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## **Simulating LCV Traffic Operations on Two Lane Rural Highways**

Gordon A. Sparks  
Professor of Civil Engineering  
University of Saskatchewan  
Saskatoon, Saskatoon  
Canada

Norm Stang  
Project Engineer (former)  
Vemax Management Inc.  
Saskatoon, Saskatchewan  
Canada

Scott Sillers  
Project Engineer  
Vemax Management Inc.  
Edmonton, Canada

Norm Burns  
Trucking Specialist  
Saskatchewan Highways &  
Transportation  
Regina, Canada

### **Abstract**

This paper summarizes the results of a study that used TARA, a traffic simulation software package, to evaluate the implications of permitting LCVs to operate on Highway #7, a two lane, two way rural highway in Saskatchewan. The operation of a 200 km section of this rural highway was simulated for a period of 24 hours using traffic conditions typical of a peak summer day. A full range of statistics quantifying the traffic operations as a function of time of day were collected and analyzed. These statistics included, for example, the number of vehicles and total time these vehicles spent in a queue behind an LCV, the total number of vehicles passing LCVs, and the safety margins for passing vehicles. These and other statistics were analyzed for operations with and without LCVs in the traffic stream. The analysis indicated that LCVs could be permitted during off peak, night time periods without adversely affecting traffic operations or overall safety.

## 1.1 BACKGROUND

Saskatchewan Highways and Transportation's (SHT) Long Combination Vehicle Program was initiated on a demonstration basis with two Saskatchewan carriers in 1979. The initial program which was extended to other carriers in 1982/83, allowed carriers to operate 38 metre vehicles on four lane divided highways. In 1986 the program was expanded to allow carriers to operate 29 metre vehicles on two lane highways during low traffic periods.

In 1994, SHT received a request from Kindersley Transport Ltd. to operate 40 metre double trailer units (Turnpike Doubles or TDs) on Route 7 between Saskatoon and Alsask (both directions) on a nighttime only basis (9pm – 7am). After assessing the safety impact of the request, SHT discussed the matter with the Canadian Automobile Association (CAA) Saskatchewan division. After receiving qualified support from the Executive Committee of the Board of Directors of CAA Saskatchewan, SHT agreed to proceed with a demonstration project. Kindersley Transport agreed to all the terms and conditions of a standard SHT Long Combination Vehicle Agreement in addition to the following:

- the vehicle would be equipped with a long load sign advising following drivers that the truck was 40 metres long;
- the vehicle would only be operated between the hours of 9pm and 7am on Route 7 between Saskatoon and Alsask.
- the driver would provide trip reports to SHT and make every reasonable effort to accommodate traffic trying to pass the overlength vehicle;
- Kindersley Transport was required to enter into a partnership agreement with SHT whereby half the net truck haul savings would be used for highway improvement; and
- Vemax Management Inc. would be commissioned to evaluate the demonstration project from a passing safety perspective and in particular, undertake an evaluation of the operations of TD's on Route 7 between Saskatoon and Alsask using TARA, a computer based traffic simulation software package that VEMAX had under development at the time (Stang, 1996). This work was to be done under the guidance of a committee comprised of members from CAA Saskatchewan, the Saskatchewan Trucking Association and SHT.

Kindersley Transport began trial operation of Turnpike Doubles on Route 7 between Saskatoon and Alsask in July 1996.

## 1.2 DETAILED ANALYSIS

The results of detailed safety and operational assessments of TD passing operations summarized herein are based on simulations completed with the software package TARA (Traffic and Roadway Analysis) (Sparks et al 1997). Traffic operations on the entire length of all control sections between Saskatoon and Alsask ( 200 km) were simulated. Adjoining control sections were taken together and each simulation was of traffic on an

average summer or autumn day through 24 hours. Two scenarios were examined for the route:

- base case - existing traffic
- test case - traffic after a predicted diversion from tractor semi-trailers to TDs.

Key assumptions in the simulation analysis included:

- a replacement rate of two tractor semi-trailers per TD was used for diverting tractor semi-trailer traffic to TDs. TDs have twice the carrying capacity and therefore fewer TDs than tractor semi-trailers are required to move a given amount of cargo.
- percentage reductions in tractor semi-trailer traffic because of the introduction of TDs were assumed to be uniform throughout the day.
- TDs were assumed to be restricted to a 9:00pm to 7:00am time period.
- TDs were assumed to be transporting goods from one end of the route to the other, rather than to intermediate points. Route 7 is the principal highway between Saskatoon and Calgary, with much of the truck traffic on the route travelling from one city to the other rather than to intermediate points.

Calibration of the simulation was performed using field data collected by staff from Kindersley Transport, SHT and Vemax. The various components of passing operations were timed, and significant driver behaviour and the existence and build-up of platoons were noted. Figures 1 and 2 show data collected from Route 7 for the free flow speeds for cars and tractor semi-trailers respectively. Passing behaviour was characterized by three principal measures: the minimum sight distance at which a pass will be attempted, the minimum gap in opposing traffic at which a pass will be attempted and the time taken to complete a pass. Each of these were examined in the field and Table 1 summarizes the results.

Note from Table 1 the conservative behaviour of drivers passing TDs. With reference to Table 1, by definition the difference between the minimum acceptable gap in opposing traffic and the passing time is the average Passing Safety Margin drivers leave themselves. For car drivers passing other cars or tractor semi-trailers, the average Passing Safety Margin was found to be 6 and 7 seconds respectively. When passing TDs, the average Passing Safety Margin was found to be 32 seconds. This is despite the fact that it takes roughly the same amount of time to pass a TD travelling at 90 km/h as it takes to pass a tractor semi-trailer traveling at 100 km/h. Tractor semi-trailer drivers passing TDs exhibited similar conservative behaviour.

## 1.2 PASSING SAFETY MEASURES OF EFFECTIVENESS

In introducing TDs onto two lane highways, it behooves authorities to answer two questions:

- are TDs inordinately unsafe in comparison to the vehicles they are replacing?

- do the TD Replacement Rate and operating restrictions sufficiently offset any increased potential for accidents?

To answer these questions as they apply to passing operations, base case existing conditions were compared to those for predicted TD diversion rates.

The danger in an overtaking manoeuvre on a two lane two way highway arises from the possibility of meeting an opposing vehicle while traveling in the opposing lane. The consequences of such a conflict include running off the road, head-on collision with the opposing vehicle, or collision with an impeding or trailing vehicle while attempting to abort or hurry the pass. After the completion of a successful pass, the time headway to the next opposing vehicle is a good measure of the safety margin with which the pass was completed (Figure 3). Larger Passing Safety Margins are desirable because they give drivers more time for decision making and comfortably completing a pass.

In comparing safety impacts of different scenarios, average Passing Safety Margins can be examined. However, exposure must also be taken into account. Exposure is simply the number of passes that are predicted to occur. Higher Passing Safety Margins may not translate into fewer accidents if the number of passes increases. As Passing Safety Margins increase, passing safety improves. In contrast, as exposure increases, passing safety worsens. To capture both of these effects, a composite measure called Passing Hazard Index was derived.

Passing Hazard Index was defined as the sum of the reciprocals of the Passing Safety Margins of recorded passes.

$$PH = \sum_{i=1}^n \frac{1}{SM_i}$$

where            PH     = Passing Hazard Index  
                      n        = Number of Passes  
                      SM<sub>i</sub>    = Passing Safety Margin (i)

The form of this equation ensures that Passing Hazard Index increases as the number of passes (exposure) increases and decreases as Safety Margins increase. The implicit assumption is that the likelihood of a crash diminishes in proportion to the inverse of the Safety Margin. No attempt was made to establish a relationship between Passing Hazard Index and accidents. However, Passing Hazard Index does allow for relative comparisons of scenarios and facilities.

### 1.3 DETAILED ASSESSMENT OF TDs ON ROUTE 7

Starting in July 1996, Kindersley Transport began trial operation of TDs on Route 7. Control sections 7-2 through 7-8 were simulated for this project. The barrier line markings in each direction were the primary input defining passing opportunities.

Average August traffic was simulated for both the base and test cases. Table 2 shows the estimated traffic levels for the control sections simulated. Figure 4 shows the hourly total and truck traffic at Kindersley. A predicted TD Diversion Rate of 8 percent (Barton, 1996) was employed in the test case. All TDs were assumed to complete a round trip from Saskatoon to Alsask and back during the operating window.

#### 1.4 RESULTS OF THE SIMULATION

Figure 5 shows the hourly simulated distribution of truck passing on Route 7. As noted, there was more passing per truck during the day and higher Passing Safety Margins at night (See Figures 6 and 7). This combination provides benefit in shifting truck traffic from day to night, as was effectively done in introducing TDs on Route 7.

Table 3 compares the number of passes (over takings) in the base and test cases by time of day. Note that the overall number of passes remained about the same (Base Case = 1416, Test Case  $1314 + 92 = 1406$ ). There was merely a shift in the day/night split from 88%/12% to 82%/18%.

Table 4 shows the base and test case Passing Hazard Index. The passing Hazard Index reduced from 70.5 to 66.3 in moving from the base case to the test case for a 6 percent overall improvement after the introduction of TDs. Most of this improvement was the result of decreased truck traffic during the day. The Daytime Passing Hazard Index dropped from 65.1 to 59.6 while conditions at night worsened slightly with the Passing Hazard Index increasing from 5.3 to 6.7.

Figure 8 shows the levels of platooning throughout the day on Route 7. Note that 3+ platoons are relatively rare, even during the peak summer traffic. With the introduction of TDs, this is not predicted to change.

Table 5 and 6 compare total delay and average delay in the base and test cases. The introduction of TDs on Route 7 is predicted to reduce total delay from 10,633 vehicle minutes to 9812 vehicle minutes or by 8 percent. Note that the improvement during the day (9271 vehicle minutes to 7915 vehicle minutes) is somewhat offset by worsening conditions at night (1362 to 1896). But even with TDs running at night, the average driver spends only about 4 minutes following a truck of any sort during the 140-minute trip from the junction of Route 60 to Alsask on the Alberta border.

## **CONCLUSIONS**

Using computer simulation techniques we were able to do an otherwise impossible analysis of the details related to the impact of introducing TDs on the traffic operations on Route 7 between Saskatoon and Alsask.

TDs were allowed to operate only at night (9 pm to 7am) when traffic volumes tended to low. Therefore the introduction of TDs tended to shift truck traffic from the busy daytime periods to low volume night-time periods. The combined effect was for overall safety related to vehicles passing trucks to improve marginally with the introduction of TDs. The benefits of fewer vehicles passing trucks during the daytime hours more than offset the disbeliefs observed related to TDs during the off peak periods.

## **REFERENCES**

- 1) Barton, Ray et al (1996) Operating Cost Savings Due to An Inter Prairie E<sup>2</sup>MV Network: Study Findings, ADI Limited. Ottawa, Canada.
- 2) Stang, Norman (1996) TARA: A-Multi-Purpose Traffic Simulation System, internal documentation VEMAX Management Inc, Saskatoon, Saskatchewan, Canada.
- 3) Sparks, Gordon, Stang Norman (April 1997) An Evaluation of Turnpike Doubles Passing Operations on Two Lane Highways in Saskatchewan, prepared by VEMAX Management Inc. for Saskatchewan Highways and Transportation, Regina, Canada.

**Table 1**      **Average Passing Behaviour**

	Minimum Sight Distance (metres)	Minimum Opposing Traffic Gap (seconds)	Passing Time (seconds) *	Passing Safety Margin (seconds)
Car passing Car at 105 km/h	650	16	10	6
Car passing Tractor Semi-Trailer at 100 km/h	900	20	13	7
Car passing TD at 90 km/h	2200	45	13	32
Tractor Semi-Trailer passing Car at 100 km/h	1100	24	18	6
Tractor Semi-Trailer passing Tractor Semi-Trailer at 100 km/h	1500	30	22	8
Tractor Semi-Trailer passing TD at 90 km/h	3100	60	23	37

\* Note that passing time is defined as the time spent in the opposing lane.

\*\* Passing data involving TDs were collected on Route 7. Other data are from various literature sources but were confirmed by observations on Route 7.

**Table 2**      **Estimated August Traffic on Route 7**

Control Section	Estimated August ADT
7-2 (Jct. Rte 60 to Delisle)	4655
7-3 (Delisle to Harris)	2900
7-4 (Harris to Rosetown)	2815
7-5 (Rosetown to Jct. Rte 30)	2150
7-6 (Jct. Rte 30 to Kindersley)	2470
7-7 (Kindersley to Jct. Rte 307)	2520
7-8 (Jct. Rte 307 to Alberta border)	1745

**Table 3**      **Number of Overtakings Comparison of Route 7 Base and Test Cases  
(both directions)**

	7am – 9pm	9pm – 7am	Total
<b>Base Case</b>			
Overtaking Tractor Semi-trailers	1241	175	1416
<b>Test Case</b>			
Overtaking Tractor Semi-trailers	1147	167	1314
Overtaking TDs	0	92	92

**Table 4**      **Passing Hazard Comparison of Route 7 Base and Test Cases**

	7am – 9pm	9pm – 7am	Total
<b>Base Case</b>			
Overtaking Tractor Semi-trailers	65.1	5.3	<b>70.5</b>
<b>Test Case</b>			
Overtaking Tractor Semi-trailers	59.6	4.9	64.6
Overtaking TDs	0.0	1.8	1.8
Combined	59.6	6.7	<b>66.3</b>

**Table 5**      **Total Delay Comparison of Route 7 Base and Test Cases**

	Total Delay (vehicle-minutes per day in both directions)		
	7am – 9pm	9pm – 7am	Total
<b>Base Case</b>			
Following Tractor Semi-trailers	9271	1362	<b>10633</b>
<b>Test Case</b>			
Following Tractor Semi-trailers	7915	1480	9396
Following TDs	0	416	416
Combined	7915	1896	<b>9812</b>

**Table 6**      **Average Delay Comparison of Route 7 Base and Test Cases**

	Average Delay per Vehicle (minutes per 140 minute trip)		
	7am – 9pm	9pm – 7am	Average
<b>Base Case</b>			
Following Tractor Semi-trailers	4.1	3.7	<b>4.0</b>
<b>Test Case</b>			
Following Tractor Semi-trailers	3.5	3.7	3.5
Following TDs	0	2.4	0.2
Combined			<b>3.7</b>

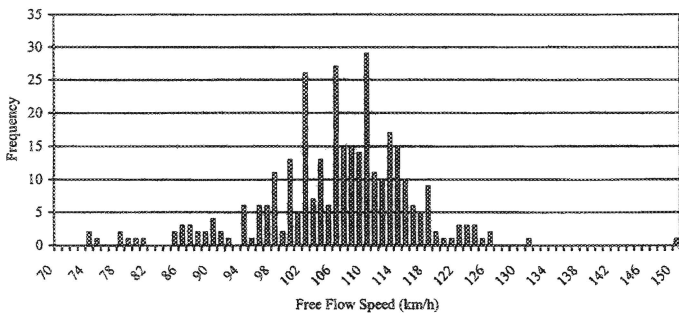


Figure 1 Car Free Flow Speed (from data collected on Route 7)

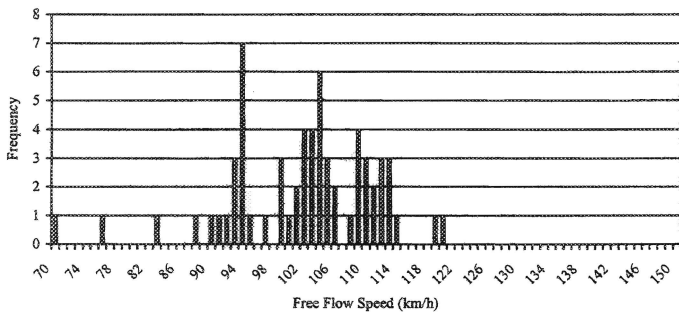


Figure 2 Semi-Trailer Truck Free Flow Speed (from data collected on Route 7)

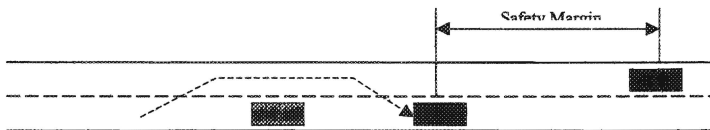
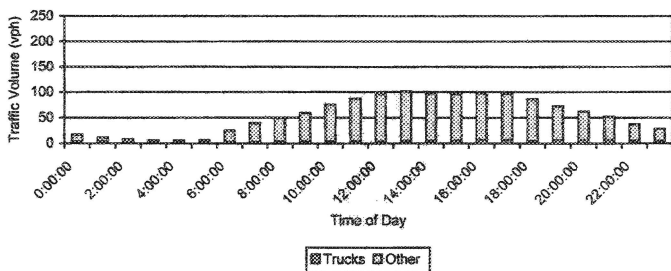
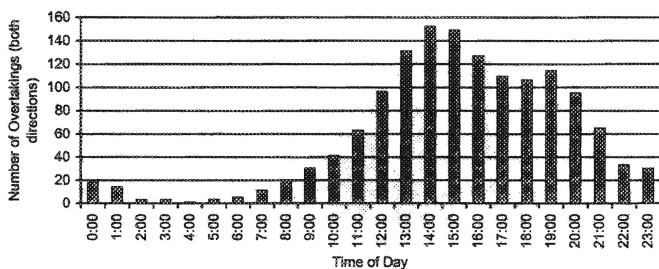


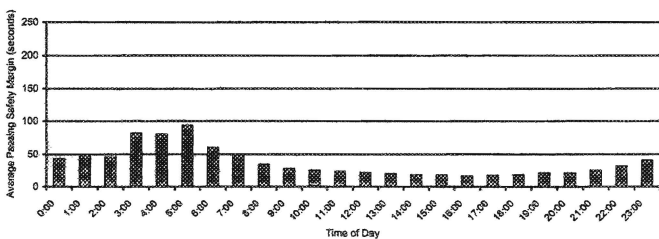
Figure 3 Passing Safety Margin



**Figure 4** Average August 1996 Single Direction Traffic Volumes On Route 7 at Kindersley



**Figure 5** Base Case Overtaking of Trucks of Route 7



**Figure 6** Tractor Semi-Trailer Passing Safety Margins on Route 7

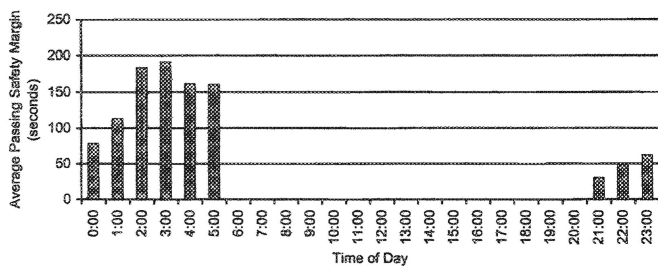


Figure 7 TD Passing Safety Margins on Route 7

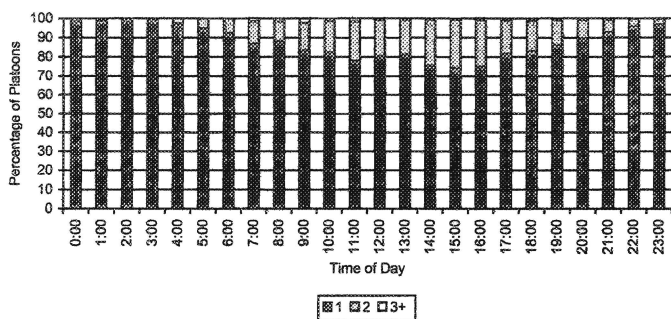


Figure 8 Route 7 Base Case Platooning

