Applications of Weigh-in-Motion Data in Transportation Planning

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Participation in the Strategic Highway Research Program (SHRP) and Canadian-SHRP (C-SHRP) long-term pavement performance monitoring programs has prompted all state and provincial highway agencies in the United States and Canada to install at least one weigh-in-motion (WIM) scale. The WIM scales provide not only the traditional traffic monitoring data but also a lot of detailed data for individual vehicles, including length, speed, axle weights, and axle spacing. Because the WIM data are often associated only with pavement research, many potential users are not yet aware of (a) the capabilities of WIM technology, (b) the type of data available, and (c) the opportunities to use WIM data in their areas of expertise. Traffic monitoring data generated by typical WIM installations are described. A number of practical examples show that WIM data are useful for a wide range of transportation planning and decision-making purposes. The specific application areas discussed include (a) planning and programming of transportation facilities, (b) pavement design and rehabilitation, (c) apportionment of pavement damage, (d) compliance with vehicle weight regulations, (e) development of geometric design standards, (f) compliance and regulatory policy development of truck dimensions, (g) safety analysis, (h) traffic operation and control, and (i) analysis related to highway bridges. WIM data can be used in all these application areas. Their usefulness cuts right across the organizational structure of any highway agency. Thus, WIM data should be considered corporate data and should be managed accordingly.

During the past few years, there has been a rapid and widespread introduction of weigh-in-motion (WIM) technology and automatic vehicle classification (AVC) technology in the United States and Canada. The main impetus for this has been the participation in the Strategic Highway Research Program (SHRP) and Canadian SHRP (C-SHRP) long-term pavement performance monitoring programs, which mandate a detailed automatic monitoring of traffic loads. Already, all major state and provincial highway agencies have installed, or are in the process of installing, at least one WIM scale. The Ontario Ministry of Transportation (MTO) experimented with the earliest WIM equipment in the mid-1970s and has been operating at least one WIM scale more or less continuously since the early 1980s (*1*). MTO is currently operating four in-highway WIM scales, six WIM sorter scales at truck inspection stations (TISs), and, to comply with the SHRP and C-SHRP guidelines, is planning to install three more WIM scales in 1991.

The existing and planned WIM scales provide a large amount of detailed traffic monitoring data for individual highway vehicles, such as axle spacing and axle weights, and vehicle length and speed. This is in addition to the traditional aggregated traffic characteristics, such as hourly and daily vehicle volumes. Installing and operating WIM scales, and their associated traffic data retrieval and analysis, are neither easy nor inexpensive. It is desirable to ensure that the wealth of traffic monitoring data generated by WIM scales is used properly.

It is often assumed that WIM data are applicable only to pavement research, because of their association with the SHRP and C-SHRP pavement research effort. As a result, many potential users of WIM-type traffic monitoring data do not know

1. The data monitoring capabilities of WIM technology,
2. The type of data available, and
3. How the data can be used within their area of interest.

The objective of this paper is to show, by practical examples, that WIM data are useful for a wide range of transportation planning and decision-making purposes. The treatment of any individual area is brief, by necessity, to provide a comprehensive overview of all the main areas of application.

In this report, axle and gross vehicle weights (GVW) results are presented in kilograms, axle spacings in meters, and vehicle speeds in kilometers per hour—the units in which Ontario regulates vehicle loads and dimensions.

DESCRIPTION OF TRAFFIC MONITORING DATA PROVIDED BY WIM SCALES

A typical WIM scale consists of magnetic loops and axle sensors embedded in the pavement and a microcomputer housed in a roadside cabinet. Magnetic loops and axle sensors respond to axles passing over the pavement by generating electric signals. The signals are processed by the computer and are transformed into engineering parameters including instantaneous vehicle speed, vehicle length, distances between consecutive axles, and axle weights. An annotated example of an individual vehicle record provided by a WIM scale is shown in Figure 1.

The majority of data used in this study were obtained from two WIM scales, one installed on Highway 7N and the other on Highway 402. The Highway 7N scale is in an eastbound truck lane of a six-lane suburban (metropolitan Toronto) arterial road and uses bending plate technology (*2*). The Highway 402 scale is in an eastbound truck lane of a four-lane rural freeway (near Sarnia) with a speed limit of 100 km/hr;

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(910)LANE £3   TYPE 7   GVW 33.1 tonnes    LENGTH 1849 cm
18-K ESAL 4.058 SPEED 57 km/h Mon Jan 15 08:54:46 1990
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UNIT	SEPARATION (cm)	WEIGHT (kg)
1		4432
2	515	9517
3	148	9618
4	763	5343
5	180	4226

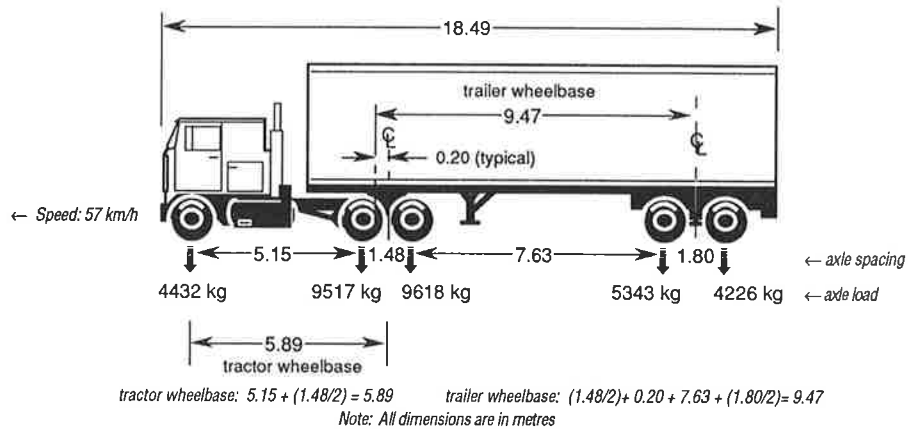

FIGURE 1 Individual truck record from International Road Dynamics, Inc., WIM scale and its interpretation.

it uses piezoelectric cable technology (*3*). Compared with static conditions, the scales provide dimensions accurate within 2 to 3 percent, GVWs within about 5 percent, and axle loads within about 5 to 12 percent. Accuracy depends on vehicle dynamics (e.g., vehicle configuration and speed) and pavement roughness in the vicinity of the scale.

The WIM computer can store a record for each vehicle passing over the scale, as well as some selected summary data. These data can be verified, edited, and analyzed to meet the various application requirements.

Common to all WIM data applications is the need to classify individual vehicles into distinct categories. An example of the basic MTO vehicle classification scheme is given in Table 1. The scheme resembles that used by the FHWA *Traffic Monitoring Guide* (*4*). However, unlike the FHWA guide, it attempts to classify nonpassenger vehicles not only according to number of axles and number of connected units, but also according to axle configuration. Thus, for example, there is a specific category for 3S2 trucks (Category 7 in Figure 2).

Although the Ontario scheme recognizes 14 highway vehicle classes, some applications discussed later require a more specific or detailed classification scheme. Figure 2 shows one method for identifying six-axle tractor-semitrailers that are loaded close to their allowable gross weight. The semitrailer is of a triaxle design, having a fixed dual axle unit at the rear and a liftable "belly axle" usually at least 2.54 m ahead of it. The scheme relies on knowledge of the impact of vehicle weight and dimension regulations on truck design. This was done by constructing a "filter" that specifies limits on various truck weight and dimension parameters so that only those trucks of interest are selected.

Considering the variety and the large samples of vehicles analyzed, there must be a certain level of speculation associated with any vehicle classification scheme based on WIM data. There is no reason to believe that these uncertainties have a significant effect on the observations made from the results or on the more global conclusions presented herein.

USE OF WIM DATA

To enhance the understanding of and to clarify the various ways in which WIM data can be used for transportation planning and decision making, the following discussion is divided into nine general application areas, some of which may overlap.

Planning and Programming of Transportation Facilities

Any WIM scale installed on a highway is, basically, a continuously operating traffic counting station. It can generate not only traditional traffic volume characteristics, such as the annual average daily traffic (AADT) and the 30th highest hourly volume used for planning and programming of transportation facilities, but also a wealth of additional detailed data for individual highway vehicles.

When planning the installation of new permanent traffic counters, or the replacement of existing ones, consideration should be given to upgrading the counters into WIM scales. The cost of upgrading is mainly due to higher-quality axle sensors and a more powerful computer in the roadside cabinet. Installation and operating costs, such as highway closure during installation, provision of power and communication lines at the site, system maintenance, and data retrieval ac-

TABLE 1 Ontario Vehicle Classification Scheme

Class	Type	Description
1	PVLC	**Passenger cars** 2-axle vehicles with spacing from 1.2 to 3.9 m
2	2	**2-axle trucks** axle spacing from 3.9 to 15.0 m
3	3	**3-axle trucks** with a dual axle spacing up to 2.4 m
4	UD-3	**All other 3-axle trucks**
5	2S2	**4-axle trucks** 2-axle tractor with one dual axle semitrailer dual axle spacing up to 2.4 m largest tractor and semitrailer axle spacing from 2.4 to 15.0 m
6	UD-4	**All other 4-axle trucks**
7	3S2	**5-axle trucks** 3-axle tractor with one dual axle semitrailer dual axle spacing up to 2.4 m largest tractor and semitrailer axle spacing from 2.4 to 15.0 m
8	UD-5	**All other 5-axle trucks**
9	3S3	**6-axle trucks** 3-axle tractor with a 3-axle semitrailer tractor dual axle spacing up to 2.4 m trailer axle spacing up to 2.6 m largest tractor and semitrailer axle spacing from 2.4 to 15.0 m
10	UD-6	**All other 6-axle trucks**
11	3S2-2	**7-axle trucks** 3-axle tractor with two semitrailers or with one semitrailer and one trailer; the first semitrailer has a dual axle tractor dual axle spacing up to 2.4 m largest tractor axle spacing up to 5.0 m first semitrailer dual axle spacing up to 3.0 m largest 1st and 2nd trailer axle spacing from 5.2 to 15.0 m
12	UD-7	**All other 7-axle trucks**
13	UD-8	**All 8-axle trucks**
14	UD-9	**All trucks with 9 or more axles**

count for the bulk of the total cost. They are not very influenced by the type of traffic counting device. The benefits of upgrading can be significant.

Pavement Design and Rehabilitation

WIM data have been closely associated with pavement design because traffic loads constitute the basic pavement design parameter (*5*). For pavement design and evaluation purposes, the effect of traffic loads on pavement structural damage has been traditionally expressed using the concept of load equivalency factors (LEFs). The equivalency factors equate the damaging effect of any given axle, or axle combination, to that of a standard axle. For convenience, LEFs have been related to the standard axle load of 8160 kg (18,000 lb) carried on a single axle with dual tires, called the equivalent single axle load (ESAL).

Understanding of the number of ESALs associated with different truck types, in different highway corridors and during different times is now shaped mainly by WIM data. As an example of the usefulness of WIM data, Table 2 compares the average ESAL per truck obtained from WIM scales with that estimated by the OPAC truck prediction subsystem (*6*). The latter is currently used for design and was established before the advent of WIM scales. The existing prediction methodology is seen to underestimate the average ESALs per truck by a factor of 2 or more. The ESALs reported herein are related to flexible pavements with a structural number equivalent to 5 (*5*).

Whereas Table 2 shows the average ESALs per truck, a rather global measure of pavement traffic load, WIM technology enables changes in ESAL for specific vehicle types during specific periods to be evaluated. For example, Figure 3 illustrates a year-long variation in average weekly ESALs for 3S2 tractor-semitrailers on Highway 7N. (For definition of 3S2 trucks, refer to Figure 2.)

The WIM data can provide the main building block for developing procedures for predicting ESALs for pavement structural design. What is required, basically, is to obtain

Criteria for Truck Definition

(a) 6-axle trucks

(b) single (steering) - dual (tractor) - single (liftable) - dual (trailer) axle arrangement

(c) axle 2-3 spacing from 1.07 to 1.83 m

(d) axle 3-4 spacing greater than 4.00 m

(e) axle 4-5 spacing greater than 2.40 m

(f) axle 4-5 spacing greater than axle 5-6 spacing

(g) axle 5-6 spacing from 1.07 to 3.05 m

(h) gross weight within 1000 kg of allowable load

Explanation

The first item simply ensures the proper number of axles. The second is descriptive, and may be redundant. Item (c) covers the known range of drive axle spreads. Item (d) ensures that the filter captures semitrailers at least 10 m (32 ft) long, so it will exclude tractors pulling 7 m (23 ft) tridem container chassis. Items (e) and (f) ensure the liftable axle is properly separated from the trailer tandem axle, according to either Quebec, Ontario, or Michigan regulations. Item (g) covers the known range of trailer axle spreads. The final item ensures the gross weight is close to the allowable limit.

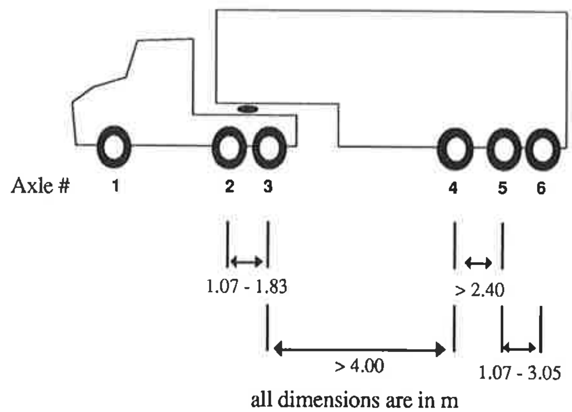

FIGURE 2 Criteria identifying six-axle tractor-semitrailers with liftable axle.

TABLE 2 Comparison of Average ESALs per Truck (5)

Location Facility type	Average ESAL per truck	
	Based on WIM Measurements	OPAC Estimate
Hwy. 7N Urban arterial road	1.40	0.40
Hwy. 402 Rural freeway	1.60	0.67

volume estimates for major truck categories and their corresponding average ESALs. Detailed step-by-step procedures are readily available.

Apportionment of Pavement Damage

In many jurisdictions there is a general tendency to set truck license fees in proportion to the highway resources (pavement damage) consumed. The WIM scales can quantify pavement

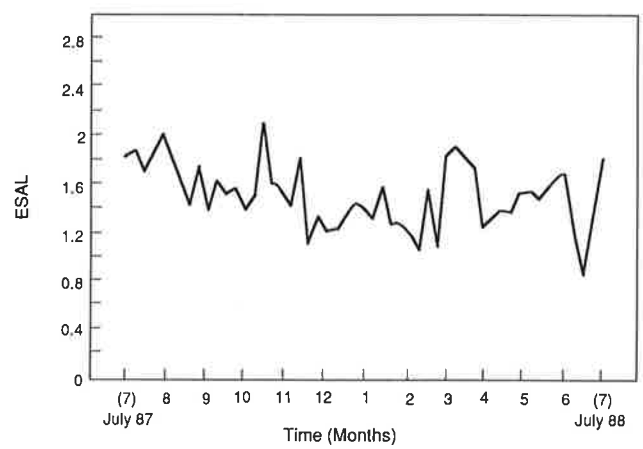

FIGURE 3 Variation in weekly ESALs for 3S2 tractor-semitrailers: Highway 7N, Lane 3.

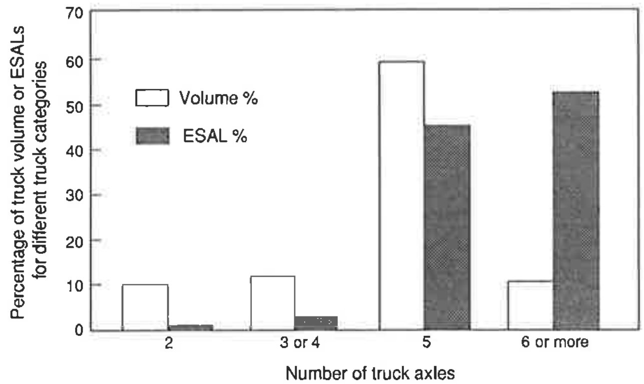

FIGURE 4 Pavement damage contribution by different truck categories: Highway 402, 1989.

damage contributions of various truck classes, as shown in Figure 4 for Highway 402. For example, trucks with six or more axles constitute less than 20 percent of the total truck volume but are seen to be responsible for more than 50 percent of pavement damage.

Compliance with Vehicle Weight Regulations

In-Highway WIM Scales

WIM scales can provide realistic and detailed insight into vehicle axle and gross overloads. The assessment is realistic because WIM scales can operate continuously and they are unobtrusive. It is detailed because by generating weight and dimension records for individual highway vehicles, they enable assessment of overloads during a specific time period and for a specific truck category. WIM scales do not directly provide a valid estimate of violation rates because of the impact of vehicle dynamics and other factors on weight estimates. Although they cannot be used at this time for vehicle weight enforcement, WIM scales are sufficiently accurate to identify substantial deviations from regulatory limits.

An example result in Figure 5 shows the compliance with weight regulations for liftable axles on six-axle tractor-semitrailers with a dual-axle unit at the rear and a liftable belly axle at least 2.54 m ahead of it. This truck type is the

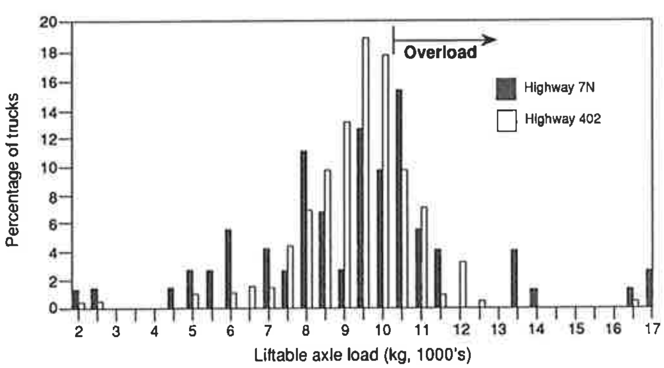

FIGURE 5 Liftable axle load distribution for selected group of six-axle tractor-semitrailers.

most common among the trucks with liftable axles and is also the most prone to axle overloads.

The trucks were identified using the filter defined in Table 1 that was applied to individual vehicle records obtained by the Highway 402 and Highway 7N WIM scales during 1 month in 1990. The same data set is used for the other examples in this paper, unless otherwise stated. The filter produced a sample of 72 trucks from the Highway 7N WIM scale and 184 trucks from the Highway 402 scale. The small numbers arise because the range of GVW of the selected trucks is very narrow (condition in filter of Table 1), ranging from about 49 000 to about 55 500 kg.

A few selected observations, related only to liftable axles and based mainly on Figure 6, follow. [A more comprehensive discussion of GVW and axle overloads for six-axle tractor-semitrailers with liftable axles is available (7). This literature also describes weight compliance observed for five- and six-axle semitrailers without liftable axles.]

- Loads on the liftable axles ranged from 2000 to 17 000 kg for each highway. The allowable load limit on the liftable axle, considering that its distance from the surrounding axles is more than 2.5 m, is 10 000 kg.
- There was somewhat better load compliance on Highway 402 than on Highway 7N. About 21 percent of liftable axles were overloaded on Highway 402 compared with about 37 percent on Highway 7N. This may be partly because of the proximity of the Highway 7N WIM scale to intersections, at which turning trucks would be raising the liftable axle in preparation for turning or after making a turn, and partly because the Highway 402 WIM scale is close to a TIS. The liftable axle overloads apply only to a selected group of trucks with the GVW close to the allowable limit (Table 1, Criterion h).
- Because the GVW of all trucks investigated was within 1000 kg of their allowable (total) GVW, when the loads on the liftable axles were significantly lower than their allowable load—say, less that 8000 kg—the slack caused by these underloaded liftable axles had to be compensated for by overloading the surrounding axles. About 20 percent of liftable axles were underloaded on Highway 7N.

Analyses of this type, based on statistically relevant samples obtained by WIM scales, are far removed from simplistic conclusions such as "10 percent of trucks are overloaded."

WIM Scales near TISs

WIM scales near TISs can be used to evaluate the effectiveness of weight enforcement programs and help in developing cost-effective enforcement strategies. This can be accomplished, for example, by comparing compliance rates, determined by a continuously operating WIM scale, achieved by various compliance enforcement strategies employed at the TIS (e.g., an intensive versus a spotty enforcement strategy).

WIM as Sorter Scale

To facilitate the enforcement of weight regulations, TIS on high-truck-volume highways have been equipped with WIM scales. These scales are referred to as "sorter scales" because

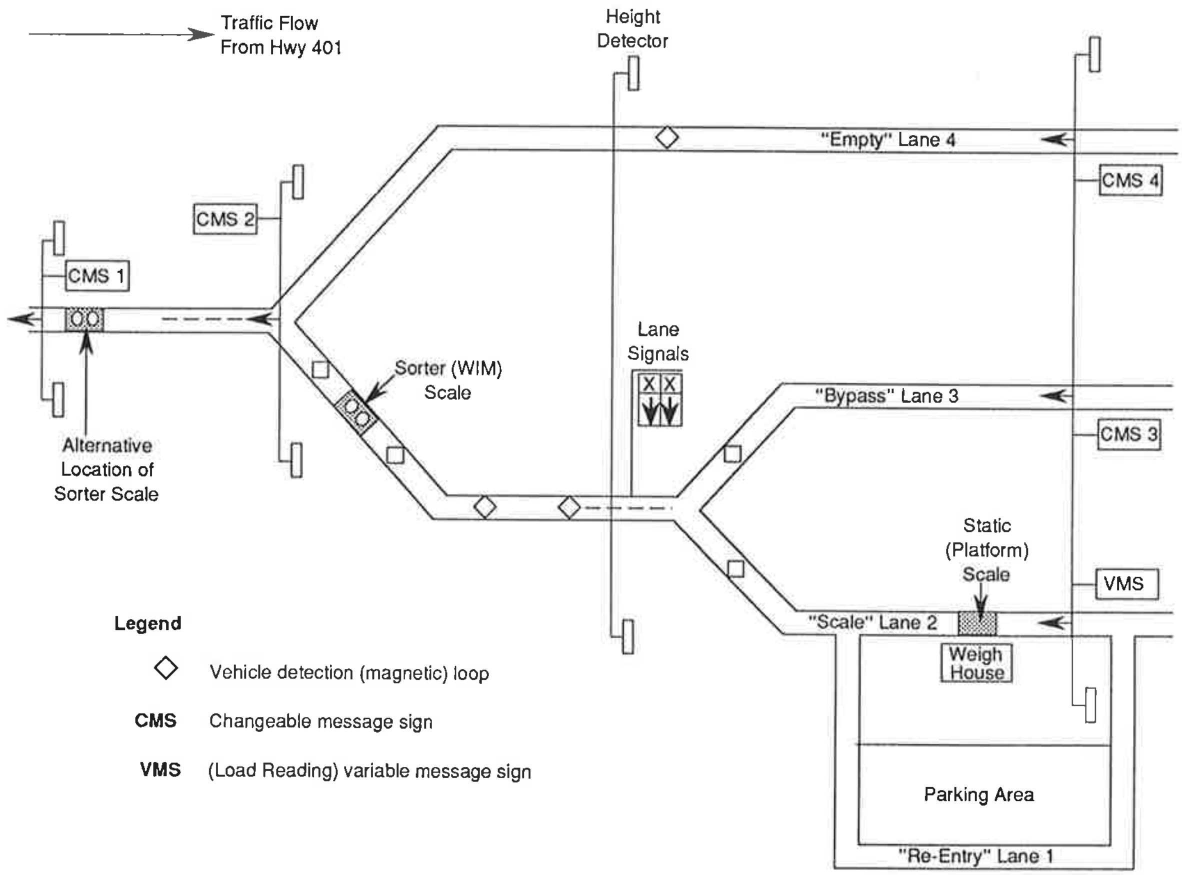

FIGURE 6 Schematic layout of TIS with sorter scale.

they are used to sort incoming trucks into two categories: (a) those that clearly comply with weight regulations, and (b) those that should be weighed at a static scale. Figure 6 shows a schematic layout of a TIS incorporating a sorter scale. Upon entering the TIS area, trucks with no payload can be directed to bypass both the sorter scale and the static scale. When this option is used, the weight data obtained from the sorter scale are no longer representative of the entire truck population and cannot be used for certain applications. Whenever feasible, the sorter scale should be used to weigh all trucks entering the TIS. Even in this case the data can be biased: the proclivity of trucks to avoid TIS is well known.

Development of Geometric Design Standards

The rational development of highway geometric design standards (turning radii and width of traffic lanes at intersections, dimensions of loading and unloading facilities, design of truck climbing lanes, etc.) requires the knowledge of vehicle weights and dimensions. In particular, it requires knowledge of the dimensions of the most common, and from the space requirement aspect, one of the most demanding, large truck configurations—the five-axle tractor-semitrailer. The realistic assessment of dimensions of existing vehicles requires a large truck population sample, which can easily be provided by WIM scales. The use of WIM data is illustrated for one of the key parameters governing the space requirements for turning movements of a 3S2 truck—its semitrailer wheelbase. A detailed analysis and interpretation of the observed dimensions of five-axle tractor-semitrailers on geometric standard development, in terms of the overall truck length, tractor and semitrailer wheelbase, and the drive and trailer axle spreads, is given elsewhere (7).

The relationship between semitrailer wheelbase (the distance from its kingpin to the center of its rear dual axle; Figure 1) and the maximum low-speed offtracking offset (the distance between the turning radii of the steering axle and the rear axle) is shown in Figure 7; Figure 8 shows the observed trailer wheelbase distribution. Some of the observations on trailer wheelbase distribution, as they apply to the development of geometric standards, are summarized as follows.

- On Highway 7N, the distribution appears to be bimodal. The first peak, about 8.8 m (29 ft), is believed to be associated primarily with a 40-ft container chassis. The second peak, about 10.7 m (35 ft), is more likely to be associated with older 13.7-m (45-ft) semitrailers now relegated to local uses. On Highway 402, the predominant wheelbase is about 11.9 m (39 ft), which is typical of a 14.7-m (48-ft) semitrailer now used for long-distance hauling.
- The maximum observed semitrailer wheelbase was about 13 m on Highway 402 (Figure 8). This wheelbase results in an offtracking of about 7 m (Figure 7). However, considering the generally shorter wheelbase distances observed for local Highway 7N traffic and the longer wheelbase distances ob-

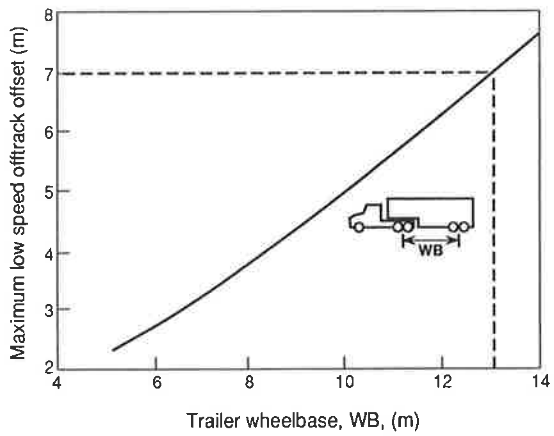

FIGURE 7 Maximum offset during low-speed turns (*8*).

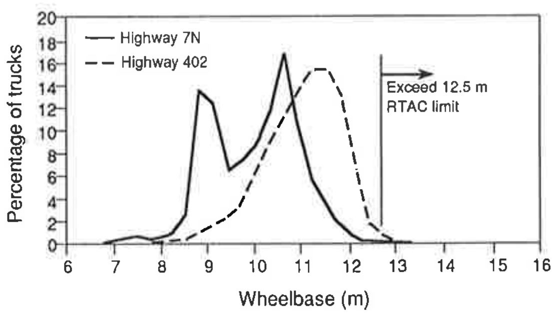

FIGURE 8 Trailer wheelbase distribution for five-axle tractor-semitrailers.

served for long-distance Highway 402 traffic, the geometric standards need not be applied uniformly to all transportation facilities.

Truck Dimensions: Compliance and Regulatory Policy Development

The knowledge of existing truck dimensions can be used to assess the consequences of regulatory changes in truck dimensions, the need to except the existing truck configurations for the present (grandfathering), or both. This issue is connected with the development of geometric design standards. However, whereas the development of geometric design standards tends to simply reflect the existing situation, exploration of the policy development issues is more proactive. For example, the following observations may be formulated when considering the results of the semitrailer wheelbase distribution given in Figure 8, from a compliance perspective:

- The Canadian *Memorandum of Understanding on Interprovincial Heavy Vehicle Weights and Dimensions* (*9*) establishes an upper limit of 12.5 m for a semitrailer wheelbase. Twenty-eight trucks on Highway 7N (0.39 percent) exceeded this limit, compared with 194 (0.49 percent) on Highway 402. Most of these exceeded the 12.5-m limit by no more than 0.6 m.
- Some of the problem trucks may be carrying a long, indivisible load and operating under permit. It would be useful to know "who" such trucks are, particularly in terms of their body style and commodity. However, the WIM data alone cannot provide such detailed information.

Safety Analysis

Safety emerges as a major issue in all debates or polemics about changes in vehicle weights and dimensions and, invariably, it is concluded that adequate information about safety implications of the proposed changes is lacking (*10*). WIM data can contribute to analysis of safety issues by providing detailed information on vehicle types using highway facilities and vehicle behavior on highway facilities.

Vehicle Types Using Highway Facilities

The knowledge of mileage traveled by various vehicle types (exposure rate) is a prerequisite for evaluating their accident rates. The accident rate (number of accidents divided by exposure) is instrumental in identifying the influence of vehicle design parameters on vehicle safety.

Trucks are often registered in several jurisdictions or in a jurisdiction other than the one in question. It is, therefore, difficult to estimate mileage traveled by different truck classes and, thus, to obtain accident rates for different truck types. WIM data can help in establishing truck exposure measures, particularly for facilities in which WIM scales have been installed. For example, referring to Figure 4, Truck Type 3S2 (defined in Table 1) composes about 55 percent of the total truck volume on Highway 402. The volume percentage of 3S2s can be directly related to the percentage of accidents involving the 3S2s on this facility.

Another descriptive parameter useful in accident studies (and provided by WIM data) is GVW. It has been observed that the accident rates of unloaded trucks are significantly higher than those for loaded trucks (*11*).

Vehicle Behavior on Highway Facilities

The unobtrusive presence of WIM scales can provide a reliable description of vehicle driving patterns and enable rational assessment of truck driving behavior. In this summary report, driving behavior is described using only simple frequency distribution functions for vehicle speed and headway. It is certainly possible to study more complex functions, such as the relationship between vehicle speed, headway, GVW, and time of day for different vehicle categories, and to provide data to develop and manage police enforcement strategies.

Vehicle Speed Distribution WIM scales routinely provide instantaneous vehicle speeds (Figure 1). Excessive vehicle speed, and particularly speed differentials between different vehicles, is considered to be a main cause of accidents. Overloaded and speeding trucks may constitute an additional safety hazard.

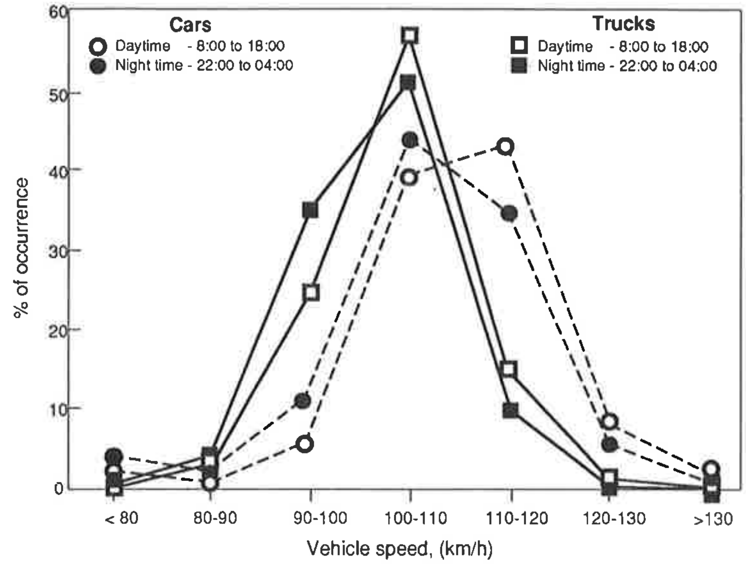

FIGURE 9 Vehicle speed distribution: Highway 402, truck lane, March 19–22, 1991.

Figure 9 shows vehicle speed distribution for cars and trucks, during the day and at night, derived from the Highway 402 WIM scale data. Data were obtained for four consecutive weekdays, without any precipitation, in March 1991. The WIM scale is in one of the truck lanes of this four-lane rural freeway, and low traffic volumes (about 300 vehicles per hour in the WIM lane during daytime and 75 vehicles per hour at night) enable a large degree of traffic operational freedom.

Overall, data in Figure 9 indicate that truck drivers are more disciplined than car drivers. Some specific observations follow:

- Most cars were speeding. The speed limit on this facility is 100 km/hr (about 60 mph). During daytime, about 53 percent of all cars exceeded 110 km/hr, whereas at night 42 percent of all cars exceeded this speed. The corresponding numbers for trucks were 16 and 10 percent, respectively.
- Compared with cars, truck speed distribution is more uniform. Looking at the extremes, during daytime, 1.3 percent of cars had speeds less than 80 km/hr compared with only 0.3 percent of trucks. At the high end, 1.3 percent of cars (in the truck lane) exceeded the speed of 130 km/hr compared with 0.1 percent of trucks.

Headway Distribution According to Ontario's *Highway Traffic Act* (*12*), maintaining "reasonable and prudent" headway is mandatory for all drivers. There is an extra stipulation for drivers of commercial vehicles who, while driving at speeds exceeding 60 km/hr, "shall not follow within 60 metres of another motor vehicle."

WIM scales routinely provide a time stamp, truncated to the nearest second, for all individual vehicle records. Only this routine time measurement precision was available for data used in this exploratory study. A more focused study of headway distribution would require software modification that gives time measurements in tenths of a second.

Figure 10 compares the difference in headway distributions of cars and trucks. The figure uses the same data set as that used for Figure 9. The greater discipline of truck drivers, indicated by the speed distribution, is also indicated by the headway distribution. Some observations follow:

- During daytime, 7 percent of all cars followed other cars with a 1-sec headway, whereas only 2.5 percent of trucks did so. Nevertheless, considering an average truck speed of 100 km/hr or 27.8 m/sec, more than 2.5 percent of all trucks appear to be in violation of the Ontario Highway Traffic Act headway requirement.
- A total of 3.5 percent of all trucks were following other trucks with a headway of 1 sec, whereas only 2.5 percent of trucks were following cars with this headway. The difference in the headway distribution for these two cases was found to be statistically significant.

Traffic Operation and Control

Several computerized analytical models are used for analysis, optimization, and control of traffic operations on highway facilities. To derive full benefits from the more sophisticated analytical models, it is necessary to divide the traffic flow into vehicle categories according to vehicle weight and length and frequency of occurrence. For example, the model TRARR (*13*), used for analysis of undivided highways, can accommodate up to 16 vehicle types, and FOMIS (*14*), a simulation model for freeway sections, can accommodate up to 100 vehicle types. Undoubtedly, WIM-supplied data can take advantage of the models' options and can increase their usefulness and accuracy.

Analysis Related to Highway Bridges

Two levels of WIM data usage can be envisaged: to determine load levels used for reviewing the design and maintenance

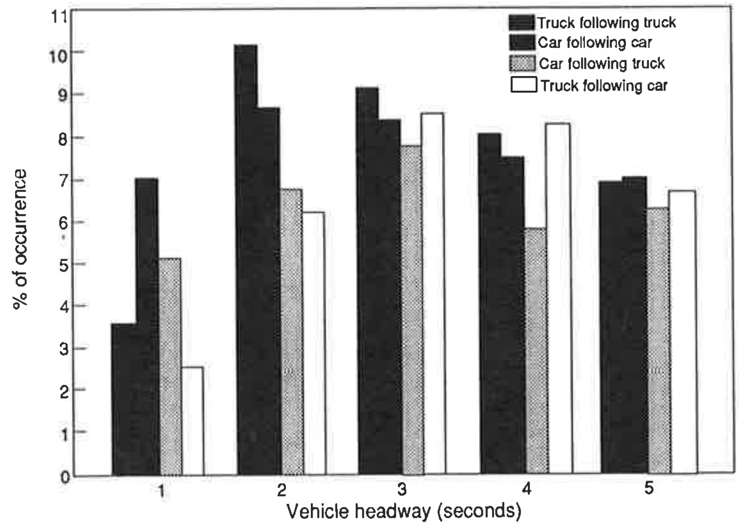

FIGURE 10 Daytime vehicle headway distribution: Highway 402, truck lane, March 19–22, 1991.

standards for bridges, and to determine load levels for a specific bridge structure.

Review of Loading Requirements for Design and Maintenance

Periodic vehicle weight surveys are essential to determine loading standards for the design and maintenance of bridges (*15*). The most recent load survey for Ontario, conducted in 1989, was done manually, by measuring (with a tape) and weighing (with static scales) a selected sample of about 2,000 trucks in 17 locations across the province. This type of survey could become obsolete as the number and accuracy of WIM scales increase. Some preliminary work on using WIM data, obtained by an instrumented highway bridge, was done by Agarwal and Bakht (*15*). At any rate, WIM scale results can supplement manual surveys and have the advantage of realistically capturing overloaded trucks, which are usually one of the main reasons for conducting such surveys.

Load Levels for Specific Bridge Structures

The loading and safety concerns about a specific bridge structure can be addressed by temporary installation of a portable WIM scale. The WIM scale can provide the loading information to the bridge owner and can also provide a warning to drivers of trucks that are overloaded for the specific bridge structure.

DISCUSSION OF RESULTS

The discussion on using WIM scale data and extracting specific information of interest in various application areas is not exhaustive. It simply illustrates possible usage in the traditional application areas. Other application areas may include modeling of goods movement and macroeconomic applications (input-output models). For example, the Pennsylvania Department of Transportation uses WIM scale data to determine total cargo weight transported by the highway on a long-term basis (*16*). WIM scales, combined with automatic vehicle identification systems, may be used for fleet management and management of truck traffic through long-distance corridors (Crescent project). On a somewhat unrelated topic, WIM scales can be installed on remote airports to document aircraft movements (e.g., type of aircraft, how loaded, and time of operation).

CONCLUSIONS

1. This paper has demonstrated, through examples, that WIM data can provide insights not previously available to a wide range of issues that cut across the organization of a highway agency.
2. WIM technology can provide statistically reliable samples that should supplant older labor-intensive manual survey methods.
3. WIM scales, because of their unobtrusiveness and continuous operation, can provide truly unbiased data yielding a realistic long-term picture of highway usage and driver behavior.
4. Currently available WIM data do not satisfy all requirements connected with analyzing the effects of regulatory policies on truck weights and dimensions.
5. When planning the installation of new permanent traffic counters, or the replacement of the existing ones, consideration should be given to upgrading the counters into WIM scales.
6. The demonstrated usefulness of WIM data requires that they be treated as corporate data. Highway agencies should consider establishing dedicated (formal) WIM data banks to facilitate data storage and retrieval as a service to potential users. WIM scale operation and WIM data storage should be integrated with other traffic data gathering and storage processes as the corporate resource.

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