration.

Because the county and municipal highway authorities require more sophisticated data base and data-reporting systems (they are more likely to be dealing with complex urban street networks), the western county highway authorities have a similar but more complex system called TARA. This system can also produce simple ASCII text files for data transfer, although these files have a slightly different header format than the TITAN files. In the end, the two systems will need to coexist, and steps are being considered to agree on a standard ASCII file format that can be used to transfer data between the TITAN and TARA systems.

6.6.2 Data Validation

Several data validation schemes are used in the United Kingdom. The most interesting systems observed by the scanning team are described in the following paragraphs.

6.6.2.1 CTG Permanent Recorder Data Validation

The basic CTG data validation scheme relies on the creation of a site-specific "parameter" file that is compared with incoming data. Data that exceed the parameter levels are flagged as suspect and manually reviewed. "Invalid" data are replaced with data extracted from the last week of valid data collected for that site. These historical data are multiplied by a factor taken from nearby sites that did work correctly and used to convert the previous week's traffic volumes to the current week.

This validation process is performed in two steps, using a statistical analysis system computer program. These steps are referred to as the "coarse" and "fine" flow analyses.

In the "coarse" flow analysis, hourly vehicle classification data, collected by lane, are summarized by direction into four vehicle types, within five time-of-day bands. The four vehicle types are motorcycles, cars, light trucks, and heavy trucks. The five time bands are associated with the two peak periods, midday, evening, and late night. (The time bands do not contain equal numbers of hours.)

These data are then averaged for a week, by direction, class, and time period. They are then compared with minimum and maximum values for that site, as computed from expected means and standard deviations. If any of the data fall outside the expected ranges, the data are marked as questionable and are subject to replacement. If any data are declared invalid, then all data for the week are replaced. Acceptable ranges are computed as the expected mean value plus or minus four standard deviations. The expected range is expanded if the week contains a holiday period.

The data replacement policy is currently under review. Some users of CTG data believe that the data replacement policy is too strict and that valid data are often discarded. Such groups ask for raw data from CTG rather than accepting the edited data that are usually supplied. Disqualification of only some of the data collected in an "invalid" week is being considered.

CTG also keeps a "fine" level of detail for these same days of data. The fine level contains volumes for all 21 classes of vehicle, by hour and direction. Using the fine data, CTG computes a daily rolling average, which is computed as 0.8 times the existing mean plus 0.2 times the data for the new day. The average is then compared with expected values.

6.6.2.2 The MIDAS Validation Process

MIDAS is the HA motorway incident detection and analysis system. MIDAS and supporting programs perform two levels of validation:

1. The system itself has an internal validation method (not explained to the scanning team) that indicates when the loop system needs recalibration and/or has failed.

2. The system produces a plot that shows volume, speed, or loop occupancy, by geographic location and time of day. This graphic provides an easy-to-use visual reference for detecting specific types of incidents and equipment errors.

The graphics are particularly useful for showing when a specific loop is malfunctioning or beginning to malfunction. This is accomplished both by comparing the detector performance over time and by making that comparison by both time of day and geographic location.

The HA data fusion system is also unique, because it can obtain two or more independent measurements of the same traffic statistic. For example, vehicle speed estimates can originate from both loop detectors and from the TrafficMaster® infrared detectors. To help the user understand the relative quality of these different types of data, each reported statistic has a "confidence level" label associated with it.

The confidence label is a function of geography (how far from the sensor), time (how long since the last data were collected), and sensor (MIDAS, TrafficMaster,® manual, or video camera with digital imaging). Recall that this system is currently oriented toward real-time driver information, not planning or roadway design. Additional use of the confidence labels for planning purposes would be beneficial.

The confidence number starts with data from loop locations that have a 90-percent confidence level and TrafficMaster® sites that have an 80-percent confidence level. These confidence levels are then halved every minute that a new data point is not collected and reported for that site.

6.6 ITS

As in much of the industrial world, transport experts in the United Kingdom have concluded that they cannot build their way out of traffic congestion. As a result, they are trying to develop the systems necessary to better manage and control the existing infrastructure, through the application of ITS techniques. Two such systems are described in the following paragraphs.

The British are building interurban traffic-monitoring systems. The current system design consists of limited closed-circuit television and loop detection systems that report data to local police centers that control variable message signs. Improvements that are being researched include development of monitoring capabilities at 2-km intervals on motorways and at 5-km intervals on "A" roads. For incident detection at locations that have frequent accidents, closer detector spacing (500 m) is planned, but most of the motorway system will have much lower levels of detection.

The proposed architecture is two-directional data transmission among the local centers and three regional centers. It will be designed to provide traveler information across local jurisdictional boundaries and to ensure that different operating agencies issue the same traveler information. The British are working with International Standards Organization committees TC204 and WG10 on traffic and traveler information.

As part of creating the traveler information systems, the British are trying to standardize location-coding systems; currently, different agencies use different referencing systems. In addition, there is some interest in performing short-term (2-hour) traffic forecasting to predict congestion in enough time to allow operational changes.

For urban motorways, HA is continuing development of MIDAS. MIDAS uses double loops spaced every 500 m; 400 km of loops are currently connected, and the central software is being completed. The central software uses 1-minute average speed, lane occupancy, and volume data to make control decisions.

The control decisions include variable speed control by lane, and TRL staff indicated that these lane-specific controls are observed by motorists. It is important to note, however, that camera-based speed limit enforcement is in use, which may affect the public's willingness to obey the changing speed limits.

As part of this system, TRL, on behalf of HA, is working on a data fusion project for all the available real-time data collection systems. The data fusion effort is primarily aimed at providing real-time motorist information and traffic control services. This approach is intended to make use of whatever data are available and use each type of data in the context of other available information. This will allow for maximum roadway coverage at the lowest possible cost.

For example, the TrafficMaster® infrared detector data are not as accurate as the loop detector data, nor are the TrafficMaster® detectors as closely spaced as the MIDAS loop detectors. However, the TrafficMaster® detectors cover a larger proportion of the motorway network and are often the only detection available in some areas. By combining the loop detector data and the TrafficMaster® infrared information, the data fusion system gains geographic coverage of the infrared system and accuracy of the loop system. Another benefit is that, in locations where both detectors exist, a set of independent measurements can be used to verify the data being collected.

Data are currently being obtained from TrafficMaster® infrared sensors, MIDAS loop detectors, and manual input from the police that control the motorway operations. The system is being built to accommodate any other real-time sources that become available. Planned uses of the data have not been addressed at this time, because that effort is not in the current sphere of influence or interest.

To help motorists or service providers understand the different types of data that are available and what those data types mean for traffic performance estimates, a confidence label will be attached to each reported piece of data. Again, this is oriented toward real-time driver information, not planning or roadway design.

Finally, the data fusion system is being designed with an open architecture, so that it can interface with a variety of private supplier applications.

7.0 AREAS FOR FOLLOWUP

The following subject areas offer the potential for significant improvements in the way State DOTs conduct day-to-day collection and data manipulation activities. The scanning team recommends that these areas be further investigated, analyzed, and reviewed.

7.1 Equipment

In the United States, inductance loops are the primary traffic data collection device for urban freeway and traffic signal control systems. Loop maintenance and repair are significant operational costs. In addition, loop failure is a significant concern, both because loop failures limit the availability of data needed for operational control decisions and because of the cost and staffing required for repair. Several of the European countries visited reported markedly superior loop performance statistics than are routinely found in the United States. Considerable benefit could be obtained from further investigation of the European equipment specification and installation procedures. Specific areas of interest are:

- Whether European specifications are actually better than those used in the United States.
- Whether European procurement systems result in better equipment.
- Whether improved loop performance can be attributed to other factors, such as differences in pavement structure or climate.

7.2 Data Applications

Another area of European success that warrants further investigation is the use of data collected by traffic control systems for routine performance monitoring and other planning and engineering functions. Significant savings in data collection costs, as well as significant improvements in the data available for executive decision-making, planning, and engineering functions, could be obtained from the use of traffic control system data in the United States. Specific subjects that can be learned from the Europeans are:

- How construction of the data storage function is incorporated into the design and cost of the traffic control systems.
- What procedures are used to ensure that the data collected are accurate.
- How large volumes of data generated by traffic control systems are managed efficiently.
- How data are reported to provide decision makers with needed information.

7.3 Purchase of Data Collection Services

Significant benefit could be derived from the purchase of data collection services from the private sector. Many States have imposed manpower restrictions on their DOTs, and staffing limitations can have an enormous impact on the effectiveness and flexibility of the traffic data collection programs. The Europeans have considerable experience with contracting for data collection, data analysis, data reporting, and equipment installation and maintenance. By learning from their experiences, costly mistakes can be avoided in this country, while providing States with viable, affordable options for data collection that may permit collecting more and better data at lower costs.

7.4 Vehicle Classification and WIM Systems

U.S. transportation experts should pay significant attention to European efforts in vehicle classification and WIM systems. Two specific areas of potential benefit exist.

The first is the Europeans' use of very limited classification schemes for trucks. This allows them to use much less sophisticated (therefore, less costly) data collection equipment for vehicle classification. The result, however, is information on truck use that is much less detailed. Further investigation in the United States is needed to determine whether the cost savings that could be obtained by simplifying our vehicle classification system outweigh the loss of detailed knowledge of truck movements.

The second area that warrants further attention are the COST and WAVE WIM tests. While the United States has invested heavily in WIM research in the last decade, the equipment available in the United States has significant limitations. Improvements in this data collection technology offer considerable benefits. Monitoring the results of the COST and WAVE initiatives will allow the United States to benefit from the research without having to duplicate the effort. This should result in both effective technology transfer and the improvement of the states of the art and practice for WIM systems in the United States.

APPENDIX A. Traffic Monitoring Questionnaire

1. Institutional Considerations

1.1 What is the overall purpose for traffic data collection?

1.2 What institutions and jurisdictions are responsible for what parts of the program? (We are interested in institutional structures, types of data collected, and operational responsibility. Types of data include volume, class, speed, travel time, pedestrians, weights.) How do you get data from transit authorities? Are the transit authority data collected in a coordinated fashion along with highway data? Who collects pedestrian and bicycle use data in urban areas?

1.3 Are there legislative mandates for traffic data collection?

1.4 Are private contractors used to collect traffic data?

1.5 What traffic data are collected from traffic operations such as from traffic control centers? What becomes of such data? Is it utilized?

1.6 How is data collection integrated with intelligent transportation systems (ITS)? Are the data collected as part of these systems saved for later analysis? Is there a group in charge of coordinating the data collection effort? What authority (funding?) do they have to encourage or enforce participation in a coordinated effort? Do you do performance monitoring? If so, how? What is measured?

2. Current Practices

2.1 Are there specific goals or objectives to your data collection efforts? Who sets these goals? What are the traffic data collection guidelines?

   a. What kinds of data are collected?

   b. What is the precision goal? (How do you calculate precision?)

   c. How do you count pedestrians? Bicycles? How do you count the number of people in each vehicle? (Primarily the number of people per car, but counting of bus passengers is also of interest.)

2.2 What is the sampling plan for traffic data collection (including the use of both permanent and portable equipment)? For example:

   a. How are the locations chosen?

b. How many permanent data collection sites are there? How are their locations chosen?

c. For portable/short-term data collection:

-- How many data collection sessions are there each year?
-- What is the typical data collection time period?

2.3 Are project counts (i.e., for a specific construction or planning effort) performed by a different group from "general" or "routine" counts?

3. Equipment Issues

3.1 What are the specifications for selecting equipment?

3.2 How are the various types of equipment tested?

3.3 What are the guidelines for installation, calibration, and maintenance of the equipment?

3.4 What types of environmental problems are there with the equipment; e.g., the effects of temperature, precipitation (including snow-plows), pavement deterioration?

3.5 How are portable counts on high-volume urban roads performed? On rural roads?

4. Data Analysis

4.1 How accurate are the data? (The US Panel has a particular interest in volume, classification, and weight information.)

4.2 How are the data edited/validated?

4.3 How are the data summarized?

a. In particular, how are annual averages computed from short-term data?

b. How are the kilometers of vehicle travel for an area estimated?

4.4 What links are there between data collection efforts and users? (That is, are there mechanisms built in to ensure that the data collected meet the needs of the users, and that also build support within the user community to expend resources on data collection?)

a. What reports are produced?

b. How are the results disseminated?

c. How are the data used in making decisions?

d. What do you do with WIM data? Do you track trends? Weight enforcement? Tracking of the effects of weight enforcement?

5. Other Questions

5.1 Are there any interesting research efforts underway? (New equipment, new ways of collecting, using, or reporting data.)

APPENDIX B. Individuals Contacted

The Netherlands		
Name	**Position**	**Agency**
Ruud Filarski	Head, Department for Transport Safety and Environment Studies	AVV
Jan J. Bouwens	Interim Manager, Information Division for Statistics & Data Management	AVV
Peter M. Mak	Senior Account Manager, Information Division	AVV
Kees Kooman	Senior Consultant, Traffic Control System Division	AVV
Bert Kengen	Data Processing Division, Department for Statistics & Data Management	AVV
Jan P.M.M. Vis	Programme Supervisor, Traffic Control Systems Division	AVV
Julis de Quartel	Department for Development & Construction	AVV
Ronald Henry	Cluster Manager, Load & Strength, Infrastructure Road Management	AVV
Devika Raktoe	Department for Strategic Research and Programme Coordination	AVV
Sten Bexelius	Research Coordinator, Safety & Environment Division	AVV
Boile Rühl	Head, Survey Department	Goudappel Coffeng
Jos Bronwer	Project Coordinator, Monika Project	Logica BV
Job Klignhout	Consultant	Logica BV
Frank Schanke	Public Affairs	Eurodelta Test Site

Germany		
Name	**Position**	**Agency**
Hans Mundry	Ober Regierungsrat	Ministry of Transport
Georgeta Ionescu	Referat, Verkehrsablauf Verkehrsbeeinflussung, Verkehrstatistik	BASt
Sylvia Piszczek	Oberregierungsträtin, Vehrkehrsabluf Verkehrsbeeinflussung, Verkehrstatistik	BASt
Fritz Bolte	Baudirektor, Referatsleiter Verkehrsabluf Verkehrsbeeinslussung, Verkehrstatistik	BASt
Peter Krieg	Oberregierrungsrat, Referatsleiter Verkehrsabluf, Verkehrsbeeinflussung, Verkehrstatistik	BASt
Rainer Lange	Sachgebietsleiter, Verkehrstechnik und-steuerung	Amt für Straßen und Verkehrwesen, Frankfurt
Rolf Andree	Leitender Baudirektor	Hessisches Landesamt für Straßen und Verkehrswesen
Gerhard Schmidt	Prokurist, Leiter Beriech Grundlagen	Heusch Boesfeldt

Switzerland		
Name	**Position**	**Agency**
Markus Caprez	Head, Highway Engineering Section	IVT-ETH, Hönggerberg
Emil Doupal	Research Engineer, Highway Engineering Section	IVT-ETH, Hönggerberg
Andreas Gantenbein	Section Chief, Traffic & Safety	Bundesamt für Strassenbau
Werner Kündig	Dienstchef, Traffic & Safety Section	Bundesamt für Strassenbau
Jean-Pierre Joris	Wissentschaftl, Adjunkt, Bridges Section	Bundesamt für Strassenbau
Olivier Michand	Director	Bundesamt für Strassenbau
Rolf Flückiger	Vehrkersplanung	Stadtpolizei, Zurich
George Eisler	Chief Verkehrswesen	Tiefbauamt des Kantons, Zurich
Thomas Berther	Engineer, Market Division Manager	Kistler Instrumente, AG
Peter Weber	Managing Director	Kistler Instrumente, AG
Gustaaf Klooijman	Consultant	SigmaPlan
Phillipe Düggeli	Verkehrsingenieur	Tiefbauamt des Kantons, Bern
Kurt Hoppe	Der Verkehrinspektor	Stadt Bern Polizeidirektion

France		
Name	**Position**	**Agency**
Bernard Basset	Chief Engineer	SETRA
Ludovic Alibert	ITPE Electronic Specialist	SETRA
Claude Caubert	Technical Advisor, Road Safety & Technology Center	SETRA
Sylvie-Anne Rambeau	Road Safety & Technology Center	SETRA
Jean Leveque	Engineer	SETRA
Genevieve Houdray	External Affairs Board	SETRA
Jean-Marc Boisseau	Chief of Traffic Service	Cofiroute
Bernard Jacob	Chief Engineer	LCPC
Bruno Inchingolo	Road Traffic Technology	SETRA
Simon Larcher	President and Director General	Mathematical & Logical Applications
Eric Boiteux	International Affairs	Ministry of Transport & Tourism
Alan Bourrel	Head, External Affairs Board	SETRA

United Kingdom		
Name	**Position**	**Agency**
Val Davies	Statistician, TSC-1	DOT, CTG
Peter Capell	Head, Transport Statistics	DOT
Ian Holmes	Network Policy Division	HA
Alan Hobbs	Project Manager	HA
Monica Brown	Network Policy Division	HA
David Avery	Project Manager	HA
Vanessa Kovacevic	Midland Network Management Division	HA
Wyn G. Lloyd	Road Engineering & Environmental Division	TRL
Phil Hunt	Programme Director, Traffic & Transport	TRL
Bill Newton	Manager, Safety & Environmental Resource Center	TRL
Barbara Frith	Traffic & Transport	TRL
Peter Still	Traffic & Transport	TRL
Dave Sentinella	Traffic & Transport	TRL
Keith Wood	Principal Traffic Researcher	TRL

ACRONYMS

AADT	Average annual daily traffic
ASTM	American Society for Testing Materials
ATIS	Advanced traveler information systems
ATMS	Advanced traffic management systems
ATR	Annual traffic recorder
AVV	Adviesdienst Verkeer en Vervoer
BASt	Bundesanstalt für Strassenweßen
COBA	Cost/benefit analysis
COST	Cooperation of Scientific and Technical
COV	Coefficient of variation
CTG	Central Transport Group
DBFO	Design, build, finance, and operate
DG VII	Directorate-General VII
DIVINE	Dynamic Interaction of Vehicles and Infrastructure Experiment
DM	Deutsche marks
DOT	Department of Transportation (United States), Department of Transport (United Kingdom)
ETH	Eidgenössische Technische Hochshule
EU	European Union
FHWA	Federal Highway Administration
FM	Frequency modulation
GIS	Geographical information systems
GVW	Gross vehicle weight
HA	Highways Agency
HOV	High-occupancy vehicle
HPMS	Highway Performance Monitoring System
INRETS	Institut Nationale de Recherche sur les Tranports et leur Sécuritié
INTENS	Intensiteiten
ITS	Intelligent transportation systems
IVT	Institut für Verkehresplanung Transportechnik
km	Kilometer(s)
kph	Kilometers per hour
LCPC	Laboratoire Central des Ponts et Chaussées
m	Meter(s)
MIDAS	Motorway Incident Detection and Automatic Signaling
NHS	National highway system
NTS	National transportation survey
RDS	Radio detection system
SCOOT	Split, Cycle, and Offset Optimization Technique
SETRA	Service d'Études Techniques des Routes et Autoroutes
SFR	Swiss francs
SIREDO	Systéme Informatisé de Recueil de Données
TMC	Traffic message signal

TRL	Transport Research Laboratory
VDT	Vehicle distance traveled
VKT	Vehicle kilometers traveled
VMT	Vehicle miles traveled
WAVE	WIM of Axles and Vehicles for Europe
WIM	Weigh in motion

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