

Truck behaviour on highway facilities

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The recent availability of weight-in-motion (WIM) traffic monitoring data is exploited for the purpose of investigating safety-related truck behaviour on highway facilities. This paper briefly describes WIM technology and its capabilities to generate traffic monitoring data which are important for traffic safety analysis. The body of the paper provides examples of data analysis that demonstrate the usefulness of WIM data for investigating safety-related truck behaviour. The examples include determination of truck exposure rates, and evaluation of vehicle speed and headway distributions as a function of truck type and truck load.

1. INTRODUCTION

With the advent of the Strategic Highway Research Programme (SHRP) and its national satellite programs, such as UK-SHRP and Canadian-SHRP, weight-in-motion (WIM) scales have become commonplace. For example, the Ontario Ministry of Transportation is currently operating eight in-highway WIM scales and, to comply with the SHRP and C-SHRP guidelines, is planning to install one additional WIM scale in 1992.

The WIM scales are providing, and will continue to provide, a large amount of detailed traffic monitoring data for individual highway vehicles, such as axle spacing and weights, vehicle length and speed. This is in addition to the traditional aggregated traffic characteristics such as daily and annual vehicle volumes and Equivalent Single Axle Loads. Considering the effort associated with the installation and operation of WIM scales, and with subsequent data retrieval and processing, we should ensure that the wealth of traffic monitoring data generated by WIM scales is properly utilized.

Because of its original association with the SHRP-related pavement research effort, it is often assumed that WIM data are only applicable to pavement damage research. Many potential users of WIM-type traffic monitoring data do not know:

- (a) the data monitoring capabilities of WIM technology,
- (b) type of data available, and
- (c) how the data can be utilized within their area of interest [1].

The objective of this paper is to show, by practical examples, that WIM data are also useful for safety-related analyses and indeed indispensable for studying truck behaviour on highway facilities.

The data used in this study were obtained from two WIM scales, both located on Hwy 402 in Ontario, Canada. Highway 402 is a four-lane rural freeway with a speed limit of 100 km/h. One WIM scale is located in an eastbound truck

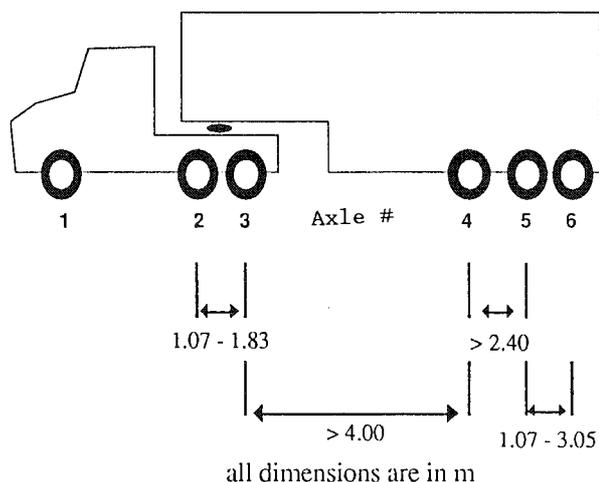
lane near Sarnia and is referred to in this paper as Location 1; the second scale spans all four lanes near London and represents Location 2. Both scales use piezoelectric cable technology [2].

Low traffic volumes (about 300 vehicles per hour during daytime and 75 vehicles per hour at night in the truck lane) enable a large degree of traffic operational freedom. However, Location 2 is about 2 km downstream from a freeway entrance ramp. Due to highway alignment constraints, traffic may not yet reach its free-flow equilibrium at this location. The highway grade for two or more kilometers before either location is at a level.

2. 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 for each individual vehicle. These parameters include a time stamp, instantaneous vehicle speed, vehicle length, distances between consecutive axles, and axle weights.

The knowledge of engineering parameters for individual vehicles, combined with a knowledge of the impact of vehicle weight and dimension regulations on truck design, can be utilized to determine highway vehicle types for classification purposes. A judicious classification scheme can pinpoint and select specific truck types of interest. For example, Figure 1 shows one such scheme designed for identification of fully loaded 6-axle tractor-semitrailers with a liftable ("belly") axle. It is possible to narrow the field even further by specifying also the period of occurrence and speed or headway parameters.



Criteria for Truck Definition

- 6-axle trucks (to identify the proper number of axles)
- single (steering) - dual (tractor) - single (liftable) - dual (trailer) axle arrangement
- axle 2-3 spacing from 1.07 to 1.83 m (to cover known range of drive axle spreads)
- axle 3-4 spacing greater than 4.00 m (to ensure that the semitrailer is at least 10 m long)
- axle 4-5 spacing greater than 2.40 m (to ensure independence of axle 4)
- axle 4-5 spacing greater than axle 5-6 spacing (to ensure that axles 4,5,6 do not form a triple axle)
- axle 5-6 spacing from 1.07 to 3.05 m (to cover known range of truck axle spreads)
- gross weight within 1000 kg of allowable load (specifies a fully loaded truck)

Figure 1/ Criteria identifying 6-axle tractor-semitrailers with a liftable axle

Considering the variety of vehicles on Ontario's highways and 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 presented herein.

3. SAFETY ANALYSIS

Safety is a major issue in all debates or polemics about changes in highway traffic regulations and in vehicle weights and dimensions. Invariably, it is concluded that adequate information about safety implications of the proposed changes is lacking [3]. WIM data can contribute to analysis of safety issues by providing unique and detailed information on

- frequency of different vehicle types using highway facilities,
- vehicle behaviour on highway facilities, and
- truck payload and its distribution.

3.1 Frequency of Vehicle Types Using Highway Facilities

The knowledge of accident rates for different truck types is instrumental in identifying the influence of vehicle design parameters on highway

safety. The accident rate is defined as the number of accidents divided by the number of kilometers travelled (exposure rate). Because trucks are often registered simultaneously in several jurisdictions, or are registered somewhere other than the jurisdiction in question, it is difficult to estimate vehicle kilometers travelled 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 where WIM scales have been installed. For example, referring to Figure 2, 5-axle trucks (defined in this case as a 3-axle tractor with one dual axle semitrailer, or 3S2) comprise about 55% of the total truck volume on Hwy 402. The volume percentage of 3S2s can be directly related to the percentage of accidents involving the 3S2s on this facility.

It should be stressed that while WIM-type data can be used to enumerate the population of trucks of any particular type (e.g., fully loaded 6-axle trucks with one liftable axle, as outlined above), the WIM data cannot discern the body style, commodity/load, owner or other information that might identify the specific nature of the truck and its owner. However, the identification of numbers and magnitudes is still very important because it does allow infrequent or low-probability events to be examined, which is not practical with the small samples that can be garnered by manual survey methods [4].

3.2. Vehicle Behaviour on Highway Facilities

Although highways are designed to serve a mix of vehicle types, the effects of various types of vehicles on traffic operations and safety are not uniform. In this context, a number of factors influencing traffic safety have been identified, including speed, passing, merging and other lane changing manoeuvres, splash and spray, aerodynamic buffeting, blockage of view, and lateral placement. Other important factors related to highway safety are vehicle handling, stability and braking capabilities, load and load distribution, and vehicle headway [5].

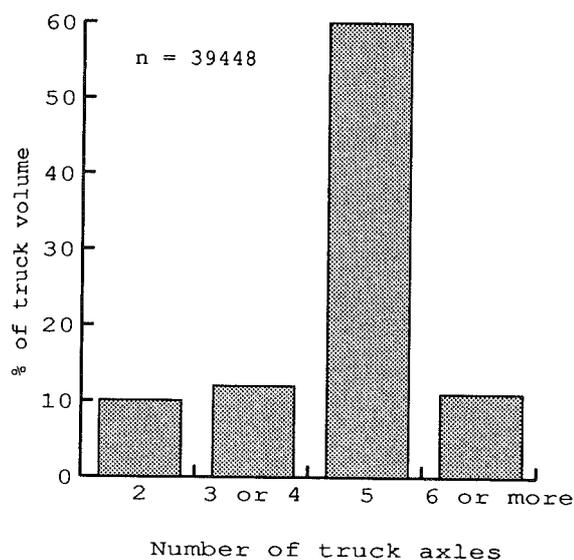


Figure 2/ Occurrence of different truck types, March 1991

WIM type data alone can be used to evaluate truck driving behaviour in terms of speed and headway distributions as a function of axle (vehicle) weight, and time of day (e.g., daytime-nighttime visibility). In addition, weather conditions (precipitation) were also taken into account in this paper. For a more comprehensive assessment of truck behaviour, WIM data need to be supplemented from other sources such as video recordings.

a) Vehicle speed distribution

Excessive vehicle speed, and particularly speed differentials between different vehicles, is considered to be one of the main causes of accidents [6]. When different vehicle types exhibit different speeds (e.g., loaded trucks moving more slowly than the prevailing traffic, particularly on upgrades), the speed variance of the traffic flow increases. The difference in speed variance has been directly linked to the increase in overall accident rates [7]. The primary vehicle characteristic affecting acceleration and speed performance of trucks is the weight/power ratio. Speed is also one of the main parameters governing energy consumption. Overloaded and speeding trucks may also constitute an additional safety hazard.

An example of vehicle speed distribution for cars and trucks, obtained by the WIM scale at Location 1 during daylight hours and at night, is shown in Figure 3. Data were obtained for four consecutive weekdays without any precipitation in March of 1991. Overall, data in Figure 3 indicate that truck drivers are more disciplined than car drivers. Some specific observations:

- * The majority of the cars were speeding. During daytime, about 53% of all car drivers exceeded the speed of 110 km per hour, while at night 42% of all car drivers exceeded this

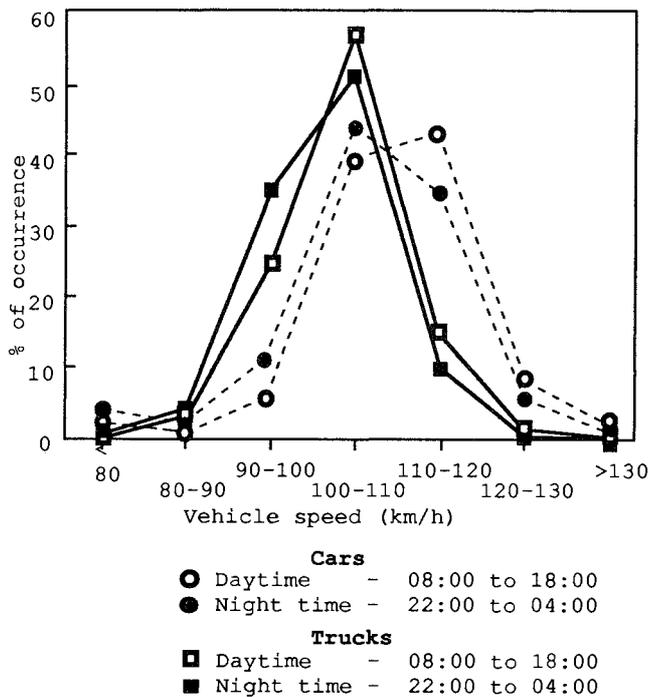


Figure 3/ Vehicle speed distribution, Hwy 402, truck lane, March 19 to 22, 1991

speed. The corresponding numbers for truck drivers were 16% and 10% respectively.

- * Compared to cars, truck speed distribution is more uniform. Looking at the extremes, during daytime, 1.3% of cars had speeds less than 80 km/h compared to only 0.3% of trucks. At the high end, 1.3% of cars (in the truck lane) exceeded the speed of 130 km/h compared to 0.1% of trucks.
- * The more uniform speed distribution observed for trucks is reflected in their lower speed variance. Using the empirical relationship between speed variance and accident rates (Equation 4 in Ref. 7), the data in Figure 3 suggest that the accident rate of cars only would be about 70 (accidents per 100 million vehicle miles of travel); the accident rate of trucks only would be 55, while the corresponding combined accident rate of cars and trucks would be about 82.

b) Headway distribution

According to Ontario's Highway Traffic Act [8], maintaining "reasonable and prudent" headway (i.e. the time between successive vehicles) is mandatory for all drivers. There is an extra stipulation for drivers of commercial vehicles which, while driving at speeds exceeding 60 km/h, "shall not follow within 60 meters of another motor vehicle".

Vehicles travelling at 100 km/h (27.8 m/s) would have a "front bumper-to-front bumper" spacing of only 28 metres with one second headway. This reduces the actual space between vehicles to only about 24 metres for an average car and, of course, considerably more for even small trucks. One or two second headways are clearly unsafe at highway speeds.

Figures 4 and 5 compare the difference in headway distributions of cars and trucks. The figures use the same data set as that used for

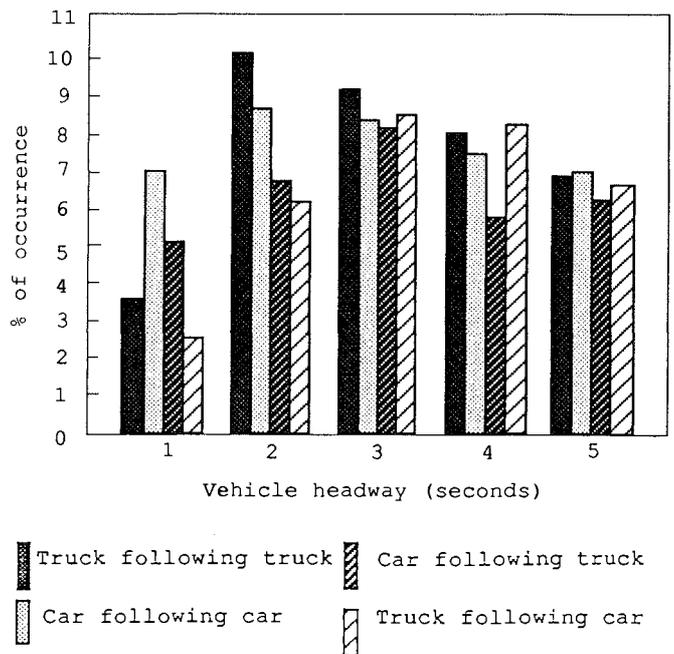


Figure 4/ Daytime vehicle headway distribution, Hwy 402, truck lane, March 19 to 22, 1991

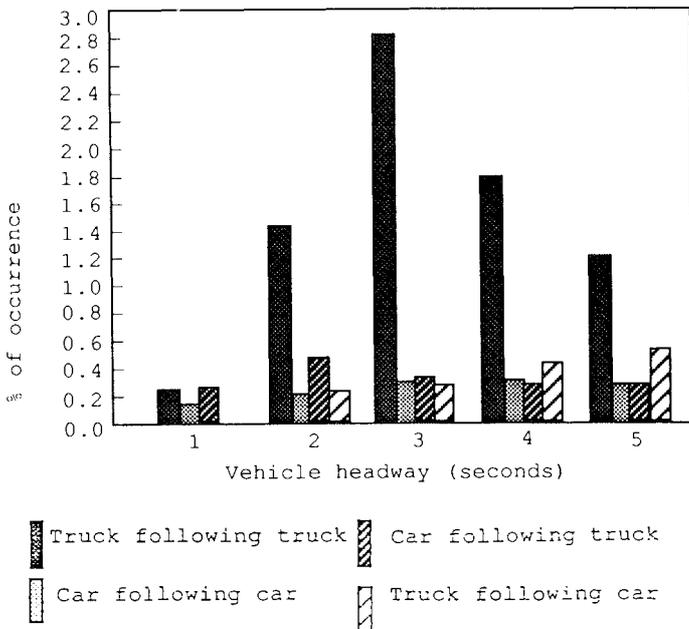


Figure 5/ Nighttime vehicle headway distribution, Hwy 402, truck lane, March 19 to 22, 1991

Figure 3. The greater discipline of truck drivers, indicated by the speed distribution, is also indicated by the headway distribution. Some observations:

- * During daytime, 7% of all cars followed other cars with a one second headway, while only 2.5% of trucks did so. Nevertheless, considering an average truck speed of 100 km/h, more than 2.5% of all trucks appear to be in violation of the Ontario Highway Traffic Act headway requirement.
- * Also during daytime, 3.5% of all trucks were following other trucks with a headway of 1 sec while only 2.5% of trucks were following cars with this headway. The difference in the headway distribution for these two cases was found to be statistically significant.
- * Trucks tend to travel in convoys. This is particularly evident at night when 7.5% of all trucks had headway of less than 6 sec compared to only 1.1% for cars.

3.3 Truck Payload and its Distribution

Another descriptive parameter useful in accident studies (and provided by WIM data) is the gross vehicle weight and its distribution - among axles and, in the case of multiple truck units, between truck units. Braking performance of trucks is not as good as that for cars - braking distances are significantly larger. A recent investigation [9] analyzed braking capabilities of different truck types for unloaded, partially loaded and fully loaded vehicles. It appears that braking distances increase substantially when trucks are partially loaded or unloaded, where the magnitude of this degradation in braking capabilities depends on the truck type. A comprehensive analysis of truck accidents in Ontario [10] indicated that except for twin trailers, the highest accident rates

were for unloaded straight trucks, semi-trailers, and bobtail tractors. This may suggest a link between braking capabilities of unloaded, partially loaded and fully loaded trucks and accident frequencies.

Payload distribution can also affect truck operating characteristics and thus safety. Reference 4 shows how WIM data can be used to evaluate payload distribution of 6-axle trucks with one liftable axle.

Systematic evaluation of WIM data for loaded and unloaded trucks can provide valuable insights into their operating characteristics and behaviour. Figure 6 provides an example of speed distribution for 6 or more axle trucks during daytime obtained on a passing lane at Location 2. While the difference in mean speed between unloaded and loaded trucks is only 1.5 km/h, the corresponding speed variance, with its safety implications, differs by 10 (km/h)².

An example of headway distribution for loaded and unloaded trucks with 6 or more axles, obtained for a truck lane at location 2, is given in Figure 7. It appears that the loaded trucks have a more pronounced proclivity to follow cars with unsafe headways than the unloaded trucks. (The difference in the headway distribution was found to be statistically significant.) The shorter headways observed for the loaded trucks can be attributed to the lack of spare power of these trucks to pass slower moving cars.

4. DISCUSSION

The above discussion on extracting specific information of interest in the highway safety area from WIM-type data is not exhaustive. It simply illustrates possible usage in the traditional application areas. For example, it is also possible to study more complex functions of traffic flow such as the relationship between

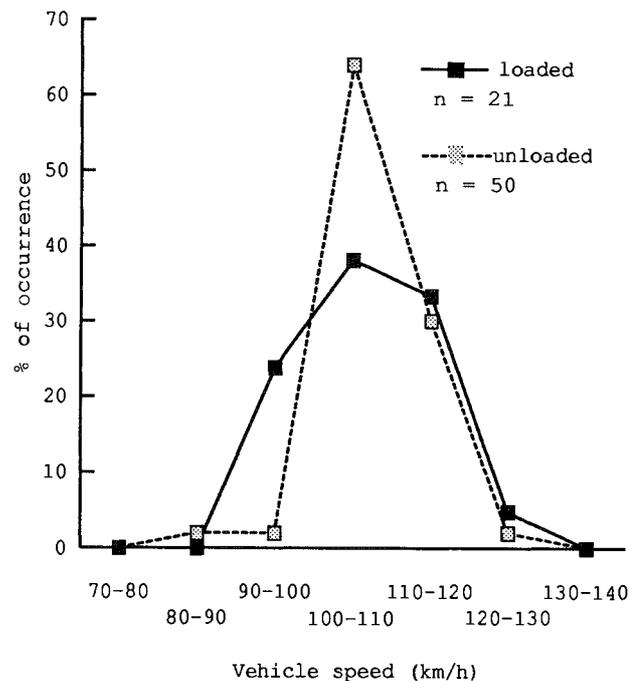


Figure 6/ Vehicle speed distribution, location 2, passing lane, March 1992

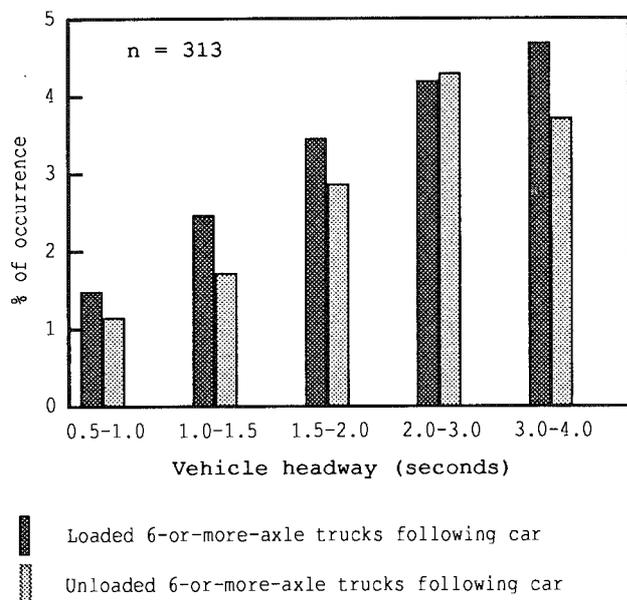


Figure 7/ Daytime truck headway distribution for 6-or-more-axle trucks, Hwy 402, lane 1

vehicle speed, headway, payload, and environmental conditions for different vehicle categories, and to provide data to develop and manage police enforcement strategies.

Spurred by Intelligent Highway Vehicle System needs, work is underway on a range of new sensor technologies, that should soon be able to supplement WIM-type data with visual and other vehicle characteristics to obtain a comprehensive picture of traffic flow.

5. CONCLUSIONS

1. This paper has demonstrated by examples that WIM data can provide insights that have previously not been available to a range of traffic safety related issues.
2. WIM scales, because of their unobtrusiveness and continuous operation, can provide truly unbiased, statistically reliable data yielding a realistic long-term picture of exposure rates for specific truck types and behaviour of the drivers. Both parameters are important for identification of relative influence of truck design parameters on driver performance and safety.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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