Service Time Variability at Blaine, Washington, Border Crossing and Impact on Regional Supply Chains

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Variable service times at vehicle processing facilities (borders, weigh stations, landside marine port gates) cause transportation planning challenges for companies that regularly visit them. Companies must either build more time into their schedules than is necessary, and therefore underutilize their equipment, or risk missing delivery windows or exceeding hours of service regulations, actions that can result in fines, lost business opportunities, or other logistical costs. Border crossing times are examined at Blaine, Washington, between Whatcom County, Washington, and the Lower Mainland of British Columbia, Canada, to assess the variability in crossing times at this border crossing and the impact of this variability on regional supply chains. Variability data collected for bidirectional trade are presented. Directional, daily, hourly, and seasonal variations are examined, and interviews are conducted with regional carriers to better understand the current response to variability, the benefit of a reduction in variability, and how that is related to the goods moved or to other business operating characteristics. This paper describes the level of variability in border crossing times and carriers' responses to this variability and shows that the primary strategy used, increasing buffer times, reduces carrier productivity. However, this cost is negligible because of the current nature of the industry.

One of the most significant logistical challenges is planning for uncertainty in travel time. Late arrivals can have significant economic costs for factories waiting for parts to assemble and for carriers who miss delivery times for those that face hours of service constraints. This makes reliability one of the single most important performance measures from a private-sector perspective (*1*). Uncertainty in travel times is caused by many factors, including mechanical failures, weather, documentation delays, and traffic incidents, but also by predictable traffic congestion when demand for the transportation service is greater than the supply of that service. This occurs on roadways, as well as at ports and borders. When the transportation system becomes unreliable, freight-related businesses and their customers are affected in several ways. First, freight assets such as trucks and drivers become less productive. Second, businesses put more trucks on the road to meet their customers' needs. Third, costs associated with holding inventory increase. The extent to which reliability affects the freight transportation system depends on how freight forwarders respond. For example, those with very low risk tolerance are more significantly affected because they need to plan for the longest travel times, but those more accepting of a late delivery or who have more flexibility in staffing see a smaller impact. Understanding the variability in border crossing times, and its cost to freight forwarders, is essential to matching infrastructure supply with demand, assessing potential operational strategies, and prioritizing investments, and is the subject of this study. The term "crossing time" is used to indicate the sum of time spent waiting and being processed when crossing the border.

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BACKGROUND

The United States and Canada are each other's biggest trading partners. The value of trade between the two is the largest between any two countries worldwide. For the United States, trade with Canada is larger than the combined trade with all countries in the European Union (*2*). The volume of freight moved by the U.S. transportation system has grown dramatically in recent decades and is projected to increase nearly 50% between 2005 and 2020 (*2*, *3*). Supply chains in many manufacturing sectors span this border daily, and bilateral trade agreements between the two countries made a point of reducing tariff barriers. The border crossing at Blaine, Washington, is the main commercial crossing between Whatcom County, Washington, and the Lower Mainland of British Columbia, Canada. It is the fourth busiest commercial crossing on the U.S.–Canadian border (*4*) and the most significant commercial crossing for the western part of the United States and Canada. The crossing is approximately 100 mi north of Seattle and 30 mi south of Vancouver, British Columbia, on Washington State Route 543 and British Columbia Provincial Highway 15. The Blaine crossing, as well as many others, is congested during peak periods. Transit times can be long and unpredictable (*5*, *6*).

International border delay is perceived as a major problem. The province of Ontario, Canada, has carried out a significant amount of work in an attempt to quantify the impact of border delay on its economy (*7*). Ontario and the states surrounding the Great Lakes area have formed a regionally integrated economy that is very dependent on the ability to move goods efficiently across the border. With future trade expected to grow by 180% by 2015, without investments and improvements in cross-border trade, Ontario will most likely "suffer tremendous economic and social costs." Because of this, Ontario has deemed it important that its border remain free from delays (*5*).

During the past 10 years, many factors have influenced the level of trade and crossing times between the United States and Canada. Examples include policies and programs such as the Advanced Electronic Presentation of Cargo Information under the U.S. Trade Act, Customs–Trade Partnership Against Terrorism, Free and Secure Trade (FAST), and U.S. Food and Drug Administration prior notice arrival. The terrorist attacks of September 11, 2001, caused an increased awareness of border security, and the resulting legislation has changed security processes. It has been estimated that up to 1 to 1.5 h have been added to the average freight transit border crossing time with an estimated annual cost impact of security measures on the Canadian trucking industry of between US$179 million and US$406 million (*8*). There was, however, also a drop in U.S. imports from Canada in the post-9/11 period. The magnitude of the percentage decreases are "quite large and substantially exceed the impact of security-related disruptions to trade" (*9*). At the same time, the liberalization of trade policies, such as the North American Free Trade Agreement (NAFTA), internationalization of supply chains, and changes in transportation and information technologies have contributed to an increase in freight movement. North–south traffic between the United States and Canada, fostered by NAFTA, has placed increasing demands on the domestic freight transportation system. U.S.–Canada trade has grown by 152% since 1989 (growth in commercial traffic of 122.5%) and trucks move just over 70% of the value of exports north to Canada (*6*). As a result, the nation's highway and rail networks, initially developed for the traditional east–west trade, are now strained, especially at border crossings such as those between Whatcom County and the Lower Mainland of British Columbia (see Figure 1), which includes the Blaine, Washington, crossing.

The issue of border crossing time variability is therefore very timely, and it is anticipated that the issue will become more pressing for the industry. This paper quantifies the variability in border crossing times, assessing the impact of season, day of the week, and time of day. Results of in-person qualitative interviews with carriers that frequently move goods across the border are included. Results of these interviews show that carriers use a range of strategies to reduce crossing time variability. This paper provides an assessment of the impact of border service time variability on regional supply chains and the economic consequences.

An important distinction to emphasize at the outset is one between average time to cross the U.S.–Canada border at a specific site and the variability around the average. The focus of this study is on the latter, although there is a statistical linkage between the two. As demonstrated with the empirical data, longer average crossing times are associated with greater variability. This paper draws a distinction between the two.

LITERATURE REVIEW

The study most relevant to this research is a study for the Michigan, New York State, and United States Departments of Transportation concerning the total cost of highway border crossing delays as well as related costs of maintaining a border. Unlike other studies, this study includes uncertainties in transit times when estimating the cost to U.S. and Canadian economies (*10*). However, this study did not consider the structure of supply chains or the potential for employers to change their logistics operations in response to border travel time uncertainty.

FIGURE 1 Border crossings between Whatcom County, Washington, and the Lower Mainland of British Columbia. (SOURCE: www.mapquest.com.)

Another relevant study is a recent publication from the Conference Board of Canada on the effects of post-9/11 security on cross-border trade (*11*). This study claims that although there have been increased costs for Canadian trucking companies as a result of border security, these trucking firms have largely absorbed the added costs of border delays such that there was little transfer of higher costs to companies. Hence, there have been limited economic consequences of additional delays imposed on the system by border security. The present study also found that, in effect, the existing flexibility in delivery times has mitigated the adverse economic consequences of variability to date.

There are several reports from efforts by government agencies on both sides of the border to quantify border delay. The U.S. FHWA conducted a detailed study in summer 2001 on traffic at the four major U.S.–Canada and the three major U.S.–Mexico crossings. For each location the study computed a zero congestion time for both northbound and southbound traffic crossing the border. Data used include average crossing per day, average delay per trip, and a buffer index. This study shows a direct correlation between delays and the number of customs booths open—the greater the number of booths open, the shorter the delay. The data also suggest that staffing at a number of crossings is not responsive to traffic in peak periods; however, this study does not consider the impact of variability on regional supply chains or economics (*12, 13*).

Many other studies relate peripherally to this study, but no other research was found that considered the impact of travel time variability on supply chains. Although it is not discussed here, a thorough literature review was conducted on travel time reliability, metrics for supply chain management, value of time for freight movement, reliability in freight transportation, and studies specific to border crossing.

BORDER CROSSING TIME VARIABILITY

Variability in possible outcomes is undesirable to risk-averse participants, such as those that incur significant penalties for late deliveries. In the context of uncertainties concerning border crossing conditions, participants have economic reasons to be risk averse. One reason is that the consequences of greater or lesser crossing times are likely to be asymmetrical. Specifically, delays (beyond the mean expected delay) in crossing the border are likely to have significant (adverse) economic effects, while delays that are less than the mean expected delay are unlikely to offer similarly significant economic benefits. Clearing the border in less time than expected, on average, is the equivalent of an unexpected (and temporary) increase in shipping capacity; however, it may not be possible for shippers and customers to engage in spot contracting such that indirect increases in shipping capacity can be put to use. That is, imperfectly anticipated improvements in border crossing conditions are difficult to translate into increased commercial shipments across the border and, therefore, into increased real output. Imperfectly anticipated delays in shipments that have already been contracted for, however, are the equivalent of unexpected short-term reductions in shipping capacity that will have real (adverse) consequences for the number of commercial border crossings that take place in a given period of time, as well as for the real output produced during that period of time.

The adverse economic consequences (in regard to forgone real output) associated with imperfectly anticipated border crossing delays will depend on the nature of the underlying economic transactions, among other things. For example, transactions involving perishable goods are likely to be more adversely affected by such delays than will transactions involving durable goods, because the former have higher opportunity costs of time for any given economic value of the shipments. In a related fashion, the economic consequences of unanticipated delays in border crossing times will depend on the degree of "slack" in the economy's logistical network. Slack in this context can be thought of as inventories of the products that are shipped across the border, as well as in other inputs that are used to produce border crossings in addition to time.

Inventories of the products that are shipped across the border can be drawn on in place of new shipments of those same products in the event of imperfectly anticipated delays in new product shipments. Although random draw downs of inventory create additional risk for supply chain managers, they need not result in a permanent loss of real output as long as inventory levels can be restored to their "steady states" before actual shortages in intermediate and final products emerge. Likewise, inputs such as truck drivers can be substituted for time. For example, if practical, drivers can be kept on call to undertake border crossings when imperfectly anticipated favorable crossing conditions exist to the extent that slack exists at the receiving end of the shipment, for example, unused warehouse space available to the receiver of the shipment. If the drivers would be otherwise unemployed and have relatively low opportunity costs of leisure time, they can effectively be considered a slack variable that can reduce the variability of the output elasticity of border crossings with respect to time.

The existence of slack capacity in transportation supply chains is not necessarily an indication of inefficiency. Indeed, a degree of slack is efficient much as it is efficient for individuals to purchase various types of insurance policies whose expected values (in regard to payoffs) are less than their costs to the acquirers; however, to the extent that the "optimal" level of slack capacity can be reduced by reducing the variability of border crossing times, resources can be freed to be used in other ways to increase real output. Whether it pays society to incur costs to reduce slack capacity, as well as other manifestations of variable border crossing times, ultimately depends on the seriousness of the consequences of the variability.

OTHER SOURCES OF DELAY

Although these costs are significant, it is important to put border delay into context. On a trip between Vancouver, British Columbia, and Los Angeles, California, the variability in travel time due to congestion in major cities (Vancouver; Seattle, Washington; Portland, Oregon; etc.) will overwhelm the variability due to border crossings. In addition there may be mechanical failures, road closures, or construction. Variable delays are also incurred at the origin or destination resulting from a variety of reasons.

Perceptions of delay were discussed with carriers during interviews. Recurrent delays are a source of significant frustration, whereas infrequent delays are seen as unavoidable. The perception among carriers is that border delays could be distinctly improved with changes that are perceived to be low cost to implement, such as increasing the level of staffing at key border crossings. Congestion in major cities, however, is recognized as a very difficult issue to solve.

So, for all carriers, and in particular those with origins and destinations outside the Vancouver and Seattle regions, the variability in travel times due to border delay is much less significant than the variability due to other sources, but is a source of more frustration because it is seen as easier to solve.

DATA

The U.S. border (southbound) at Blaine, Washington, operates with either two or three gates available for truck crossings, including one Free and Secure Trade (FAST) lane. The FAST lane can be used by carriers who comply with procedures outlined by the Free and Secure Trade program. Compliance with the FAST procedures offers shorter average crossing times for carriers and increased information about shipments for Customs and Border Protection (*14*). In this paper the term FAST is used to refer to a vehicle that can use the FAST lane when transiting the border (therefore carrier, driver, and owner of the goods must all be FAST approved).

Border crossing time data used in this study come from two sources: (*a*) a short duration but more detailed data collection southbound (entry into the United States) sponsored by the Whatcom County Council of Governments (referred to as WCOG data) and (*b*) a longer-duration but less-detailed collection both southbound (into the United States) and northbound (into Canada) using probe vehicles (referred to as probe vehicle data). The following is a description of the two data sets:

1. The WCOG data were collected between the hours of 8:00 a.m. and 5:00 p.m. from Monday, June 5, through Thursday, June 8, 2006. By using surveyors with personal data assistants, time stamps were collected when trucks arrived in queue, entered, and exited processing at the border. The usable data set includes 579 FAST observations covering a 3-day period (June 6 was removed because the FAST lane was opened to all traffic) and 1,480 non-FAST observations. Only southbound data are available (vehicles entering the United States).
2. The probe vehicle data were collected using a fleet of vehicles such that one vehicle crosses at Blaine, Washington, approximately every 30 min. Border crossing times both northbound and southbound were collected between August 1, 2005, and July 17, 2006 (excluding January 2006). Drivers work for a single company that moves fuel from Washington to British Columbia. Trucks cross the border northbound full and return to Washington empty. Drivers self-report arrival at the back of the queue and at the border and departure from the border. Drivers are paid by the hour regardless of whether they are waiting in a queue at the border or driving. The company and its drivers are FAST approved and use the FAST lane whenever possible. The FAST lane is available southbound only. The data set includes 5,658 observations southbound and 5,805 observations northbound.

The WCOG data do not contain data from a long enough period to consider variations across day, week, and hour, but they do contain non-FAST vehicles. The probe vehicle data contain many observations, but only for FAST vehicles (southbound). The distribution of crossing times in the two data sets is essentially equivalent, with average crossing time for FAST vehicles 22 min for the WCOG data and 23 min for the probe data. The standard deviation is 21 min in the WCOG data and 24 min for the probe data. Recall that the WCOG data represent only 3 days in June 2006 whereas the probe data represent nearly 1 year (less January) between August 2005 and July 2006. Given the FAST vehicle distributions match in the two data sets, it can reasonably be assumed that the non-FAST data for June 2006 are representative of average non-FAST crossing times. The average crossing time for southbound non-FAST vehicles is 1 h 23 min, and the standard deviation is 26 min. Although the average crossing time for southbound non-FAST vehicles is distinctly longer than for southbound FAST vehicles, the standard deviation, or level of variability, is not significantly longer.

During the 3-day period the average arrival rate per lane (southbound) for the WCOG data is the same for FAST and non-FAST (21.5 vehicles per hour), but FAST service rates are shorter (86 s compared with 119 s and 121 s for the two non-FAST lanes). This means that differences in crossing times are due to differences in service rates rather than differences in arrival rates.

STATISTICAL EXAMINATION OF THE PROBE DATA SET

Here the probe data are considered in more detail. The average crossing time across all trips (north- and southbound) is 22 min 37 s; the standard deviation is 22 min 1 s; and the 90th percentile, 47 min 5 s. The crossing time will exceed the 90th percentile only once in 10 trips and is a commonly used measure of variability in travel times.

Crossing times are more variable southbound. The standard deviation of crossing times southbound is about 23 min, and the 90th percentile value is almost 50 min, whereas northbound the standard deviation is approximately 20 min and the 90th percentile is approximately 45 min. Northbound gate staffing tends to be more demand responsive than southbound gate staffing, which can help in reducing the frequency of especially long delays. North- and southbound gates are subject to different policies with respect to freight inspections according to Canadian and U.S. customs and freight inspections, respectively. A summary of the descriptive statistics is shown in Table 1.

Figure 2 shows the average crossing time in each 1-h period. Note that each number represents a 1-h period followed by the start time designated by that number. For example, 8 means the 1-h period from 8:00 to 9:00. As expected, average crossing times tend to be higher during the morning, particularly southbound. Figure 3 demonstrates the variability by hour of the day. Broadly, the standard deviation trends with the average. Recall that the southbound vehicles are using the FAST lane. At the time there was no equivalent lane in the northbound direction.

TABLE 1 Descriptive Statistics for Border Crossing Times

Data Set	Observations	Mean	Standard Deviation	90th Percentile	Arrival Rate	Average Service Time
WCOG fast	579	22 min	21 min		21.5 vph	86 s
WCOG nonfast	1,480	1 h 23 min	26 min		21.5 vph	119 s and 121 s
Probe, southbound (fast)	5,658	23 min	24 min	50 min		
Probe, northbound (nonfast)	5,805	23 min	20 min	45 min		
Probe (overall)	11,463	23 min	22 min	47 min		

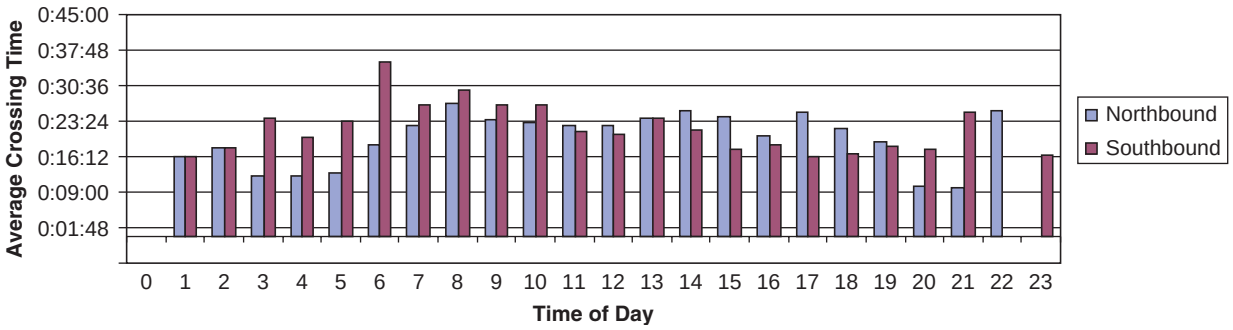

FIGURE 2 Average crossing time by time of day.

Figure 4 shows the variability across months. For the given year, the southbound variability peaks in the late summer–fall (except for some large values in April). Northbound, the variability peaks earlier, in the summer, but with some particularly large values in February.

The average delay, which represents FAST-approved commercial vehicles southbound, is on the order of 20 min, and delays of more than 1 h are very infrequent.

QUALITATIVE INTERVIEWS

To better understand the current response to variability, the benefit of a reduction in variability, and how this is related to goods moved or to other business operating characteristics, 20 interviews were done with carriers in the Pacific Northwest, 13 with U.S. companies and seven with Canadian. These companies transport an assortment of goods across the border, including aircraft parts, agricultural products, food products, lumber, paper and wood products, steel pipe, chemicals, ocean containers, and empty containers. A key feature of the Blaine border crossing is that most of the goods are not time critical, that is, with the exception of some perishable or particularly time-critical goods such as frozen seafood and air freight, a delay of 1 h or 2 or even several hours, will not unduly affect the quality of the product, nor greatly affect the supply chain downstream. Currently deliveries typically are not expected within time windows shorter than a few hours.

RESULTS

Increases in the standard error of the elasticity of border crossings with respect to time may impose expected losses in real economic output on participants in the economy. Risk-averse participants can therefore be expected to react to those potential losses. The magnitude and nature of the reactions will be a function of (*a*) the magnitude of the increase in the standard error and (*b*) the economic consequences of the increase in the standard error. The larger the magnitude of the increase in the standard error, the larger the associated economic losses. Larger economic losses make it more likely that participants will undertake (costly) actions to mitigate the increase in the standard error or the economic losses associated with increases in the standard error or both.

Data were collected on participants' actions through a series of interviews with commercial carriers. The interviews identified several strategies that companies use for minimizing the impact of variability of border crossing times on their operations. These strategies are identified in Table 2.

The primary commodities crossing at Blaine are wood, pulp and paper products, food and farm products, metals, and petroleum products. Approximately 15% to 20% of the trucks crossing are empty vehicles. Typically, empty containers and resource-based commodities are not moving in a particularly time-critical environment. This differentiates the border between British Columbia and Washington from that between Ontario and Michigan, where a significant number of automotive plants exist on either side of the border that exchange parts and operate in a Just-In-Time manufacturing environment.

Increase Buffer Times

Although the average crossing time southbound for non-FAST vehicles is about 1 h and 23 min, most carriers allow 2 h to cross the border. In doing so, they are building in 37 min to accommodate longer than average crossing times. This strategy is called increasing buffer times. This is the most common response to variability. Typically,

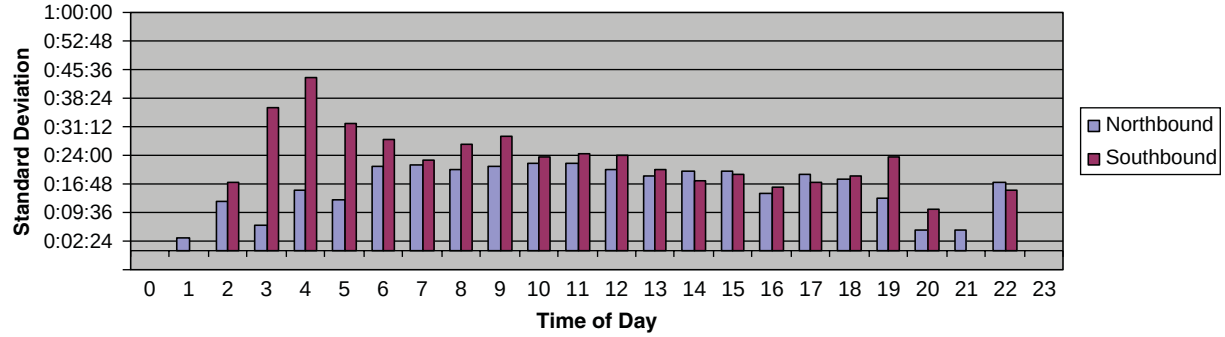

FIGURE 3 Standard deviation of crossing time by time of day.

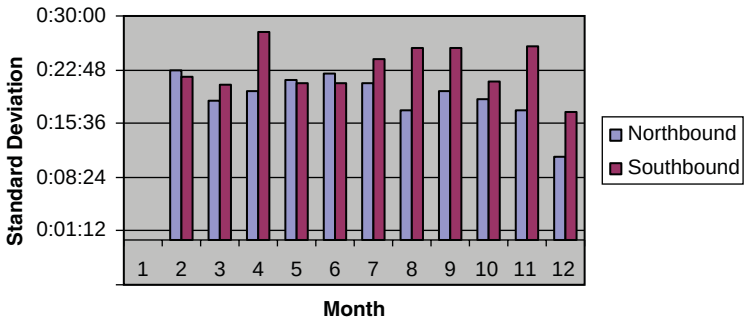

FIGURE 4 Standard deviation of crossing time by month.

FAST-approved vehicles allow an hour for border crossing (significantly more than the average of approximately 20 min). Increasing buffer times reduces the possibility that the driver will arrive late for an appointment. The authors did not speak to any carriers that incur specific fees for late arrivals, but there are other consequences:

- Customer dissatisfaction with late deliveries can lead to a loss of business (in one case a carrier operating in a Just-In-Time framework is contractually obligated to arrive on time at least 94% of the time).
- With less than truckload (LTL) carriers, it is possible that outbound trucks from a handling facility will be delayed by incoming trucks. Delay to one vehicle can therefore affect many outbound vehicles and customers whose goods were not delayed in the original shipment. These customers have little sympathy for the delay and will not bear the financial consequences of delay (missed business opportunities, staff overtime, perished goods, etc.).
- Missed appointments at the port of Vancouver can lead to a loss of future appointment times.
- If outbound rail cars are not filled at a transload facility, the company is charged demurrage for empty rail cars.

TABLE 2 Carrier Responses to Variability in Cross-Border Travel Times

Strategy	Consequence
Increase buffer times	Reduces capacity of existing infrastructure or requires additional hires and equipment Increases transportation and inventory cost Reduces late arrivals and stock-outs
Increase dwell times at intermediate handling facilities	Reduces impact of delay on outbound vehicles, particularly relevant for LTL (less than truckload) operations Increases total transit time and therefore inventory cost
Implement routing changes	Reduces the impact of variability on operations
Implement schedule changes	Reduces the impact of variability on operations
Reduce level of activity in cross-border trade	Reduces the impact of variability on operations Stop providing courier or same-day service Reduce revenue to carrier and level of cross-border economic activity
Change transportation mode	Change border procedures which, depending on local circumstances, may improve travel time reliability

- If trips are particularly long and a driver cannot make the return trip because of hours of service regulations, a replacement driver may need to be hired or overnight accommodation expenses may be incurred.

There are also consequences of arriving too early, which happens on the majority of occasions. These are primarily underutilization of the driver and rolling stock.

Typically drivers are paid per trip (rather than per hour), so that individuals would bear the cost of increasing the buffer time, but in many cases drivers are compensated for border wait times over some threshold. This cost is borne by the transportation company and has increased rates. In the case that drivers are not specifically compensated for border delay, the carrier may keep the increased revenue. One company estimates a 7% increase in its freight rates during the past year due solely to border crossings; another estimates 11%.

Increase Dwell Times at Intermediate Handling Facilities

For an LTL firm that uses an intermediate handling facility, longer than expected inbound delays can disrupt outbound trucks. The firms the authors spoke with have therefore increased the dwell time of goods at the handling facility to reduce the possibility of delay to outbound trucks. This increases the time between pickup and delivery, reducing the quality of service offered by the provider.

To minimize the impact of very long delays, for carriers with handling facilities in which goods are moved between vehicles, it is best to cross the border after handling goods and loading trucks to their final destinations, as opposed to crossing the border before handling goods. For southbound supply chains this benefits Canadian firms with handling facilities in the Lower Mainland. For northbound supply chains, this benefits U.S. firms with handling facilities in Washington State. The net effect given trade in the region most likely favors Canadian carriers. If the level of variability in border crossing times could be reduced, this benefit for Canadian firms would be removed.

Implement Routing Changes

When feasible, some companies have decided to use border crossings that offer a shorter crossing time. The authors' interviews suggest that the risks associated with imperfectly anticipated border crossing times are likely to be of modest economic consequence against the background of other determinants of the costs of pro-

ducing cross-border shipments and that the routing changes that do take place are in response to average crossing times rather than the variability in crossing times.

Implement Schedule Changes

The authors observed companies shifting their regular schedules to take advantage of shorter and more reliable crossing periods. The fact that some companies do not shift their schedules suggests that increased variability of crossing times had only modest impacts on the elasticity of border crossings with respect to time or that the requisite investments to allow substantially more real-time expediting of shipments are prohibitively expensive. Several survey participants indicated that they engaged in real-time (Internet) monitoring of border crossing conditions and were able (at relatively low cost) to alter shipping times to take advantage of "favorable" crossing conditions. Although the ability to engage in real-time management of border crossings will not be identical across all shippers, many respondents are located relatively close to the British Columbia–Washington State border. Furthermore, all have access to relatively low cost Internet monitoring of border crossing conditions. It was felt that these schedule changes were in response primarily to average delay rather than the variability in delay, because the costs associated with variability in border crossing times are of modest importance.

Reduce Levels of Activity in Cross-Border Trade

Several Canadian carriers have decided to exit the business of cross-border trade partially or entirely. Several firms that 2 years ago offered same-day service between the Lower Mainland of British Columbia and the Puget Sound region of Seattle have discontinued this service because of their inability to reliably deliver and return to British Columbia on the same day. This was due primarily to the magnitude of border delay, rather than its variability, and also reflects increased levels of regional congestion on roadways, at ports, and in rail yards. For example, two companies the authors spoke with that move containers between ports and rail yards in Vancouver and destinations in Washington State have moved from doing so in 1-day operations to doing so in 2 days. Only 2 years ago it was possible to pick up containers at the rail yards very early in the morning, cross the border, drop off a container, pick up a container, and return to Vancouver on the same day; now this trip requires 2 days, so the rates have increased significantly.

Change Transportation Mode

In the Whatcom County–Lower Mainland region, it may be possible to substitute rail or marine transportation for truck transportation. For example, one fuel company that delivers fuel by truck from a coastal refinery in Washington State to Vancouver International Airport faces competition from a barge company that can serve the same route with less border delay and less variability in travel time.

CONCLUSIONS

Survey respondents provided little indication that typical variability of border crossing times was a matter of substantial concern to them, and in general their actions in response to variability are modest. However, respondents did indicate that although infrequent, very long delays were of particular concern. The data indicate that about 1% of delays to FAST participants are more than 2 h and 8% of delays to non-FAST participants are more than 2 h. These delays, although uncommon, are particularly disruptive. However, they do not currently occur so frequently that any of the interviewees takes any measures to mitigate their impact. Results indicate that transportation companies are currently implementing strategies to accommodate typical variations in border crossing times. Most commonly, this is introducing a buffer time to increase the likelihood of an on-time delivery.

The cost of increasing buffer times seems to be in some cases absorbed by the trucking firm, and in other cases rates have been increased to account for this operational cost. In very competitive markets trucking companies have not been able to increase rates, but in markets in which the transportation company offers a unique service, the company has been able to maintain its profit margin. In the cases in which rates have not been increased, this cost has been borne primarily by truckers who are paid the same rate for longer trips.

In the Pacific Northwest, transportation providers schedule delivery windows of about 4 h. Recall that the commodities moved typically are resource based and not particularly time sensitive. This would be different at many of the Michigan–Ontario crossings that are operating in a Just-in-Time environment. Therefore, only very long delays at the border cause significant disruption. Given current buffer time implementations, typically the time between arrival and the end of the buffer will be about 40 min. This means that for each round-trip, about 1 h and 20 min is "wasted." The cost of this time depends on the industry's ability to use it for other purposes. If it cannot be used in a productive way, the cost is essentially zero. Vehicles crossing the border at Blaine typically are moving between the Lower Mainland of British Columbia and the Puget Sound region, or a longer distance. Given this, it is difficult for a company to put the 1 h and 20 min to use, because the time is much smaller than round-trip travel time. Therefore, although the "wasted" time exists, it is not currently of much value. A driver paid by the trip absorbs the unanticipated border crossing delay in the form of uncompensated time spent on the job. The magnitude of this cost from a social perspective depends on the opportunity cost of the drivers' time. If the opportunity cost is relatively low, the social cost of the slack associated with using drivers' time as a "buffer" is correspondingly low.

It is clear from the interviews that truck drivers are becoming an increasingly scarce input. Part of this has to do with demography; the average age of truck drivers has been increasing in recent years and large numbers are on the verge of retirement. It also has to do with drivers reacting to their providing slack for the logistics networks of North American firms. In the short run, effective reductions in real wages will be absorbed largely by the drivers themselves. Over time, the supply curve for truck drivers becomes more elastic as younger drivers leave the industry for other forms of employment and older drivers choose retirement rather than work an incremental year or two. Over time also, the implementation of technology is expected to improve the industry's ability to predict travel times. This will increase expectations of efficient operations in the industry as competitive companies will offer tighter delivery windows or similar windows at lower cost through cost savings by better equipment utilization. In addition, increasing fuel prices and emissions restrictions will put pressure on transportation companies to operate more efficiently, thereby reducing cost by reducing idling and empty trips. The consequences of variable border crossing conditions are therefore likely to be more economically significant in the future.

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