SIMULATING IMPACTS OF CRITICAL TRANSPORTATION INFRASTRUCTURE DISRUPTIONS USING OPEN-SOURCE DATA: RECREATING AND UNDERSTANDING A HIGH-PROFILE HIGHWAY DISRUPTION IN NB

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Introduction

Transportation and public safety agencies are continuing to adapt to the risk of catastrophic disruptions to critical transportation infrastructure and the resulting impacts on economies and supply chains. In addition to understanding this risk, there is the need for agencies to understand the mechanisms of disruptions at a micro-level to help them tailor their local response to the disruption. This can assist in quantifying the second and third order effects of the disruption on the broader economy. The Critical Infrastructure Branch of the New Brunswick Department of Public Safety (NBDPS) contracted researchers at the University of New Brunswick (UNB) to develop three "worst-reasonable case scenarios" for disruptions to critical transportation infrastructure in New Brunswick, then to quantify the impacts of the disruptions.

This paper is a detailed version of a summary paper on one "worst-reasonable case scenario" originally published in November, 2014, in Carleton University's *Infrastructure Risk Reporter*. This paper profiles the detailed approach, scenario development and simulation methodology, analysis and results to study the potential effects of a four-day independent truckers strike on the import and export of food, fuel, and other goods via the Trans-Canada Highway (TCH) at St-Jacques, New Brunswick, near the Quebec border. The project goal was to develop a better understanding of the significance of this route to the New Brunswick and regional economy and its sensitivity to disruption. The goal of this paper is to highlight how a simulation approach developed from open source (public or non-confidential) data can provide considerable insight into how a localized event can manifest itself to exploit a regional vulnerability.

Background

From September 6 – 8, 2005, independent truckers in New Brunswick undertook a wildcat strike in response to high fuel prices. According to media reports [1-3] the strike began on the TCH at St-Jacques, NB near the border with Quebec, but also spread to 10 locations throughout NB. The St-Jacques strike was estimated to have been the largest, with approximately 300-500 trucks participating for up to three days by parking their trucks on the side of the highway. Queues on the highway at the protest site were reportedly up to 15 km in length. The media reported localized shortages of fresh produce, perishable goods, and fuel, with some reports of people near Edmundston, NB travelling to Maine to do their shopping [4]. Several large local companies dependent on trucking shipments reported that their products were being blocked from delivery [5] and that they could be faced with layoffs, or even closure, should the protest be prolonged.

The same media reports from 2005 described the details of the operational elements of the three-day strike:

- A protest site was established at a specific point on the TCH;
- Protestors would stop a commercial vehicle, ask them to sign a petition, and invite them to participate in the strike;
- Trucks not participating could leave the site immediately;
- Participating trucks would park on the side of the highway;

- Although passenger cars were waved through the protest site, most were caught in the truck queue and had to wait; emergency vehicles were not subject to queues;
- The protest disrupted vehicle traffic flows in both directions.

The strike highlighted three key vulnerabilities. First, there are no convenient all-weather parallel routes for trucks at this key Provincial entry point location. Second, the local and regional economy appears highly dependent on this segment of the TCH trade corridor for the movement of food and goods. Third, protestors deliberately chose this location because of the bottleneck it would create.

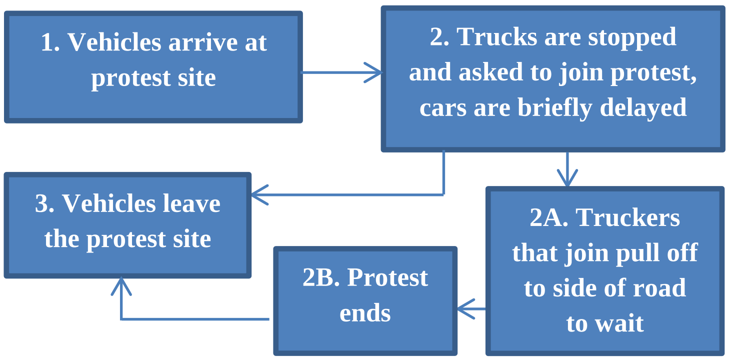
Though there was a general recognition at the time that this disruption had a widespread impact, the repercussions were not well understood: How much and what types of cargo were detained? What would be the impact if this were to happen again and could it be mitigated with a better understanding of the mechanisms of the disruption? Answering these questions required data and analytical approaches typically employed in transportation engineering to manage traffic and infrastructure. A microsimulation approach was chosen to model each operational element of the disruption, with parameters adjusted to explore a worst-reasonable case scenario.

Methodology

Developing a worst-reasonable case scenario requires each element of the possible disruption to be explored and evaluated in terms of whether the scenario is possible or would result in alternative actions that would limit the impact of the disruptions. A worst-reasonable case scenario was sought that would involve some type of prolonged disruption of the TCH at St-Jacques, yet not result in a complete diversion of commercial traffic to other less convenient routes or result in trucking companies holding back trucks at the distribution centres to protect perishable goods. An independent truckers strike similar in breadth and scope of the 2005 disruption was considered to be a worst-reasonable case scenario since:

- It had historical precedence and apparent widespread impact;
- Traffic was permitted to flow through the area, albeit delayed, meaning there would be little reason to hold back trucks at distribution centres or divert them to other routes;
- Delay encountered by passenger vehicles and non-participating trucks at the protest location would be less than the delay incurred by taking alternate routes, leading to normal traffic volumes approaching this location;
- No single point of disruption rather the collective action of hundreds of independent operators, each of whom had the choice to participate or not;
- The end time to the disruption was not predetermined.

A four-day disruption period was assumed to be a worst-reasonable case scenario to magnify the impacts of the original three-day strike. While other independent trucker strikes have lasted longer, such as a month-long strike at a port in British Columbia in 2005 [6], this strike was an illegal disruption of the highway network rather than job action on private property. An illegal blockade of a public highway of known critical importance to interprovincial trade likely would quickly elicit an enforcement and political response. Other factors that would likely limit strike duration include: lack of washrooms, food and other facilities; the lack of alternative income for the truckers. The media reports were unclear about duration of the blockade itself. Given the high-speed nature of the roadway, the disruption was assumed to have occurred during daylight hours to ensure the conspicuity and safety of the protestors and traffic. A 12-hour disruption (8am – 8pm) was assumed, and 2012 traffic volumes were used. The following diagram represents the high-level simulation logic describing the roadside disruption worst-reasonable case scenario:



Each module in this model needs to be programmed into the simulation software, including all data needs, estimates and assumptions. **Table 1** shows the data needs and their sources.

Table 1: Data Requirements, Sources and Value for Analysis

Data need	Source
Protest parameters	Online media reports
Traffic volumes and arrival times	NBDTI (NB Dept. of Transportation and Infrastructure)
Truck counts & classification	
Empty truck weights by class	
Truck cargo	Video, company websites, USDOT border data
% of trucking fleet as independent	Transport Canada data
Vehicle delay and processing times, Hours of protest, Participation by independent truckers, disruption, % truck loaded (kg)	Assumed parameters varied to match known outputs

Analysis tools:

Simulation permits the generation and processing of traffic subject to probability distributions associated with each component of the protest. ARENA by Rockwell Automation was selected as the simulation software following a pilot test. Data from the simulation was then exported to MS Excel for further analysis. Analysis with ARENA was guided by "Simulation with Arena" [7].

Data summary:

Data on interprovincial truck cargo is limited and may only be reported in aggregate form, restricting the usefulness of the data for a local study based on a short-term disruption. Given that straight trucks and transport trailers are typically designed specifically for a particular commodity or cargo, a video log was used to classify truck traffic manually. Trailer types were tallied and classified by axle counts and configuration as per the NBDTI truck classification scheme (Classes 5 – 19). The NBDTI traffic data were explored to identify the busiest time and day of week to collect truck cargo data at the location, which appeared to be a Wednesday between 10 am and 2 pm. Truck cargo data were collected through a four-hour video log survey of the TCH at St-Jacques which also included a roadside tally of passing trucks (433 trucks were observed). This was refined through the review of the video log, from which attribute information such as company name, trailer type, cargo type and vehicle class were obtained through manual transcription and analysis. Local data on the distribution of private carriers and owner-operators (independent truckers) at the St-Jacques location could not be determined from the video data; therefore the national value reported by Transport Canada [9] (17% of the truck fleet) was used.

It was not possible to identify empty trucks with any degree of precision from the portable weigh-in-motion (WIM) device at the location. NBDTI was able to provide empty weights on 64 vehicles from 2 – 8 axles with varying trailer configurations collected by NBDPS during routine safety checks of trucks crossing the permanent weigh scales. These vehicles were organized into vehicle classes as per NBDTI classification with an average gross vehicle weight calculated for each class. Maximum gross vehicle weights were taken from the NBDTI truck class information sheet, with the difference between the two values representing maximum payload.

Table 2: Estimated payload from estimated empty weights

No. of axles	NBDTI Class	Empty (kg)	Max GVW (kg)	Est. max payload (kg)
2	5	7200	14600	7400
3	6	11900	26000	14100
4	8	16600	32600	16000
5	9	20300	41500	21200
6	10	17800	49500	31700
8	15	15900	62500	46600
7	19	22100	51500	29400

These values were compared to gross vehicle weight data collected from the unadjusted NBDTI traffic counters and portable WIM. In some cases (as for the Class 5 and 6 vehicles), the recorded average weight by the portable WIM was less than the average empty weight recorded by NBDPS, suggesting some misclassified records. The larger and heavier vehicles (Class 9, 10 and above) seemed to have more realistic weights. The observations for the lower classes introduce doubt into the reliability of the percentage loaded estimates; however, assuming that the error is equally distributed among all observations, it appears that gross vehicle weights eastbound to New Brunswick are approximately 9% higher than vehicles leaving New Brunswick. Given the lack of comparable loading data, eastbound vehicles were assumed to be 50% loaded while westbound vehicles were assumed to be 45% loaded, corresponding with the approximately 9% difference (rounded to 10%) in average gross vehicle weight by direction. Cargo was broadly classified into 12 categories corresponding to the most detailed cargo assignment possible given a visual review of the data. For example, any truck with a refrigerated unit was classified under “perishable goods”, though the goods could be vegetables, fruit or milk. In 25% of cases it was possible to identify the specific commodity by the labelling on the side of the truck or by an internet search of the company name.

The video data were used to identify the number of axles for each truck observed in the sample, then organized into NBDTI classes. This information was combined with cargo information to create a matrix to develop a percentage breakdown by truck class and cargo type. For example, 100% of the trucks carrying automobiles for retail were a Class 9, while 36% of the trucks carrying bulk liquids were a Class 10. This information was calculated for both directions separately and formed the basis for the simulation values. A comparison of the four-hour sample to four days of NBDTI data suggest that the sample underrepresents information on less frequently observed truck classes, though this is in the conservative direction (providing a higher estimate of cargo weight in the protest).

Developing assumed parameters for simulation:
Arrival time information was available from NBDTI traffic data, but processing time by the protestors was not known. A number of initial assumptions were made and varied to explore their sensitivity in the simulation model:

- Protestors process one vehicle at a time in each direction
- Processing did not change in response to growing queues
- Automobiles would be subject to a constant 5 second delay, emergency vehicles waved through
- Trucks would be delayed for 30 s +/- 10 s to 60 s+/- 10 s triangularly distributed to determine sensitivity to delay
- Only 50%-75% independent truckers would strike
- Accumulation of trucks at the roadside protest was proportional to the vehicle arrivals
- Roadside protest queuing was First in, Last out

- Cargo and truck class distribution of all arriving and striking trucks did not change on a daily basis
- Trucks were 23 m long, other vehicles 5 m, spacing 2 m

Simulation development:
Six simulations were undertaken involving varying delay times, protest times and trucker participation one parameter at a time. Five replications were run for each simulation, with results averaged for all five replications. The simulation produced traffic counts nearly identical to the NBDTI data (within 1%), indicating that the simulation values appeared to be valid. The truck class inputs from the four-hour count were similar to the truck output from the model. The model slightly overrepresented the largest trucks compared to the inputs, but this appeared to be in the conservative direction. Overall the distribution of the outputs generally followed the same distribution of the input values.

The only source for independent trucker behaviour during the 2005 disruption was the media reports that anecdotally described the number of participating vehicles and the queue lengths. These values were used as a benchmark to validate the assumptions. The media reported 500 trucks at the roadside and queue lengths of up to 15 km for a three-day event. Variables were adjusted from initial assumptions until conditions were observed that appeared consistent with media reports and extension to four day event.

Modelling results and analysis

The model parameters used for the queuing analysis and cargo estimation were: traffic counts for Tuesday-Friday in August 2012; protest running from 8 am – 8 pm, trucks and cars delayed 60s +/- 10s 5s, respectively; and 12.75% of all trucks choosing to participate in the roadside protest. These parameters produced values most consistent with the media reports: 536 trucks in the roadside protest, and single file queue lengths of 10.2 km and 13.1 km in each direction, respectively.

Highway queuing at protest location by day and time:

The data in Figure 1 highlights how delay caused by protestors translates into extended queue lengths on the highway in both directions. In both cases, the average queue length peaks at 8 pm or shortly before, with Wednesday having the longest queues eastbound and Friday having the longest queues westbound. The sharp drop off after 8 pm is a function of the simulation which terminates the protest by 8 pm. In reality, additional time would be needed to clear the queue and it would not empty instantaneously. These simulations were also run for 24 hours (instead of 8 am – 8 pm only) to explore this phenomena and the 8 pm peaks were evident there as well.

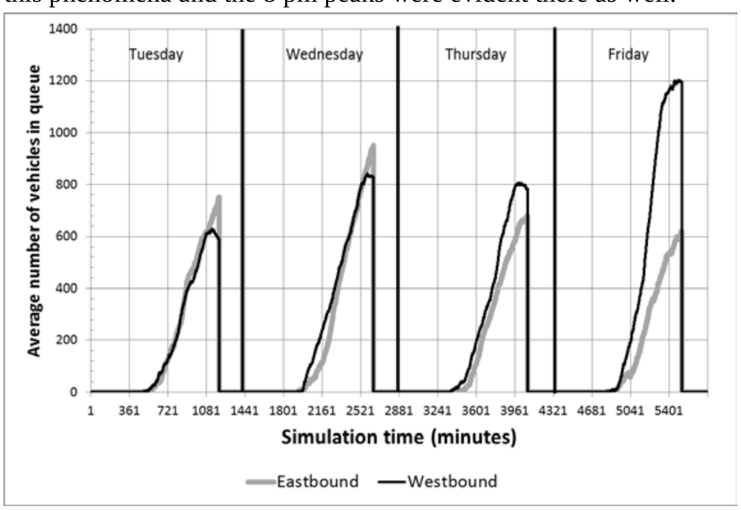


Figure 1 - Highway queuing by direction, time of day/day of week

Cargo composition of the protesting trucks:

While the cargo composition between the two directions is slightly different, in both cases the simulation indicates that general freight, perishable goods, construction material and raw materials form the bulk of the transported goods. Figure 2 provides an estimate of the amount of cargo housed within the trucks during the roadside protests assuming 50% loading eastbound and 45% loading westbound.

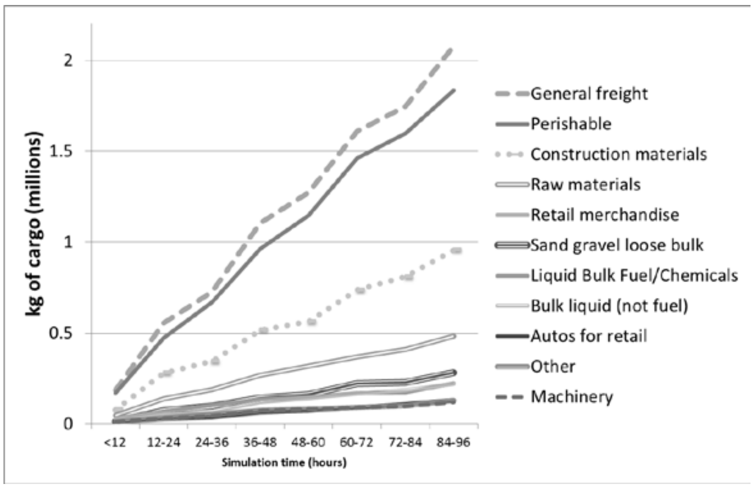


Figure 2 - Estimated cargo in protesting trucks by time

Note that it should be possible to estimate a dollar value for each commodity to determine the overall value of cargo (and potentially the value of spoiled perishable goods); however, this was beyond the scope of this report.

Queuing delay costs:
Time delay costs (*i.e.*, lost driver and equipment time) can be expressed on a per hour basis by vehicle and trip type and by jurisdiction. A detailed economic analysis was beyond the scope of this report; however conservative estimates of $15/hr for Class 1 – 4 vehicles (passenger cars, motorcycles, *etc*.) and $65/hr for Class 5 + vehicles (trucks of all axle configurations) were developed from

online sources [10] [11] and used to estimate delay costs from the protest and are presented for illustrative purposes only. After 96 hours, the cumulative delay cost was estimated at $785,000.

Discussion of limitations and caveats:

This report was based on a simulation of real events based on real traffic data; however, readers of the paper should be cautious about drawing concrete conclusions from the simulation and its data. The simulation was based on a set of assumed parameters and circumstances. While practical efforts were made to ensure logical assumptions regarding arrival and processing times, the protest simulation logic, protestor behaviour and trucker participation rates, there may be errors in these assumptions as there was no direct measurement of disruption parameters at the time. There is also the possibility of transcription and classification errors when transcribing information manually from the video log. Nevertheless, verified and validated model outputs provided results consistent with anecdotal observations at the time of the original disruption.

It should be noted that due to time and financial constraints, the video log of truck traffic at the St-Jacques protest location was limited to four hours. A review of the video data against traffic counts suggest some truck classifications have been underrepresented. A longer video log, including a sampling plan, could improve the representativeness of the data for future research efforts. It should also be noted that it was not possible to know how much each truck was loaded, though weigh-in-motion data at St-Jacques suggested that average gross vehicle weight was 9% higher eastbound than westbound. Determining cargo capacities with greater precision remains a research need.

Conclusions and recommendations

A simulation model was successfully prepared and run for a four-day disruption of traffic at St-Jacques, New Brunswick near the Quebec border between August 21 and 24, 2012. It involved the use of open source data from NBDTI, as well as a video log of traffic at the location. Data from the model output appears to be consistent with the anecdotal observations of a similar disruption in 2005 had they been extrapolated to a four-day strike and 2012 traffic volumes.

This simulation presents a learning opportunity for agencies looking to better understand similar disruptions. For example, it seemed the main goal of the protestors was to draw government attention and earn public sympathy for their situation. They appeared to structure their protest in a way that they hoped would have accomplished this (*i.e.*, waving through cars and delaying only commercial vehicles to invite them to join the protest), but the tactics resulted in considerable queuing and highway delay of all vehicle types. The simulation data suggests that trucks were delayed approximately 1 minute in order to achieve the queue lengths reported in the media. If an agency is monitoring a similar situation, they should monitor the delay activities of the protest as the effects of the delay (such as queuing) can be compounded with the normal daily variations of traffic patterns and the effects may not be fully evident if started at an off-peak time.

It is likely that the vulnerabilities of the transportation network were already known to those looking to exploit them, though it is possible they may only have known that their actions will cause a disruption, not necessarily the detailed impacts of that disruption. With the knowledge that approximately 2 million kg of perishable goods could be delayed or lost in a similar disruption, authorities may not permit the disruption to extend multiple days. A better understanding of the impacts of supply chain disruptions, both from a spatial and temporal perspective, may influence the enforcement response to this disruption and contribute to the development of contingency plans.

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