WEIGHT CHARACTERISTICS OF PREDOMINANT TRUCK CONFIGURATIONS IN MANITOBA

By

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ABSTRACT

The thesis researches truck weights in Manitoba. Its purpose is to develop axle load spectra that accurately represent static and dynamic axle load distributions for trucks operating on Manitoba highways. Monitoring and understanding truck weights has become a principal focus for traffic monitoring activity in North America, especially with increased levels of awareness of the impacts truck traffic have on transportation systems. This focus on trucking activity and truck weights is reflected in traffic data collection guidelines provided in the most recent U.S. FHWA Traffic Monitoring Guide and Long Term Pavement Performance Program (LTPP) publications. The need for axle load spectra is further magnified with the shift to a mechanistic-based design procedure for pavements by AASHTO. The imminent introduction of a new (2002) AASHTO Pavement Design Guide will require axle load spectra as traffic load inputs for the pavement design software included.

The thesis provides a comprehensive analysis of static truck weights accumulated using a truck data collection system created during the course of the research, and also dynamic truck weights from Weigh-In-Motion (WIM) devices. The analysis uses Manitoba weight data available in 2001. The research provides new insights into the spatial and temporal characteristics of static and dynamic truck weights. It develops a detailed understanding of the entire population of 17,264 trucks sampled using the static truck weight data collection program at the Headingley, Westhawk and Emerson weigh scales in 2001, as well as over 600,000 trucks sampled by various WIM devices during the same time frame. The research proposes a methodology and the related criteria for accepting or rejecting the massive amounts of WIM data collected on the basis of the results obtained from the analysis of static truck weights. Finally, the thesis formulates a methodology to generate representative static and dynamic axle load spectra for roadways with readily available weight information, and a procedure concept to determine truck load distributions for roadways without available weight data but having volume and classification counts.

The thesis reveals significant findings in the analysis of axle and gross vehicle weights for 8-axle B-trains, 5-axle and 6-axle tractor semitrailers. These three configurations constitute 85 to 95 percent of heavy trucks operating on principal highways in the province. The static and dynamic weights for these three truck configurations are analyzed by location, direction, and season, and related to the governing weight limits. The research indicates large directional differences in the static weights of trucks sampled at the weigh scales over the research period. The static weights examined also show some seasonal effects, with weights being somewhat higher in the winter months at some locations presumably as a result of winter weight premiums, and lower at some locations in the springtime seemingly due to spring bans being applied on roadways adjacent to the data collection sites. Static axle loads analyzed reveal that the steering axle weights for all predominant truck configurations in Manitoba fall within a narrow range. Further, trucks in Manitoba operate at gross vehicle weight levels substantially lower than the allowable limits. The detailed analysis of dynamic truck weights indicate that WIM devices drift out of calibration as early as one week after and where direct comparisons with static weights were possible, dynamic truck weights measured are generally lower than the static weights. The creation of a comprehensive system to collect and understand static and dynamic truck weights would facilitate better-informed decision-making about pavement design and management, and can also be used to improve the enforcement procedures in place.

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Chapter One:

INTRODUCTION

1.1 PURPOSE

This thesis is a comprehensive and systematic analysis of the weight component of truck traffic in operation on Manitoba highways. The purpose is to develop axle load spectra that accurately represent the static and dynamic axle load distributions for trucks operating in Manitoba. These truck weight spectra are generated to conform to the latest Federal Highway Administration (FHWA, 2001b) and American Association of State and Highway Officials (AASHTO, 1999) guidelines while being cognizant of the differences inherent in Manitoba and western Canada. The findings and developments from this thesis form the basis of the truck weight component of the Manitoba truck traffic monitoring system (Clayton et al, 1998a).

1.2 BACKGROUND AND RESEARCH NEEDS

Truck weight data is an indispensable part of the data input used by highway agencies to design, maintain and manage highways. Although the collection of this data is difficult and expensive, it is in many respects the most important traffic monitoring activity (FHWA, 2001). Truck weight data is used for a wide variety of tasks including pavement and bridge design and maintenance, the determination of loading restrictions, and also the determination of the need for and success of weight enforcement practices (Kishore, 2000 and Stoner et al, 1994). Traffic loading not only determines pavement depth during the design process but also plays a role in the selection of pavement maintenance treatments.

Freight movement by trucks has long been a focus of interest because of the impact trucking has on the lifespan and performance of highway infrastructure (Luskin et al, 2001). The desire for greater productivity in goods transportation creates pressure for highway policies that allow larger, heavier trucks but on the other hand, the effect of truck size and weight on the wear and fatigue of bridges and pavements is a major factor in setting policy constraints on road use (Fancher et al, 1997). Although this is not the only cause for concern, the magnitude of the costs related to the design and maintenance only cause for concern, the magnitude of the costs related to the design and maintenance of highway infrastructure provides justification for the added attention. There has been increasing awareness on the impact truck weights have had and this is reflected by the greater focus of traffic monitoring programs and schemes on truck weight data collection. Fekpe (1994) identified traffic volumes, traffic classification data and vehicle weights as the three major components of traffic data needed for proper design, maintenance and management of highway infrastructure. In Manitoba, the use of classification and weight data has been limited despite the abundance of data collected. In part, this has been due to the lack of understanding of the nature of truck traffic and its weight characteristics as well as a lack of convenient and adequate means of reporting this data. This task has become even more onerous as weight and dimension regulations have become increasingly liberal (allowing a wider spectrum of truck weights and sizes) and technically complex.

In 1998, a report was submitted to Manitoba Transportation and Government Services (MTGS) as part of a contract to develop a new truck traffic information system (TTIS) for Manitoba (Clayton et al, 1998). The report detailed the truck traffic database that existed at the time and its inherent inability in meeting the truck traffic data needs of the Department (Van Cauwenberghe,1997). The report also identified, among other problems, the lack of accurate and reliable truck load distribution data that would reflect temporal changes in truck weights. As Van Cauwenberghe (1997) pointed out, this data is crucial for pavement design and maintenance projects. The TTIS report ended with the submission of the findings from a preliminary analysis of truck data available as of October 1998, and an outline for the operation plan of the imminent truck traffic information system.

There are several fundamental deficiencies in the existing truck traffic monitoring program adopted in Manitoba. The first is that not much is known about the temporal (i.e. seasonal and day-of-week) weight characteristics of trucks operating on Manitoba highways. There has been no sustained effort to continuously collect accurate and reliable truck weights at the permanent scales. Although Weigh-In-Motion (WIM) devices collect large amounts of weight data, past studies (Zhi, 1998) have shown that the weights drift with time and due to the nature of dynamic weight measurements, can be imprecise even when the devices are well calibrated. The second problem is that little is known about the directional differences in truck weights. WIM devices cannot be relied upon to tackle this issue because with the exception of the site in Russell, the devices are only installed on the traveling lanes in either the westbound or northbound directions. The third problem is that despite the costs invested by MTGS to install and maintain WIM devices, there is a lack of awareness on how much of the data collected by those devices is actually useful. There is no knowledge on how quickly the WIM devices go out of calibration.

There is the need for Manitoba to collect, analyze and understand truck weight characteristics across the different truck classes, by region and by season. As indicated by past studies (Fekpe et al, 1995, TRB, 1990a and 1990b), the results of such an analysis must be taken in the context of the governing weight limits. With this understanding, truck load distributions that accurately represent fleet characteristics operating within the province can then be developed.

1.3 OBJECTIVES AND SCOPE

The objectives of the research are:

- To create an automated truck weight data collection system installed at the largest permanent weigh scales that accumulates static truck weights and other operational characteristics. The purpose of this system is to provide comprehensive and representative understanding of static weights of trucks operating on major provincial highways.
- To systematically analyze and interpret the resulting static weights and to compare and contrast these with dynamic truck weight knowledge generated from selected WIM sites throughout the province.
- To develop a methodology and related criteria to evaluate the acceptability of retention of weight data collected by WIM devices.

- To evaluate and to make determinations of the stability of both static and dynamic truck weight data as functions of temporal and spatial characteristics, and doing so in relation to the governing weight limits.
- To develop and apply a methodology to determine axle load spectra as it is understood to be required by pavement design engineers in Manitoba in anticipation of AAHSTO's new pavement design guide.

The results for the thesis are presented in two phases. The first phase presents the findings of the research on the weight characteristics of specific types of trucks operating on Manitoba highways. Truckload distributions are analyzed for effects of seasonality (i.e. the advent of winter premiums and spring bans), temporal differences (i.e. by day-of-week) and by region. For this phase of the research, truck data available from the permanent weigh scales at Headingley, West Hawk and Emerson are used in conjunction with available WIM data. The research focuses on the most common classes of trucks and truck combinations encountered in Manitoba and the adjacent provinces and states, namely the 5 and 6-axle tractor-semitrailer combinations and 8-axle B-train combinations.

The second phase develops methodologies to report on the results from the first phase in fulfillment of the truck traffic data requirements of the various users. In particular, summary load distributions associated with each truck class are developed. In order to keep within the scope of this thesis, the analysis of truck traffic data has been restricted to the main truck traffic corridors in Manitoba and roads that have abundant truck-data.

1.4 ORGANIZATION OF THESIS

The thesis has seven chapters. Chapter two presents an overview of the truck weight and dimension (W&D) regulations in Manitoba, Western Canada and the U.S. In addition, the chapter also reviews the policies regarding spring bans and winter weight premiums in the province.

Chapter three discusses the truck weight data needs in Manitoba and the importance of this data for effective highway infrastructure management. The chapter describes the weight data needs in the mechanistic-empirical approach recommended in AASHTO's new pavement design guide as well as the truck weight data requirements specified in the SHRP and C-SHRP programs.

Chapter four provides details on the static and dynamic truck weight data collection systems used in the research as well as the limitations associated with the collection of this data. The focus of the chapter is on the design and implementation of the static weight data collection system at the permanent weigh scales. The methodologies used to screen and evaluate the data are also described and illustrated.

Chapter five reports on the details of the research done on the characteristics of trucks operating on Manitoba highways with particular attention paid to the fleet classification mix by the season, time-of-day and day-of-week.

Chapter six presents the results of the analyses of both static and dynamic truck weight data collected. The gross vehicle weight (GVW) and axle weight characteristics are presented by truck class and distinguished by direction, by location as well as by season. Comparisons are made between the static and dynamic weights, and the respective axle load spectra are generated. In addition, a methodology is developed to generate truck load distribution tables for road sections using representative load spectra, the Annual Average Daily Truck Traffic (AADTT) and site-specific classification mix. This methodology is applied in an illustrative example.

Chapter seven presents the conclusions and summary of the research, and identifies avenues for future research projects.

Chapter Two:

WEIGHT AND DIMENSION REGULATIONS IN MANITOBA

Truck weight and dimension regulations are rules governing the maximum permissible dimensions of vehicles and vehicle combinations in terms of width, height and length, as well as axle weights, tire size and pressure, and gross vehicle weights. These regulations were traditionally motivated by concern for protecting pavements and bridges from the effects of heavy loads but with the role that trucking now plays in both national and local economies, policy makers now face the task of balancing concerns for the highway system, trucking productivity and safety.

Pavement deterioration increases with axle weight and the frequency of axle loadings to which the pavement is subjected. As a result of this, changes in truck size and weight regulations can affect the cost to a highway agency of maintaining the condition of its pavements.

In addition to highway maintenance costs, truck weight regulations can also affect highway safety and traffic operations in several ways (TRB, 1990):

- Changes in regulations can increase or decrease the amount of truck traffic, which in turn affects the number of accidents and highway congestion
- These changes affect truck operating weights and weight-related performance characteristics such as rollover potential and speed, acceleration, and braking capacities
- New regulations can encourage carriers to adopt different types of vehicles, which may have higher or lower accident rates than those currently in use, and can cause changes in vehicle design, which may affect safety.

This chapter reviews the basic weight regulations in place in Manitoba and adjacent provinces and states during the observation period in 2001 because they are a major factor when determining what types of trucks are operating on the highways, and the maximum weights they observe. In addition, the winter weight premiums and spring weight restrictions are described since they have implications on the seasonal differences of operational and weight characteristics of trucks.

2.1 BASIC TRUCK WEIGHT LIMITS IN MANITOBA, WESTERN CANADA AND THE U.S.

Basic truck weight limits refer to regulations that apply in a manner where trucks can operate without obtaining special overweight and/or over-dimension permits, and seasonal exemptions (Montufar, 2002).

Basic weight regulations in Manitoba are defined in terms of three highway classes and two generic vehicle classes. The highway classes are: (1) RTAC routes; (2) A1 highways; and (3) B1 highways. The generic vehicle classes are: (1) RTAC vehicles—vehicles that meet all requirements defined in the 1988 Roads and Transportation Association of Canada (RTAC) Memorandum of Understanding; and (2) non-RTAC vehicles. Although there are some exceptions to the rule, class A1 highways generally refer to provincial trunk highways (PTH) or highways with numerical designations between 1 and 101, and class B1 highways are provincial roads (PR) or highways with three digit designations. In addition, some PTHs and PRs are designated RTAC routes.

Table 2.1 shows the basic weight regulations governing regular operations on Manitoba provincial highways for the truck configurations of interest. In general, basic weight limits for the truck classes of interest to the research are similar in Saskatchewan and Alberta. Detailed descriptions of the basic weight limits in these provinces can be found in the study done by DS-Lea and the Prairie Freight Studies Alliance (1998).

For trucks operating between the U.S. and Canada, weight limits of 20,000 lbs. and 34,000 lbs. on single and tandem axles respectively govern the axle weights of most trucks crossing the western U.S.-Canadian border. For most border crossings in this region, the effective GVW limits on trucks are 80,000 lbs. for provinces adjacent to Minnesota, 105,500 lbs. for provinces adjacent to North Dakota and 131,060 lbs. for provinces bordering Montana (with the exception of the CANAMEX corridor in Alberta)(U.S. DOT, 1995). An integral part of the U.S. truck size and weight regulations is the Federal Bridge Formula and for the most part, this formula is more restrictive than equivalent load distribution requirements specified for connecting highways in Canada.

Table 2.1 Basic Weight Regulations Governing Operations on Manitoba Provincial Highways

	Highway Class		
	RTAC	A1	B1
Tire Weights			
Weight/unit width (kg/mm)	10	10	10
Max load per tire (kg)	3,000	3,000	3,000
Axle Weight (kg)			
Steering			
Straight Truck	7,300	7,300	7,300
Tractor	5,500	5,500	5,500
Single	9,100	9,100	8,200
Tandem (1.00m - 1.85m)			
RTAC	17,000	16,000	14,500
Non-RTAC	16,000	16,000	14,500
Tridem			
RTAC (2.4m - less than 3.0m)	21,000	21,000	20,000
RTAC (3.0m - less than 3.6m)	23,000	23,000	20,000
RTAC (3.6m - 3.7m)	24,000	23,000	20,000
Non-RTAC	16,000	16,000	16,000
Gross Weight (kg)			
5-axle Tractor-semitrailer			
RTAC	39,500	37,500	34,500
Non-RTAC	37,500	37,500	34,500
6-axle Tractor-semitrailer			
RTAC	46,500	44,500	40,000
Non-RTAC	37,500	37,500	34,500
8-axle B-train Double			
RTAC	62,500	56,500	47,630
Non-RTAC	N/A	N/A	N/A

Notes: Numbers in brackets refer to allowable axle spreads

All limits are subject to proper axle spacing and adequate tire and axle capacity

Sources: Adapted from Montufar et al (2000), MTGS (2001 and 2002)

This point is particularly pertinent when examining truck flows on PTH 75 in Manitoba that connects to the I-29 in North Dakota. Some other relevant observations include the following:

- Split tandems (with axle spreads up to 10 feet) are allowed in the States bordering western Canada but are prohibited in western Canada.
- Tridem axle load limits are 24,000 kg in Manitoba and Western Canada but in the states of Minnesota, North Dakota (on Interstate Highways only), Washington and Idaho, the limits for Tridem axles are governed by Bridge Formula B.
- The study done by the U.S. DOT (1995) noted that the 5,500 kg limit on steering axles forces some truckers entering Manitoba via the I-29 to move their fifth wheel. According to the study, some of these trucks probably shifted their loads to reduce the weights on the drive tandems while operating in the U.S. but have to do the opposite upon entering Manitoba.

Further details on the comparisons between truck size and weight limits (and the implications) can be found in studies done by the U.S. DOT (1995), and DS-Lea and the Batelle-UMTIG Prairie Region Freight Studies Alliance (DS-Lea, 1998).

2.2 LAWS, REGULATIONS AND POLICIES GOVERNING WINTER WEIGHT PREMIUMS

Some jurisdictions, including Manitoba, allow winter premium loadings during the winter season to allow additional loads on highways. The rationale for doing this to take advantage of the extra strength available in frozen pavement structures for the more efficient hauling of dense or heavy commodities.

Manitoba provides premium weight allowances during the winter period starting from December 1 to the last day of February of the following year. These weight allowances are applied using two methods: (1) the "10 percent premium" method; and (2) the "designated seasonal route" method.

2.2.1 Method 1: Application of a 10 percent premium weight allowance.

In this approach, Manitoba provides a winter weight premium (WWP) of 10 percent on PTHs and PRs from December 1 to the last day of February of the following year, subject to the statutory maximum GVW for that highway class. The 10 percent WWP applies to