A2B08: Committee on Highway Traffic Monitoring
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Highway Traffic Monitoring

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As the 20th century comes to a close, the need to understand the number and type of vehicles using our nation's roadways is becoming more and more important. Since the construction of paved roads, we have struggled with ways to record vehicular movement. Not only is this information required for proper design of roadways, but also new intelligent transportation systems (ITS) require real-time knowledge of traffic movement to be effective. Protection of our nation’s aging infrastructure requires detailed understanding of the number, type, and weight of the vehicles using roads and bridges. With the movement toward design-build highway projects and warranties on performance, accurate measurement of vehicular movement is required to ascertain if the roadway has met or exceeded the design requirements. New state and federal initiatives, many of which concern the protection of the environment, require detailed traffic information. These needs and others strain available resources within the industry, pushing technology to develop better, faster ways to accurately measure and record vehicular data and transmit this information reliably to where it can be safely analyzed.

As the need for highway traffic monitoring grows, public appreciation of the problems in this area remains poor. In general, the public believes that monitoring should be relatively easy and does not understand either the importance or the cost. Because public perception drives legislative decisions, the lack of support has created a crisis in state highway agencies across the nation as staff resources are constrained. Although the burden to build new highways lessens, state highway agencies are desperately trying to maintain the existing infrastructure in a safe condition and at the same time provide the level of service that highway users have come to expect. None of these things can be accomplished without understanding how highways are used.

With this in mind, we take a brief glance at the state of the art and the practice and a look to the future of highway traffic monitoring. What will the 21st century bring? It is hard to say, given the leaps and bounds that technology has taken since the invention and mass distribution of the computer. But as we move into this new era, one thing can be said with certainty: the need for highway traffic monitoring will grow, and as necessity is the mother of invention, new and creative ways will be found to approach this problem.

STATE OF THE ART

For simplicity of discussion, the state of the art of highway traffic monitoring may be subdivided into

- Sensor technology,
- Data recording and transfer, and
- Data sampling and analysis.

Sensor Technology

Since the invention of the pneumatic road tube in the 1920s, efforts to find a safe, effective, and reliable method to measure the passage of vehicles on roadways have continued. The simplicity and low cost of the road tube have stood the test of time, and it is still in widespread use today. Still, the limitations of the road tube alone, including its limited ability to determine the type or weight of specific vehicles, have pushed the industry to explore new sensor types and configurations. Inductance loops went a long way to solving these problems, providing a means of actually recording not only the passage of a vehicle, but also certain parameters including the length and speed. These powerful tools have provided the groundwork for much of the sensor technology in use today.

Another of the earliest tools for highway traffic monitoring, manual data collection, required no mechanical or electrical devices at all. As with the road tube, the simplicity of this approach has resulted in its continued use today. Still, the application of manual data collection is generally limited, primarily because of safety and cost concerns.

With the increased use of the highway system for transportation of goods nationwide, it became necessary to also consider the measurement of vehicle weight. Most pavement design procedures depend on some knowledge of loads expected during the pavement's life. Allocation of user costs remains a hotly debated topic, since taxing structures are developed or modified to apportion the cost of maintaining the infrastructure in proportion to the damage done by certain vehicles. Capacitance pads, load cells, strain gauges, and most recently piezoelectric sensors have all been developed in an effort to measure not only the passage of a vehicle, but also the weight of each axle as it passes. All of these technologies require installation within roadways or bridges, creating safety and performance concerns.

Nonintrusive technologies, including video, infrared, laser, radar, and others, have sought to provide a means of recording traffic movement without direct impact to the roadway, thereby providing a safer alternative to in-pavement sensors. Because these technologies cannot provide weight information directly, their use has generally been limited to urban applications, where high traffic volumes make it difficult to install and maintain intrusive sensors.

Finally, the use of automated vehicle identification sensors bears mention as a technology with potential for significant impact in the area of highway traffic monitoring. Systems of this type are heavily used for toll applications, and a number of studies have been conducted to explore their application to general highway use. If the logistical problems of instrumenting every vehicle can be overcome, this technology would provide a means of determining the required weight information without repeated weighing of the vehicle, thus simplifying the recording requirements.

Data Recording and Transfer

Of all the technological advancements of the 20th century, the development and broad application of the microcomputer provided opportunities for recording, processing, and transfer of large quantities of data. The microcomputer is believed to have had the greatest impact on the monitoring of highway traffic. In the last two decades, the increases in mass

data storage capability and data transfer speeds have been nothing short of phenomenal. These advancements have allowed for safer operations and have set the stage for necessary links to ITS applications. Cellular phone service has provided access to remote sites where direct line service is unavailable, providing for increased efficiency and safer data collection. New algorithms for data compression and increased data transfer speeds have helped to reduce data transfer times, greatly reducing the costs of data transfer. Although it is still necessary to travel to some sites to collect recorded data, increased data storage capacity has allowed for less frequent visits, also reducing costs.

Data Sampling and Analysis

It is impossible to continuously monitor traffic at every discreet point along the roadway. Therefore, there has always been a requirement to collect a data sample from the traffic stream and apply this sample to the roadway in general. Two sampling needs existed—one to sample a portion of a year and apply this sample to a full year, and a second to sample a portion of the roadway network and apply the result to other points in the network. Short-duration volume and classification counts were used extensively for estimation of the current and anticipated traffic load. These counts were generally less than 48 hours in duration because of safety and economic concerns. Advancements in equipment technology have allowed for longer samples, but it is still quite unusual (and some believe unnecessary) to operate sites continuously throughout the entire year. Numerous studies have been conducted to address each of these needs, but given the unpredictability of traffic movements, much improvement is still possible. Advanced statistical methods for sampling and analysis may be applied, but a comprehensive, continuous data set is needed to develop sampling and analysis strategies. The efforts of the Long-Term Pavement Performance (LTPP) studies have sought to provide a data set, but concerns exist with the accuracy of the data that are currently being acquired.

STATE OF THE PRACTICE

The basic practice of highway traffic monitoring has not changed dramatically since its beginnings early this century. The tools to accomplish this task have changed as technology allowed, but in general the approaches to monitoring have not changed that much. Efforts to define vehicle classification schemes have been frustrating and only partially effective, since vehicle configurations continue to change to meet the needs of the traveling public. Traditionally, classification schemes have developed as a means of saving data storage space, to infer weight and size from the vehicle classification. As the ability to store, process, and transmit larger quantities of data has developed, the need for more detailed classification schemes has increased. This is evidenced by the move toward axle load spectra over equivalent single-axle loads in mechanistic pavement design. Pavement designers are betting that the practice of highway traffic monitoring is poised for a dramatic change, one that will provide accurate, dependable measurement of the weight and spacing of every axle on the roadway, storage and transmittal of this huge quantity of data, and statistically valid forecasting and reliability estimates. This is a significant challenge to meet.

As technology has allowed, the parameters being measured have grown to meet data demands. Basic measurements include vehicle and axle count, speed, gross vehicle weight and axle loads, and axle spacing. Relatively new data demands, including vehicle occupancy, travel times, and origin and destination, are required for ITS applications. Turning-

movement counts at intersections and ramps have grown in importance for congestion management.

Although the bulk of the highway traffic monitoring efforts in the past have focused on rural applications, the advent of nonintrusive technologies has allowed growth in the monitoring of urban settings. New data demands have changed and will continue to change the equipment and approaches to traffic data collection, particularly in urban areas.

LOOK TO THE FUTURE

When polled as to the anticipated developments of the future, members and friends of the highway traffic monitoring committee almost unanimously identified integration with ITS operations as the highest need and most likely development of the new millennium. The needs of traffic monitoring and traffic management complement each other. Safe and efficient highway operations require thorough and accurate traffic data. At the same time, traffic management activities collect a wealth of data useful to traffic monitoring. This touches on the broader issue of integration of traffic and other sensor data and the marketing of traffic data as a commodity to a broader audience. Use of monitored traffic data will have a direct impact on the public and may garner greater financial support.

Nonintrusive monitoring is also widely recognized as a technology in its infancy but desperately needed for many monitoring applications. Certainly the combination of both intrusive and nonintrusive technologies provides for the safest optimization of data collection activities. With the advancements being made in image processing and the commercialization of remote sensing, we might advance to the point that satellite images are used to capture traffic flow patterns and volumes and image processing coupled with fuzzy logic is used to project time-series information to long-term patterns. This combination of technologies provides the door to the future of this industry.

We may never escape the need for in-pavement sensors of some type, especially as long as weight information is required. Therefore, continued sensor development is a must. In the short term, efforts must be made to reduce the differences in properties between sensors and the surrounding pavement to overcome the problems that the current generation of sensors is experiencing. In the long term, new materials may be developed that will enable the measurement of pressure quickly and accurately. More than likely, as has been the case in the past three decades, developments from the aerospace program will find their way to a wider audience and be put to use for new sensor materials or configurations.

As previously stated, taxation of vehicles has always been a delicate subject. As the trucking industry looks toward heavier vehicles for reduced costs and increased profits, it may become more heavily involved in the deployment of traffic monitoring equipment, if for no other reason than to argue against significant increases in its tax burden. The trucking industry may also become even more proactive in the development of automatic vehicle identification systems, which would aid in the integration with ITS.

Another area ripe for improvement is the application of advanced statistical methods to the sampling, processing, and analysis of highway traffic data. The challenge is to find statistical methods that better represent traffic conditions between monitoring sites and to develop information management systems that link geographically to other information used by state and local transportation agencies and the public. The need for improved calibration methods is obvious and may also require the application of advanced statistical methods. As with any statistical sample, estimates of reliability must be defined and, over time, refined so users of traffic data can assess the precision of their calculations based on those data.

CONCLUSION

What does the 21st century hold for traffic monitoring? It can be safely said that integration of monitoring efforts with the needs of ITS will be forthcoming, since the needs of both are complementary. Sensor technology will continue to advance, providing more accurate and reliable sensors. Combinations of intrusive and nonintrusive sensors will be used to meet monitoring needs. With the impetus on lower cost and less impact to the roadway, sensors may be actually paved into the roadway during construction and remotely transmit vehicle parameters to a receiver. Application of advanced statistical methods is expected to yield better samples and more reliable summary statistics.

Beyond these simple extensions of current technology, only creativity and innovation limit the possibilities. As we usher in the new millennium, the real challenge is to educate a new generation of professionals, arming them with the finest tools of our trade. From their minds and hands will come the exciting advancements that will meet challenges yet unforeseen.