# REMOTE SAMPLING OF TRUCK SECTOR PRODUCTIVITY AND SAFETY

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## Introduction

Since 2004, the British Columbia Ministry of Transportation (BCMoT) has sampled Satellite tracking information for Class 8 Highway Trucks in order to assess travel speeds for large heavy vehicles on main provincial highways.[1] For this, anonymously collected raw vehicle tracking records have been secured from Shaw Tracking Services[2] and mapped against a network of provincial highways, with samples of successive data points on the network used to calculate average truck speeds for defined highway links.

This work has been conducted for three months during August, September and October in each year 2004 through 2008 inclusive. Sampling was conducted continuously for 24 hours per day during each 91 day period. Each year, over half a million point samples of vehicle positions and times have been gathered. The complete historical file thus represents a total in excess of 2.5 million samplings of vehicle positions and times. Such information may also be very useful for investigating other aspects of trucking activity.

With consent to use this data from BCMoT, and release time from Mount Royal College, the author is researching whether operating factors other than link speeds can be usefully derived from this remotely sampled information.

Operating factors that would be of interest to various transportation audiences include daily and monthly hours worked by a driver, distances travelled daily and monthly, travel speeds, and length of individual driving segments in terms of distance and time.

The foregoing information is directly related to truck productivity in terms of outputs divided by inputs, for example, achievable tonne-km per driver day. It also relates partly to vehicle safety and driver fatigue as driving time and distance in one sitting is a pertinent factor for the regulatory regime represented by Hours of Service regulations under the National Safety Code (NSC[9]).[3]

In noting the possible relationship to regulation, the author recognizes that satellite data sheds light primarily on the "driving activity" that is regulated by NSC[9] as the driver's activity is only certain for moving segments detected. While it does identify when, where and for how long a vehicle is stopped, the satellite does not know how the stopped time is being used. Such time may be a rest period or it may be a period when the driver is on duty but not driving such as loading freight, vehicle inspection, or performing another type of standby service.

In this context, this paper presents results obtained from some very preliminary investigations based on using a sample portion of all the data collected these past 5 years.

## Data Processing Approach

Rather than operate on all 2.5 million$^{+}$ samplings of truck location and time, the author has constructed some processing algorithms and tested them using a subset of all the available data. For now, our work has focused on a single month that was collected between August 1, 2008 and August 31, 2008. This paper documents our findings obtained so far from these preliminary investigations.

To begin work on this project, we initially selected records from all the raw data samplings collected during the time period. This approach differed from the previously cited link speed studies[1] as that prior effort had discarded any data samplings that were not on primary highways of interest for determining BCMoT link speeds.

This first step was to bring together all the truck positional and time information in sequences that were essentially a time series of locations. Based on whether position changed between samplings, this creates a series of intervals where the vehicle was either stopped or was in motion.

Our data sample was found to contain such sequences for a total of 624 vehicles sampled that month using the satellite tracking system.

Following is a sample of the raw vehicle position sequence of satellite information for one of the vehicles, identified as unit ID 63516. Note this information was provided from the satellite tracking contractor on an anonymous basis. Vehicles sampled are identified to us only with a unit number used for connecting travel sequences together.

| BCVID | BCDATE | BCTIME | BCLATD | BCLATM | BCLATS | BCLATH | BCLOND | BCLONM | BCLONS | BCLONH |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000063516 | 20080807 | 161640 | 50 | 39 | 50 | N | -120 | 23 | 46 | W |
| 0000063516 | 20080807 | 162503 | 50 | 39 | 50 | N | -120 | 24 | 4 | W |
| 0000063516 | 20080807 | 163241 | 50 | 39 | 50 | N | -120 | 24 | 19 | W |
| 0000063516 | 20080808 | 184105 | 50 | 39 | 50 | N | -120 | 24 | 15 | W |
| 0000063516 | 20080808 | 214531 | 50 | 39 | 50 | N | -120 | 24 | 14 | W |
| 0000063516 | 20080808 | 220141 | 50 | 42 | 50 | N | -120 | 19 | 48 | W |
| 0000063516 | 20080809 | 000442 | 50 | 42 | 50 | N | -120 | 19 | 48 | W |
| 0000063516 | 20080809 | 011809 | 50 | 42 | 50 | N | -120 | 19 | 48 | W |
| 0000063516 | 20080809 | 023140 | 50 | 42 | 50 | N | -120 | 19 | 48 | W |
| 0000063516 | 20080809 | 034507 | 50 | 42 | 50 | N | -120 | 19 | 48 | W |

In the above sequence, unit 63516 has been logged in 10 positional samplings. For each sampling we know the latitude and longitude (in hours, minutes, seconds) as well as the date and time (GMT) as (hours, minutes, seconds). The raw dataset follows the convention that West longitude is a minus and North latitude is a plus sign.

Time intervals between samplings can be directly estimated from the raw data file for every interval. In order to estimate the driven distance, the positional latitude-longitude information was converted to a format compatible with PC*Miler[4]. This permitted calculating road distance for the intervals in Excel using the PC*Miler distance add-in feature for batch distance inquires. For this purpose, the PC*Miler option for assignment discipline was set to select shortest travel distances.

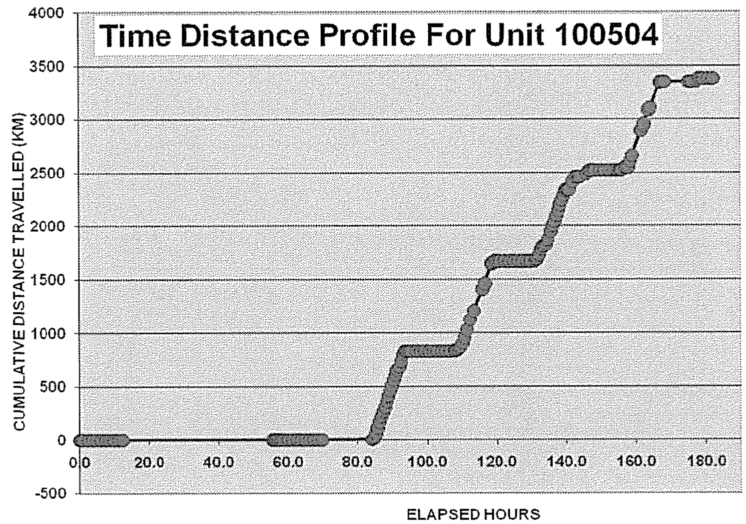
Using PC*Miler for such estimates is more likely to reflect actual truck travel rather than using the formula for direct straight line point to point distances based on latitudes and longitudes. Because we chose a "shortest distance" discipline versus "practical routing", our evaluated travel distances may be somewhat understated in comparison to the actual route followed by the trucks. However, as the sampling intervals are usually of less than one hour, or are for one hour, chances are that the PC*Miler indicated travel distance from one sampling point to the next is very close to what a driver will have actually chosen. A possible follow up activity to this research would be to run the investigations again using practical routing and to compare the results from both disciplines.

By these means, the sequence of samplings permitted time versus distance estimates to be developed for every vehicle sampled. Following Exhibit 1 shows one way of viewing this information, graphically, showing time versus distance for a single truck.

While creating graphs like Exhibit I helps to illustrate and understand the type of data we have in hand, it is not particularly helpful for generalized analysis of the many trucks, operating over varied routes and with different operator habits and schedules that are reflected in the data. It is also time consuming. If we are to make effective use of the large samplings of data available, our ultimate research objective must be aimed toward a more automated analysis of the data.

A finding that does emerge from having created a small sample of such time distance profiles is that any given stopped or moving segment is often composed of more than one of the sampling intervals. Thus, we see that for the first 84 sampled hours, the vehicle did not move. During this time period, the position and timestamp was polled several times.

**EXHIBIT 1**




At time = 84 hours, the vehicle is seen to move. The upward graph slope is a moving segment with an over-all average travel speed of approximately 83 km/hour. This activity lasts approximately 10 hours. Cumulatively, in the driving segments sampled between 84 hours and 94 hours, the vehicle travels almost 830 km. Inspecting the data records representing the underlying point data, which the graph does not readily portray, one finds that the vehicle was continuously in motion, with a series of sample segments travelled at speeds that averaged between 46 km/hour and 106 km/hour and no "stopped segments" in that 10 hour interval.

The foregoing detailed representation of travel behavior, and how it can be graphically inspected using the satellite records, becomes cumbersome and time consuming when one considers that a one month sample of raw data consisted of 160,000 individual samplings of truck location and time.

To overcome these difficulties, and to aid in addressing our study objectives, an algorithm was created that sequentially reviewed all of the sampled time segments for vehicles and combined them into fewer segments where successive segments were of the same type (either moving or stationary). In this way, for example, a series of 5 successive samplings, all in the same location, can be combined into a single longer "stopped segment" for a particular vehicle where the pertinent measures were the beginning and ending times of the first and last segments respectively and total distance travelled is zero since they all share the same location coordinates.

Successive moving segments, likewise may be combined as a single moving (driving) segment, with similar treatment of start and finish time while the over-all driven distance reflects the sum of the PC*Miler determined distances for each of the smaller prior segments.

In this way, the sampling identifies periods of "continuous driving" and has these in series with the stopped segments. Whenever a sequence encounters any two successive points in the same location, this indicates that a stop has occurred, ending the prior driving segment. If the sampling only has one stop interval before the vehicle position begins to again change, it still represents a short stop that has interrupting the "driving" activity. This may reflect a driver making a short coffee stop, a tire check or a brake inspection, for example.

By a combining methodology that reflects the approach described above, our algorithm reduced the 160,000 raw sampling segments to about 46,000 sequential activity segments (activity, in this case being either "driving" or "stopped").

This reduced dataset was then used to directly portray samples of total time and distance travelled by a truck in a single driving session, which may be relevant to considering driver fatigue. It can also be used to determine for how long and when (during the day) the vehicle is stopped. Again, we recognize that not all stopped time is off duty, so the satellite system is limited for exploring these aspects of driver fatigue and hours of service compliance.

As the algorithm for creating stopped and driving intervals was being developed, a need presented to add a third type of segment to our previously discussed moving and stationary segments. These time segments represent sampling gaps that showed up in the raw sample of information.

Referring back to Exhibit 1, note there is an apparent 42 hour gap between time = 16 hours and time = 58 hours when there are no apparent satellite samplings of the vehicle location and time. A second shorter gap occurs between time = 70 hours and time = 84 hours. Since the position did not change, it is probably safe to conclude that the vehicle was at these times stationary. However, sometimes in the database, we found that vehicles had moved somewhat during the gap periods. This was not investigated in detail as we were generally not profiling the gap data with respect to location for the early analysis phase and attributed the slight change possibly to position sampling error in the tracking system. The satellite supplier had indicated positions have a tolerance of 300 meters, for example, using their technology.

In reducing our test data, we found approximately 900 gap segments and also became aware of other time periods at either the beginning, or end of sampling of a particular vehicle, when no satellite data was collected. The latter, for example, would be the case where a sampled vehicle did not show up until August 12$^{th}$, for example, even though it is subsequently sampled through August 31.

One can only speculate as to the actual cause for the various sampling gaps. Some plausible explanations are:

- A gap may be caused by the truck being "out of service" with satellite sampling turned off or by the satellite system on the vehicle not functioning for a period. For the gaps discussed in Exhibit 1, for example, the time period in question is during the first weekend in August which is a BC holiday weekend.

- Another cause for a sampling gap in the set is the situation where a vehicle travels outside of British Columbia for some of the 31 days in August. Our satellite data supplier had indicated they would include itinerant truckers in the sampling, but only the BC segments of their movement. Such data is useful for the original data purpose as many of the provincial links of interest in the speed study are the international and transprovincial highway linkages such as the Trans Canada Highway, Pacific Highway or Yellow head Route.

As such partially sampled truck activity may still pertain to our study purpose (for example measuring the average length of "driving segments" and for reviewing stopped time intervals), it may be useful. But, care must be exercised when considering the intervals just before and after each "gap" as samples for trucks having information gaps may distort over-all estimation of kilometers travelled and hours worked by trucks monthly unless we take account of the reduced sampling time.

Also to extent transient interprovincial trucks may also cover the BC portion of their trip in less than a 24 hour day, such data could also introduce distortion when trying to factor information to account for total hours driven or kilometers travelled per 24 hour day from the data. This is because we are missing the portions of that workday that occurred outside of the province.

Because of these concerns, in our preliminary analysis, we discarded all the records for those trucks where gap time exceeded 10% of total sampled time and where sampled time was less than 2 full days. After this filter was applied, approximately 1/3 of our samplings were discarded and the resulting data set for analysis consisted of records from 277 of the originally sampled 624 trucks.

An area still for future analysis can be to take account of the original segment locational parameters. For example, one might compare the locations and links for the province's ports of entry to the location where the vehicle was last sampled prior to a gap and also to where sampling was resumed after the gap period. Such analysis might give us the flexibility to at least include many of these vehicle driving and stop segments, for fatigue evaluation. However, such an approach would still preclude using their data for per truck day or for monthly total activity estimates when we only have partial activity within the province.

For this preliminary paper, we have not attempted to analyze the gaps in sampling, but have instead focused on the identified driving and stationary segments for our reduced sample of 277 trucks where gaps did not appear to be able to significantly distort our statistical measures.

## Preliminary Findings From Our Sample Investigations

Firstly looking at driving segments, following Exhibits 2 and 3 show that the average driving segment was 2.91 hours in duration and was a distance of 157.8 kilometers. Statistically, both exhibits are skewed right, with averages significantly exceeding the median values. An interesting but strange finding, in the sample, is that approximately 4% of driving segments exceeded 10 hours without stopping and 1% of segments exceeded 575 km in total travel.

For this same sample of driving segments, speeds averaged 53.7 km per hour with a standard deviation of 31 km per hour as shown in Exhibit 4. In this case, the median speed was determined at 55.1 km per hour.

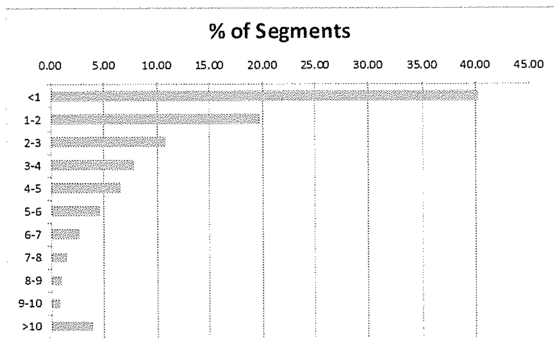
Notice also that Exhibit 4 seems to indicate two speed regions overlapping. We see two local peaks. One is at the speed interval between 20 and 30 km per hour and the second between 70 and 80 km per hour. What may be happening here is that our sample has a

## EXHIBIT 2

### Driving Segment Length in Hours

MEAN 2.91 MEDIAN 1.38
STDV 5.47 COUNT 13787

| Range | % of Segments |
|---|---|
| <1 | 40.29 |
| 1-2 | 19.75 |
| 2-3 | 10.86 |
| 3-4 | 7.90 |
| 4-5 | 6.52 |
| 5-6 | 4.65 |
| 6-7 | 2.68 |
| 7-8 | 1.48 |
| 8-9 | 1.04 |
| 9-10 | 0.86 |
| >10 | 3.97 |

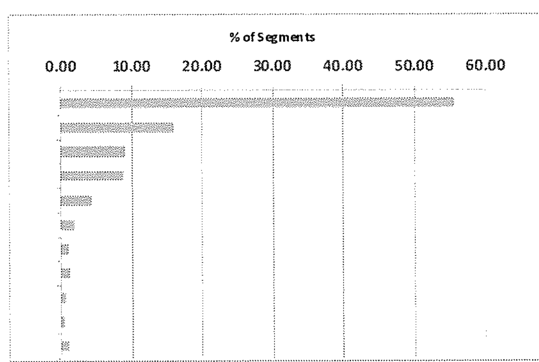



## EXHIBIT 3

### Driving Segment Length in Kilometers

MEAN 157.77 MEDIAN 74.10
STDV 209.82 COUNT 13787

| Range | % |
|---|---|
| <100 | 55.62 |
| 100-200 | 16.00 |
| 200-300 | 9.09 |
| 300-400 | 8.75 |
| 400-500 | 4.48 |
| 500-600 | 1.93 |
| 600-700 | 1.07 |
| 700-800 | 1.27 |
| 800-900 | 0.54 |
| 900-1000 | 0.31 |
| >1000 | 0.94 |

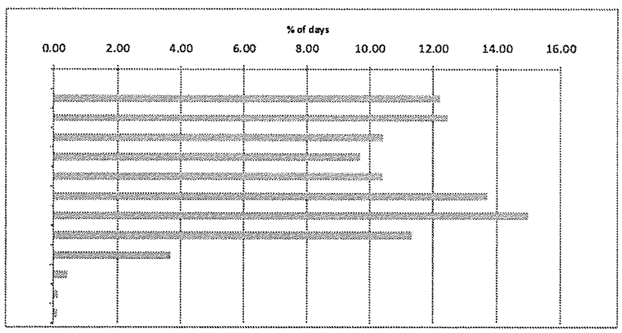


## EXHIBIT 4

**Driving Segment Average Speed (km/hour)**

MEAN 53.69 MEDIAN 55.13
STDV 30.92 COUNT 13787

| Range | % |
|---|---|
| <10 | 0.00 |
| 10-20 | 12.22 |
| 20-30 | 12.47 |
| 30-40 | 10.44 |
| 40-50 | 9.70 |
| 50-60 | 10.41 |
| 60-70 | 13.70 |
| 70-80 | 14.97 |
| 80-90 | 11.32 |
| 90-100 | 3.68 |
| 100-110 | 0.45 |
| 110-120 | 0.13 |
| >120 | 0.12 |




large number of predominantly urban travel segments at the slower operating speeds as well as a significant population of mostly rural driving segments that permit a higher travel speed.

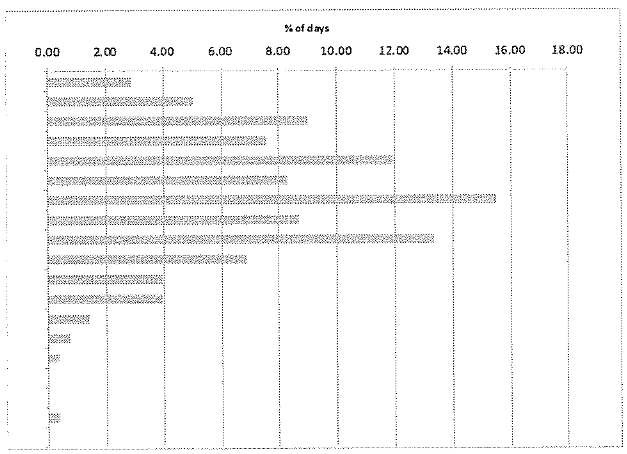
Now considering driving activity per day, per truck, Exhibits 5 and 6 point to a mean driving time per day of 6.3 hours and a mean distance travelled per 24 hour sampling period of 351 kilometers. Comparing this amount of driving to NSC[9] Hours of Service limits of 13 hours driving per day, we note that only 1.5% of the sample appear to exceed the daily regulatory restriction for driving.

# EXHIBIT 5

## Hours Driven Per Day Per Truck

MEAN 6.29 MEDIAN 6.44
STDV 3.07 COUNT 277

| Range | % |
|---|---|
| <1 | 2.89 |
| 1-2 | 5.05 |
| 2-3 | 9.03 |
| 3-4 | 7.58 |
| 4-5 | 11.91 |
| 5-6 | 8.30 |
| 6-7 | 15.52 |
| 7-8 | 8.66 |
| 8-9 | 13.36 |
| 9-10 | 6.86 |
| 10-11 | 3.97 |
| 11-12 | 3.97 |
| 12-13 | 1.44 |
| 13-14 | 0.72 |
| 14-15 | 0.36 |
| 15-16 | 0.00 |
| 16-17 | 0.00 |
| 17-18 | 0.36 |
| >18 | 0.00 |

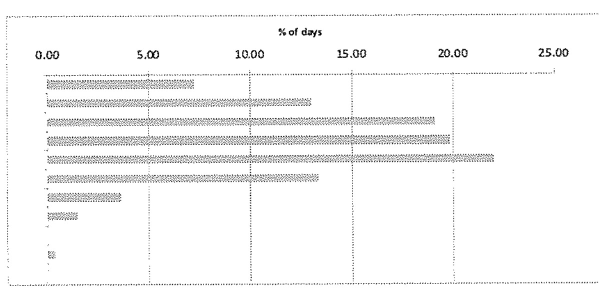



# EXHIBIT 6

## Kilometers Driven Per Day Per Truck

MEAN 350.78 MEDIAN 358.27
STDV 166.89 COUNT 277

| Range | % |
|---|---|
| <100 | 7.22 |
| 100-200 | 13.00 |
| 200-300 | 19.13 |
| 300-400 | 19.86 |
| 400-500 | 22.02 |
| 500-600 | 13.36 |
| 600-700 | 3.61 |
| 700-800 | 1.44 |
| 800-900 | 0.00 |
| 900-1000 | 0.36 |
| >1000 | 0.00 |



## GENERAL CONCLUSIONS

Over-all, satellite tracking has been shown to have some encouraging possibilities for investigating driving behavior and productivity as it relates to distance travelled daily, by trucks.

## LIMITATIONS

Our findings from this study are interesting, but still are preliminary.

The average speed of only 54 km per hour and the median segment length of only 78 km suggest that the analysis may benefit from "geo sorting" the data to separate travel near urban areas (essentially the lower mainland of BC) from driving segments occurring in more rural settings where trip distances will be larger and travel speeds higher because of reduced traffic and access to longer stretches of open road.

Patterns for trucks having significant gaps need to be reviewed in more detail. There may be an opportunity to identify gaps that occur from vehicles moving outside of the province versus those actually going out of service.

We have not explored whether there is bias in those types of trucking firms that employ satellite tracking when compared to the general population of trucks.

We also have not investigated whether drivers significantly alter their behavior when they are driving satellite tracking equipped vehicles versus how they would drive otherwise.

## REFERENCES


1. Ash and Conquist, "Satellite Tracking to Sample Route Travel Speeds of Class 8 Highway Trucks in British Columbia", CTRF Proceedings 2006.

2. http://www.shawtracking.ca/, Internet, Feb 2009.

3. Commercial Vehicle Driver Hours of Service Regulations, http://www.tc.gc.ca/RoadSafety/SafeDrivers/CommercialDrivers/HoursofService/index.htm, Internet, Feb 2009.

4. ALK Technologies Software, http://www.alk.com/pcmiler/pcmiler.asp, Internet, Feb 2009