AUTOMATED VEHICLE MONITORING AND AUDIT SYSTEM
FOR ADMINISTERING PARTNERSHIP HAUL AGREEMENTS

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ABSTRACT

Saskatchewan Department of Highways and Transportation has been a leader in road and short-rail transportation initiatives that facilitate efficient commercial transportation to remote northern and rural areas. A recent initiative undertaken by Saskatchewan Department of Highways and Transportation is a public-private partnership with commercial carriers to allow larger truck configurations to haul primary weights on select secondary rural roads if the carrier deploys road friendly vehicle technologies, such as air-spring suspension and central tire inflation. The pilot partnership haul program has resulted in haul cost savings of between 20 and 50 percent, generating approximately four million dollars per year in total, which is subsequently shared between the carrier and Saskatchewan Department of Highways and Transportation.

At the present time, equitable distribution of partnership haul cost savings and compliance audits are determined manually based on submitted logbooks and waybills. Because this manual system is labor intensive and prone to accounting errors, the administration of the partnership haul program is only tenable for larger carriers with semi-automated administration systems. As a result, a system that automatically allocates partnership haul cost savings and performs compliance audits is the enabling technology to expand the partnership program to small and mid-sized carriers.

International Road Dynamics Inc. proposed and developed an automated vehicle monitoring and audit system that is designed to facilitate the Saskatchewan partnership program. This paper discusses the Saskatchewan partnership program and describes the technological features and advantages of the automated vehicle monitoring and audit system. This paper also discusses other potential applications of the automated vehicle monitoring and audit system.

Key words:
Commercial vehicle operations, automated vehicle monitoring system, central tire inflation, geographic information systems, global positioning systems, transportation sustainability, road preservation, intelligent transportation systems, rural road management.
Introduction

The Saskatchewan road network is comprised of approximately 202,000 kilometers\(^1\) of two lane equivalent roads, with an estimated value of seven billion dollars (SDHT, 1996). The export of bulk commodities such as grains, timber and mined ore generates approximately two thirds of Saskatchewan's annual gross domestic product ($20.6 billion (SDHT, 1997)). As a result, efficient road transportation has, and will continue to have, a profound influence on the Saskatchewan economy. Therefore, preservation of Saskatchewan’s capital investment in roads, while at the same time promoting improved transportation efficiency to facilitate provincial economic development is of paramount importance to Saskatchewan.

Currently Saskatchewan spends approximately $300 million per year maintaining and rehabilitating Saskatchewan roads. However, recent rationalization of the grain transportation system and replacement of thousands of local grain elevators with a handful of regional inland terminals has shifted the assembly of grain from rail branch lines to the rural road network. This shift in the assembly of grain from rail to road coupled with economic diversification and value added initiatives within the Saskatchewan economy, such as development of the mining and oil sectors, has and will continue to, increase truck traffic on Saskatchewan roads. As a result, future traffic related damage inflicted onto the Saskatchewan road system is expected to increase dramatically over coming years. Of particular concern in this regard is the approximate 8500 kilometers of thin paved roads that were not initially designed to carry significant numbers of commercial trucks.

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1. The Saskatchewan highway network consists of 11,578 km of structural pavements, 8,470 km of thin membrane surface (TMS) nonstructural dust free roads, and 5,640 km of gravel highways for a total of 25,688 km in the provincial highway network of which 14,110 km (8,470 km TMS and 5,640 km gravel) are nonstructural. The Saskatchewan municipal road network consists of 8,573 km of primary grid (3,040 km paved, 5,543 km gravel); 12,641 km of grid; 29,357 km of farm access; 2,654 km of special roads (435 km paved; 2,219 km gravel) and 63,388 km of local access roads for a total of 116,613 km. There are also 45,416 km of land access or bladed trails and 14,500 km of prairie trails.
Saskatchewan Partnership Haul Program

In efforts to promote efficiency in the Saskatchewan commercial carrier industry, while at the same time reduce road impacts, Saskatchewan Department of Highways and Transportation (SDHT) is currently piloting a public-private partnership with commercial carriers to allow larger more efficient truck configurations and to haul primary weights on select secondary rural roads if the carrier deploys air-spring suspension and central tire inflation road friendly vehicle technologies. Because the partnership haul program is still in the initial trial stage, the costs and benefits have not yet been fully quantified, however, the potential benefits of the partnership program are:

- support economic development through reducing truck haul costs;
- provide additional revenue for highway improvement projects;
- encourage the use of road friendly truck equipment;
- improve highway safety; and,
- provide a mechanism to manage truck traffic on the highway system (i.e. select optional route and/or times of the year for moving commodities).

Pending the success of the Saskatchewan pilot partnership program, the partnership program may be expanded to additional small and mid-sized carriers and public road authorities to cooperatively route commercial traffic off the thin pavement system onto roads with higher load carrying capacity such as full pavement systems and/or roads with lower maintenance costs such as gravel roads. This ability to better manage the tonnage hauled on the rural road system could potentially mitigate millions of dollars per year in traffic induced damage on thin paved roads while at the same time, continue to facilitate and encourage efficient commercial transportation. The resulting haul cost savings coupled with road infrastructure preservation savings generated from the partnership program could be significant for the province of Saskatchewan.

Under current partnership haul agreements, SDHT and the commercial carrier enter into a three-year agreement to share in the haul cost savings generated by more efficient truck configurations. SDHT’s portion of the haul cost savings are used for road improvements after covering the program’s administration costs. The carrier’s portion of the haul cost savings are used to recover capital investment in specialty equipment specifically designed for the partnership program and profit margin. SDHT is responsible for the overall management of the system.

Although vehicle weights and dimensions may change with specific client needs, most partnership vehicles fit within the regulations from a dimensions perspective and a primary focus of the partnership program is to allow primary weight limits on specified secondary roads. In some cases, heavier vehicle
configurations are permitted within the program under a trial basis such as nine-axle and twelve-axle B-Trains. Figures 1 through 5 show typical truck configurations that have been piloted in the Saskatchewan pilot partnership program.

As seen in Figure 1, partnership program configurations include a standard six-axle semi-trailer unit allowed to increase its gross vehicle weight from secondary load limits of 40,000 kg to primary load limits of 46,500 kg while operating on secondary roads, resulting in haul cost savings of up to 20 percent. The partnership haul program allows nine-axle B-trains to increase their allowable gross vehicle weight from secondary load limits of 54,500 kg to 70,500 kg, 77,500 kg, and 94,500 depending on the specific situation. These increases in allowable vehicle weights and dimensions using 9-axle b-trains may result in haul cost savings of up to 50 percent.

<table>
<thead>
<tr>
<th>Partnership Agreement Weights and Dimensions</th>
<th>Approximate Partnership Haul Cost Savings</th>
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<tbody>
<tr>
<td>46,500 kg</td>
<td>20%</td>
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<tr>
<td>5500kg 17000kg 24000kg</td>
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<tr>
<td>70,500 kg</td>
<td>30%</td>
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<tr>
<td>5500kg 17000kg 24000kg 24000kg</td>
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<tr>
<td>77,500 kg</td>
<td>40%</td>
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<tr>
<td>5500kg 20000kg 26000kg 26000kg</td>
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<tr>
<td>94,500 kg</td>
<td>50%</td>
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<td>5500kg 25000kg 32000kg 32000kg</td>
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</tbody>
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**FIGURE. 1.** Pilot Partnership Haul Cost Savings
FIGURE 2.  Grain Sector 9-Axle B-Train

FIGURE 3.  Mining Sector 9- Axle B-Train
FIGURE. 4. Rural Fuel Truck 9-Axle B-Train

FIGURE. 5. Forestry Sector 12-Axle B-Train (One Week Trial)
Need for an Automated Vehicle Monitoring System

To date, the pilot partnership program has operated under a voluntary basis and has generated approximately four million dollars per year in total haul cost savings. These haul cost savings are subsequently shared between the carrier and Saskatchewan Department of Highways and Transportation. If the partnership program were to be expanded to include small to midsize carriers, SDHT estimates annual generated haul cost savings could increase to 10 to 15 million dollars per year with expanded implementation. However, in order to maximize the benefits from the partnership haul program, there is a clear need to expand the partnership program to include the thousands of trucks registered in small to mid-size carriers, and to the over 600 Saskatchewan city and rural municipality public road authorities. In addition, there is the potential to include foreign carriers if the business case shows potential benefits for the agencies and carriers involved.

At the present time, equitable distribution of partnership haul cost savings and compliance audits are determined manually based on submitted logbooks, waybills and typical elements of truck operator costs (i.e. fuel, equipment costs, driver, repair and maintenance, license and insurance, overhead and administration). Because manual administration of the partnership haul program is labor intensive and prone to accounting errors, the partnership haul program is only tenable for large carriers with semi-automated administration systems. As a result, many small to mid-sized carriers and Saskatchewan public road authorities are not able to cost effectively participate in the partnership program. Given the inherent administrative barrier to entry into the partnership haul program, IRD and SDHT have proposed and developed an automated vehicle monitoring and tracking system specifically designed to be the enabling technology that will facilitate expansion of the partnership program.

Automated Vehicle Monitoring System

International Road Dynamics Inc. (IRD) proposed and developed an automated vehicle monitoring and audit system that is specifically designed to facilitate partnership haul programs. There are currently two general types of commercial vehicle monitoring systems. The first is an onboard monitoring system similar to an electronic log book. These systems monitor and record operator information, speed, departure, arrival, gear shifting patterns, engine functions, hours of service, etc. The second general type of truck monitoring systems are global positioning tracking systems that provide accurate tracking and real time two-way communication for dispatch administration and routing. Although these systems are readily available, they do not provide the administrative and enforcement capabilities required by the Saskatchewan partnership program.

The automated vehicle monitoring and audit system designed for the Saskatchewan partnership program, as illustrated in Figure 6 (Bergan, et al., 1998), employs four primary systems: onboard vehicle
data collection/storage system, communication network, central administration system, and remote user query systems. The automated vehicle monitoring system has the ability to continuously monitor and sample data from a wide variety of onboard vehicle sensors. All information is transferred to the central administration system and may be queried at any time by the public road authorities and commercial carriers involved in the partnership program. For confidentiality, commercial carriers are not able to access information on other carriers and public road authorities are not able to query data regarding other road authorities.

Queries may be in the form of billing invoices, logistics summary reports, audit reports, or user defined special reports. In addition, public road authorities can use the assembled data to perform commercial traffic studies, road use evaluation, regional economic activity studies, and road preservation planning based on truck traffic and/or economic activity.

The primary advantages of the partnership program automated vehicle monitoring and audit system over other systems is its reduced communication costs and the system’s inherent flexibility to be readily customized for small to mid-size fleets for diverse fleet management applications. These applications include: near real time vehicle tracking, dispatch and communication, traffic generation/destination studies, road preservation operations management, traffic data collection, onboard system monitoring, fleet logistics administration, and cargo tracking.

**Onboard Data Collection/Storage System**

The onboard data collection/storage system continuously monitors and samples data from onboard global positioning systems (GPS), central tire inflation (CTI), and air-spring suspension weight sensors. An onboard keypad and monitor screen is installed in the truck cab within easy reach of the driver. The keypad is shock mounted in a rugged, dust-proof housing and is used to enter driver and vehicle information. The onboard system can sample onboard sensors up to once per minute. Several standard user defined messages can also be pre-programmed into the keypad to help facilitate efficient communication and data storage. As well, the onboard keypad can be used to send messages to the central dispatch or to other vehicles within the fleet. For direct voice communications, cellular phones can also be integrated into the onboard system.

System power is drawn from the vehicle battery when the vehicle is in operation, however, a back up battery power system keeps the unit operational without drawing power from the vehicle battery when the vehicle ignition is off and is automatically recharged when the vehicle is operating.

The onboard system can determine the approximate weight (± five percent) of the vehicle according to the pressure in the air-spring suspension system. The onboard system can be programmed to
automatically monitor pressure readings whenever the vehicle stops for more than one minute. CTI sensors are used to monitor inflation pressures of all tires. All onboard sensor information is automatically stored and cross referenced with position by the onboard data storage unit to determine if tire pressures and/or weights are correctly set in relation to the allowable axle weights corresponding to the type of road on which the vehicle is operating (i.e. secondary or primary) and the seasonal environmental conditions.

Central Administration System

The primary function of the central administration system is to create and maintain a truck fleet database, perform compliance audits and billing, and to perform user defined queries. The central administration system employs an Oracle database and is operated and maintained by the system administrator.

Because many public road authorities employ a geographic information system (GIS), the central administration system is designed to interface with industry standard GIS systems to provide highway names and section locations referenced by GPS coordinates. Based on the highway identification and chainage, the central administration system can determine truck routing and the corresponding road usage and display this information graphically. When integrated with GIS, each vehicle trip can be traced to specific routes and automatically assign road usage and revenue generation allocation.
The central administration system maintains a comprehensive database with which public road authorities and carriers involved in the program can easily obtain historic information based on user-defined queries. For example, the database can be used to determine haul cost savings generated by each highway according to season, the comparison of highway usage according to jurisdiction, the frequency of road usage, and so forth. The central administration system employs simplified windows based screens, point and click commands, and drop down menus to help facilitate the following user specified queries:

- Reports: daily non-compliance, monthly routing for invoicing purposes;
- Audit: information checks on an as-needed basis;
- Configuration: permit rates according to season, company information, vehicle information;
- Editing: to enter missing data or to correct data; and
- Registration: to register new companies, trucks and other identifiers.

The central administration system also performs quality control and quality assurance checks on all data incoming from the onboard units. In case of any data inconsistencies, discrepancies or system failures, the central administration system produces a warning report and automatically identifies the specific problem.

**Communication Network**

The automated vehicle monitoring and audit system employs an innovative approach to a communication network as shown in Figure 6. The data stored by the onboard units can be programmed to download to the central administration system several times per day. Vehicle data transmission is over circuit switched cellular network and can be programmed to transfer data only during off peak hours to minimize transmission costs. The pilot partnership program has shown that during a normal day of operation, approximately 50 kilobytes of data is collected by each onboard unit which can be transmitted in less than ten minutes. In the case of congested data transmission from a fleet of onboard units, the units may be programmed to occur over a period of two or three hours. If transfer problems occur, the units automatically retry transmission up to four times per night.
The central administration system is connected to the cellular network via a high-speed internet data line. This internet line has a capacity of transferring 1.5 megabytes per second resulting in a download time from a fleet of 1,000 vehicles in less than 30 minutes. Remote terminals are connected to the central administration system for commercial carriers and public road authorities to extract data to perform audits, print reports, and perform other specialized functions specified by the partnership agreement. Communications to all public road authorities and commercial carriers are via a secured, restricted internet link.

Enhanced features of the communication system include real-time two-way messaging, real-time vehicle tracking, and other communication methods for remote region operations such as satellite modem, cellular data packet and trunk radio.

Remote Query Systems

Remote query systems provide the ability for commercial carriers and public road agencies to generate reports including vehicle routing, non-compliance, and audit reports. Routing reports are provided for billing and revenue allocation purposes and may include a summary of trips with a daily breakdown with respect to primary, secondary and municipal roads by route number, section number, and public road authority. Road usage reports can be provided across commercial carriers and road authorities by truck and/or road section.
Non-compliance reports may be viewed or printed from remote query systems. Trucks with non-compliance infractions are grouped according to carrier, with one report issued for each carrier with respect to the following categories:

- no driver identification/invalid driver identification;
- no configuration/invalid configuration;
- speeding;
- overweight;
- excessive tire pressure corresponding to the specified weight and road section;
- no data received (unable to communicate with communications network);
- malfunction of onboard units (sensors not working properly);
- non-highway location (truck location is not on a highway); and
- permit violation (such as period of travel limitations).

**Other Applications of the Automated Vehicle Monitoring System**

The automated truck monitoring system employs the internet for a significant portion of its communication activities. As a result, communications costs are significantly reduced when compared to the costs associated with cellular and satellite based systems. This cost effectiveness and flexibility renders the automated truck monitoring system uniquely suitable for diverse fleet management applications and can be customized for small to mid-size fleets in both public and private sector applications. These applications include: near real time vehicle tracking, dispatch and communication, traffic generation/destination studies, road preservation operations management, traffic data collection, routine maintenance equipment monitoring, onboard system monitoring, fleet logistics administration, and cargo tracking.

The private sector has expressed interest in enhancing fleet management and operations. The automated vehicle monitoring system can be customized to suit the carriers needs to include such features as near real-time truck tracking using GPS. A specific application in this regard is the monitoring of high risk and high value cargo. The transport of high risk goods, including wastes and hydrochloric acid for example, is quite regulated, however compliance is sometimes a problem. In order to improve safety, the automated vehicle monitoring system will monitor the trucks’ speed, route, along with any other onboard systems necessary in the regulations. Monitoring the transport of high value cargo, including mail, tobacco and alcohol, is also of great importance to those involved.
Another potential application is deployment of road authority maintenance equipment and crews. Presently, SDHT spends considerable resources recording and administering maintenance and preservation activities for their asset management system. Because road preservation activity information is critical to accurate cost accounting of preservation expenditures and for financial optimization and performance prediction models, automated recording and compiling of road preservation activities could not only generate direct savings in manpower, but also improve the quality and efficiency of road asset management database information which is used to optimize the allocation of hundreds of millions of dollars spent on road preservation.

Summary and Conclusions

Saskatchewan Department of Highways and Transportation (SDHT) has been a leader in innovative road and short-rail transportation initiatives that facilitate efficient commercial transportation to remote northern and rural areas. One of the more recent initiatives is a public-private partnership program with commercial carriers to allow larger, more efficient truck configurations to haul primary weights on select secondary rural roads if the carrier deploys road friendly vehicle technologies, such as air-spring suspension and central tire inflation. These pilot partnership haul agreements have resulted in haul cost savings of between 20 and 50 percent, generating approximately four million dollars per year in total, which is shared between the carrier and Saskatchewan Department of Highways and Transportation.

Under the pilot partnership haul agreements, SDHT and the commercial carrier agree to share in the haul cost savings generated by the increased haul efficiency. Pending the success of the pilot partnership program, the partnership program may be expanded to channel commercial traffic off the thin pavement system onto roads with higher load carrying capacity such as full pavement systems and/or roads with lower maintenance costs such as gravel roads. This ability to better manage the tonnage hauled across the rural road system could potentially mitigate millions of dollars per year in traffic induced damage on thin paved roads while at the same time, continue to facilitate and encourage efficient commercial transportation. The resulting haul cost savings and road infrastructure preservation savings generated from the partnership program could be significant for the province of Saskatchewan.

Although the partnership program shows the potential for significant benefits (up to 50 percent reduction in haul costs), current manual methods for determining haul cost savings and performing compliance audits are labor intensive and prone to accounting errors. Therefore, if the partnership program is to be expanded to small to mid-size carriers, and to the over 600 Saskatchewan city and rural municipality public road authorities, a system that automatically allocates partnership haul cost savings and performs compliance audits is needed.
International Road Dynamics proposed and developed an automated vehicle monitoring and tracking system specifically designed to provide the enabling technology that will facilitate the economic benefits to be gained by expanding the partnership program. The advantages of the automated vehicle monitoring and audit system over other commercial systems is its reduced communication costs and the system’s inherent flexibility to be readily customized for small to mid-size fleets for diverse fleet management applications. These applications include: near real time vehicle tracking, dispatch and communication, traffic generation/destination studies, road preservation operations management, traffic data collection, onboard system monitoring, fleet logistics administration, and cargo tracking.

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