EXPLORATORY EVALUATION OF COMMERCIAL VEHICLE INSPECTION TECHNOLOGIES IN BRITISH COLUMBIA

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ABSTRACT

All states and provinces carry out on-going inspection of commercial trucks: (1) to check for overweight vehicles; and (2) to conduct safety inspection of the vehicles. Inspections cause delays to vehicles which entail economic costs. There is a tradeoff between the number and thoroughness of inspections – with attendant delay costs to the driver and vehicles -- and the benefits of the resulting reductions in overweight damage and improved safety. This paper addresses a subsidiary issue: what technologies can be adopted to affect the choice of trucks to be brought in for inspection and those that can by-pass inspection thus saving time. If low risk vehicles could be identified and not delayed, this would save time for the vehicles and make inspection more effective by concentrating on higher risk trucks.

The two technologies are: (1) a combination of weigh-in-motion (WIM) technology and automatic vehicle identification (AVI) to pre screen vehicles with respect weight and to historical safety records including previous inspections from upstream weigh stations. This technology requires a transponder be installed in the vehicle, which at present is a voluntary decision by commercial vehicle owners.

Because it is not mandatory, the compliance rate is low. (2) The second technology replaces AVI with an automated license plate reader (ALPR) which does not require voluntary action by vehicle owners hence a much higher compliance is achieved. Using British Columbia practices and procedures, some preliminary benefit and cost calculations are carried out and a number of research questions are raised.

Introduction

All states and provinces carry out road side inspection of commercial trucks. This can occur at any location where it is safe to pull vehicles off the road and can occur when an enforcement official has reasonable cause to inspect the vehicle. This includes the observation of obvious vehicle defects, erratic driving and roadside "blitzes" where enforcement officials seek to identify all unsafe vehicles and drivers at selected locations for a sustained time period. On a regular basis, road side inspections are performed at static and portable weigh stations whose main purpose is to check for vehicle weight restrictions. It is also an opportunity to perform safety checks of vehicles. Traditionally this is done by an inspector "eyeballing" the vehicles as they pass through and/or randomly selecting vehicles for a physical inspection, which could be brief or thorough.

Weigh-in-motion (WIM) technology has been utilized in many jurisdictions to screen trucks at highway speeds to reduce the number of trucks pulled in unnecessarily. Until recently, and it is still mostly true in Canada, there has been little pre-screening of vehicles pulled off the highway for vehicle inspection. There was also no communication between inspection stations; hence trucks have to stop at every inspection station. But once a truck has been inspected, subsequent inspections probably are redundant unless the truck has been reloaded or traveled a considerable distance. Delays for inspection are costly and hence there is growing interest in speeding up the highway inspections and exempting trucks from subsequent inspections that day once they have been examined.

This paper reports on an evolving practice in British Columbia and does a preliminary evaluation of the costs and benefits of using two different technologies to automate and improve the commercial vehicle inspection process; Automated License Plate Readers (ALPR) and Automatic Vehicle Identification (AVI). Both are used in conjunction with WIM. This is a "preliminary" analysis because several research questions and data requirements arise in the course of the evaluation.

The Traditional Inspection Process in British Columbia

The typical inspection process starts from an overhead variable message sign (VMS) that warns all commercial motor vehicles (CMVs) to keep in the right lane and whether the scale station is open or not. If the inspection station is open, CMVs will drive through a static weigh scale at a low speed so that the inspectors can obtain an accurate measure of the vehicles' gross weight. During this time, inspectors will visually pre-screen passing CMVs and use their experience and intuition to choose some of them for further physical mechanical inspection. During this pre-screening process, the inspector may also check the CMVs credentials by manually entering their license plate (LP) number into their proprietary software which would query the vehicle against multiple databases, such as vehicle registration, driving records and insurance records. There is a high correlation between CMV having credential violations with equipment safety violations such as brake or tire defects. A VMS is used to inform truck drivers of the inspector's decision after they have been weighed and pre-screened. If a vehicle is chosen for further inspection, one of three CVSA levels of inspection is performed. The CVSA Level I inspection is the most detailed and time consuming physical inspection which could result in putting a CMV out-of-service (OOS) or the CMV removed from the road permanently. The time spent on going through the 37 steps of a Level I inspection takes about 40 minutes but can vary widely depending on the number of violations or defects that a truck actually has (Bridgestone, undated). After the inspection, the inspector will take corresponding actions based on the inspection results. Based on the number and types of

violations that a CMV might have, this vehicle may be placed OOS or just issued a ticket with the corrective action stated on it.

This traditional inspection process is labour-intensive and combined with the capacity limitations of the inspection station constrains the ability of the inspection station to function. It can even cause the station to close for a time. The station's entry and exit ramps limit the number of trucks that can enter the station. If the ramps are full, the inspector may suspend operations; this allows CMVs to bypass the scale until the queue is cleared. With the growth of traffic this will become an increasing problem.

The effectiveness of the pre-screen inspection of vehicles that have been pulled into the inspection station can also be questioned. A four hour travel time study at a station observed that the average visual inspection time per CMV was 3.63 seconds, with a 1 second standard deviation (Chow and Lee, 2008). Based solely on the inspector experience and intuition, this 4 second window for identification of high-risk CMVs does not yield a high OOS rate. This means the inspectors are spending much of their time on trucks that do not have problems instead of concentrating on the exceptions which would be high-risk CMVs.

Finally there is also an issue in that there is no communication between inspection stations. Therefore, it is possible that on the same day, non high-risk CMVs are pulled into all open inspection stations to be pre-screened and potentially physically inspected, wasting time for both inspectors and drivers. The information exchange is not only lacking between inspection stations within the Province but also between provinces and countries.

The British Columbia Weigh2GoBC System (formerly Green Light Transportation System GLTS)

In Spring 2009, the British Columbia Ministry of Transportation and Infrastructure launched the Green Light Transportation System (GLTS) program for commercial motor vehicles (CMVs), since renamed Weigh2GoBC (W2GO) (CVSE, 2010). This program is

intended to enable freer movement of CMVs by gathering specific data from them at highway speeds using weigh-in-motion (WIM) and Automatic Vehicle Identification (AVI) technologies. The W2GO is an electronic preclearance system, which uses sensors, transponders and WIM devices to reduce necessary stops by CMVs through pre screening of the vehicle and driver. (The WIM technologies are a separable issue in evaluating the merits of alternate communication technologies). The benefits of implementing the W2GO are highly dependent on the W2GO registration rate which is entirely voluntary and requires the participating vehicle to purchase and install a transponder for AVI.

The Ministry anticipated that the highest achievable W2GO registration rate is likely to be no more than 50% with that rate only being achieved over a number of years. In the initial years only a few percent of CMVs will have the transponder. This will gradually increase over time. An alternate solution would be to integrate an Automated License Plate Recognition system (ALPRS) and imaging technology that accurately identifies the CMV without the need for a transponder. ALPRS uses highly sensitive video cameras in secure castings to capture a vehicle's plate number, whether the vehicle is incoming or outgoing. The ALPRS is able to convert a digital image of a license plate to readable and editable license plate text. Both the AVI and ALPRS collect and transmit the key vehicle identification information that is used for background checks and database updates. The whole process is conducted in no more than 1 second. The license plate information is linked with Provincial and Federal safety and enforcement databases in real time. Instructions to the driver whether or not to pull into the inspection station must be communicated via the transponder for the AVI equipped vehicles and through an illuminated sign for the ALPR application.

The ALPRS is not 100 percent reliable but it is very high, industry reports up to 95 percent reliability. A four hour test at one of the B.C. weigh stations resulted in an accuracy of 88 percent. We adopt a more conservative figure in calculations below (the remaining trucks whose license plates could not be read would go through the traditional visual inspection). Similarly, even if widely adopted, the

AVI technology cannot have 100 percent coverage. Some fraction of vehicles will still have to go through the weigh station in a traditional manner.

Incremental Benefits and Costs of the ALPR System

Either of the vehicle identification technologies can work. And approximately the same investment is needed to support the data base development and ability to interrogate the safety and other records about the CMV approaching a weigh station. The up-front investment costs for the W2GO system have not been revealed by the Province but it has been estimated in other jurisdictions that the costs on the order of $500,000 per site including the WIM technology and all the hardware and software to communicate with vehicles and link with the data bases. These costs are sunk once the investment decision is made.

The AVI approach requires investments in transponders by truck owners but these are a trivial cost and the Province may make them free to initial users. The big difference between the two technologies is the high participation rate by CMVs via the ALPRS compared to expected relatively low compliance in the voluntary adoption of transponders with the AVI system.

Because the Ministry has committed to the AVI system, there is a case for the ALPRS system only if the benefits associated with screening a larger fraction of the CMV population would be greater than the costs of investing in the ALPRS as a supplementary system.

The W2GO system is to be installed at 8 weigh stations on major highways across B.C., with the prospect of further expansion in the future. Three stations are in operation and some detailed data were available to enable a provisional evaluation of these technologies.

Data Development and Data Assumptions

In order to conduct even a cursory economic evaluation of screening technologies, data are needed about the number of trucks traveling on

the highways over the years, the probabilities of trucks failing the safety inspection, how effective the data bases will be at identifying more risky trucks, the safety benefits realized by requiring unsafe trucks to be repaired, and the time and fuel savings for the safe-rated trucks who will often bypass the weigh stations. Some data do not exist and must be estimated, for example the total number of truck trips and distances traveled in B.C. are not compiled so we must work without these data. There are data records on the probability of trucks failing the safety inspection and receiving an out-of-service (OOS) order, and the relationship between past OOS events and the probability that it will fail again at a later time (thus a candidate to be reviewed in contrast to trucks with a good record). There are data records and estimates from other jurisdictions that can be used to estimate the reduction in crashes if there are fewer unsafe vehicles on the road. This section of the paper summarizes the data requirements and assumptions.

First, as noted above, the total expenditure for W2GO has not been released yet by the Province. This prevents an evaluation of W2GO itself, but we are still able to do an incremental analysis of adding the ALPRS. So we turn to the impacts of the new system on increasing the detection rate of unsafe CMVs and the benefits to trucks having been inspected.

Twenty-one and one half (21.5) percent of vehicles are put OOS by the annual 72-hour provincial Roadcheck program during the 2007/08 operating year (B.C. Ministry of Transportation, 2008a). This figure is used to estimate the CMVs on the road which would fail a serious inspection. Traditional visual pre-screening has resulted in an OOS rate of 27%, i.e., "eyeballing" by inspectors does improve the detection rate somewhat[1]. But use of historical records on specific CMVs and/or companies can increase the detection rate significantly. A test examination of records supplementing visual inspection resulted in an OOS detection rate of 57% (Intelligent Imaging Systems, 2008). If the majority of CMVs would be equipped with transponders and can be linked to data records, a significant increase in safety can be obtained. However, participation in the program is voluntary, and for various reasons many CMVs are not equipped with

transponders (e.g., it is a new technology that will be adopted only gradually; if drivers' routes do not go through subsequent electronic stations these CMVs do not benefit from the system; and there could be vehicles with poor records that do not want closer time-consuming inspections even if all previous violations have been corrected).

The AVI-equipped CMVs will gradually increase in number but it is expected to take several years to reach more than 20%. A benefit cost study would have to allow for the changing percentage of AVI-equipped vehicles over time. Instead we do a simpler one-year calculation of benefits which is sufficient to give an indication of what a larger study would reveal. Adopting the APLRS would dramatically increase the ability to incorporate historical records for CMVs for safety evaluations, increasing the rate to as much as 88% (from the test sample); we adopt a conservative figure of 60% to calculate the incremental benefits of the APLRS and an optimistic 10% for the proportion of CMVs with transponders.

First Year Benefit and Cost Estimates

The investment costs for ALPRS for three weigh stations total almost $500,000, obtained from a supplier. The facilities and software would last at least five years.

Hardware costs	$181,500
Software costs	207,000
Back office costs (Province wide)	49,000
Installation and other costs	54,450
Total	$491,950

The benefits of either electronic system include time savings of CMVs because some trucks can bypass weigh stations if they had already been cleared through one or if their safety profile puts them a lower risk class, and remaining trucks benefit because fewer trucks are going through the weigh station, resulting in reduced delay time from reduced congestion. Detailed data were made available for three weigh stations reporting the total number of CMVs passing through on a daily basis over a full quarter and which could be

extrapolated to an annual basis. This enabled the calculation of annual time savings for CMVs reflecting the reduced number of trucks pulled into weigh stations as more CMVs are pre-cleared to bypass the weigh station.

The estimated average daily number of CMVs passing through three weigh stations during 2009 was estimated based on data provided by the B.C. Ministry of Transportation[2]:

Port Mann West weigh station	3241
Golden East weigh station	890
Golden West weigh station	1067

There could be some double counting as some trucks may have passed through more than one station, but this does not matter for calculating time savings. Registered vehicles or those pre-cleared by data bases save time by bypassing the weigh station. This varies slightly among stations but is about a three minute saving. There are also some time savings to trucks going through stations because congestion is reduced because some trucks bypassed the station. Using 2009 traffic estimates for these three stations, the estimated annual total time saved is shown for the assumed (optimistic) 10% of CMVs equipped with transponders, and the pessimistic assumption that 60% of vehicles could be have their license plate read and linked with data records for the CMV.

Estimated total hours saved, 3 weigh stations, 2009 traffic level	
Assumed W2GO 10% registration	10,670 hours
Assumed ALPRS 60% CMV identification	54,863 hours
Incremental hours saved	44,193 hours

The time savings are significant. At the B.C. value of time used for CMVs of $46.96[3], incremental saving is valued at $2,075,303, i.e., the first year time saving is greater than the cost installing the ALPRS. There is a slight over-estimate in that a few vehicles may be randomly chosen for detailed inspection and not save the bypass time at a station. A more serious source of overstatement is that all trucks must stop at one station per day to verify they are within the weight

limit, and thus cannot bypass one station. But even allowing for these overstatements, there is still a very substantial time saving to be realized.

These time savings benefits accrue to CMVs (and/or their users) whereas the costs are incurred by the Province. Note that the value of time for the assumed 10% of CMVs equipped with transponders would be over $500 thousand, many times more than the cost of transponders. As this is realized it should hasten the adoption rate by truckers.

In addition to the time savings, the reduction of time in weigh stations will also result in fuel savings and emissions reduction. Fuel savings for one year for the three inspection stations amounts to 109,921 litres for the assumed 10% transponder-equipped CMVs, and a saving of 588,279 litres for the assumed 60% identification rate for the ALPRS[4]. This is an incremental saving of approximately 480 thousand litres. At $0.90 per liter this is an additional incremental annual benefit of $431,089. Again, this is based on only three weigh stations currently in operation.

There are also benefits of reduced emissions. The valuation of these savings is contentious but they are calculated at over $100,000 for the year. We exclude this benefit category for this paper.

Safety Benefits

The most significant benefit is yet to come: safety. Crash rates are usually linked to the total number of vehicle miles traveled. Unfortunately, reliable estimates of total CMV travel in B.C. do not exist. But a model developed by the U.S. DOT on data from Kentucky provides a method of predicting the number of crashes avoided based directly on the number of vehicle inspections carried out. This model can be adapted using B.C. values for parameters. The formula (Brown, et al. 2006) for the annual crashes avoided via inspections equals:

$$\frac{Inspection\ \# * P(V|Inspection) * SM * \lambda}{P(V)} * \frac{P(V|C) - P(V)}{1 - P(V)}$$

Where:

P(V| Inspection): the probability that a vehicle has an OOS violation given that the vehicle was inspected;
P(V|C): the probability that a vehicle has an OOS violation given it is in a crash;
P(V): the probability that a vehicle has an OOS violation
SM: the number of safe miles traveled as a result of "fixing" an OSS condition; the US data assume 15,000 miles;
λ: the probability of a crash estimated by the national crash rate for large trucks.

To calculate the number of avoided collisions involving CMVs, we use:

Inspection #: 6,000 (estimated)
λ: 2.68 Collisions per Million Vehicle Kilometres (B.C. Ministry of Transportation, 2008b)
SM = 15,000 miles/24,140kilometres (Brown, et al. 2006)
P(V) = 21.5% = current OOS rate among all CMVs in B.C on the road (B.C. Ministry of Transportation, 2008a)
P(V|C) = 32.38% (U.S. DOT, 2006)
P(V| Inspection): 30% (W2GO) and 45% (ALPRS)

The number of vehicles inspected is our estimated annual figure for the three weigh stations for which we have data. The probability of finding an OOS violation [P(V| Inspection)] is a weighted average of traditional methods of visually scanning trucks to decide which ones to subject to further inspection (with 27% OOS rate) and the higher OOS rate of 57% for trucks pulled in based on pre screening information from either the AVI or ALPR systems.. Hence the initial W2GO has 10% of vehicles subject to data review while 90% are reviewed in the traditional manner. The ALPRS assumes 60% of vehicles are subject to a data review (with 57% OOS rate) and 40% go through the traditional visual scan with its lower OOS rate of 27% (0.6 x 57%) + (04 x 27%) = 45%.

P(V|C) = 32.38% is the probability of a CMV involved in a crash has an OOS violation. This is the figure from U.S. data. However, presence of an OOS defect does not necessarily mean that this was a

causal factor in the crash. Lacking better information, we arbitrarily reduce the predicted collision impacts by 50%, i.e., we assume that only in half of the crashes are the vehicle defects a significant factor in the crash.

The predicted crashes avoided by the W2GO and ALPRS are:

Predicted Collisions Avoided	W2GO	ALPRS	Difference
One year, 2009 data	36.41	54.62	18.21
94% include injuries	34.23	51.34	17.11
6% with fatalities	2.18	3.28	1.10

The assumed 6000 inspections will reduce crashes and save lives because unsafe trucks are removed from the road at least for a period of time. Supplementing W2GO with ALPRS predicts a further reduction of 17 injury crashes and an additional life saved. These are probabilistic estimates. There are standardized values used to express these in monetary terms. Skipping property damage only crashes (relatively few for CMVs), the B.C. figure for CMV injury crashes is $97,000 and using $4.17M per life is an incremental safety benefit of over $6 million (de Leur, 2004). Even if we were to adopt much lower valuation figures and even more conservative calculations, the first year benefits more than justify the expenditures for the ALPRS.

Summary: Incremental Benefits of ALPRS

The incremental benefits gained by being able to review the records of CMVs to identify those with higher risk of OOS conditions more than justify the investment in the first year alone.

Time savings	$2,075,303
Fuel savings	431,089
Injury crashes avoided	1,659,670
Fatalities avoided	4,587,000
Sub total	$ 8,753,062
Investment costs	$ 491,450

Even if we were to cut the benefits by 50% and double the investment costs, the license plate reading technology and its use are well worth the investment.

Like many public projects, the benefits are realized by various groups and not as revenue by government who must incur the costs. Finance-constrained governments may have difficulty carrying out projects. When CMVs are given an OOS order, there is also a fine. A representative fine is $580[5]. Capturing more unsafe vehicles will generate more revenues from fines. These are not included in a benefit cost study because fines are a transfer; one group's loss is another group's gain. The W2GO with 10% participation is expected to identify 1800 OOS vehicles out of the sampled 6000 CMVs. Supplemented with the ALPRS the OOS rate would be 45% or 2700 vehicles. An incremental increase of 900 OOS vehicles would result in additional revenue from fines of $522,000, i.e., more than enough to finance the ALPRS completely in the first year of operation.

Conclusions

There are numerous calculations to evaluate the merit of adopting technologies to more accurately identify unsafe CMVs. Any of the estimates, calculations and valuations above is a worthwhile subject for additional study. Is there really that proportion of unsafe CMVs on the road? Will the detection rate be as high as we estimate? How often are OOS conditions a causal factor in crashes? Have we used appropriate values for time saving, injuries and fatalities? But the calculations here suggest that even with a wide sensitivity analysis with different assumptions and valuations, there are major social benefits to be gained by improving the detection rate of unsafe CMVs. And the sooner, the better. More rapid deployment of transponders, even mandating them, would hasten the benefits. In the meantime, the rapid deployment of license plate reading technology and accompanying software and data bases is worthwhile to bring about these benefits more quickly.

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ENDNOTES

[1] This OOS rate is obtained by dividing the number of CMVs that are issued OOS orders by the number of Level 1 CVSA inspections that were performed (McDermid, 2008).

[2] See Lee and Chow (2008) for details on this data set and how it was processed.

[3] $46.94 per hour was BC MOT's default time value of for a combination truck (Leung, 2008)

[4] For detailed calculations, see Lee and Chow (2008) where the Weigh2GO estimate was made. The same methodology was used to estimate fuel savings for the ALPR scenario.

[5] For example, brakes are one of most common causative factors in truck accidents and the primary focus of a vehicle inspection. In B.C., for each service brake not in effective working order there was a fine of $138 plus, if 50% or more of the vehicle's service brakes are not in effective working order, an additional $598 (B.C. Ministry of Public Service and Solicitor General, 2007).