Design, Development, and Implementation of the Manitoba Highway Traffic Information System

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A thesis submitted to the Faculty of Graduate Studies
in partial fulfilment of the requirements for the degree of Master of Science

Department of Civil Engineering
University of Manitoba
October 1996

ISBN 0-612-16200-1

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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DESIGN, DEVELOPMENT, AND IMPLEMENTATION OF THE MANITOBA HIGHWAY TRAFFIC INFORMATION SYSTEM

BY

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Abstract

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The Manitoba Department of Highways and Transportation requires a variety of traffic volume and other statistics on the usage of provincial highways. This paper describes a review of the Department's former traffic data collection system and the design, development, and implementation of a new traffic information system. The research includes: (1) characterization of traffic data systems generally and the former Manitoba traffic monitoring system in particular; (2) formulation of performance criteria for the system based on general principles of data collection, definition of particular data needs in Manitoba, and technical criteria related to efficiency and effectiveness; (3) an evaluation of the former data collection program against these performance criteria; and (4) the design and implementation of numerous improvements to the system to address the identified shortcomings. Key components of the new system are a new method of specifying traffic pattern groups and a "factorless expansion" process for expanding short-term traffic counts to estimates of average annual daily traffic.

Table of Contents

Chapter 1 Background

1.1 Context of this research

This research is the result of five years' work undertaken with the support and co-operation of Manitoba Highways and Transportation (MHT), the University of Manitoba Transport Institute, and the University of Manitoba Transportation Information Group (UMTIG). This work led to the design and implementation of a new system to provide information about the usage of Manitoba highways to support MHT's planning, design, maintenance, safety, traffic operations, and research functions.

This process included four basic steps:

1. ***Characterize the system.*** The former system was not well documented, so the first step was to define the system and its operation.
2. ***Establish criteria for evaluation.*** To determine the effectiveness of the former system, performance criteria were established. Three broad groups of criteria were used: (1) general principles of data collection, (2) data needs which the system must support, and (3) technical criteria related to system efficiency and accuracy.
3. ***Carry out the evaluation.*** System performance was evaluated against the three main groups of criteria, and any shortcomings of the system were noted.
4. ***Design and implement new system components to address failures.*** Where the former system failed to meet the performance criteria, modifications were suggested and eventually implemented.

This is an ongoing process. The new system continues to be evaluated against performance criteria, and modifications continue to be made. The author was responsible for leading the initial review of the former traffic information system and for leading the development and implementation process from project inception through the summer of 1995. This paper draws on working papers, reports, and other documents published during this period.

1.2 Historical Background

The MHT-UMTIG partnership is the result of a process that began in the fall of 1991, when MHT commissioned the University of Manitoba Transport Institute to "design a traffic monitoring system to service the needs [of] Manitoba Highways and Transportation." MHT was concerned about costly and inflexible mainframe-based data processing procedures, accuracy and reliability of data summaries, long lag times between data collection and the availability of reports, and isolation from MHT's traffic data needs. The resulting document, *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation*, (called *Design* hereafter) was submitted in April 1993, making fifty-one recommendations. A parallel research project, *A Reliable System for Monitoring Truck Movements and*

Characteristics in Manitoba, led by A. Ostroman, developed recommendations related to the collection and analysis of trucking information.

Further discussions between MHT and the University led to the submission of a Concept Outline in February 1994 and Discussion Notes in March, in which a co-operative venture to operate a new traffic information system was proposed. The University was to take on responsibility for data analysis, preparation of annual reports, and needs assessment, while MHT would remain responsible for overall management, setting policy, and data collection. A series of meetings was held in the following months to discuss details.

In May 1994, a draft agreement between MHT and the University regarding the development of a new Traffic Information System (TIS) was developed and presented for approval by both parties. On June 1, the University was instructed to begin the first stage of the project: "to prepare a detailed proposal which addresses, identifies, and/or quantifies the steps necessary to place [the] proposed TIS project into operation." This detailed proposal, the draft *System Specifications*, was submitted in July and accepted in principle by MHT. After some revisions, an agreement between MHT and the University was signed in August 1994, and development of the TIS proceeded over the following months. The first annual report by the new team, *Traffic on Manitoba Highways 1994*, was produced in July 1995, followed by special reports on vehicle-kilometers of travel and truck traffic covering the year 1994. The second annual report, *Traffic on Manitoba Highways 1995*, was completed in June 1996.

1.3 Structure of this Paper

This report describes the process followed in reviewing the former Manitoba Highways Traffic Information System and designing an improved system. It is structured as follows:

Chapter 1 Background, Definitions, and Description of the Former Traffic Monitoring System
This chapter introduces the context of the research, defines terms related to traffic information systems, and provides a summary description of the former traffic monitoring system.

Chapter 2 Principles of Data Collection
This chapter defines fundamental principles that should govern a traffic data collection system, evaluates the former system's performance with respect to these principles, and describes system improvements resulting from this research.

Chapter 3 Traffic Data Needs in Manitoba
As part of the review of the former system, each Branch's need for traffic data was examined. This chapter summarizes the result of this needs study, evaluates the former system's performance with respect to meeting the needs, and shows how system performance was improved as a result of this research.

Chapter 4 Technical Evaluation
This chapter describes a series of technical criteria dealing with issues such as accuracy and efficiency, evaluates the former traffic monitoring system with respect to these criteria, and shows how measures to improve system performance were implemented.

Chapter 5 Traffic Information System Current Status
This chapter briefly outlines the operation of the new traffic information system, shows the evolution from the former traffic monitoring system to the current system, and suggests directions for further research.

1.4 Additional Research of Interest

This paper summarizes the work performed by the author in connection with the development of the MHTIS. Additional research at the University of Manitoba including contributions from other researchers, which may be of interest to readers seeking more information about the MHTIS or about traffic information systems generally, includes:

A. Clayton, B. Lucas, M. Alam, and P. Cordeiro, *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation*. University of Manitoba Transport Institute, April 1993.

A. Clayton, B. Lucas, M. Alam. *Manitoba Highway Traffic Information System: System Specifications*. University of Manitoba Transportation Information Group, July 1994.

B. Lucas, A. Clayton, D. Hurl. *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation: A Case Study*. Presented at the Canadian Society for Civil Engineering Annual Conference, 1994.

Ostroman, A. *A Reliable System for Monitoring Truck Movements and Characteristics in Manitoba*. M. Sc. Thesis, University of Manitoba, 1993.

Penner, A. *Truck Data Collection for the Engineering Needs of the Manitoba Department of Highways and Transportation.* Departmental report, 1991.

The annual *Traffic on Manitoba Highways* reports as well as vehicle-kilometers of travel and truck traffic reports are also available from the University of Manitoba Transport Information Group.

1.5 Historical Overview of North American Traffic Monitoring Practices[1]

The first traffic counting programs began in the 1930s in an effort to quantify highway capacity analysis and speed-volume relationships, and to identify the stochastic properties of traffic. Early surveys were short-duration manual counts but by 1940 mechanical counters came into wide use.

By the mid-1950s, the modern system of using a permanent mechanical counter as a control station to expand nearby short-term counts had been developed. Since the 1950s, as computers became available, more people turned to the analysis of the data, searching for ways to quantify and reduce the errors known to be involved in short-term sampling.

Boris Petroff, one of the pioneers of traffic data analysis, began considering the problem of estimating the errors of short-term counts in 1954. At the time, short-term counts were expanded by selecting the nearest permanent counter as a control station. By 1958, this practice was recognized as inappropriate and agencies began to switch to using highway functional classification as the main criterion for assigning control stations. The current edition of the FHWA *Traffic Monitoring Guide* traces its recommendations in this area back to Petroff's work in the mid-1950s.

Petroff's work was based on the assumption that machine breakdown was the primary source of errors in AADT estimates. Because of this, methods for "patching" data were developed throughout the 1960s to account for missing data and correct data believed to be in error.

Throughout the development of traffic data analysis in the 1950s and 1960s, the inherent variability of traffic was neglected. In 1956, Petroff wrote that AADT estimates with 10-12% error for roads with an AADT of 500 vehicles per day or more were satisfactory. The inherent variability in his best samples, however, was around 8%. The suggested error range of 10% was accepted by later writers as a level which would normally be satisfactory -- and attainable -- in any traffic survey. The Bureau of Public Roads, the Institute of Traffic Engineers, and others echoed the 10% error range into the 1970s and 1980s, but all ignored the effect of the inherent variability of traffic. Statistical methods were proposed in the 1980s for handling errors arising from many sources except the inherent variability of traffic, which can have an effect far greater than the errors introduced at any other stage.

The 1960s was the "golden age" of highways in North America, and traffic monitoring grew in importance accordingly. Changes and innovations were occurring rapidly, enthusiasm was high, and many people were working on the problems of traffic monitoring. After the 1960s, however, the "golden age" of highway construction ended and highway departments began to lose some of their power. Traffic monitoring programs were cut, since they were viewed as not essential to department operations.

Despite the erosion of support for traffic monitoring, information continued to be provided but with less accuracy, and little effort could be spared to improve techniques. The accuracy and reliability of the data were seldom questioned by data users, and the people providing the information had few resources to spare for research and self-analysis. For many years, traffic monitoring programs were allowed to drift, and each highway department developed its own techniques to handle cutbacks. In the United States, the only force holding programs together was the requirement for states to report certain statistics to the federal government in order to qualify for federal highway funds. These requirements described the information that was required but did not define how to collect it, so states developed techniques independently. In Canada, there was no such federal requirement and provinces developed completely independent traffic monitoring systems.

In 1987, traffic monitoring suddenly became important again with the launch of the Strategic Highway Research Program (SHRP). One portion of the program, the Long Term Pavement Performance (LTPP) program, was a twenty-year data collection and analysis program intended to track pavement deterioration and relate it to various construction, environmental, and traffic factors. The inconsistencies, errors, and biases in available traffic data, however, were so great as to make it impossible to carry out its mission without first creating a new set of traffic monitoring standards.

Supported by the requirements of SHRP, the analysis of traffic data has been completely re-evaluated and re-designed. Many of the assumptions previously made about traffic flows have been proven incorrect, and many of the methods used to analyze traffic data have been cast into doubt. For example, traffic flows vary from day to day, and this variation has always been assumed to be normally distributed. In fact, a 1989 review of New Mexico traffic data demonstrated that two-thirds of that state's permanent traffic counters showed significant skewness; not one of the 14 urban arterial locations monitored showed a normal distribution. The inherent variation of traffic was also shown to be far higher than the 10% error margin that had been considered acceptable; only two of New Mexico's 62 monitoring sites showed variations under this 10% margin. ASTM, AASHTO, FHWA, and ITE have all recently released new standards for traffic monitoring.

Traffic monitoring programs in the past have always concentrated on volumetric measures. Vehicle classification, truck weights, and other programs were typically treated as adjuncts to the volume monitoring program and were sampled by short-term manual surveys on a subset of the volume counting network. As such, many of the problems with volume counting, such as the inherent variation of traffic and non-normal distribution, also apply to other traffic monitoring programs.

Non-volumetric programs have relied in the past on short-term manual surveys, with little or no year-round continuous data. Recently, automatic vehicle classification (AVC) technology has become widely available, with the result that it is now possible to obtain the year-round continuous coverage required to develop a reliable program. Work is also proceeding on weigh-in-motion (WIM) equipment, but so far WIM is not yet advanced enough to be a reliable design or enforcement tool.

1.6 Overview of Traffic Statistics -- What is Traffic?

"Traffic" may be defined as the movement of vehicles, people, and goods on the highway system. "Traffic information" includes all measurable characteristics of traffic, some of which are listed in Table 1. This report, like most transportation studies, concentrates on vehicle movements and in particular, volumetric measurements of vehicle movements. Some key definitions related to particular traffic volume measurements which will be of interest for this study are described below.

Table 1: Types of traffic information

Vehicle Movements	People Movements	Goods Movements
Volumes	Numbers	Quantities and commodities
Types	Demographics	Spatial properties
Weights	Trip purpose	Temporal properties
Dimensions	Spatial properties	
Speeds	Temporal properties	
Performance		

1.6.1 Vehicle Movements

1.6.1.1 Volumes

Volume and flow: The quantity of vehicular traffic on a road, or flow, is denoted q, and has units of vehicles per unit of time. The flow q is calculated as Q/t, where Q is the number of vehicles observed and t is the time period over which the observations are made. When the number of vehicles is observed over standard intervals t such as one year, one month, one day, or one hour, q is given standard names. Some common intervals and their uses are described below.

Average Annual Daily Traffic (AADT): The number of vehicles passing a point on an average day of a given year. This is the flow Q/t when the time interval t is equal to one full year -- in most jurisdictions, this is taken as the calendar year. AADT is a gross average representation of the usage of a road, and is probably the most frequently referenced statistic. It is used for such applications as[2]:

- establishing traffic growth trends
- calculating accident rates
- evaluating system improvements
- identifying capacity deficiencies
- programming maintenance activities
- environmental impact studies
- geometric design
- pavement design

Average Summer Daily Traffic (ASDT): The number of vehicles passing a point on an average day of the summer. Summer traffic on most roads in Manitoba is higher than the winter traffic and the annual average. In Manitoba, the summer period is defined as May 1 through September 30, but in other jurisdictions, other definitions of the summer period may be appropriate.

Monthly Average Daily Traffic (MADT): The number of vehicles passing a point on an average day of a given month. This is the flow Q/t when t is equal to one month.

Other measures of Average Daily Traffic (ADT): The average daily flow Q/t can be calculated for any combination of days over any period, in which case the generic term "average daily traffic" is used. For example, on a road serving a recreational area, one might be interested in the average daily traffic, Friday through Sunday, for the two-month peak season.

Hourly Variation: The flow Q/t can be reported in units of vehicles per hour, and is sometimes even reported as vehicles per quarter-hour. Different types of traffic show very different patterns at the hourly time scale. For example, commuter traffic tends to peak on weekday mornings and afternoons, while recreational traffic peaks on Friday and Sunday evenings, and some rural roads show significant peaks during the weekday lunch hour. Hourly variation is used for:

- geometric design
- determining capacity deficiencies
- justifying, planning, and locating traffic control devices
- justifying and planning regulatory measures such as parking restrictions and speed limits
- highway classification for geometric design and traffic engineering purposes
- justifying and planning enforcement measures

30th Highest Hour: For design purposes, many jurisdictions follow a practice of ranking all of the hourly traffic volumes at a site for the entire year and selecting the 30th highest hourly volume as the design input. This means that the design volume would be expected to be exceeded for 30 hours out of the year. The 50th highest or any other rank may also be used.

Peak Hour: Many analysis and design techniques use the concept of the *peak hour*, the number of vehicles passing a point during the peak 60-minute period of an average day of the year. The *peak hour factor* is the percentage of the AADT that occurs in this period.

Directional Distribution of Traffic: The directional distribution is the difference between traffic flows in opposite directions on the same road over some time period. On a long-term basis, it would be unusual for this split to be unbalanced; one expects that traffic proceeding in one direction on a road will normally return via the same route. On a daily or hourly basis, however, directional distribution is often unbalanced. Recreational roads often show heavy traffic towards a recreational area on Fridays and away on Sundays. Areas with a concentration of jobs show heavy traffic to work in the morning and away in the evening. Peak hour directional distribution is required for the design of roads with more than two lanes[3].

Lane Distribution: This is the proportion of vehicles using each lane in the same direction on a multi-lane highway. The lane distribution factor on rural highways is primarily influenced by the number of slow vehicles, which occupy the outer lane and force other traffic into the inner lane, increasing its volume.

Turning Movements: Monitoring intersection turning movements requires either a human observer counting manually or a large number of automatic counters able to isolate movements on each leg of the intersection. Turning movement counts are important because intersections are usually capacity bottlenecks and have high accident rates compared to the rest of the system. Turning movement counts are used in the following procedures[4]:

- planning new facilities
- analyzing system capacity
- geometric design of intersections
- planning maintenance activities
- planning and justifying traffic control devices and signalization
- safety studies

1.6.1.2 Vehicle Classification

Vehicle classification means determining the types of vehicles on the road, as distinct from the total number of vehicles. After the total traffic is measured, the proportion of vehicles in each of a number of classes is determined. Some applications require traffic to be separated into only two classes - passenger cars and trucks - in which case vehicle classification is usually reported as *Percent Trucks (%trucks)*. Other applications may need more detailed information, especially about the truck population, and may classify vehicles by axle configuration, weight, dimensions, or other characteristics. Various agencies use classification schemes ranging from only a few classes to as many as the 44 classes once used in Manitoba.

Since the traffic mix on a road changes from season to season and by hour of the day, the monthly, daily, and hourly variation of traffic can be determined by calculating the proportion of vehicles in each class over any time period, as discussed for total traffic. Vehicle classification can also be found by direction and lane.

Potential applications[5]:

- maintenance planning
- capacity analysis
- safety analysis
- environmental impact assessment

- project identification and selection
- geometric design
- pavement design
- highway system investment analysis
- public policy and legislation
- taxation

1.6.1.3 Vehicle Weights

Information about *gross vehicle weights (GVW)* and *axle loads* for different vehicle classes by axle configuration is important for pavement design and management, bridge design and maintenance, and various system policy decisions. Truck weights are recorded for each class of truck by weighing trucks at permanent and portable scales, or using weigh-in-motion sensors. The directional and lane distribution of truck loads can be very important in some circumstances. For example, a gravel pit haul road will carry fully-loaded trucks in one direction and empty trucks in the other, resulting in differential damage to the pavement. As well, because trucks tend to use the outer lanes of multi-lane roads, AASHTO standards recommend that the outer lanes be designed to sustain 25% more loading than the inner lanes.[6] Monthly distributions of truck weights are also of interest because pavement damage is related to the seasons.

1.6.1.4 Vehicle Dimensions

Roadway horizontal alignment and vehicle dimensions are inter-related. On the average, passenger cars have been getting smaller over the years while trucks are getting larger. Highways must be designed to accommodate the turning radii and wheel-tracking of large articulated trucks. Information about vehicle dimensions provides input to geometric design and the establishment of weight and dimension regulations.

1.6.1.5 Speeds

Information about vehicle speed is usually collected either by paired vehicle sensors that calculate the time it takes the vehicle to move from one sensor to the next, or by a roadside observer with a radar gun. Traffic speed information is used for[7]:

- evaluation of traffic control devices
- accident analysis
- geometric design
- evaluating or identifying the need for enforcement programs

1.6.1.6 Performance Characteristics

Horizontal and vertical alignment considerations such as curve radii, grade selection, provision of passing lanes, and many others influence and are influenced by the performance characteristics of vehicles. These characteristics include articulation, ability to maintain speed on grades, maximum speed, acceleration and deceleration rates, stability, and control.

1.6.1.7 Vehicle-Kilometers of Travel

Estimates of the total distance travelled by road users -- *vehicle-kilometers of travel, VKT* -- are made by multiplying the total number of vehicles using a road segment (the AADT is typically used) by the length of the road. VKT information is not relevant on a site-specific basis, but is used to track changes in regional traffic patterns for the following purposes[8]:

- project planning
- policy assessment
- environmental impact assessment
- energy consumption estimates
- safety studies
- taxation studies
- funds allocation

1.6.2 People Movements

1.6.2.1 Vehicle Occupancy

One of the most important factors in highway decision-making is the quantity of traffic using a road. This is usually expressed in vehicles, but the number of people using the road is also of interest. This is normally calculated as the average number of people per vehicle, or *vehicle occupancy*. If resources are to be allocated so as to benefit the greatest number of people, it should be noted that two roads carrying the same number of vehicles are not equivalent if the vehicle occupancies are different. A similar argument can be made in risk assessment when evaluating and priorizing safety improvements: a road carrying more people might have a higher priority than another carrying the same number of vehicles but fewer people.

1.6.2.2 Traveller Demographics

The demographic characteristics of travellers can be significant in analysing their trip-making behaviour, as linked to age, sex, income, occupation, and education[9]. They can also be used to identify the need for highway improvements. Driver age, for example, affects physical abilities such as reflexes and visual acuity, so a road with a high proportion of elderly drivers might warrant special treatment to accommodate them. Age, sex, and marital status are all used by insurance companies to identify high-risk drivers; highway agencies might use these factors as well to indicate roads which are at a priority for various safety improvements.

1.6.2.3 Trip Purpose

Trips are generally classified as one of five types[10]: work, school, shopping, social/recreational, or business. All but the last are considered to be home-based. The purpose of the trip affects its other characteristics, such as destination, route, time, and number of people travelling together.

1.6.2.4 Trip Spatial Properties

The spatial properties of a trip are its origin, destination, and the route travelled. Planning departments are the major users of this information, normally collected in some form of origin-destination (O-D) study. An O-D study identifies major trip origins, destinations, and routes in the study area, and can be used in network planning functions like evaluating highway relocation or town bypasses. The principal methods of conducting an O-D study include license-plate surveys and interviews conducted at roadside, in the home (in person or by telephone), or at work.

1.6.2.5 Trip Temporal Properties

The time of day and day of the week that a trip is made is important for planning and design functions. Work trips, for example, are mostly made on weekdays during short periods in the morning and afternoon, requiring commuter facilities to be designed to handle these peak flows. Shopping and business trips, on the other hand, are made throughout the week and often start later in the day but return home at the same time as work trips, making the afternoon peak higher than the morning one. Finally, recreational trips tend to peak on weekends, especially to resort destinations.

The duration of trips is also an important statistic of interest to planners. Travel time studies are used to identify problem locations in the network, to measure the overall network level of service, to evaluate the economic impacts of the system, and as an input to planning models. Travel time can be measured by test-car runs, license-plate observations, or roadside observations.

1.6.3 Goods Movements

1.6.3.1 Commodities

It is important to consider the commodities carried by trucks, just as it is important to consider the people inside their cars. If resources are to be allocated where they will provide the greatest overall benefit, a commodity-flow survey might allow planners to identify roads carrying large quantities of goods or high-priority goods. Identifying commodities carried on particular routes will also help in understanding the truck fleet mix and performance characteristics, since commodities are linked to the truck types that carry them and many trucks are specially designed to carry certain types of commodities.

1.6.3.2 Hazardous Goods Movements

Because of the risks associated with many hazardous goods, it is useful to identify routes where they are carried, and to monitor the types and quantities of goods moved. Some cargoes might be restricted to certain roads where the probability of an accident is low, the consequences minimal, and emergency response is good. Safety improvements or emergency planning might be warranted on roads identified as high risk.

1.6.3.3 Spatial Properties

The spatial properties of a freight trip are its origin, destination, and the route travelled. Freight movements may often be more complex than passenger movements, because there may be multiple stops as trucks follow delivery routes, and because there may be a mix of through and local movements. It is important to identify major terminals where goods are transshipped, as well as the ultimate trips origins and destinations.

1.6.3.4 Temporal Properties

The time of day and day of week that movements occur are important for planning and design. For long-distance movements, many trucks operate at night and terminals have extended hours of operation. On the other hand, travel times for local movements are more restricted because of business hours of operation. Scheduling commodity movements can be critical considering new strategies such as just-in-time delivery. Trip duration remains the primary measure of network level of service, since truck operators must always try to minimize travel time.

1.7 Overview of the Former Traffic Monitoring System[11]

The former traffic monitoring system had been set up in the 1960s following the recommendations of a review of the department's overall operations. Since then, the system had evolved without an overall plan or regular review. At the time this review was conducted in 1991-93, there was little documentation about the system, and the documentation that existed was not centralized or easily accessible. Most of the information about the system obtained in this review came from numerous personal meetings with the Department staff members responsible overseeing the system. A full description of the system can be found in the *Design* report itself; a summary of some of the important aspects of the program are reproduced below.

Volume Monitoring: The core of the former traffic monitoring system was the volume monitoring component, made up of permanent counting stations providing around-the-clock hourly traffic volumes at 48 locations, and coverage counting stations, providing traffic volume estimates at 1692 sites updated every second year. Permanent counter data was retrieved weekly over telephone lines and analysed using the manufacturer's Transpac software. Missing data, or data with suspected errors and anomalies, is adjusted or "patched"before calculation of summary statistics. Coverage counts, taken for 24- or 48-hour periods, were written on count sheets, delivered to the central office, and typed into a computer for expansion to AADT estimates. Expansion factors were developed based on groups of permanent counters using weekly factors in a method developed by Department staff which was not well documented.

Town Counts: Short-term volume counts were taken every three years at approximately 2000 locations in built-up areas on roads under provincial jurisdiction using portable counters. Town counts were conducted for 24- or 48-hour periods in June and not expanded to AADTs, since it was believed that June ADTs are very close to AADTs. Raw counts are screened for gross errors or anomalies based on comparisons with historical trends at the same location. Town counts were used within the department and not included in published reports, although they were given out to the public on request. No permanent counters were located within towns.

Turning Movements: Turning movement count sites were selected based on needs identified by various Branches for upcoming projects, as well as to update certain old counts and to maintain a five-year schedule of counting certain major intersections. Almost all turning movement counts were manual counts using electronic "Titan" devices for recording observations, and incorporating vehicle classification.

Vehicle Classification: The main source of vehicle classification information was the manual turning movement counts. However, automatic vehicle classification (AVC) data began to be collected in 1991 as part of Manitoba's commitment to the SHRP Long Term Pavement Performance program. Seven AVC sites have been operating since January 1991, providing around-the-clock classification data.

Vehicle Weights: No reliable truck weight information was collected under the former traffic monitoring system, and no large-scale truck weight data collection program had been in place in Manitoba since 1986, when the Department had conducted annual truck weight surveys using portable scales[12]. As part of Manitoba's involvement in SHRP, weigh-in-motion (WIM) equipment was installed in 1991 at six SHRP test sections, but the system was not yet fully functional.

Speed Monitoring: Speed monitoring was handled by the Traffic Engineering Branch on a special-needs basis. When a speed study was required, a staff member (typically a summer student) with a radar gun was stationed at the site in question to manually record traffic speeds.

Data Presentation: Annual traffic data were published in the form of a traffic flow map and a book of traffic statistics. The map showed the estimated average annual daily traffic and average annual daily truck traffic at each count location, but did not identify the source of the estimate. There was no differentiation between permanent and short-term traffic counts, between actual measured values and estimates, or between one-day and four-week classification counts. The book identified all count locations and provided AADT and %trucks estimates. No historical trends or regional information were available. Town counts were used within the Department but were not published for public use, although they were released on special request. The

Department published an index to turning movement / vehicle classification and truck weight surveys, which were available at the central office in tabular form or as intersection turning movement diagrams. Truck weight surveys had not been conducted since 1986 but records for the old surveys were available at central office.

Cost: The former traffic monitoring program cost approximately $324 300 in directly attributable costs, summarized in Table 2. These amounts did not include items which the Department considered to be fixed overhead, such as equipment maintenance, office staff, computer equipment for analysis and presentation of data, and some installation costs.

***Table 2**: Estimates of direct costs of the former traffic monitoring system, 1991*

		Capital cost (Annualized over 15-25 years at 10%)			*Annual operating costs*			*Total cost*
		Number of counters	*Cost per counter*	*Total*	*Number of sites or visits*	*Cost per site or visit*	*Total*	
Permanent counting program		48	$590	$28,320	48	$530	$25,440	$53,760
Short-term counting program	*Pneumatic counters*	155	$25	$3,875	905	$41	$37,085	$44,460
	Loop counters	70	$50	$3,500				
Turning movements / manual classification	*Four-week surveys*	6	$330	$1,970	20	$6,890	$137,800	$150,220
	One-day surveys				31	$340	$10,450	
Automatic classification and weigh-in-motion		7	$1,420	$9,940	7	$640	$4,480	$14,420
Total annual program cost								*$262,860*

This table only includes costs directly attributed to the traffic monitoring system. Additional costs such as installation crews, office staff, equipment repair, and computer equipment for data analysis and presentation are considered to be fixed overhead are not included here.

Source: Personal interviews and memos, Manitoba Highways and Transportation staff.

Chapter 2 *Principles of Data Collection and Evaluation of the Former Traffic Monitoring System*

The first section of this chapter was presented at the 1994 Canadian Society for Civil Engineering Annual Conference as part of the paper *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation: A Case Study.* These Principles were developed primarily from a review of the literature on traffic data collection -- the leader in this area in the 1980s and 1990s has been David Albright -- as well as on data management principles in general. These principles were a key component of the review of Manitoba's former traffic information system. The remainder of the chapter summarizes the evaluation of the former traffic monitoring system with respect to these principles.

2.1 Definition of the Principles of Data Collection

2.1.1 Responsiveness to Need

The most important requirement of a data collection system is that it must collect all required information, and for greatest efficiency, it should collect only the required information. This seems obvious but if this principle is not made explicit, there is often a tendency for the system to drift from its objectives. Users' needs must be re-assessed regularly, and the system changed to accommodate new needs as they arise and to stop collecting data where the need has disappeared. Users' needs also govern the format for presenting information (paper or electronic graphs, charts, or maps) and the timeliness of the response.

2.1.2 Truth-in-Data

Truth-in-data means disclosing the methods used throughout the data collection and analysis process. Traffic reports should describe the equipment used to collect the data, the time period over which the data were collected, the analysis methods used, and the accuracy of the estimate. This enables users to judge the quality of the data, its appropriateness for their application, and to relate the sensitivity of decisions to the quality of the data.

An example of truth-in-data can be seen in SHRP's Long Term Pavement Performance component (LTPP). The LTPP project requires data from test sites across North America, but the equipment and analysis methods vary depending on the agency collecting data at each site. SHRP could not mandate specific types of equipment and procedures; instead, it required agencies to include with their data a description of how the data were collected and analyzed. With this disclosure, it is possible for researchers to account for differences in data collection methods.

2.1.3 Consistent Practice

Until recently, there were no comprehensive traffic monitoring standards, so "the measurements or estimates underlying traffic summary statistic reports have varied from agency to agency, from office to office within agencies, and from year to year within offices."[13] The problem is that traffic statistics produced using different methods are really measuring different things, and should not be compared. For example, a review of traffic counting programs in New Mexico found some agencies counting traffic seven days a week, while others counted only Monday through Friday. These two very different statistics were both reported as AADT and displayed side-by-side on the same maps.[14] While truth-in-data requires disclosure of how the numbers were derived, the principle of consistent practice requires all agencies to use the same methods. ASTM and AASHTO standards emphasize the need for consistent practices and provide standard methods.

2.1.4 Base Data Integrity

The base data are the raw, unsummarized observations, which should be screened or verified before being accepted. Equipment failures, accidents, special events, construction, or storms can cause unusual traffic flow patterns so that data from a traffic survey may not be representative of typical conditions. Base data must be compared against historical patterns at the same site before being included in the database.

If errors or anomalies are suspected, the data should be accepted or rejected, but not altered. Many agencies adjust anomalous data, estimating what the numbers might have been if the breakdown or error had not occurred. For example, if a counter breaks down on a Tuesday, missing data might be estimated by averaging Monday and Wednesday, or using data from other Tuesdays in the month. This is known as "patching" data, and the methods used vary greatly from agency to agency, from analyst to analyst, and from year to year. The problem is that while errors can cause bad data which do not reflect typical road conditions, the "patched" data also do not reflect real events. It is better to discard such data rather than adjusting data to match preconceived ideas. All of the new standards agree on this point. ASTM, for example, states firmly, "missing or inaccurate unedited base data shall not be completed, filled-in, or replaced for any type of traffic measurement."[15]

2.1.5 Sampling Procedures

Selection of appropriate sampling procedures is important for collecting traffic data which is used to compile an average value over several sites, or used to estimate values at other locations. This means that the locations and times of monitoring must be selected so as to observe a representative sample of the population desired. For example, if a truck weight monitoring program is intended to determine typical weight distributions for various truck configurations, monitoring should be done at locations and times where "normal" or "typical" weight distributions are found.

2.1.6 Data Storage

Traffic data must be stored permanently and safely. Raw data should be retained permanently for use in future analysis, as analysis techniques change or new needs arise. Information must be protected against erasure or changes due to users' actions or equipment failures. The systems used to safeguard the data must be well-established and readily available standards, to ensure their long-term viability.

2.1.7 Data Security

Data must be protected against unauthorized use. A policy on the confidentiality and distribution of traffic data must be established and implemented, and any information deemed confidential must be protected using means that are appropriate for the level of risk and the sensitivity of the data.

2.1.8 Interagency Co-operation

Agencies operating in the same geographic area (for example, municipal and provincial transportation departments) and branches within an agency often conduct independent traffic surveys for their own purposes. Agencies and branches should establish channels for sharing data and reducing duplication of effort. Although some agencies or branches have special needs that general-purpose surveys cannot address, it is more often true that data collected by one agency are usable by another. Traffic data can also be shared between adjacent jurisdictions, because most traffic characteristics do not change sharply at jurisdictional boundaries. This can save resources and increase the accuracy of system-wide statistics by allowing larger samples. In order to efficiently share data, however, agencies must first follow the principles of Truth-in-Data and Consistent Practice to ensure that they information they share is equivalent.

2.1.9 Integration with other databases

Traffic data should be integrated with other databases. Information about traffic is most useful when it is integrated so that relationships can be found between different types of information. For example, accident records are most useful after they are combined with traffic flow data to find accident rates, or when compared with the physical inventory to find accident patterns related to traffic control devices or streetlights. One such method of integration is the Geographic Information System (GIS).

2.1.10 Future Developments

A traffic data system should be able to incorporate new methods and technologies as they become available. AASHTO, for example, recommends a "dynamic approach, encouraging further development"[16] while specifying certain minimum requirements. This allows the system to meet new needs as they arise and incorporate new technologies and analysis methods as they are developed. This includes keeping staff members up to date on the latest techniques in the field.

2.1.11 Summary of System Goals

From these principles, the following goals arise that the traffic information system should address:

Principle	*System Goals*
Responsiveness to Needs	• Supply users with required data in the preferred format • Requests for information should be handled quickly enough to be of greatest benefit to the user. • Information provided must be timely (i.e. not outdated)
Truth-in-Data	• Disclose all methods and technologies used. • Provide estimates of the accuracy of all statistics.
Consistent Practice	• Adopt standard methods or press for standards to be established.
Base Data Integrity	• Screen raw data for errors and anomalies • Data may be accepted or rejected but not adjusted
Sampling Programs	• Traffic monitoring locations must be selected appropriately considering the information to be collected and the characteristics of the population being sampled.
Data Storage	• Raw data should be stored permanently and secured against loss using well-established and readily useable systems.
Data Security	• Information which should remain confidential should be identified and appropriate steps taken to guard it against unauthorized access.
Interagency Co-operation	• Steps should be taken to share data with other jurisdictions and to co-operate in the collection of traffic data.
Integration With Other Databases	• The traffic information system must link easily with other data systems in the Department.
Future Developments	• The system should be flexible and modular to accommodate new technologies and new methods, and staff must be kept up to date on innovations in the field.

2.2 Evaluation of the Former Traffic Monitoring System with Respect to Principles

2.2.1 Responsiveness to Need

Assessing the responsiveness of the former traffic monitoring program to users' needs required an in-depth examination of those needs, which is described in Chapter 3. Most users' needs were met by the system; in fact, the larger problem was that in several areas, the former system collected extra information which was not needed.

2.2.2 Truth-in-Data

This principle was not followed by the former traffic monitoring system. Traffic estimates were not identified as to their sources (e.g. permanent counters, short-term counters), no indication was made as to whether estimates are based on patched data or not, and the methods used to arrive at traffic statistics were not disclosed.

The *Design* report recommended that all traffic reports include a description of the source of all information presented, the procedures used to process the information, and an assessment of its accuracy. In the 1993 annual report, traffic statistics were identified as to the type of device used to collect the information, but the analysis procedures were not included, nor was an assessment of the accuracy. In 1994 and 1995 annual reports, descriptions of all analysis procedures were also included. However, no procedures are as yet in place to calculate the accuracy of traffic statistics.

2.2.3 Consistent Practice

The former traffic monitoring program failed to comply with standards in existence at the time in several areas, including permanent counter AADT estimation, coverage count expansion, and coverage count durations. In the years since the *Design* report was accepted, improvements have been made in the following areas:

- Permanent counter AADT is now estimated by the method specified in the ASTM standard
- Data are not edited, although they may be discarded in case of errors
- The method used for expanding coverage counts is now well documented and based on methods used in other Canadian and American jurisdictions. The expansion method addresses concerns regarding the use of patched data, the unreliability of axle conversion factors, the overgeneralization of expansion factors, and the neglect of inherent variation.
- Coverage count durations have been standardized at 48 hours.

2.2.4 Base Data Integrity: Data Patching

Under the former traffic monitoring system, permanent counter data was adjusted or patched routinely by the Transpac data analysis program. Current standards clearly state that this is not acceptable. By 1994, no data were being patched or edited in any way, although data were screened for errors and discarded if appropriate.

2.2.5 Base Data Integrity: Screening data

Permanent counters: Under the former traffic monitoring system, permanent counter data were screened by the Transpac software package supplied by the manufacturer of Manitoba's permanent counters, Golden River Traffic. Transpac flagged data as anomalous whenever zero volumes were observed or where successive hourly volumes differ by more than a factor of two, and permits missing or anomalous data to be filled in or adjusted using one of several algorithms.[17] Current standards (ASTM[18], AASHTO[19]) recommend a series of checks including comparisons to known historical patterns, comparisons of directional distribution of traffic, and large changes in consecutive hourly or daily flows, and they prohibit the adjustment of data, stating that data may be accepted or rejected but never altered.

The new traffic monitoring system screens permanent counter traffic data using some of the criteria specified by ASTM and AASHTO, as well as some criteria selected in-house, but the official standards have not yet been completely implemented. Automatic screening procedures have not yet been implemented for other data sources.

Coverage Counters: Under the former traffic monitoring system, data from coverage counters were checked first of all by the field operator who recorded the counts on paper, and who checked for unusual valus and correct machine operation at every reading. The counts were then typed into a Lotus 1-2-3 spreadsheet and expanded. After expansion, the AADT estimates were checked for errors manually and adjusted if this was felt to be necessary by the person doing the expansion. The results were then entered into the computer. Error-checking was done manually, so it was time-consuming, errors may have gone unnoticed, error identification was subjective, and the method did not include the standard criteria recommended by ASTM and AASHTO.

Under the new Traffic Information System, the procedure remains essentially unchanged except that data are not adjusted; they are only entered or rejected in accordance with current standards. However, UMTIG staff generally make the assumption that if the field operator did not observe any unusual situations or equipment malfunctions at the site, then the count reflects true conditions at the location and so data are rarely discarded.

Vehicle classification and weigh-in-motion data are screened automatically for gross errors in individual readings which are caused by equipment errors, such as vehicles with a dozen axles or axle weights or spacings that are outside wide limits.

2.2.6 Sampling Procedures

Permanent counter distribution by traffic pattern group: Under the former traffic monitoring program, traffic pattern groups were defined by weekly expansion factors developed by MHT staff, such that sites in the same group had factors within 15% of the group mean. This implies that there is some variation within each traffic pattern group, which causes uncertainty in the expansion factor process. Applying a single expansion factor to all members of the group introduces some inaccuracies.

As part of the review of the former program, the random variation within each group was assessed. (Table 3) For some groups, the *Design* report recommended the addition of permanent counters to reduce the within-group error; for the least variable groups, counters could be removed and relocated without adversely affecting the precision of the estimates. Since the completion of that report, several counters have been added to increase coverage in certain areas.

Table 3: Within-group error for expanding short-term counts

Traffic Pattern Group	*n*	*Within-group error*
Urban	11	3.4%
Trunk	9	5.2%
Trunk Seasonal	5	11.3%
Rural Commuter	8	5.8%
Rural Commuter Seasonal	3	22.5%
Resort	2	26.6%

Coverage counter representativeness: Coverage counts should be taken at times and in locations which are representative of normal traffic in the area. Counts should not be taken which are likely to record unusual activity, unless the objective of the count is specifically to monitor that activity. There has been no comprehensive review of coverage count locations, although field staff have demonstrated good understanding of the need to position counters appropriately and it is believed that counters are in general well-positioned.

2.2.7 Data Storage Period

Traffic data must be stored permanently and safely. Raw data should be retained permanently for use in future analysis, as analysis techniques change or new needs arise. Information must be protected against erasure or changes due to users' actions or equipment failures.

Under the former traffic monitoring system, data were stored analyzed on the mainframe computer and stored on magnetic tapes. With the shift towards a PC-based system, data are now being stored on optical disks, which are less expensive, have a longer shelf life than magnetic tapes, and are more convenient to store.

2.2.8 Data Storage Safety

All data must be stored in a compact form and protected against accidental loss. Under the former system, data were stored on the mainframe and data storage was primarily the responsibility of the computer services department. However, accidental erasures of data could and did occur. With the transfer to PCs, data storage has been addressed by performing regular backups on tape and optical disks, with duplicates stored off-site for disaster recovery.

2.2.9 Data Security

Traffic data has never been considered confidential by Manitoba Highways and Transportation and is given out readily and without charge on request. There is therefore no need to restrict access to data.

2.2.10 Interagency Cooperation

It has been shown that highways in Manitoba and Saskatchewan have similar characteristics, and that using permanent counter data from both provinces can result in improved traffic pattern grouping.[20] In turn, this may allow a reduction in the number of sites required and result in overall cost savings.

Under both the former traffic monitoring system and the new system, the Department exchanges traffic flow maps and statistics with neighboring jurisdictions. The new traffic information system is specifically designed on an open platform to allow easy interchange of information through a variety of means, including the Internet. Research is currently underway at the University of Manitoba into ways of unifying the Manitoba and Saskatchewan traffic data sets.

2.2.11 Integration with Other Databases

Traffic information is not currently linked directly to other Departmental databases. Under the former mainframe-based traffic information system, this would have been difficult. The new traffic information system was developed on an open platform which readily supports information interchange, so as other databases are developed it will be possible to integrate traffic data.

2.2.12 Future Developments

The former traffic monitoring system was poorly documented and difficult to operate. The new traffic information system is well-documented, and now includes an illustrated binder of instructions covering all aspects of system operations.

Chapter 3 Traffic Data Needs in Manitoba and Evaluation of the Former Traffic Monitoring System

3.1 Introduction

Traffic data collection is a support function which must provide information that meets the needs of the data users. As part of the review of the former traffic monitoring system, a review of the data needs of Manitoba Highways and Transportation was conducted in March and April 1992[21]. The survey consisted of personal and telephone interviews with Department staff members. Additional information was taken from the engineering literature and from a 1991 study on truck data needs conducted for the Department[22]. The data requirements of users outside the Department were investigated through interviews and literature review. After the interviews were completed, each Branch was asked to review its needs summary and to confirm that the report accurately represented its needs. There has been no similar survey conducted since that time. This chapter summarizes the findings of the needs study and the evaluation of the former traffic monitoring system with respect to those needs.

The survey's objectives were to determine:

- the types of data required by the Branches to carry out their functions
- the relative importance of each type of data
- whether data were required on a periodic basis or for special surveys
- whether data were required for individual locations or summarized over highway classifications or regions
- how low-volume roads are dealt with, and the lowest-volume road relevant to the Branch's operations
- the level of accuracy required for traffic statistics
- the degree of coverage of the network required
- the Branch's level of satisfaction with the current traffic monitoring program, and any improvements which could be made.

Needs surveys in other jurisdictions have reported that identification of data users' needs is difficult. Most data users do not have a good idea of their exact requirements, and where they can identify their needs, the priorities are often subjective and can change over time. For example, following completion of one FHWA survey of its operating units' data needs,[23] the units were contacted to develop plans for meeting some of the needs identified in the survey and it was discovered that "their top priority needs, in many cases, had changed and sometimes disappeared altogether. Much of the change was the result of personnel turnover, emergence of new issues, or declining interest in previously identified issues."[24] Any needs assessment must undergo periodic review to ensure that it meets the current priorities of the users. A re-evaluation of data needs in Manitoba is now underway by J. Yeow of the University of Manitoba.

Traffic data of all types are used in a wide variety of applications, including:

- setting design and maintenance standards
- evaluating the need for, and priorizing, system improvements such as interchange construction, highway relocation, highway twinning, town by-passes, location of rest stop areas, installation of traffic control devices and intersection illumination
- setting traffic signal timings
- preparation of environmental impact statements for all types of highway projects
- conceptual, functional, and geometric designs for most roadway projects
- calculating accident rate statistics, resolving accident liability claims, and conducting safety studies
- long-term strategic highway planning
- allocating traffic enforcement resources
- economic evaluations.

Traffic data plays only a minor role in day-to-day maintenance activities. Most maintenance warrants are intended to keep a facility at a specified standard of repair, without reference to traffic. Bridge designs are based on standard AASHTO design vehicles, not on observed traffic.

***Table 4**: Summary of data needs in Manitoba*

Type of data	***Number of requests***	***Type of program***
AADT	♦♦♦♦♦♦	Annual
Vehicle classification	♦♦♦♦	Annual
Hourly variation of traffic	♦♦♦	Annual
Seasonal variation of ADT	♦♦♦	Annual
Turning movements	♦♦½	Special-needs
Vehicle weights	♦♦	Annual
Speeds	♦♦	Special-needs
Day-of-week variation of ADT	♦	Special-needs
Directional distribution of traffic	♦	Special-needs
Lane distribution of traffic	♦	Special-needs
People movements	♦	Annual
Goods movements	♦	Annual
Vehicle-kilometres of travel	½	Annual

Note: ♦ symbols indicate the number of Branches indicating that the information is essential; Branches considering the information useful but not essential are counted as ½. This does not include the Policy and Research Branch, SHRP/LTPP commitments, or external users. Source: *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation*, Chapter 4.

3.2 Average Annual Daily Traffic (AADT)

The most important data type is Average Annual Daily Traffic (AADT), required by almost all Branches and regarded as essential by most. Estimates of AADT must be available and periodically updated at a large number of sites, and preferably on every highway segment in the province.

The former traffic monitoring program estimated AADT at most locations on the highway network based on counts conducted every second year. This coverage was more than adequate for most Branches, but one Branch requested additional AADT survey locations in order to ensure that every possible highway segment was monitored.

Under the new traffic information system, short-term counts are taken for AADT estimation every two years on roads with AADT above 200, and every four years on lower-volume roads. Every highway section in the province is monitored at least once between major intersections, and many are monitored at more than one location to ensure complete coverage.

3.3 Vehicle classification

The next most important data type is vehicle classification, required by almost all Branches. This information should be available on a special-needs basis at project locations. Vehicle classification summaries by highway functional class and updated periodically were requested.

Different branches required vehicle classification to be reported using different classification schemes. Most branches were satisfied with two, three, or four classes (passenger cars and trucks, which might be separated into broad categories such as recreational vehicles, straight trucks, semi-trailers, and multiple-trailer units). Pavement design, however, requires highly detailed information on a seasonal basis, summarized by highway load level class (RTAC/A1/B1) and occasionally at specific project locations. FHWA Scheme F, a 13-class scheme which was the standard in the province, was not considered detailed enough because it did not differentiate between certain types of dual and triple-axle trucks, and a new 22-class scheme was under consideration.

Under the former traffic monitoring system, vehicle classification information was available through manual turning movement counts and through automatic vehicle classifiers installed at SHRP sites in 1991. Classification was reported in a 15-class extension of FHWA Scheme F. Classification counts were not expanded to annual averages, so a one-day turning movement survey would be assumed representative of traffic for the entire year.

Some users suggested that vehicle classification be summarized by highway functional class. This is not, however, a meaningful basis of summarizing vehicle classification. The functional classes were developed by considering the traffic volumes and the size of the destinations they serve - the number of trips produced by and attracted to the destinations. The vehicle classification mix does not depend on the size of a destination, but on other destination characteristics. For example, Provincial Trunk Highway (PTH) 1 and 75 have the same functional classification, but the fleet mix on the two highways is very different. PTH 75 carries almost exclusively 5-axle semi-trailer trucks (3-S2's) which can operate in the United States, while PTH 1 carries large proportions of other trucks which are permitted in Canada but not the USA.[25] A useful vehicle classification system must report classification for individual roads or find other patterns or characteristics on which to group the highways.

Under the new traffic information system, the collection of vehicle classification information is largely unchanged in methods and analysis procedures. The 1993 through 1995 annual reports provide a percent-trucks statistic, but no detailed vehicle classification information. UMTIG has produced separately a report titled *Truck Traffic on Manitoba Highways 1994* which reports vehicle classification in detail.

3.4 Monthly or seasonal average daily traffic

Most Branches require information about the monthly or seasonal variation in traffic, estimated annually and summarized by highway classification or route.

The former traffic monitoring system did not routinely provide seasonal or monthly traffic data at any location, although this information was available at permanent counter locations with some additional data processing. Seasonal or monthly traffic data were not available at all for the majority of coverage count stations without conducting a special survey.

The new traffic information system's annual report provides graphs of the monthly average daily traffic expressed as a percentage of AADT for every permanent counter, and average summer daily traffic expressed as a percentage of AADT for every coverage counter location. In addition, weekly updated graphs at showing daily traffic totals for each day of the year are readily available for all permanent counting stations, and WIM/AVC sites.

3.5 Hourly variation of traffic

Information about hourly traffic flows is required in built-up areas and on high-volume rural highways where the AADT is over 3000 or the seasonal or monthly ADT is over 5000. This information should also be available on a special-needs basis at specific project sites.

The former traffic monitoring system was able to provide this information only at permanent counter locations, and then only with some additional data procesing. The information was not available at other locations without conducting a special survey.

The new traffic information system provides in the annual report for every permanent counting station a graph showing the hourly traffic patterns for weekdays and for weekends, averaged over the year. The equipment used to conduct coverage counts cannot record hourly traffic flows.

3.6 Vehicle-kilometers of travel

Vehicle-kilometres of travel statistics (VKT) are used for long-range strategic planning, environmental impact statements and fuel consumption calculations. VKT should be presented annually, summarized over the entire system and by highway functional classification.

The former traffic monitoring system presented VKT estimates for every highway control section in the province. The new traffic information system presents this information on a link-by-link basis on station detail reports, and a separate province-wide VKT report was produced in 1995 showing VKT information in detail and summarized in various ways. MHT has shown increasing interest in VKT information summarized by road class, vehicle type, region, and other ways for strategic planning purposes, especially when combined with statistics such as fuel consumption.

3.7 Turning movements

Under the former traffic monitoring system, observers using Titan electronic counting boards manually collected information about turning movements and vehicle classification at intersections. Sites were selected each year based primarily on requests from the branches and to maintain historical records at certain high-volume intersections on a five-year schedule. These surveys were the main source of vehicle classification information, as well as providing the intersection turning movements and hourly traffic approaching the intersection.

In many of the cases where turning movement counts were carried out, the data need was actually for vehicles-approaching or for vehicle classification, which raised the possibility of using alternative methods of data collection which cost much less than the full manual turning movement surveys. Under the new traffic information system, the number of turning movement counts has been reduced, but further reductions are still possible as alternative methods of data collection have not yet been fully explored.

Under the former system, turning movement counts were only 14 hours long. In order to get a daily traffic volume estimate, the total approaching volumes were multiplied by 1.2. The *Design* report, however, has shown that the appropriate factor varies from location to location and could range from as low as 1.00 (the lowest possible, meaning that there was no nighttime traffic) to as high as 1.92, with a mean of 1.17. No provision has yet been made for incorporating this variation in the new traffic information system.

3.8 Speed studies

Speed studies are used on a special-needs basis for investigating specific locations for safety and geometrical alignment problems, and occasionally in traffic signal design. This information is always very strongly site-specific.

Both the former and the new traffic data programs collected speed data through manual radar-gun surveys on special request only. Some automatic counters are capable of collecting speed information, but they are not widely used for this purpose.

3.9 Weight studies

Vehicle weight information would be useful for pavement and bridge design and for studying the effect of traffic on deterioration. This information should be collected and updated seasonally for studies at specifically selected project sites, and also summarized by highway functional classification.

The former traffic monitoring system did not collect vehicle weight data. Pavement design procedures used vehicle weight information derived from truck weight surveys conducted in Alberta. A. Ostroman[26] has analyzed the truck weight data situation in detail and has made recommendations about the program. The new traffic information system has not yet introduced changes to the data collection procedures, although numerous improvements have been made to the analysis procedures to increase the efficiency of analysis and generating summaries of data for submission to LTPP. Increasing effort is being made to produce detailed information about the truck fleet through use of the WIM and AVC data collected for the LTPP.

3.10 Lane and directional distribution

Directional distribution information may be useful for certain applications on a project-specific basis, if classified by vehicle type. Lane distribution may also be useful when summarized by highway functional class. These types of data were not used by the Department at the time of this needs survey.

Under the former traffic monitoring program directional distribution and lane distribution data were not provided routinely but were available at certain permanent counter and coverage counter locations with some additional data manipulation. In fact, at many permanent counters, data were collected lane by lane, transmitted lane by lane, and then totalled at head office to show all lanes together, discarding the lane-by-lane data without analysis.

The new traffic information system reports AADT information by direction where available (generally for divided highways) as well as for the combined directions. When aggregated over the entire year, it would be very unusual for the directional distribution to be unequal in opposing directions outside a very small margin.

3.11 People and goods movements

Certain people and goods movement characteristics such as could be determined through large-scale origin-destination (O-D) surveys were identified as areas of interest to some Branches. One Branch indicated a special interest in hazardous goods movements.

Under the former traffic monitoring system, no such data were provided. No province-wide O-D study has ever been carried out, although small-scale studies such as roadside interviews and license plate surveys have been used to evaluate individual projects. This type of information is not considered to be within the mandate of the new traffic information system.

3.12 Uncommonly-requested data

Vehicle dimension information was described as interesting to one Branch, but not important to any. Two Branches expressed an interest in people and goods movement information for developing province-wide origin-destination models, and one Branch expressed a special interest in hazardous goods movement information.

Neither the former traffic monitoring system nor the new system provide any of this information on a routine basis.

3.13 Network coverage

Most Branches were satisfied with the existing coverage of the highway network, and there were some indications that the existing coverage provides more detail than most users required. Several Branches noted that near towns, traffic volumes can change over short distances so counters should be closely spaced (10-20 km); on remote rural highways, counters may be spaced further apart. The exception was Traffic Engineering, which would like significantly more AADT survey locations. The *Design* report recommended that short-term counts be taken on every highway link in the province. All sites should eventually be converted to induction loops as resources permit, to improve accuracy and remove the need for axle conversion factors.

Under the new traffic information system, short-term counts are taken for AADT estimation every two years on roads with AADT above 200, and every four years on lower-volume roads. Every highway section in the province is monitored at least once between major intersections, and many are monitored at more than one location to ensure complete coverage. Counter locations are being converted to induction loops as resources permit.

3.14 Low Volume Roads

The needs analysis showed that many traffic data applications include a lowest significant volume, below which minimum standards apply. For most Branches, this lowest volume is an AADT of 200. For roads below this level, there is little justification for collecting traffic volume information because there is no application which makes a distinction between, for example, a road with AADT of 50 and a road with AADT of 150. Forty-one percent of the traffic count locations in Manitoba in 1990 had AADT less than 200 vehicles per day, indicating that significant effort was being spent in measuring insignificant volumes.

Some sort of ongoing monitoring is necessary even on these low-volume roads, in order to determine if volumes have increased such that they are no longer low-volume roads, but this monitoring can be much less frequent than for higher-volume roads. Under the new traffic information system, roads with AADT over 200, are counted on a two-year cycle, while low volume roads are counted on a four-year cycle. For both groups, the standard count duration remains 48 hours. Additional research is recommended to determine whether this frequency is adequate or whether it may be reduced further.

3.15 Accuracy

Most traffic data users have never addressed the issue of the sensitivity of decisions to inputs and have no idea of the impact of variability on activities. Most transportation decision-making relies heavily on engineering judgement and experience as opposed to rigidly defined quantitative standards, making it difficult or impossible to estimate the sensitivity of decisions to variations in the quantitative inputs. In the needs study, some Branches indicated an accuracy requirement, usually "±10% of the estimate", but in most of these cases it was not possible to identify an objective basis for selecting that figure.

Although ±10% is a traditionally-accepted margin of error for traffic statistics, it is often not achieved. In Manitoba, sampling variation at the 95% confidence level for a two-day count at the highest volume (lowest variability) site in the province ranges from ±7.4% to ±30.7%, depending on the time of year; the average variation over all sites and all months of the year is ±31.9%. Longer counting periods reduce this variation.[27] Despite these high percentage variations, however, the variation expressed in numbers of vehicles is quite low because of the low volumes on most Manitoba roads. Forty-one percent of the coverage count locations in the province show AADT of less than 200 vehicles per day; a 30% variation in such a count means a difference of 60 vehicles per day, which is insignificant for most applications.

Even at permanent counting locations, variability in traffic counts can be quite high when expressed in terms of the percentage of AADT. Figures 1 and 2 illustrate the coefficient of variation of weekday traffic (Monday through Thursday) from day to day based on analysis done by M. Alam in connection with the original *Design* report in 1991. The day-to-day variation drops as a percentage of AADT at higher-volume sites, and as descibed above, the variation would be even higher if considered at the 95% confidence level. When expressed in numbers of vehicles, however, the variation at the majority of sites is well under 200 vehicles per day. This is significant in percentage terms because of the low volume at most counting locations, but is a fairly small number of vehicles in itself.

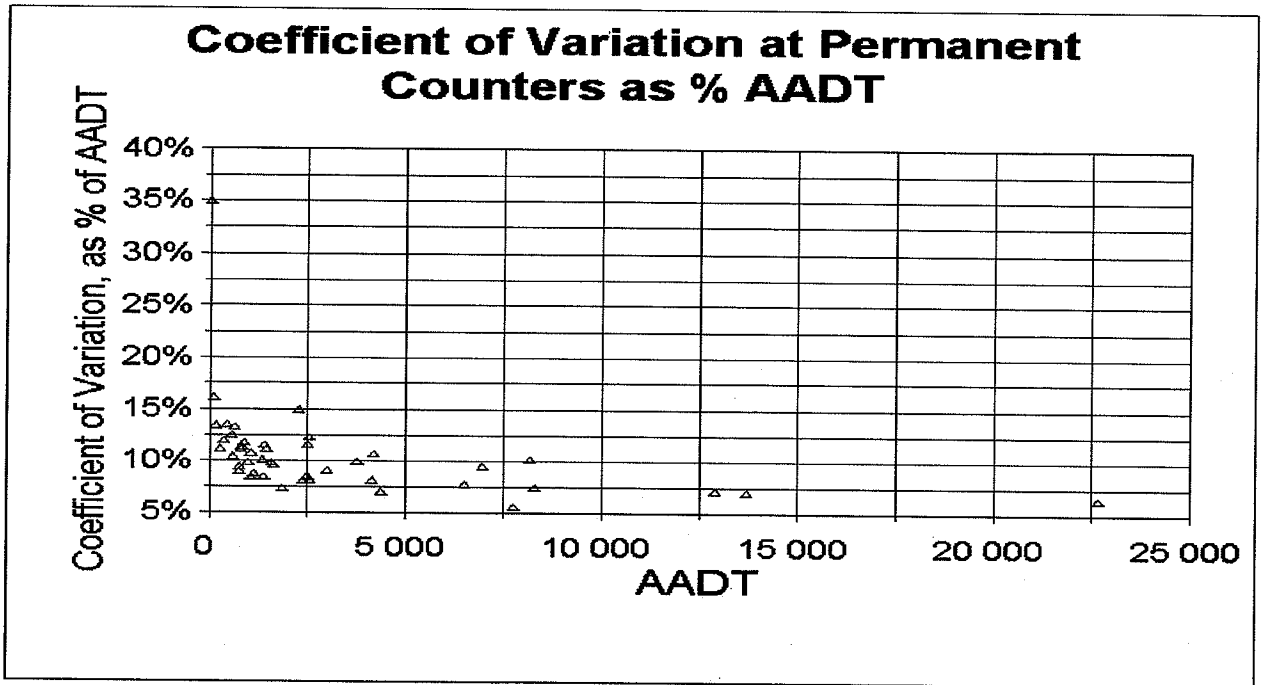

Figure 1: *Coefficient of Variation at Permanent Counters Expressed as a Percentage of AADT*
Analysis by M. Alam in Clayton, Lucas et. al., *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation.*

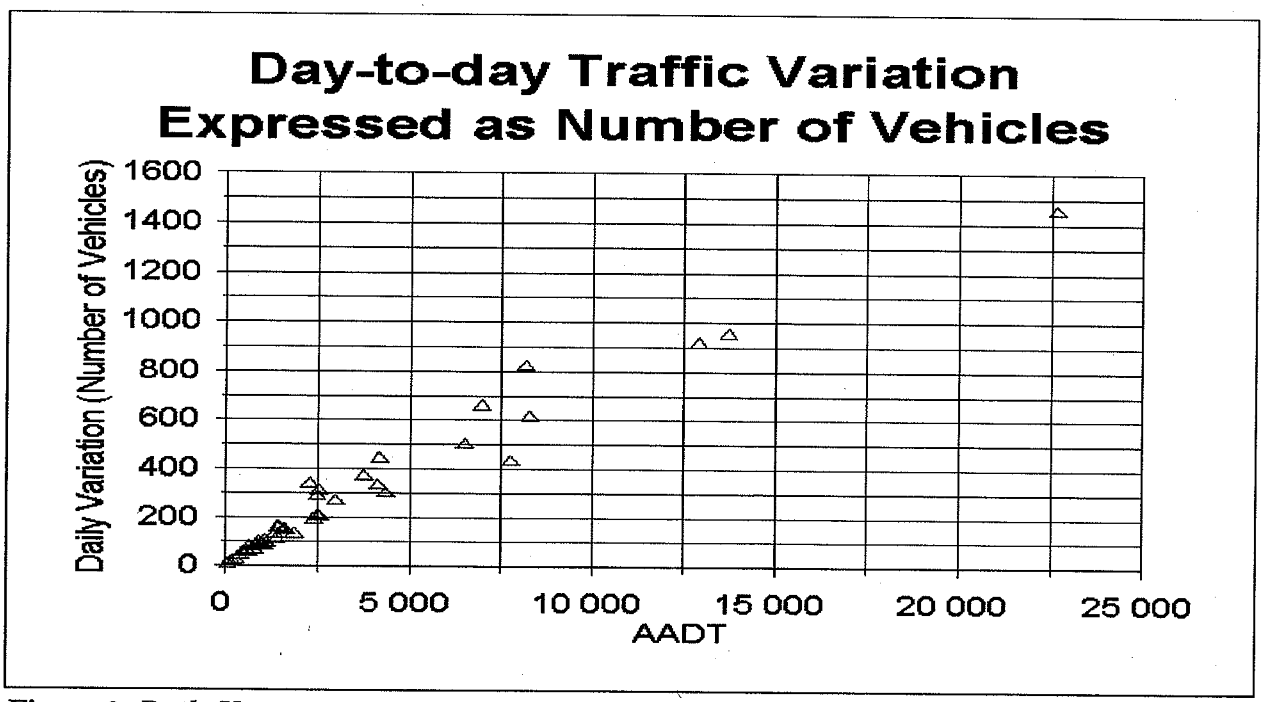

Figure 2: *Daily Variation at Permanent Counters Expressed as Numbers of Vehicles*
Analysis by M. Alam in Clayton, Lucas et. al., *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation.*

Neither the former traffic monitoring system, nor the new system, provide any indication of the accuracy level of any traffic statistic on a routine basis. Methods for estimating the accuracy of traffic statistics have been developed by M. Alam in connection with the *Design* report but have not yet been placed into production on the new system.

3.16 Timeliness

All Branches prefer to work with data as up-to-date as possible, although none specified any limits. Under the former traffic monitoring system, traffic estimates were often two years out of date by the time they were used. For example, planning began on the 1992 construction program in the fall of 1991, when only the 1990 annual report was available. The 1991 annual report was issued in early 1992, too late for use in developing the 1992 program. Work done in 1992, then, was based on traffic counts from 1990.

The new traffic information system strives to produce its annual reports as close to the end of the calendar year as possible. The first annual report produced by the new system, covering 1994, was released in July of 1995; the 1995 report was released in June 1996. Further improvements in speed are likely as the system continues to be upgraded.

Chapter 4 *Technical Summary and Evaluation of the Former Traffic Monitoring System*

4.1 Introduction

As part of the *Design* process, the former traffic monitoring system was evaluated for its performance with respect to the needs study and the principles of data collection as previously described. As well, a set of additional technical criteria were established in order to evaluate the system in areas not addressed in the needs and principles evaluations. This chapter describes this additional evaluation process.

4.2 Coverage Count - Control Station Assignments

Under the former traffic monitoring program, coverage count stations were assigned control stations for the purposes of expanding short-term counts to annual averages. However, as Figure 3 shows, eighty percent of all coverage count stations were expanded in a way which appeared to be incorrect upon review. Two-thirds of all stations did not even have a designated control station and were expanded using a "default" expansion factor; other stations were expanded using imaginary controls made by averaging expansion factors from other sites; and 8% of all coverage count stations were assigned control stations in a different Traffic Pattern Group (following the new TPGs that were developed for the *Design* report) and/or different functional class from their own.

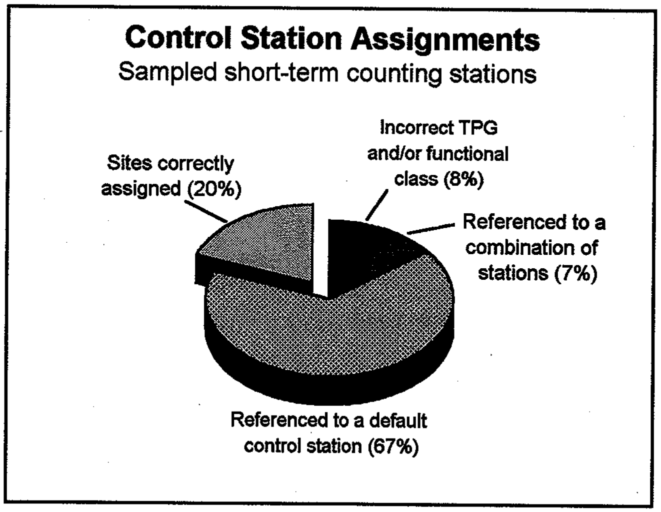

***Figure 3**: Control station assignments, former traffic monitoring system*

As part of the *Design* process, a complete review of control station assignments was carried out. Although not all coverage count stations have been assigned directly to control stations, they are all assigned to traffic pattern groups and are expanded against their TPG if no direct control station is available.

4.3 Axle conversion factors

As part of the coverage count expansion process, an axle conversion factor is used to change pneumatic tube axle counts into vehicle counts. Induction loop devices count vehicles directly and do not require axle conversion factors. Under both the former and current traffic information systems, axle conversion factors are developed from percent-trucks estimates based on manual vehicle classification counts. This process has a significant potential error, because the classification surveys are short-term, few in number, and are not necessarily representative samples of the vehicle population. The errors due to each of these factors have not been calculated. Work is proceeding on converting coverage count stations to induction loop operation as resources permit. Expansion of the vehicle classification data collection program would be necessary to provide the kind of baseline data needed to properly quantify the axle conversion factors. Work is proceeding on converting pneumatic tube counting sites to induction loops, which removes the need for axle conversion factors.

4.4 Expansion of coverage counts

Under the former traffic monitoring system, coverage counts were expanded using weekly expansion factors developed from permanent counter data. This procedure was reviewed in depth and Chapter 5 presents a detailed discussion of the former system, its evaluation, and the factorless expansion method used in the new traffic information system.

4.5 Data retrieval

Permanent counters: Under the former traffic monitoring program, permanent traffic counter data was retrieved by modem at approximately 1200 bits per second (bps), the maximum speed for the counters currently owned by the Department. WIM/AVC sites use 14.4 kbps modems. The *Design* report found that no significant saving would be achieved by purchasing faster modems, no changes have been implemented.

Coverage counters: Under the former traffic monitoring system, coverage counts were recorded manually in the field and typed into a computer at head office. Under the new traffic information system, data entry is done by UMTIG staff but no substantial changes to the data retrieval method was recommended.

4.6 Town Counts Program

Under the former traffic monitoring program, volume counts were taken in built-up areas on roads under provincial jurisdiction in June, every three years. The results were used within the Department and released to the public only when specifically requested. Expansion of town counts was not possible because there were no permanent counters located within towns, and town traffic patterns are different from rural patterns. All town counts were conducted in June, since June ADTs were believed to be close to AADTs for most stations.

Under the new traffic information system, the town counts program does not exist as a separate entity, but counts in built-up areas are included in the regular coverage count program. These counts are not expanded in the annual report, because there are no permanent counters in towns to serve as control stations.

4.7 Presentation and Reporting

Under the former traffic monitoring program, the annual report consisted of a map showing traffic and truck volumes for the entire province, and a book listing all control sections with their AADT, AADTT (truck travel), and VKT. In addition, records of past AADTs at permanent counters, and past turning movement / classification surveys were available. All data users indicated that they found the data presentation acceptable, although a few indicated that it would be useful to have summaries available by highway classification or by region.

Under the new traffic information system, the annual report includes permanent counter AADT, and graphs of average hourly traffic variation, monthly average daily traffic, AADT growth, and the highest 100 hourly volumes. It also includes AADT, ASDT percentage, 30th highest hour percentage, and percent-trucks estimates for all counting locations in the province, raw observed traffic volume counts at coverage count stations, and an assortment of traffic flow maps. Most of this information, plus day-by-day graphs of permanent counter traffic volumes, is also available on UMTIG's World Wide Web site on the Internet.

Additional special reports are produced from time to time. In 1995, special reports on Vehicle-Kilometers of Travel and on Truck Traffic were released, based on analysis of the 1994 data. A brief summary update to the VKT study was produced in conjunction with the 1995 annual report.

Maps used to be produced manually by the Department's drafting section; they are now produced from UMTIG's Geographic Information System which enables color maps at a variety of data scales and levels of detail to be produced quickly at any time.

Chapter 5 Control Stations, Traffic Pattern Groups, and Expansion Factors

This chapter describes the methodologies developed to group counting stations and expand short-term traffic counts. These methodologies are based on current standard practices, with some modifications and improvements. The methods described here are used in the operation of the new Traffic Information System.

5.1 Relating short-term and permanent counting stations

Most traffic engineering and planning applications require annual traffic statistics. Indeed, the single most frequently used traffic statistic is the Average Annual Daily Traffic (AADT)[28]. The only way to obtain exact measurements of the AADT at a particular location would be to continuously monitor traffic at that location for the entire year -- and this would assume perfect operating conditions and no breakdowns. Installing and maintaining permanent counting stations on every section of every highway would be prohibitively expensive, so the practice of counting traffic for short periods (typically 48 hours) and expanding these samples into estimates of AADT has been universally accepted and used by highway authorities.[29] The process of extrapolating this short-term count data to provide an estimate of traffic statistics for the entire year is called *expanding* the short-term count. Expansion is done by using a relationship established between the short-term count location and a location where year-round data is available. The permanent count station selected is called the *control station* for the short-term counter. *Traffic pattern groups* are used to identify appropriate relationships between short-term and permanent counters.

The modern procedure of selecting control stations to expand short-term traffic counts was established in the 1950s. Originally, short-term counters were assigned control stations which were selected on the basis of geographic proximity, but this was soon replaced with highway functional classification as the selection criterion. More recently, grouping techniques have been proposed which do not rely on the road classification, but use inherent characteristics of the traffic on the highway in order to group together roads with similar temporal flow patterns.

Most methods for grouping counting sites use the same general approach. They start by considering only permanent counting stations. For each week or each month of the year, the average daily traffic at each permanent counter is determined and divided by the AADT. The resulting factors provide a picture of how traffic volumes change on a weekly or monthly basis compared to the annual average. These factors can then be grouped using methods such as linear regression, cluster analysis, or hierarchical grouping. The groups of sites that form as a result are, it is assumed, related in some fundamental way which causes the traffic patterns to vary similarly. By examining the groups formed through this mathematical analysis, we hope to discover some common physical, geographical, or other characteristics. It is then assumed that any other highway location (where a permanent counter is not installed) which shares these characteristics also belongs to this traffic pattern group.

The most common problems encountered in performing these grouping procedures are that the groups can be unstable, with counters switching from group to group in successive years, and that clearly defined groups may not emerge. In either case, this suggests that the groups may by artificial creations of the analysis procedure and that the sites which emerge as members of the groups may not in fact share any fundamental characteristics. This would make it very difficult to justify assigning short-term counting sites to the groups.

5.2 The previous method for grouping permanent counters in Manitoba

The method used prior to 1995 in Manitoba relied on grouping sites based on the average daily traffic for weekdays in each week of the year. At each permanent counter, the weekly expansion factors -- the ratio of AADT to the average weekday traffic in each week -- were calculated to produce weekly factors. These factors were then grouped together, beginning with sites with weekly factors within 15% of each other. For each of the resulting groups, average weekly factors were then found, and the process was repeated using the averages as the starting points, and creating groups of the sites whose factors were within 15% of the average. This process was repeated until stable groups emerge, which usually happens after eight to ten iterations.

Four main problems with this method were identified by MHT staff. (1) Sites switch groups from year to year, indicating that the method does not identify a fundamental characteristic of the site. (2) It uses the week-to-week variation of traffic, which is a coarse measurement that does not take into account daily or hourly variations. Sites may have similar seasonal patterns with different hourly patterns. (3) The results are influenced by the initial groups chosen; if different initial groups are chosen, then the final results may be different. (4) The 15% criterion is selected arbitrarily.

Control stations for short-term counters were established based on geographical proximity, a subjective assessment of traffic characteristics, and general knowledge of the highway system. The expansion factor for the control station's group was applied to the short-term counts which it controlled. If no suitable permanent counter existed, a default factor, or a factor which was made up of a combination of factors from two or more permanent counters, was used.

A short-term count was expanded by multiplying the recorded volume by the weekly expansion factor for its control station's group. A 48-hour count was divided in half to get a 24-hour estimate which was then expanded. The final AADT estimate for the site was taken as the average of the 24-hour estimates made during the year. This average was influenced by the judgement of the staff member responsible for preparing the estimates, who regularly adjusted estimates to match historical trends, adjacent counts, or other factors.

5.3 An improved method of grouping permanent counting stations

As part of the development of the new Traffic Information System, Manitoba adopted a method of traffic pattern grouping based on a hierarchical grouping algorithm which was proposed by

J. H. Ward in 1963 and applied to traffic counter grouping by Sharma and Werner in 1981. This author implemented the algorithm as a computer program and analyzed Manitoba traffic data from 1992-93 in order to develop traffic pattern groups for the province.

The algorithm begins by considering all observations and calculating a matrix of the errors which would result if any two observations were grouped together. Observations which are far apart have large values in the error matrix, and observations which are close together will have small values. The two observations with the least error are selected and combined to make a group, with the error preserved as an "in-group" error. The two observations become one, so there is one less observation in the matrix. The errors which would result from any two observations being combined are re-calculated, with the in-group errors included in the calculations. Again, the combination which results in the smallest error value is selected and a new group is formed. At this and later stages, single observations can be combined together to form groups, single observations can be included in existing groups, and existing groups can be merged. The process of recalculating the errors and combining groups is repeated until all observations are combined into a single group. The implementation developed by this author displays the number of group formed, lists the stations in each group, and displays the error associated with the formation of each group at each stage. The operator may select the number of groups and the acceptable error.

This implementation groups stations based on hourly observed traffic volumes throughout the year. The hourly traffic at each site is divided by the AADT at the site, and the resulting values used as the basis for the grouping. Using hourly data allows the seasonal and hourly peaking characteristics to be considered simultaneously. Data from Manitoba permanent counters were analyzed in 1992-93 to identify traffic pattern groups in the province. The stability of the groups was checked by re-running the analysis using data from subsets of the available sites. If the method were sensitive to small changes in traffic volumes, it would be expected to produce significantly different groups when provided with only a subset of the data. In fact, similar groups emerged no matter how the data sets were fed to the program.

5.4 Relating short-term counters to the permanent-counter groups

When the resulting permanent counter groups were examined, clear connections were immediately noted between the geographic locations of the traffic counters, the traffic flow patterns visible when plotted on hourly or daily graphs such as Figure 4, and the groups that they formed. For example, one group of counters was found to show distinct morning and afternoon peaks and a flat seasonal distribution. These counters were found only in and around Winnipeg. Another group showed very high summer peaks with distinctive differences between weekday and weekend hourly patterns. These counters were found to lie on highways which were known to serve major summer recreation spots. For almost all of the groups that had formed, it was possible to identify geographical characteristics that they shared. This would make it possible to assign short-term counters to the groups based on their geographical characteristics. The traffic pattern groups were named according to these characteristics which they shared.

Urban Commuter

Site	Highway	Location	Functional Class
1	8	Winnipeg	E
2	7	Winnipeg (inside Perimeter)	E
3	9	Winnipeg - Selkirk	A2
7	210	Winnipeg	CA
8	59	Winnipeg	E
9	75	Winnipeg	E
14	12	Steinbach	A1
47	100	Winnipeg (Perimeter highway)	E
51	3	Winnipeg	A1
70	100	Winnipeg (Perimeter highway)	E
77	101	Winnipeg (Perimeter highway)	E

These routes are almost all directly feeding Winnipeg; the exception is one site adjacent to Steinbach. They are characterized by very distinct morning and afternoon peaks with relatively flat seasonal variation.

Trunk

Site	Highway	Location	Functional Class
16	7	North of Teulon	A2
21	10	North of Boissevain	A1
25	1	Saskatchewan Border	E
40	2	PTH 83	A1
43	16	East of Strathclair	A1
46	16	Northwest of Portage la Prairie	A1
49	5	Southeast of Dauphin	A1
60	6	South of Ashern	A1
62	1	Oak Lake	E
79	1	North of Carberry	E

Trunk routes are those segments of major highways which are not adjacent to towns, so they serve mainly through movements. They are characterized by an hourly pattern that shows very little morning/afternoon peaking in the summer (although morning and afternoon peaks are discernible in the spring and fall) and a moderate summer seasonal rise.

Trunk-Seasonal

Site	Highway	Location	Functional Class
13	1	East of PTH 12	E
74	1	Ontario border	E
75	317	East of PTH 59 (to Lac du Bonnet)	A2
96	10	South of Riding Mountain Nat'l Park	A1
97	357	East of PTH 10, S. of Riding Mtn	A2

These sites are not located adjacent to towns, but serve largely recreational areas. They are characterized by a high summer rise and an hourly pattern similar to Trunk routes.

Rural Commuter

Site	Highway	Location	Functional Class
24	10	Brandon	A1
28	21	Hamiota	A2
32	5	Dauphin	A1
36	10	Swan River	A1
39	3	Morden	A2
41	83	Roblin	A1
56	3	Melita	A2
58	34	Holland	A2
59	325	Ashern	A2

Rural Commuter sites are directly connected to a population centre. Their hourly patterns show clear morning and afternoon peaks, with the afternoon peak being higher than the morning one. Weekends show steady flow all day long. The seasonal pattern is very flat, identical to the Urban Commuter group.

Rural Commuter-Seasonal

Site	Highway	Location	Functional Class
12	44	Beausejour	E
78	59	South of Birds Hill Park	E
93	313	Pointe du Bois	CB

Rural Commuter Seasonal roads carry both commuter traffic to adjacent towns and serve a major recreational component in the summer. The hourly pattern is the same as the Rural Commuter group, with a higher summer rise.

Resort

Site	Highway	Location	Functional Class
76	59	Lake Winnipeg beaches	E
94	315	Nopiming Provincial Park	CB

Resort routes serve areas where the traffic is almost exclusively seasonal recreational. The hourly pattern shows afternoon peaks during the week, a morning peak on Saturday, and steady traffic all day Sunday. The seasonal rise is very high; summer daily traffic is more than twice the annual average.

Ungrouped Sites: Seven sites remained ungrouped, because of a unique pattern or excessive variability. Two sites were on or adjacent to the newly-constructed Selkirk Bridge and show patterns similar to trunk routes but with a higher summer peak. Two sites were northern sites near The Pas, which are unique in showing an hourly pattern that is typical of urban commuter traffic with a high seasonality due to their far northern location. The remaining sites were three of the four lowest-volume permanent counters in the province; they were difficult to match with other groups because their low volume means high variability.

Once the TPGs were developed and it was clear what geographical characteristics they shared, it was possible to examine the characteristics of short-term counting stations and see which group they seemed to belong to. This process is highly manual and requires many judgements on the part of the people making the assignments.

Table 5: Traffic Pattern Groups

Traffic Pattern Group	***Geographic Characteristics***	***Hourly Pattern***	***Seasonal Pattern***
Urban Commuter	Roads in and around Winnipeg	Very distinct morning and afternoon peaks	Flat
Trunk	Major highways, not adjacent to towns	Traffic increases through the day, steady on weekends	Moderate summer peak
Trunk-Seasonal	Major highways carrying both through traffic and a significant recreational component.	Similar to Trunk routes	High summer peak
Rural Commuter	Roads adjacent to towns, carrying commuter traffic	Morning and afternoon peaks; afternoon peak significantly higher	Flat
Rural Commuter-Seasonal	Roads carrying both commuter traffic to towns and significant recreational traffic	Same as Rural Commuter	High summer peak
Resort	Roads serving almost exclusively summer recreational traffic (parks, beaches)	High afternoon peak during the week, especially Friday; high Saturday morning peak	Very high summer peak

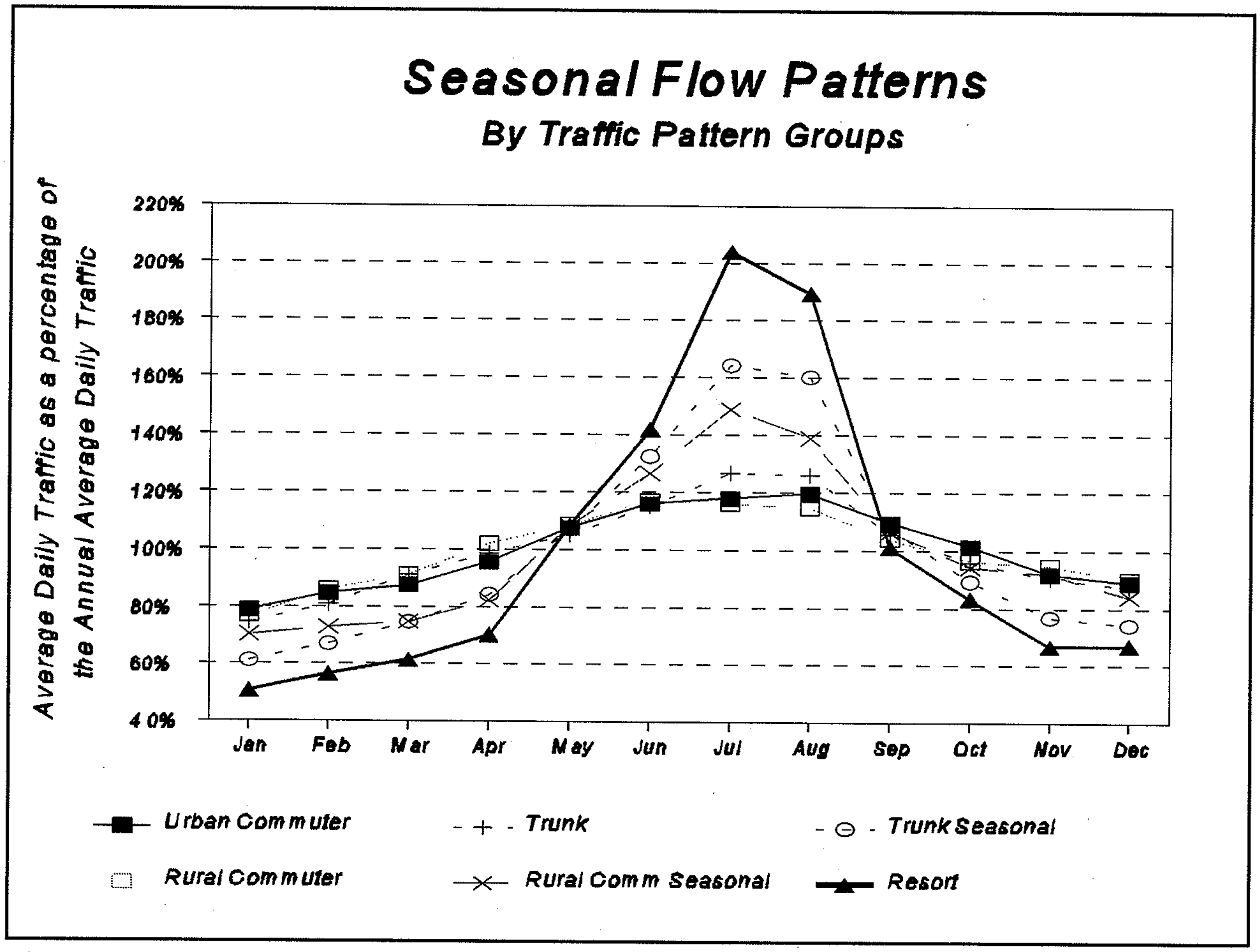

Figure 4: Seasonal patterns of traffic pattern groups

5.5 Expansion Factors: Common Practices

It has been common practice in most jurisdictions to expand short-term traffic counts by applying a series of *expansion factors*. Agencies use an axle conversion factor (required only if the counting equipment counts axles rather than vehicles) to obtain the number of vehicles observed, and then apply expansion factors based on the day of week, the season, and the geographic region[30]. The typical expansion formula to calculate the AADT from a short term count is:

$$AADT = V \times D \times S \times R$$

AADT = Annual Average Daily Traffic estimate at the short count site
V = Observed traffic volume for the short count, in vehicles
D = Day-of-week expansion factor
S = Seasonal expansion factor for the time of year
R = Regional expansion factor by geographical region or highway type

Each of these expansion factors is described in more detail below.

5.5.1 Axle Conversion Factor

An axle conversion factor is necessary if the counting equipment used counts axles rather than vehicles. The axle conversion factor takes into account the fact that such devices count two impulses for every car, but large trucks may trigger three, four, five, or more impulses each.

Axle conversion factors are based on vehicle classification studies conducted at or near the site in question. These studies record the number of vehicles of various types and the number of axles on each vehicle passing the survey location, and thereby permit the calculation of the average number of axles per vehicle. The total number of impulses recorded by an axle counter is then divided by the average number of axles per vehicle to estimate the number of vehicles.

5.5.2 Temporal Factors: Day of Week and Seasonal

Day-of-week factors account for the fact that on many roads, the traffic volume changes systematically from day to day. This effect is most pronounced when comparing weekday and weekend traffic volumes (Figures 5 and 6). Friday traffic patterns show characteristics which are between weekday and weekend patterns. If a highway serves a recreational area, a short-term traffic count which includes a weekend, or even Friday afternoon, will show a higher volume than a count taken at the same location on a Tuesday; conversely, surveys taken on a commuter road will show higher volumes during the week than on the weekend. Some agencies use only two day-of-week factors, for weekdays and weekends; others apply a factor for each day of the week individually.

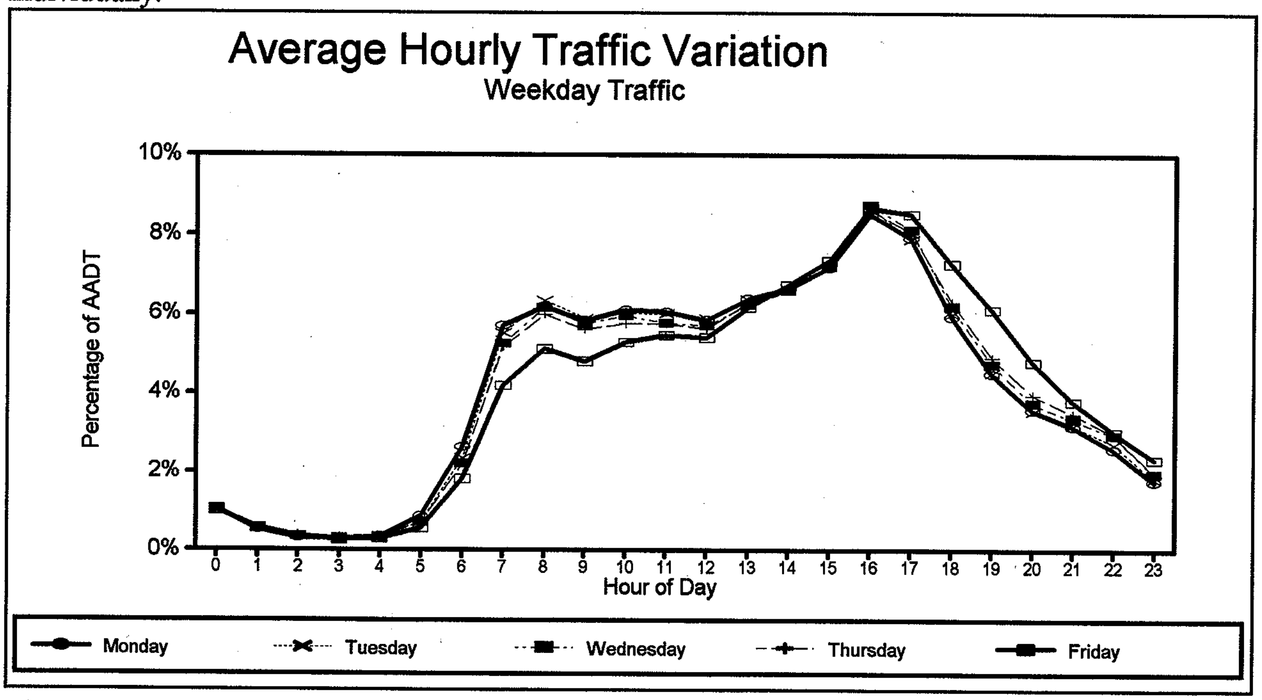

Figure 5

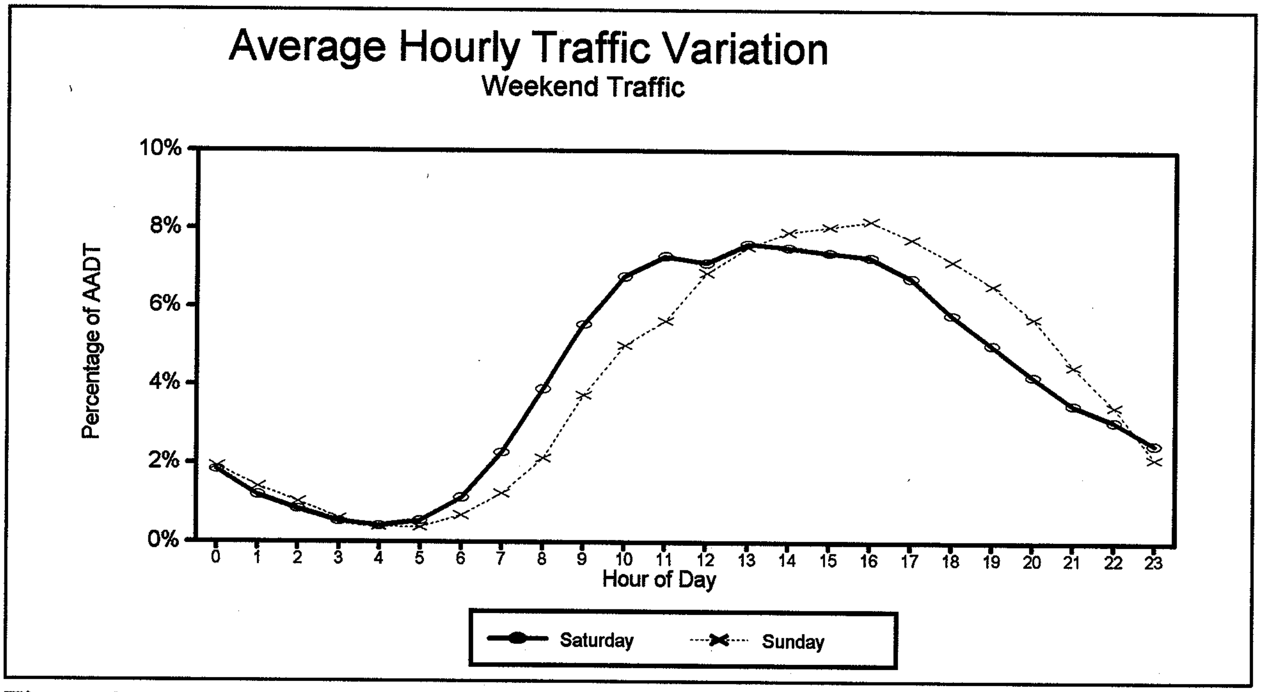

Figure 6

In order to be most accurate, day-of-week factors may also be tied to the seasons. For example, at a location which serves summer recreational activities, there may be a marked difference from day to day during the summer but there may be little or no difference from day to day during the winter; a winter ski resort area may show the reverse. Therefore, different day-of-week factors should apply during each season. Similarly, commuter traffic may show different day-to-day characteristics in the summer and the winter as well.

Day-of-week factors can be difficult to manage where short-term counts are conducted over several days, which is the norm. Most short-term counts start at some time in the middle of one day and carry on for 48 hours, leaving doubt as to which day-of-week factor or combination of factors should be applied. If a high degree of accuracy is desired, the large number of factors (individual day-by-day factors for each season) require a large amount of effort to establish.

Seasonal expansion factors are intended to take into account the systematic gradual changes in traffic volumes observed throughout the year. They can be developed for any time period desired: for each of the four seasons, for each month of the year, each week of the year, or even finer time scales. The finer the time scale (e.g. weekly, as opposed to monthly or seasonally), the more accurate they are likely to be. Figure 7 illustrates how some months have highly variable traffic volumes, while others are less variable; this inherent variability of traffic introduces potential errors into the expansion factor process. Seasonal factors developed on the basis of seasons or months are rather coarse and arbitrary; the finer the resolution, the better the analysis. A seasonal factor scheme which is tied to the calendar is insensitive to the possibility of well-defined traffic events which are seasonally-based (such as hauling certain agricultural products) but which are not tied to specific calendar months. For example, a four-week agricultural haul which spans two

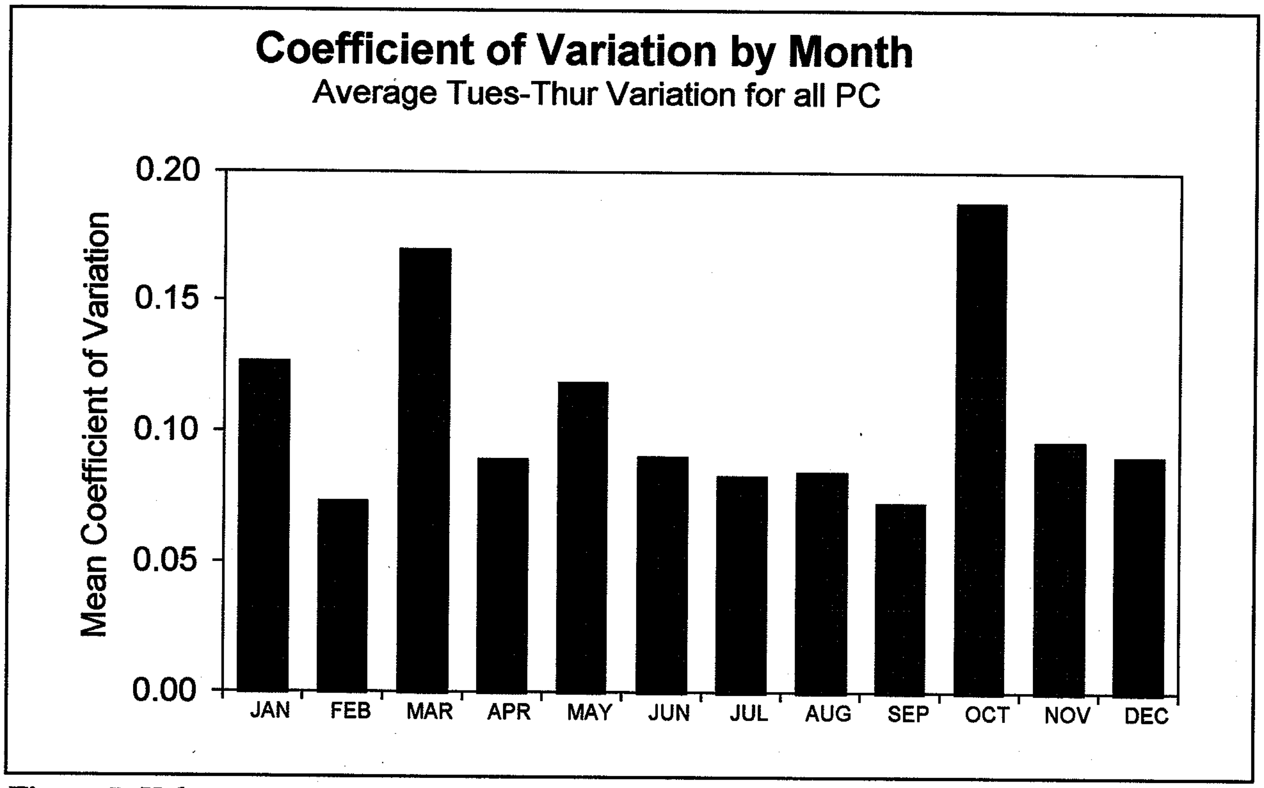

***Figure** 7: Volume variation at permanent counters.*
Source: Analysis by M. Alam of data for Tuesdays, Wednesdays, and Thursdays in 1991, examining variation of daily traffic from the monthly average.

months might result in the factors overcompensating in part of the period and undercompensating in the rest, while never really being appropriate in either of the two months. The finer the resolution (months instead of seasons, weeks instead of months), the less problematic this becomes.

Both daily and seasonal factors are developed in the same way. The process starts with a complete annual data set from a permanent counting station, from which the annual average daily traffic is determined. The data are then summarized to the time periods desired for the factors -- seasons, months, weeks, or other periods -- and the average daily traffic over each of these shorter time periods is determined. The ratio between the AADT and the average daily traffic over the shorter period is the factor for that period. For example, the seasonal factor for January is the average daily traffic in January divided by the AADT. Similarly, the day-of-week factor for Tuesday is the average daily traffic observed on all Tuesdays divided by the AADT. In the latter case, it would be possible to narrow the scope further, and perhaps identify a factor for Tuesdays in the summertime, or in Tuesdays in July, or any other combination.

Once the expansion factors are determined for each permanent station, they can be used to expand any short-term counts that are taken at locations which have similar traffic patterns. This is a central assumption of traffic data analysis: that traffic data and these factors are transferrable from one location to another.

5.5.3 Regional Factor

ASTM standard E-1442 suggests that agencies may wish to introduce additional factors to account for regional variations in traffic patterns which might not otherwise be considered. No suggested methods for determining these factors are given. Effectively, this means that agencies are free to develop additional factors as desired.

5.6 Factorless expansion

Although the expansion factor method described above is well-established, it has some drawbacks as discussed above. The most serious of all is the effort required to develop the set of expansion factors for each station for the year. In order to make the factors as accurate as possible, a very large number of factors is needed, such as seasonal factors developed on a week-by-week basis along with day-of-week factors which vary by month. Taking this to the extreme, the most accurate set of factors would use the finest time resolution possible, which is hourly data.

To simplify calculation, some agencies (New Mexico[31] and Alberta[32] are examples) use a form of analysis which might be called "factorless expansion." When a short-term count is taken, the start and end time of the count is recorded. The observed traffic volume at the short-term counter over this time period is related to the traffic observed during the same time period at a permanent station which is called the control station, using the following formula:

$$AADT_{site} = V_{site} \times \frac{AADT_{ctrl}}{V_{ctrl}}$$

$AADT_{site}$	=	Average Annual Daily Traffic estimate at the short-term counting site
V_{site}	=	Observed traffic volume at the short-term counting site, in vehicles
$AADT_{ctrl}$	=	Average Annual Daily Traffic at the control station
V_{ctrl}	=	Observed traffic volume at the control station

As with the traditional expansion factor procedure, if the traffic volume is measured by equipment which records the number of axles rather than the number of vehicles, it may be necessary to use an axle conversion factor to convert the observation from axle impulses to number of vehicles, in order to find V_{site}.

This method makes the basic assumption that hour-by-hour traffic patterns at one location are related to those at another location and that data collected at one site is transferrable to another. That is, it assumes that as traffic volumes change at one location, traffic volumes also change in similar ways at locations which are related to it, and that they change proportionally to their AADTs. It also assumes that we can readily identify these related sites. Under the method adopted in Manitoba, if a single permanent counter is identified as the control station for a coverage counter, then the coverage count is expanded against that station. If no control station has been identified, or if data for the required time period is missing at the control station, then the coverage counter is expanded against each of the permanent counters in its traffic pattern group, and the average of these trial expansions is taken as the AADT estimate for the counter.

This method has the advantage of not requiring calculation of a set of fixed expansion factors in advance, so it permits expansion of short-term counts using interim data from the current year rather than having to wait until the expansion factors are calculated at year-end. It also eliminates confusion about which day-of-week factor to use when a short-term count spans more than one day, and any confusion about non-smooth seasonal variations. In addition, phenomena such as unusual weather do not have to be treated as anomalies under this method, if it can be assumed that a weather phenomenon affected both the short-term count location and its control station in similar ways. Only very localized events would still require special treatment.

Examination of AADT estimates has shown that factorless expansion produces consistent and realistic results based on the available data. AADT values estimated using the former expansion factor method, on the other hand, have been shown in some cases to be unrealistic. For example, AADT estimates have been produced in past years which are higher than observed summer counts, despite the fact that the average summer daily traffic at the site is believed to be higher than the annual average daily traffic. Such incongruities may arise due to problems with the expansion factor or control station assignment process. However, factorless expansions have been observed to always produce estimates which are in accordance with this basic rule of thumb. Finally, tests involving expanding subsets of data against known AADT values show very close agreement between estimates and known values.

Chapter 6 Current Status of the Traffic Information System

This chapter is a brief outline of the status of the new Traffic Information System (TIS), with suggestions for future improvements and new directions for investigation. Many of the recommendations of 1993 design report have been implemented, and the system is now operated jointly by Manitoba Highways and Transportation and the University of Manitoba.

6.1 Overview

Under the TIS partnership, Manitoba Highways and Transportation (MHT) and the University of Manitoba Transportation Information Group (UMTIG) share responsibilities for operating the system. MHT is responsible for data collection, including placing, calibrating, and servicing counters and AVC/WIM equipment, and carrying out manual traffic counts. UMTIG is responsible for data storage, analysis, and reporting, assisted by Manitoba-based professional consultants to ensure high technical standards and continuity.

As a result, Manitoba Highways and Transportation enjoys an improved state-of-the-art traffic information system with greater depth and detail of analysis than was previously possible, at a cost comparable to the former system. The University of Manitoba makes use of the collected data in research projects, and uses the program as an excellent training ground and source of jobs for undergraduate and graduate students.

6.2 Management Structure

The TIS is a partnership between MHT and UMTIG, under MHT's Traffic Engineering Branch. Figure 8 shows the management structure of the TIS as defined in the system specifications. The key people and groups involved are:

- **Director of Traffic Engineering, Manitoba Highways and Transportation:** Oversees the traffic information system and provides ultimate direction to MHTIS activities. A staff member within the Traffic Engineering branch has been designated as MHT's supervisor for the system on a day-to-day basis.
- **Needs Advisory Committee:** This committee is described in the System Specifications but has not been formally constituted. It was to be composed of the Directors of all of the Branches of Manitoba Highways and Transportation which use traffic data, chaired by the Director of Traffic Engineering.
- **Manager of UMTIG:** This manager is responsible for planning, managing, and supervising the operation of UMTIG and liaises with the Director of Traffic Engineering.

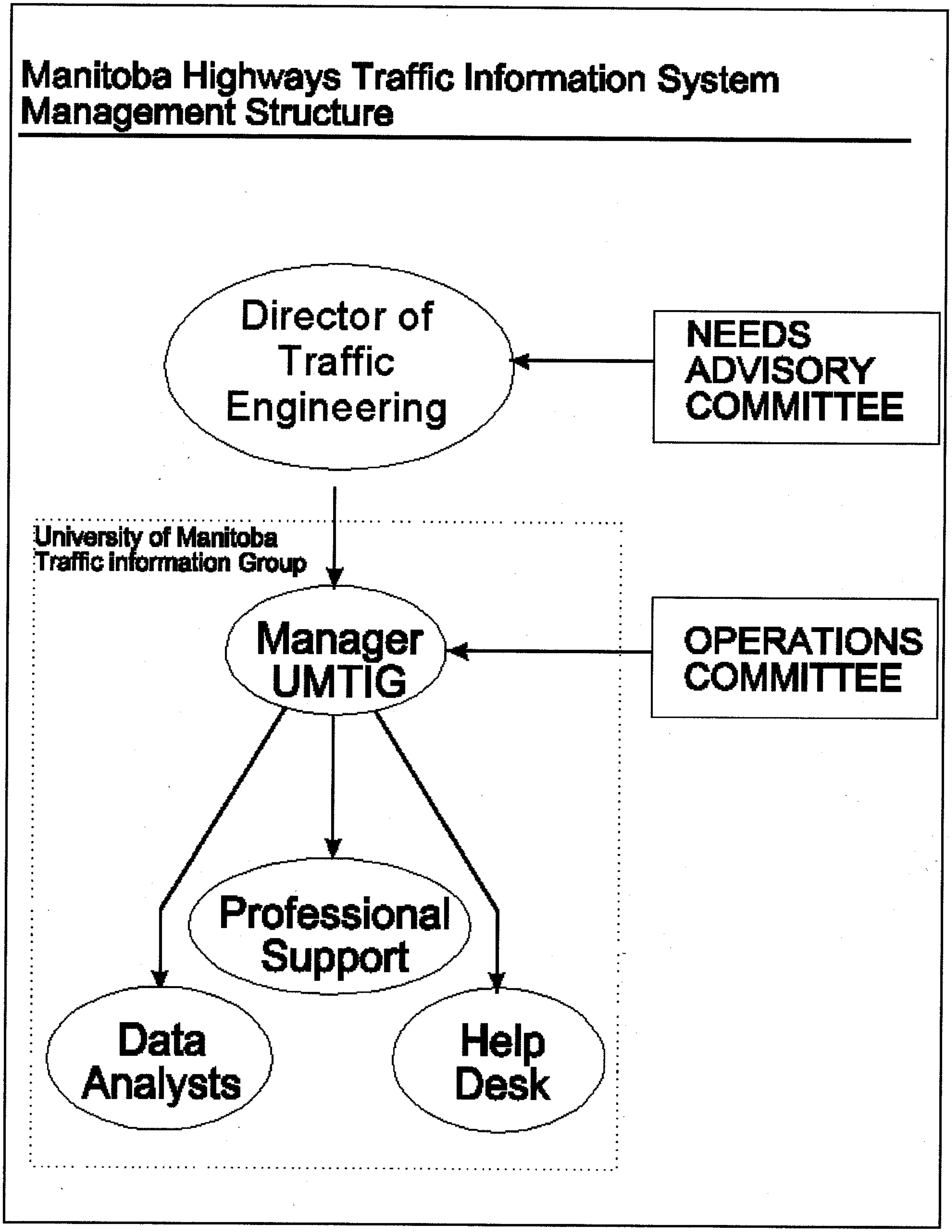

***Figure 8**: Management structure of the MHTIS*

- **Operations Committee:** The System Specifications calls for a committee composed of two representatives of the Traffic Engineering Branch, the MHT staff member responsible for directly supervising MHT field staff involved in data collection, and the Manager of UMTIG to meet monthly to co-ordinate activities and ensure the smooth operation of the system. This committee has not been formally constituted, although MHT's field staff supervisor, the MHT Traffic Engineering Director's designate, the Manager of UMTIG, and the TIS staff communicate regularly and meet from time to time to discuss the operation of the system.
- **Professional Support:** UMTIG retains professional services to plan and analyze certain non-routine traffic information requests, head the production of the annual report, and to undertake special projects as required.
- **Help Desk:** UMTIG operates a "help desk" service which handles day-to-day operations, including interacting with MHT staff, providing MHT and other data users with the required reports for routine data requests, retrieving and screening permanent counter data, analyzing and reporting on turning movement counts, and keypunching coverage count data sheets. This position is held by a full-time staff person.
- **Data Analysts:** UMTIG employs graduate and undergraduate students, working under the direct supervision of the Manager of UMTIG, on a part-time basis to do the majority of the work required in compiling and analyzing traffic data.

6.3 Physical Facilities for the MHTIS

UMTIG's data analysis centre is located in the Drake Building on the Fort Garry Campus of the University of Manitoba. Facilities include two computers with a wide assortment of software, an optical disk drive and tape backup unit, a laser printer and a color inkjet printer (for production of small maps), telephone and fax lines, and local area network service linked to the Internet.

For data storage and analysis, and production of tabular reports, UMTIG uses the Paradox database system. Maps are produced by the Maptitude and TransCAD geographical information systems (GIS), allowing quick visual reporting of information at any scale (Provincial, regional or sub-regional), illustrating traffic statistics, trip information, and infrastructure characteristics. Data are readily interchanged between the two systems.

6.4 Data Collection

MHT's data collection program is currently made up of four main components:

- ***Permanent Counter Program***, which monitors traffic continuously at locations around the province and is the foundation of the traffic information system.
- ***Coverage Count Program***, the main function of which is to provide AADT estimates on all roads in the province.
- ***WIM/AVC*** continuous monitoring at SHRP/C-SHRP LTPP sites in the province
- ***Special counts*** of which the most frequent are Titan turning movement counts.

The former town counts program has been eliminated as a separate program, although some locations within towns are still monitored through the coverage count program. Turning movement counts are now done only on special request, whereas in previous years additional surveys were carried out to maintain a historical profile of certain intersections.

MHT carries out all data collection activities in the field, including scheduling and supervising staff activities, and calibrating and maintaining data collection equipment. Data are delivered to UMTIG for analysis in the form of count sheets, disks, or files transmitted via modem.

Permanent counter stations are polled each weekend by telephone and modem from MHT's Headingley field office. Every Monday, the data are transferred via modem to UMTIG's computer at the University of Manitoba, where they are screened for anomalies. The data screening process, carried out semi-automatically by the Paradox database import routine, includes checks for repeated zeroes and sudden increases or decreases in hour-to-hour volume.

When anomalies are detected, the operator is alerted and asked to accept or reject the data. After screening, all data are incorporated into the master count database. As of June 1996, fifty-five locations in Manitoba are monitored by permanent counters.

Coverage Counts: Coverage count record sheets are delivered to UMTIG periodically throughout the counting season, and the data are keypunched by UMTIG staff into the Paradox master count database by UMTIG staff. The data are stored for analysis which takes place at the end of the year. No data screening takes place other than simple arithmetic checking. The short-term counts are expanded at year end to produce AADT estimates following the method described in Chapter 8 of this report. As of 1995, there are 1,991 sites in Manitoba which are monitored on a regular basis. On roads where the AADT is less than 175, counts are taken on a four-year cycle. On higher volume roads, counts are taken on a two-year cycle. The standard count duration is 48 hours, and sites are normally sampled twice in the year in which they are counted. Most sites are counted with pneumatic tubes; 8% use induction loops.

WIM/AVC stations at the LTPP sites are polled each weekend by telephone from MHT's Headingley field office, and transmitted each Monday to UMTIG along with the permanent volume counter data. The data are checked as they arrive but no analysis is done until year-end. Some steps toward automation have been taken but the analysis procedure remains labour-intensive.

Turning movement count data taken on the Titan counting boards are transferred by MHT staff into a laptop computer, and sent to UMTIG via modem. The data are analyzed using the Ideas program provided by the manufacturer of the Titan boards, and with a Lotus 1-2-3 spreadsheet originally developed by MHT staff and slightly modified by UMTIG. The process requires extensive manipulation by the operator. Turning movement reports are printed out and returned to MHT.

6.5 Data Analysis

6.5.1 Permanent Counters

Annual Average Daily Traffic: AADT estimates at permanent counters are produced using a Paradox database application following the method specified by ASTM Standard Practice E-1442-94, *Standard Practice for Highway-Traffic Monitoring*. Briefly, the procedure is as follows:

- Calculate the seven monthly average days of the week (MADW), Monday through Sunday, for each month.
- Each month's average daily traffic (MADT) is the sum of the month's MADWs divided by the number of MADWs (normally seven, except in cases of severe data loss)
- The annual average daily traffic (AADT) is the sum of the MADTs divided by the number of MADTs.

Average Summer Daily Traffic: ASDT is expressed as a percentage of AADT. It is calculated by simply adding up all the traffic observed during the period May 1 through September 30, and dividing by the total traffic observed during the year. This is easily done by the Paradox database, which simply sorts all observations by date and then totals observations within the given date ranges.

30th Highest Hour: The 30th highest hour is obtained by ranking all observed hours of the year by their traffic volume, and selecting the 30th highest. This is easily done by the Paradox database, which simply sorts all observations by observed traffic volume and counts down to the 30th in rank.

6.5.2 Coverage Counters

Average Annual Daily Traffic: AADT estimates at coverage count stations are arrived at using the factorless expansion method described in Chapter 5.

Average Summer Daily Traffic Percentage: Coverage count ASDT estimates are expressed as a percentage of the site's AADT. The ASDT percentage at any coverage count site is assumed to be the same as the ASDT percentage at its control station if one is designated, or as the average of the ASDT percentage for all permanent counters in the site's traffic pattern group.

30th Highest Hour Percentage: Coverage count 30th Highest Hour estimates are expressed as a percentage of the site's AADT. The 30HH% for a coverage count site is assumed to be equal to the 30HH% at the site's control station if one is designated, or equal to the average of the 30HH% for all permanent counters in the site's traffic pattern group.

Data from permanent counters and coverage counters are stored in the Paradox database and most analysis is done by programs written in the Paradox Application Language. Data and summaries are transferred to other packages for plotting or for further analysis.

6.6 Reporting

The MHTIS produces three standard types of traffic reports:

- *Traffic on Manitoba Highways*, the annual report including statistics and analysis for the entire province.
- Station reports, providing detailed information about individual count stations.
- Turning movement count reports, analyzing any turning movement counts performed.

In addition to these, UMTIG produces special reports on request to meet special needs that arise.

6.6.1 Traffic on Manitoba Highways

The report *Traffic on Manitoba Highways* is an annual report covering the calendar year. It is delivered to MHT approximately six months after the end of the data year. It includes the following components:

Permanent Station reports: Detailed information about all permanent traffic counters (PCS), including AADT, a graph of the top 100 hours of the year, a graph showing monthly average daily traffic throughout the year, a graph of average hourly traffic variation, and a graph of year-to-year changes in AADT over recent years. All of this information, plus a historical record of year-to-year AADTs, is included in the Internet station detail reports.

Coverage Count summary: A site-by-site report of traffic statistics for each count station, including AADT, ASDT, 30th highest hour, and percent trucks estimates at each location for the past two or more years.

Coverage Count Raw Data: The raw data for all coverage counts is included as an appendix, to permit users to check the estimates against the actual observed counts and to draw their own conclusions from the raw data if desired.

Methodologies: Brief descriptions of all procedures used to collect and process the information in the report are included.

System-level AADT Flow Map: Maps showing AADT estimates on all highways are included. They are produced by the TIS' geographic information systems.

Counter Location Maps: Showing the locations of all permanent counters in the province using a series of maps at regional and subregional scales.

Internet Access Instructions: Beginning with the 1995 report, instructions for accessing UMTIG's Internet site have been included.

Although the System Specifications describes a variety of regional summaries and reports to be included, facilities to produce them have not yet been implemented.

6.6.2 Station Detail Reports

These reports give detailed information about specific traffic monitoring stations. A sample report is included on the following pages. The reports are automatically-generated, provide all readily-available information on each count station, and answer most site-specific information requests. Although it is possible to update Station Detail reports continuously as new data about the station or its controls become available, they are generally only updated annually as part of the process of producing the annual report.

Station detail reports include the following components:

Station identification: A description of the station, including an orientation map, the highway number, control section number and location within the control section, type of device deployed, traffic pattern group, functional class, and load class.

Estimates of basic statistics for the current year: Average Annual Daily Traffic, Average Summer Daily Traffic, 30th Highest Hour, and Percent Trucks are estimated for each counter.

Graphs: For permanent counting stations, graphs illustrate daily traffic flow throughout the year. These graphs are also available on the World Wide Web version of the station reports, along with all of the information available in the annual report as listed in section 6.6.1.

Station Detail reports are available 24 hours a day through the Internet World Wide Web at http://umtig.mgmt.umanitoba.ca, or on request from the Help Desk by telephone, fax, or memo.

6.6.3 Turning Movement Count Reports

Turning movement count data are collected by MHT and forwarded to UMTIG for processing. UMTIG analyzes the data using the Ideas software program supplied by the manufacturer of the Titan boards along with a Lotus 1-2-3 spreadsheet originally written by MHT staff and slightly modified by UMTIG.

6.6.4 Special Reports

UMTIG staff prepare special reports of all kinds on request. Most commonly requested are tables or maps showing statistics for certain highways, regions, or province-wide. These requests are handled either from the Paradox database for tabular reports, or by the Maptitude or TransCAD GIS's which quickly plot maps of all kinds.

6.6.5 LTPP (SHRP) and C-SHRP Reports

UMTIG prepares and transmits all reports required by MHT's existing commitments to the Long Term Pavement Performance research project (LTPP), formerly known as SHRP/C-SHRP. This process is highly labour-intensive, although efforts are underway to automate it to a greater degree.

6.7 Other UMTIG Functions

6.7.1 Involvement in Data Committees and Interagency Co-operation

It is important for the continuing improvement of the MHTIS that personnel be involved with national and international committees of agencies such as TAC, SHRP, AASHTO, ASTM, and FHWA which have developed or are developing standards for data collection. MHT and UMTIG staff maintain active participation in committees and at conferences, and maintain ties with staff in neighboring jurisdictions to share traffic information.

Work is proceeding on sharing data across jurisdictional boundaries. This is expected to save resources and increase the accuracy of system-wide statistics by allowing larger samples, because most traffic flow characteristics are a function of the road network and land-use patterns, not political boundaries. Pooling traffic data from adjacent jurisdictions, such as Manitoba, Saskatchewan, and northwestern Ontario, may allow all jurisdictions to reduce the number of sites while maintaining or increasing the precision of traffic reports. In order to efficiently share data, however, agencies must first follow the principles of Truth-in-Data and Consistent Practice to ensure that they information they share is equivalent. If different means are used to collect and process the data, then the information stored at each agency might be difficult or impossible to correlate. J. Yeow of the University of Manitoba is currently working on integrating Saskatchewan and Manitoba permanent counter data.

6.8 Status of Implementation of the Recommendations

Table 6 describes the progress of the Traffic Information System in implementing the recommendations of the 1993 design study. The information in this table is based on discussions with staff members at Manitoba Highways and Transportation and the University of Manitoba. Numbers in square brackets [ ] refer to recommendations made in the original *Design* report. The first three columns of this table (1994 and earlier) have previously been published as part of the paper *Design, Development, and Implementation of a Traffic Monitoring System for Manitoba Highways and Transportation: A Case Study* presented at the 1994 conference of the Canadian Society of Civil Engineers.

Table 7: *Status of Implementation of the Recommendations of the 1993 Design report*

Annual Average Daily Traffic

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
The most frequently requested traffic statistic is AADT. The program surveyed 1692 locations on a two-year cycle, using 24-hour and 48-hour counts with automatic pneumatic tube and induction loop counters.	AADT estimates should be made on all roads with AADT>=200 [2] based on counts taken every two years [22]. Counting should be reduced to a five-year cycle on low-volume roads (AADT<200) [3]. Count durations should be not less than 48 hours [21].	Counts reduced to a four-year cycle on roads with AADT<175. Count durations standardized at 48 hours. Stations being converted to induction loops as resources permit.	Count cycle and durations as 1994; induction loop conversion continues.

Seasonal Variation of Average Daily Traffic

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Seasonal variation (e.g. ASDT) can be estimated from permanent counters and some manual turning movement / classification surveys. 72% of rural count stations had no volume expansion control stations, and 40% of those that did were likely to be incorrectly assigned.	Additional permanent counters should be installed and valid expansion factors developed for all count stations [4].	Additional permanent counters have been installed and more are on order. Traffic pattern groups and expansion factors have not been revised.	Traffic pattern groups and expansion factors revised 1994-95.

Day-of-Week Variation of Average Daily Traffic

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Estimates could be made using permanent counter data, but this was only done on special request.	Continue to provide this service on request only [5].	No change as per recommendation.	No change as per recommendation.

Hourly Variation of Traffic

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Estimates can be made when necessary using permanent counter data, manual count data, or one of five portable counters able to record hourly volumes.	Hourly volumes should be monitored on high-volume (AADT>3000, ASDT>5000) roads using portable induction loop counters [6,7].	No change from 1992-93.	No change from 1992-93.

Directional and Lane Distribution of Traffic

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Using portable counters, it was possible to determine directional and lane distributions of traffic on special request.	Maintain the ability to collect this information but do so only on special request [8,9,43].	No change as per recommendation.	No change as per recommendation.

Vehicle-Kilometres of Travel

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
VKT information was calculated easily and published with other control section data.	VKT estimates should be made where AADT information is available [10].	No change.	Special comprehensive report on VKT published in 1995. VKT by control section is available at all count locations.

Turning Movements

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Manual one-day or four-week surveys were done on request, and regular four-week surveys were done at 20 or more sites per year, rotating among major intersections on a five-year cycle and other intersections on a five to twenty year cycle.	Turning movement data should be collected only where specifically required. Use alternative methods (e.g. portable AVC) for collecting vehicle classification information [11].	Turning movement surveys now done on request only. Portable classifiers not used.	No change from 1994 status.

Vehicle Classification

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Collected through manual turning movement counts or at SHRP/C-SHRP AVC sites. No expansion to annual averages. Uses FHWA Scheme F.	Install additional AVC equipment on major routes to allow expansion of short counts [12,47]. Vehicle classification scheme should be changed to proposed	Two additional AVC stations installed, with two more to be installed this summer. No development of expansion factors. All equipment uses FHWA Scheme F.	Additional AVC stations installed, operating well. No expansion factors. No change in classification scheme but adoption of 22-class scheme is planned.

Vehicle Weights

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
No vehicle weight surveys were done away from permanent scales, which were used for enforcement but data was not recorded. WIM sites not reliable enough.	Develop ability to do special-needs weight surveys with portable equipment [14]. Continue to develop WIM technology but do not undertake a major data collection effort until the technology has matured substantially [49].	Two WIM sites operating but not continuously reliable; there are many gaps in the data.	WIM sites more reliable but calibration problems continue. Work is proceeding on analysis techniques which may be able to compensate for calibration slippage and convert WIM to static weight data using a probability framework.

Speeds

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Speed data is collected by those branches which require it themselves. Data is strongly condition-dependent and non-transferable.	The ability to conduct a speed survey at any location in the province should be maintained [15].	No change as per recommendation.	No change as per recommendation.

Other Vehicle Characteristics

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
No vehicle performance or other characteristics were collected.	Do not collect vehicle performance or other characteristics [16].	No change as per recommendation.	No change as per recommendation.

People and Goods Movement

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
No province-wide origin-destination study has ever been carried out, although small-scale studies are used at the project level.	Do not develop a large-scale O-D study at this time. A separate design and implementation study would be required if the need becomes a higher priority [17].	No change as per recommendation.	No change as per recommendation.

Data Retrieval

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Portable counter data was recorded on paper in the field and typed into a computer in head office. Permanent stations (PCS, AVC, WIM) and downloaded their data by telephone directly to the head office computer. Manual Titan counts were dumped directly from the recorder into the head office computer.	No change in data retrieval methods. In the future, purchase portable counters which can dump their data directly into a computer in order to eliminate writing the count on paper [44].	No change.	No change for most equipment. Some new electronic counters have been purchased.

Data Processing

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Raw data from permanent counters screened for errors/anomalies by Transpac software automatically. Apparent errors or anomalies are patched using a variety of methods. Raw data from other counts is checked manually and adjusted according to judgement.	An automated error-checking procedure compliant with ASTM E-1442 should be implemented [23]. Data should not be adjusted or patched in any way [24].	No change in data handling procedures. Data are still patched.	Permanent counter data are screened using some of the criteria from ASTM / AASHTO standards. No patching is performed at any stage of data analysis.

Data Analysis - Expansion Factors

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
The AADT and expansion factor algorithms did not conform to new standards. Traffic pattern groups were developed on the basis of average weekly traffic volumes. 72% of rural count stations had no volume expansion control stations, and 40% of those that did were likely to be incorrectly assigned. Axle conversion factors difficult to determine because they are based on limited vehicle classification data.	AADT [19] and expansion factors [20] should be calculated using current ASTM or AASHTO standard methods. Some permanent counters should be relocated and new counters installed to provide better expansion factors [25]. More consultation with district engineering staff [26,27]. Develop traffic pattern groups and assign count stations to TPGs using objective methods [37,38]. Develop expansion factors using hourly data instead of weekly data [39,42]. Convert tube count stations to loop counters to reduce the need for axle conversion factors [40].	No change in analysis procedures. One counter has been relocated, others are being installed.	New traffic pattern groups and expansion methodology have been adopted. Some additional counters installed, conversion of tubes to loops is proceeding.

Data Storage and Security

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Data was once stored on mainframe but is moving to PCs. Data is given out freely to all users.	All raw data must be stored permanently. Optical disks and good backup procedures are recommended [28,29].	All data has been migrated from the mainframe to PC. Backups are not completely secure.	Backup and data protection procedures are in place.

Reporting

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Reports produced include: Annual traffic statistics book, Flow map, turning movement / classification count index.	All traffic information should include a description of the information's source, the procedures used to process it, and an assessment of the accuracy of the information [18,34]. Traffic surveys for high-accuracy requests should be designed in consultation with the user [35]. Greater summarization and analysis of data [50]. Consider using a GIS to manage data [51].	Traffic reports now describe the device used to collect the information, but do not include the procedures or accuracy.	Traffic reports describe the devices used and the analysis procedures, but do not include a quantitative accuracy estimate. GIS forms integral part of the data reporting system.

Interagency Co-operation

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
The Department exchanged annual reports and flow maps with neighboring jurisdictions and used truck weight data from Alberta in pavement design.	Further sharing of data is encouraged [31].	No change.	No change.

In-house Database Integration

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Traffic information was not readily linked to other in-house databases. Two known database projects which could potentially link to the traffic database were a Pavement Management System and an accident database.	The traffic database should be integrated with other databases [32].	A province-wide Geographic Information System is being planned which may be able to link these databases.	No progress on linking departmental databases.

Future Development

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
The system made use of a set of independent analysis tools, mostly Lotus 1-2-3 spreadsheets, with little documentation.	The system should be designed as an integrated whole, allowing additional data sources and services to be added easily [33].	No change.	New Paradox-based database system is highly flexible and modular. Additional components are easy to add.

Town Counts

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Volume counts were taken in built-up areas on roads under provincial control. Sites were counted for 24 or 48 hours in June every three years, and the results used only in-house.	The town count program should be eliminated and requests for data within towns handled on a special-request basis [45]. If a need for more data develops, a within-towns permanent counter network is required to establish expansion factors [46].	The town counts program was greatly cut back, but some data users indicate they require more data than is now being provided. Discussions are underway to determine exactly how much coverage is required.	Town counts program integrated into coverage count program. Some coverage counts performed within towns.

Miscellaneous

1992-93 Status	*Recommendations*	*Summer 1994 status*	*Summer 1996 status*
Counters can mis-count traffic if they are placed too close to an intersection or in areas where lane discipline is poor.	A written policy on the placement of counters should be developed [36].	No policy written. Field staff show good understanding of counter placement issues.	No policy written.

6.9 Topics for Future Investigation

Many opportunities for further improvement of the Traffic Information System remain, in addition to new areas of investigation, some of which have been newly opened up by the new system which provides new data and the ability to conduct analyses which could not have been carried out previously. Some of these areas, described below, may yield improvements to the efficiency of the TIS, while others are research areas which may reveal new relationships and characteristics in traffic information.

Automate turning movement count data processing: Turning movement count reports are now prepared in a highly manual process which requires two or more separate computer programs depending on the type of count taken and the type of analysis required. The volume counts are not automatically integrated into the coverage count data set, nor are they expanded to provide AADT estimates or other estimates. The vehicle classification information that they provide is used to produce percent-trucks estimates but this process is labour-intensive. Better integration of this data stream into the TIS would provide additional volume data points and reduce the labour involved in producing turning movement and percent-trucks reports.

Automate WIM/AVC analysis: Although some steps have been taken towards automating WIM/AVC data analysis, the process is still fairly labour-intensive. The data are not smoothly integrated into the TIS and are not available for use as control stations when expanding short-term counts during the year. Significant work is currently underway to improve this analysis system.

Expansion of vehicle classification information: There is currently no information available on the variation of vehicle classification information over time. It is therefore impossible to expand a short-term vehicle classification study or identify patterns in the fleet mix. A detailed analysis of vehicle classification data from AVC sites and manual turning movement/classification surveys may yield information about the variation of the traffic mix through the year which will allow improved estimates of vehicle classification information. Truck traffic is increasingly seen by the Department to be of great importance.

Evaluate alternative technologies for vehicle classification: Manual vehicle classification studies are expensive; alternative technologies exist can be used to automatically classify vehicles more cheaply. Some examples include automatic photography which can be viewed and manually classified in a fraction of the time of a full manual survey, fully-automatic classification by means of axle impulse patterns, magnetic induction patterns, computer vision, or other sensors. In addition, existing weigh scales currently provide a location where trucks are observed but the information is not stored; the potential for capturing and analysing this data should be investigated.

Evaluate alternative technologies for other data collection: The traffic data collection and analysis staff should keep up to date on available technologies for traffic data collection, evaluate the performance of equipment currently used in the data collection program, and be prepared to take advantage of newly available equipment and systems when suitable options become available.

Improve percent-trucks procedures: Percent-trucks estimates are difficult to obtain and to apply to other stations. Additional research into truck traffic routing and behaviour may enable vehicle classification data to be better transferred, resulting in more accurate estimates at coverage count locations. As well, greater effort must be made to record and use all available vehicle classification information. Currently, it is difficult to integrate vehicle classification information from the variety of sources that produce it.

Improve screening of incoming data: Current screening procedures for permanent counters are very basic, checking only for gross errors and large gaps in incoming data. More sophisticated screening methods which check new data against historical data and trends would make it possible to identify errors and anomalies more readily and might result in a cleaner data set. Screening procedures for other data sources should also be implemented.

Investigate inherent variation of traffic and confidence intervals: It is known that highway traffic volumes vary randomly from day to day. Some work has already been done to quantify this variation in Manitoba, but the question of confidence in AADT and other traffic statistic estimates should be more thoroughly investigated. M. Alam has already calculated confidence intervals for weekday traffic as part of the original *Design* report, and has presented a series of factors which may be used to estimate the inherent variation. This work should be confirmed, expanded upon, and incorporated into UMTIG's regular data analysis procedures in order to provide data users with more information about the reliability of the traffic statistic estimates.

Review town counts program: Although the former town counts program has been cancelled, coverage counts are still taken within towns. However, there are no permanent counters located within towns. This means that it is impossible to reliably expand the in-town coverage counts to produce annual average statistics. A review of data requirements for town counts should be conducted, and if warranted by this review, procedures should be developed for expanding coverage counts in towns. This will likely require additional long-term data collection efforts in towns and the development of new in-town traffic pattern groups.

Investigate hourly traffic patterns on all highways: In order to verify and further investigate traffic pattern groups, and provide additional data for analyzing temporal variations, hourly traffic flow samples should be collected at coverage count stations. The Department of Highways and Transportation has several portable counters which can collect hourly traffic flow measurements. Samples should be taken at coverage count locations and the results correlated with control stations and traffic pattern groups to characterize traffic flows in more detail.

Re-assess data needs within and outside the Department: The traffic data needs of the Department should be re-assessed periodically. This is especially important considering the significant reorganizations that have taken place within the Department recently. The review should also consider the uses to which data are put outside the Department, including consulting with users of the new Internet service. A review of data needs is currently being undertaken by UMTIG staff member J. Yeow.

Integrate data with other jurisdictions: More sharing of data and statistics with neighboring jurisdictions is likely to prove highly rewarding. This includes external jurisdictions such as neighboring provinces and states, external data collectors such as Canada Customs at border crossings, and internal jurisdictions like the City of Winnipeg, which operates its own traffic data collection system. Additional data from permanent counters will improve the traffic pattern grouping and expansion factor process, as has already been shown in research conducted at the University of Manitoba[33]. Discussions should be opened with highway authorities in neighboring jurisdictions to increase the exchange of traffic information. Currently, UMTIG staff member J. Yeow is investigating unification of Manitoba and Saskatchewan permanent counter data for the purpose of traffic pattern grouping. This might go so far as establishing a central highway traffic data centre, jointly funded by participating agencies but independent of them, to co-ordinate traffic data collection efforts, and to store, analyse, and transmit data. Such a data centre might build on and expand the capabilities established by UMTIG with the MHTIS. By using data from the entire prairie region, the centre would be in a position to conduct analyses impossible with the limited data available in each jurisdiction individually.

Investigate techniques for dealing with low-volume roads: Since so many roads in Manitoba carry very low volumes, additional investigation into methods of monitoring low volumes of traffic is needed. Although the percentage variation from day to day of traffic on low volume roads is often large, the quantity of vehicles is small, and for many applications an error of plus or minus one hundred or several hundred vehicles is not significant. It should also be noted that many techniques for traffic data analysis come to us from studies dealing with Interstate highways in the USA, which show volumes much higher than Manitoba highways. For example, the capacity of a two-lane roadway is usually taken as 2000 vehicles per hour, but on average, three-quarters of Manitoba's highways carry less than 2000 vehicles in an entire day. In this environment, it is important to determine exactly what Manitoba's data needs are and how they can be met, remembering that techniques appropriate to Interstate highways may not be applicable in Manitoba.

6.10 Conclusion

This paper has described the process followed in the design, development, and implementation of the new Traffic Information System for Manitoba Highways and Transportation. The project arose from some concerns originally put forward by MHT about their former traffic monitoring system. In order to carry out the project, four basic steps were followed. First, the former system was thoroughly investigated and defined. Second, criteria arising from basic principles of data collection, traffic data needs of the Department and other users, and technical criteria related to efficiency and accuracy were established. Third, the performance of the system was evaluated with respect to the criteria established. Finally, new methods intended to alleviate the identified shortcomings of the system were designed and implemented.

This research has resulted in the development of a much improved Traffic Information System through a creative partnership between MHT and the University of Manitoba, now in its third year. The TIS meets the needs of data users in an efficient and effective manner while continuing to be refined and improved and providing an excellent learning experience for graduate students at the University of Manitoba. Although the TIS is greatly improved over the former system, there are still many areas of further investigation and avenues for improvement in the years to come as development, re-assessment, and refinement continue.

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The author is indebted to the assistance offered by staff members of Manitoba Highways and Transportation in personal interviews and meetings throughout this project. The author would especially like to recognize Doug Hurl, Luc Fouillard, Harry Beamish, Glen Cuthbertson, and Ron Weatherburn for their extensive co-operation and assistance.

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