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**Long Combination Vehicle
Operating Characteristics in Urban Areas**

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Combination vehicles (up to 25 m in length) such as B-Trains have been operating in Calgary since 1988. More recently, long combination vehicles (LCVs) with lengths up to 38 m have been operating on designated trucks routes. The impact of these vehicles on urban traffic operations, and geometric design considerations, are critical elements of providing a safe and efficient transportation system. This paper discusses the findings of recently completed field studies of the operating characteristics of long combination vehicles (LCVs) in Calgary. The study included the following LCV configurations, Rocky Mountain Double, Turnpike Double, Triple Trailer, Super B-Train, Tridem Axle Semi-trailer, Tandem Dump Truck and Trailer extended "A" hitch) and a Heavy Haul configuration consisting of a tractor, jeep and low-boy trailer.

The field tests included a low speed 180 degree turn where the actual turning path of each test vehicle was surveyed and plotted to establish a turning template, a timed acceleration from a stop over a distance of 61 metres to determine intersection crossing times. The times were taken at the 6, 12, 18, 24, 30, 46, and 61 metre intervals to obtain enough information to plot the acceleration curve which can be used to approximate the clearance time at intersections for vehicles of similar configurations to the test vehicles. Left turn movements and right turn movements were also observed and timed to approximate the clearance times for the test vehicle configurations at typical urban intersections.

INTRODUCTION

Long combination vehicles (LCVs) are those vehicles in excess of 25 m in overall length and are allowed to operate under permit on Alberta Highways. The permit specifies particular routes and intersections that may be used. To allow intersections to be designed to accommodate LCVs Alberta Infrastructure (1999) has developed guidelines and turning templates. However, where truck (LCV) routes fall within a city boundary, the operation of overlength (greater than 25 m) combination units is controlled by the city. Research into the operational characteristics of LCVs has been limited to date and as noted by Harkey et al (1996) the most severe problem locations for LCVs with respect to vehicle off-tracking are at grade intersections. The authors note that "AASHTO recommends curb radii of 12.2 m or greater to accommodate large trucks", however, this is less than the design turning radius of 18.3 m for a turnpike double. It is noted that the Transportation Association of Canada design guidelines (1993, 1997, 1999) do not include provisions for LCVs.

The importance of the LCV in Calgary is underscored by the fact that Calgary has evolved into a major transportation hub for Western Canada. The findings presented in this paper are based on a research project undertaken in response to the need to accommodate LCVs on city streets once they leave the provincial highway system.

LOW SPEED TURNING MOVEMENTS

The increasing use of LCVs in Alberta has created some operational difficulties, particularly in urban areas such as Calgary where older infrastructure was not designed or built to accommodate the operational needs of truck combinations up to 38 metres in length. This design shortfall is usually noticed at intersections where the vehicles are required to make tight turning manoeuvres. In the case of channelized turns, the outcome is damaged curbs, boulevards and traffic controls that are placed close to the edge of pavement (Figure 1). For non-channelized turns, the vehicle is forced to make an extremely wide turn, often across several travel lanes (Figure 2). In addition to the damage to the infrastructure, there is a serious safety concern as the truck driver, while executing these tight manoeuvres has extremely limited use of the vehicle's rear view mirrors and a poor view behind and along the sides of the vehicle. As most truck routes are on a City's major road network, the traffic volumes are typically high and with the higher exposure rate, the conflict risk also increases. In addition to the geometric issues at intersections, concerns have also been raised by the trucking industry about inadequate driveway standards where LCVs are required to access sites for picking up and delivering freight or obtaining services. The visible damage to infrastructure and the issues raised by the trucking industry clearly pointed to a need to review the current design standards

for truck routes and industrial driveway access.

The first challenge in reviewing the design standards was a shortage of good information on the operation needs of the LCVs. As vehicle configurations such as the turnpike double, rocky mountain double and triple trailer combinations were typically only used in the western provinces, national standards were not available. The largest vehicle design template published by the Transportation Association of Canada (TAC 1993) is a 25 metre B-Train combination. LCVs are not included in the TAC report on Design Vehicle Dimensions for use in Geometric Design (Transportation Association of Canada 1997) or The Geometric Design Guide for Canadian Roads (TAC 1999). In fact, the only highway design guide in Canada that refers to LCVs is the Alberta Highway Geometric Design Guide (Alberta Infrastructure 1999). Clearly, this single template could not accurately represent the operational needs of the larger long combination vehicles. Discussions with representatives from the trucking industry indicated that the following common configurations should be studied: turnpike double, rocky mountain double, triple trailer and tridem axle semi-trailer. Additionally, a single unit tandem dump truck with an extended "A" hitch and trailer and a heavy haul configuration (tractor, jeep and low boy) were selected for testing. Although there was an existing design template for the B-Train configuration, this unit was also selected, primarily for comparison and validation. Representatives of the trucking industry in Calgary provided the test units, loaded where possible, with experienced drivers.

A number of different options were considered to track and record a low speed 180 degree turn for each of the test vehicles. The challenge was to track the tire paths of the vehicle that would provide sufficient information to develop design templates. Additional, it was desirable to have the vehicles complete the manoeuvre at a normal operating speed in order that observations could be made to determine if trailer off tracking would be a concern. To complete these tests, a large gravelled section of the City of Calgary yard was levelled, graded and raked to allow the test vehicle to complete a full 180 degree turn at a typical operating speed. The test vehicle's tires produced clear imprints in the soft surface which were recorded by a survey crew utilizing total station survey technology. After each vehicle, the course was raked to provide a fresh surface for each test.

Prior to starting the turning test, each vehicle was weighed and measured for length, width and axle spacing. Each of the test drivers was briefed on the study and requested to complete the 180 degree turn from a rolling start, typical of how they would operate the vehicle under normal working conditions. The object of this test was to simulate typical conditions and not to complete the smallest possible radius turn. Representatives of the Alberta Trucking Association, the Calgary Police Service Truck Unit and a professional

truck driver training school observed and monitored these tests to confirm that the vehicle movements were typical and representative for these configurations.

The survey information collected was used to develop design templates with Autoturn software. Samples of the completed design templates for the Rocky Mountain Double and the Turnpike Double configurations are shown in Figures 3 and 4. Due to space limitations in this paper, it is not possible to show the full set of templates for the test vehicles, however, full sets of templates will be available at the presentation.

Based on the results of this study, the City of Calgary is using this information to develop new driveway standards for commercial/industrial facilities and will use this information for roadway designs on designated truck routes. The goal of this exercise is to provide an environment where LCV configurations can operate safely and complete turning movements without rolling over curbs and boulevards or crossing over a number of travel lanes.

TIMED ACCELERATION TEST

Another concern arising from the increased use of LCVs is the longer clearance times due to the extended vehicle length, the increased weight or the combination of both. This, in turn, creates a safety issue where it may be necessary to take the longer clearance times of these vehicles into consideration in the design of traffic controls on truck routes. For the purposes of this discussion the clearance time was determined to be the period of time between the front of the truck entering an intersection and the rear of the trailer exiting the intersection on the other side. In establishing this test a number of considerations were discussed; the need to have a controlled test where the weight of the test vehicles was known and the test field would allow each vehicle to be tested under identical road and climatic conditions. It was understood that the test results could vary from actual conditions due to vehicle weights, road and climatic conditions as well as the great variety of engine horsepower, transmissions and final gearing combinations. Similarly, there was a potential for considerable variation in time due to driver performance. Since the drivers knew they were being timed on this test, there was a potential for them to attempt to operate the vehicle to best demonstrate its potential rather than simulating a typical driving condition. To validate this test, representatives from the Alberta Trucking Association, Calgary Police Truck Unit and a professional truck driver training school observed and audited this test to confirm that the manner of vehicle operation was a reasonable simulation of typical driving conditions. Additionally, to verify these results, a number of uncontrolled tests were done at various intersections where the acceleration of randomly selected LCVs was timed over fixed distances without the knowledge of the driver.

For the controlled acceleration test, the same vehicles used for the turning movement tests were utilized. As these vehicles were weighed prior to that test, the weights were known. Additional information on the engine horsepower and transmission were recorded during the acceleration test. A section of roadway adjacent to the City Yards was selected for this test. This four lane undivided arterial was straight, level, paved and in good condition. Also, the traffic was known to be very light on Saturdays. The test course was marked out with traffic cones at 6, 12, 18, 24, 30, 46 and 61 metre intervals. These intervals were selected to simulate crossing a narrow two lane section to a wide cross section multilane divided facility. Times were taken by an observer using a stop watch at each interval. Most vehicles were tested twice to establish consistency.

Following the completing of these tests, the data was analyzed and plotted on graphs to establish an acceleration curve. The acceleration curves for the Rocky Mountain Double and Turnpike Double configurations are shown in Figures 5 and 6. Due to space limitations in this paper it was not possible to include the acceleration curves for all of the test vehicles, however, they will be available at the presentation. These acceleration curves can be used to establish an approximate crossing time for the various configurations by determining the distance across the intersection plus the total length of the vehicle. The total distance can be plotted on the "x" axis of the chart and the approximate crossing time can be found where the acceleration curve intersects.

The City of Calgary is using this information to evaluate the traffic signal minimum green times at controlled intersections in industrial areas. This information can also be used to evaluate crossings to determine if sufficient gaps are occurring in traffic to allow the LCVs to cross an intersection or safely enter the traffic flow.

LEFT AND RIGHT TURN MOVEMENTS

The final test conducted in this series was to determine the left and right turn clearance time required for the various LCV configurations at a signalized intersection. Again, the same set of test vehicles and drivers supplied by the trucking industry was used for this test. Two signalized intersections adjacent to the City of Calgary yards were again selected as the configurations were typically common in an urban area and the traffic volumes were known to be very light on Saturdays. The clearance interval timed started when the front of the vehicle entered the crosswalk and stopped when the rear of the trailer passed the crosswalk on the intersection street. Again, the operation of the vehicles was observed and audited by the representative from the Alberta Trucking Association, Calgary Police Service Truck Unit and a professional truck driver training school.

In this test, only a single fixed travel distance was considered for each of the right turn and left turn movements as the goal was to determine a specific time/space relationship for a typical right or left turn manoeuvre at an urban intersection and not to establish an acceleration curve for a turning movement.

The following chart list the vehicle configurations, turning distance and observed times.

Vehicle	Left Turn (secs) (25 m travel distance)	Right Turn (secs) (12 m travel distance)
1. Tandem Dump Truck & Trailer	17.3	13.4
2. Heavy Haul Configuration	26.6	19.3
3. Super B-Train (8 axle)	24.6	12.0
4. Rocky Mountain Double	19.6	19.0
5. Turnpike Double	23.9	16.8
6. Triple Trailer	21.0	15.1
7. Semi-Trailer 53' Tridem Rear Axles	18.3	15.0

The City of Calgary will use this information to evaluate clearance times at signalized intersections, particularly for left turns to determine if there are adequate gaps to allow these vehicles to complete a left turn in safety and also to evaluate if existing advance left turn signal phases are adequate to permit the LCV to clear the intersection during the protected signal phase.

CONCLUSIONS AND COMPARISONS

There is very little published data dealing with low speed turning requirements for LCVs, particularly in the form of turning templates, as they are often called. The Transportation Association of Canada (1993) provides a template for the B-Train only and does not address the other LCVs studied here. A comparison of the published template with the B-Train tested and surveyed in this study indicated that the published template radius was approximately one metre less than the test indicated was required. In Calgary, the most common commodity carried in B-Trains (8 axle configuration) is fuel. Reviewing locations such as gas stations, where these vehicles make deliveries and the current design standards were used, indicated signs such as tire marks on curbs or boulevards where the manoeuvring distance was inadequate. The conclusion drawn from this observation and the actual surveyed test results indicate that a larger design radius than the current standard is required. This finding was also reported by Harkey et al (1996) who observed

that at-grade intersections pose the most serious problems for LCV off-tracking and that some LCV combinations may encroach into adjacent lanes on the exiting or receiving leg of the intersection. The authors also reported one study that "Rocky Mountain Doubles and Turnpike Doubles would be forced into opposing traffic lanes far more often than semi-trailers to make right turns at intersections without running over curbs and possibly knocking over signs, poles and other roadside features."

In comparing the test results for acceleration from a stop, it was found that the results from the controlled test varied considerably from the random field observations. Some probable reasons for this are;

- a. Driver Behaviour. In the controlled test the drivers knew they were being timed and waited until the start signal to begin accelerating. During the uncontrolled tests, the drivers were unaware they were being timed and would start accelerating when ready, often in anticipation of the light turning green. This made it difficult for the observer to determine exactly when to start the clock.
- b. Field Conditions. The variety of conditions at the intersections in the uncontrolled tests made it difficult for the observers to collect the data. Visibility was often blocked by other traffic making it difficult to determine when the test vehicles were passing the interval points.
- c. Vehicle Consistency. The observer had no means of establishing the vehicle weight, whether it was full or empty or the horsepower and gearing. Without this information, it is difficult to draw comparisons to the controlled test data.
- d. Sample Sizes. Approximately 1000 trucks were randomly observed during the uncontrolled study, however, the wide variation in trucks weights, configuration and driving styles made it difficult to establish any consistent standard. On the other hand, the controlled test only looked at one vehicle for each test group which is far too small a sample to establish a standard.

This test data was compared to Transportation Association of Canada (1999) and Alberta Infrastructure (1999) published data. The results from the controlled tests indicated slower acceleration and longer clearance times than previous suggested in these publications. As these controlled test results were really only a "spot" check, they do suggest that further work and more testing is required to ensure that the design information is accurate and adequately provides for the operating needs of the LCV.

Similar results were found with the tests for right and left turn clearance times. Again, the

controlled test samples were too small to be conclusive, however, they tend to indicate that further work is required to collect and analyze sufficient data to establish safe clearance and crossing times at signalized intersections.

REFERENCES

Alberta Infrastructure, *Highway Geometric Design Guide*, Edmonton 1999

Harkey, D.L., Council, F.M. and Zageer, C.V., *Operational Observations of Larger Combination Vehicles and Related Geometric Design Issues*, Transportation Research Board, Transportation Research Record Number 1523 Washington D.C. 1996

Transportation Association of Canada, *Design Vehicle Dimensions for Use in Geometric Design*, Ottawa 1997

Transportation Association of Canada, *Geometric Design Guide for Canadian Roads*, Ottawa 1999

Transportation Association of Canada, *Turning Vehicle Templates*, Ottawa 1993

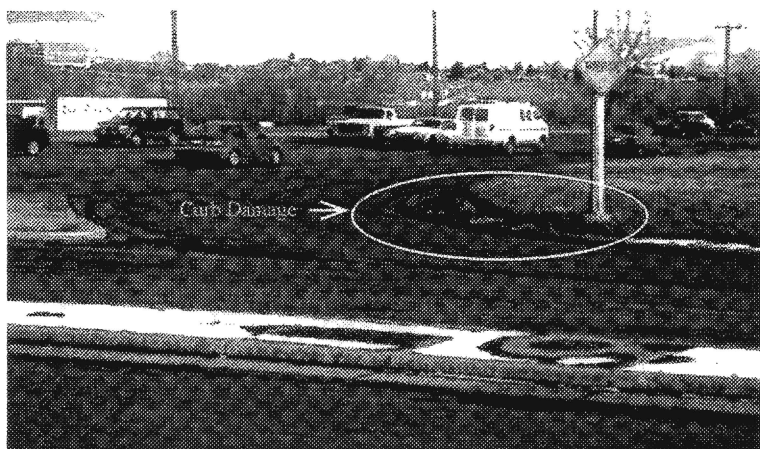


Figure 1 - Curb Damage Due to Low Speed Off-Tracking



Figure 2 - Turnpike Double Executing a Right Turn

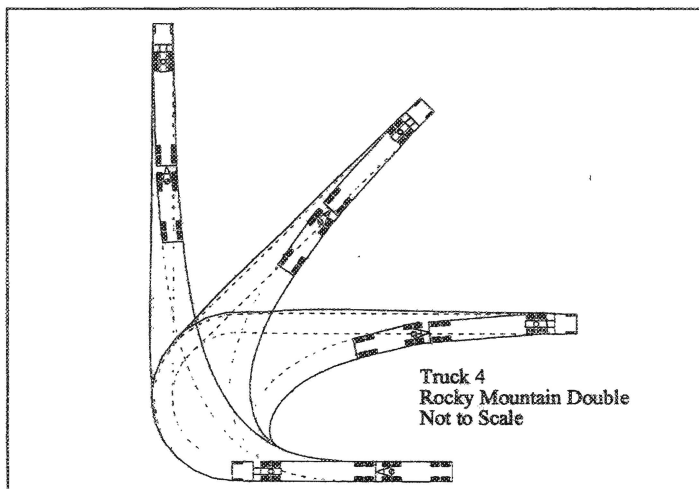


Figure 3 - Sample Turning Template Rocky Mountain Double

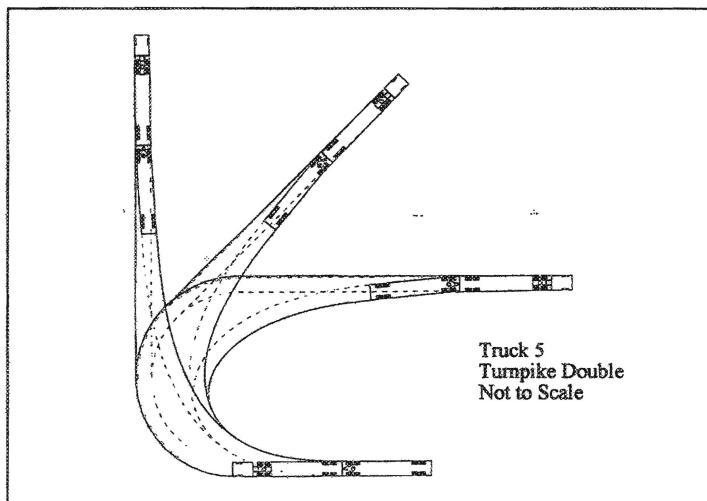


Figure 4 - Sample Turning Template Turnpike Double

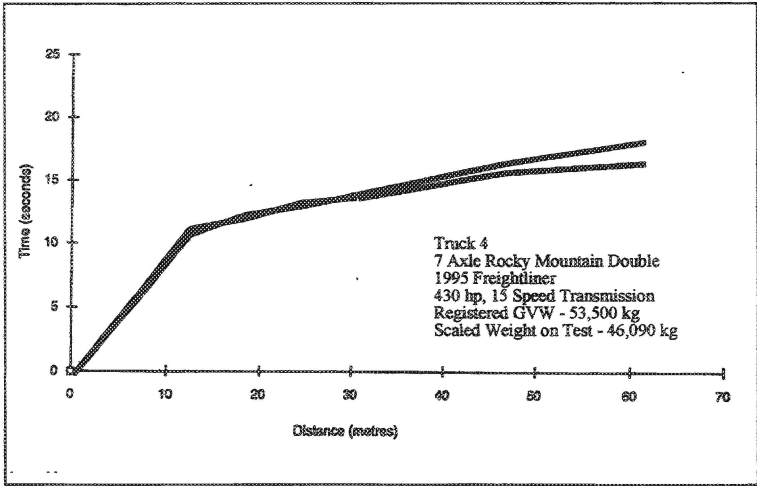


Figure 5 - Sample Acceleration Chart - Rocky Mountain Double

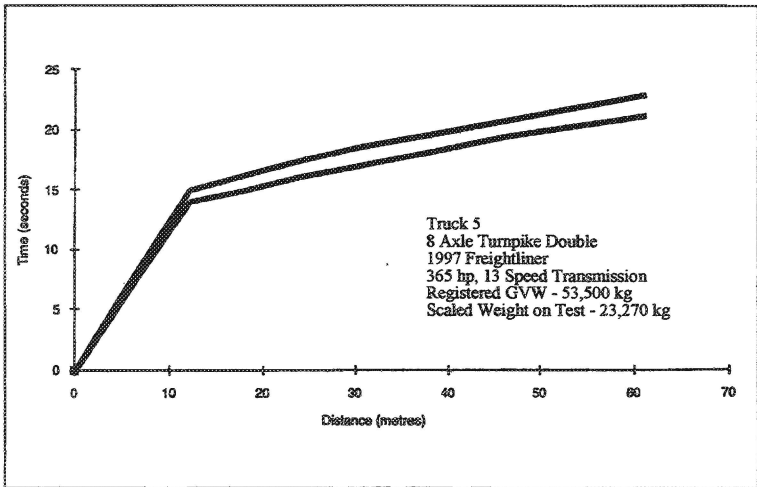


Figure 6 - Sample Acceleration Chart - Turnpike Double

