Automated Trucking and Border Crossings

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Submitted to:
Transport Canada

March 31, 2018

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Introduction

The purpose of this report to examine the likely issues associated with passage of highly automated trucks, including trucks with no person on board, through Canada's highway border crossings. We consider a range of issues, but the main question we seek to answer is "Will it be possible for an automated truck with no driver or passenger on board moving between an origin in the US and a destination and Canada be able to pass through a Canadian Port of Entry (POE)?" If the answer is a provisional "yes" the natural follow up question is "What steps does the Government of Canada need to take to facilitate such a passage?"

These are important questions because if the answer is "no" there could be significant negative outcomes for Canada's economy. The reason is as follows. While there is much debate (discussed herein) about when or even whether "driverless" trucks will become a standard means of intercity freight movement, the most likely scenario is that it will be phased in as "exit to exit" rather than "dock to dock" movements.[1] This means that unstaffed trucks will move between transfer stations located close to exits on limited access highways, from where either they will be moved under a driver's control to their final destination or their cargo will be transferred to conventional trucks for final delivery. This will make it possible to develop a technology that can manage all the necessary movements of trucks on the highway, without being able to execute the detailed maneuvers needed to pass thought city streets and back the truck into a loading dock. If such a truck were to move between a transfer station in the periphery of a US city and a transfer station in the periphery of a Canadian city, the most complex driving environment the truck is likely to encounter would be the border POE. If the truck is unable to navigate through the POE, automated, unstaffed trucking service would be available for domestic freight movements in the US and Canada, but not for cross-border movements. Since such a service would likely cost less than conventional service, the higher cost of cross-border trucking relative to domestic trucking would represent a significant trade friction, similar to a tariff.

The report is organized as follows. The next section (Part 1) provides background on highly automated trucks including definitions, major functional technology systems, standard levels of automation as they apply to trucks, and the concept of Operational Design Domain (ODD). It also defines the major players in the industry, economic drivers, general legal issues, security and terrorism issues and current opinions about the likely timelines for market adoption of highly automated trucks. Part 2 is an overview and process mapping of border crossing systems, which is used in Part 3 to guide a discussion of challenges that highly automated trucks may face as they cross the border and Part 4 briefly discusses necessary preparations for Transport Canada, CBSA, other government departments, and the operators of border infrastructure.

[1] Clevanger (2017); UberATG (2017, 2018).

Part 1: Overview of highly automated trucks

Terminology and functions of automated trucks

There is a variety of terminology with sometimes inconsistent usage around automated vehicles in general and automated trucks in particular. The generally recognized standard for terminology and for defining levels of automation is SAE International.[2] The five SAE levels of driving automation are shown in the table 1 of their September 2016 report, a copy of which is in Appendix 1. They range from level 0, with no automation to level 5 with full automation under all possible driving conditions. The key dimensions used to define the levels in this taxonomy are Dynamic Driving Task (DDT) and Operational Design Domain (ODD). DDT includes functions that control the movement of the vehicle, including lateral (steering) and longitudinal (acceleration and braking) control and Object and Event Detection and Response (OEDR). In an automated vehicle system, various sensors and cameras provide input to OEDR and mechanical actuators provide lateral and longitudinal control. The taxonomy depends in part on “DDT fallback,” which refers to what happens if the principle automated driving system fails. In levels 0 through 3, a person on the truck takes the fallback responsibility. Levels 0 though 2 have active drivers while level 3 has “fallback-ready user,” who only takes control in the event of a systems failure. But this naturally means that levels 1 through 3 must have a person on board the truck at all times.

The ODD refers to a set of circumstances under which the automated driving system can function effectively and safely. This may include geographic restrictions (within a geofenced area, on dedicated freight roads), mode of driving (stop and go traffic, limited access freeway), environmental conditions (in dry weather), or time of day (during daylight hours). The idea of “exit to exit” as opposed to “dock to dock” means that the ODD is limited. As we will see, the concept of ODD is very important to the topic automated trucks at the border.

The SAE also provides some rules about terminology, although they are far less observed in the literature than the 5 levels of automation. It defines a set of “deprecated” terms that have created confusion in the past and should therefore be avoided. Two prominent examples are “autonomous” and “driverless.” Because the term “autonomous” is often used in robotics and artificial intelligence to refer to systems requiring no input from outside systems, it does not fit the case of even Level 5 vehicles, which may be receiving inputs from vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) systems as well as periodic directions from people. Therefore “automated vehicle” is the correct term. Despite this, one often finds the term “autonomous” to refer to a vehicle without a human driver. “Driverless” is also an SAE deprecated terms because the automated system or a remotely located person may be viewed as the driver. Since we will be leaning heavily on the SAE terminology and taxonomy in this report we will avoid these terms and use “highly automated” to refer to level 4 and 5 trucks and “without a driver onboard” to refer to a moving truck with no human occupant.

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[2] SAE International (2016).

The SAE taxonomy does not make a distinction between light duty vehicles (cars and SUVs) and heavy duty trucks. While the level descriptions apply intuitively in either case, there are important differences to bear in mind. The first is that most intercity trucks are of the “tractor-trailer” variety. References to automated driving systems in trucks are usually limited to the tractor, which means that there are is no OEDR capability at the rear of the truck. While “smart” trailers are a possibility, they would add significant expense and the problem of ensuring that automated tractors can be matched up with automated trailers would complicate fleet management. It should be noted, however, that human drivers do not generally have a view from the rear of a trailer. A simple backup camera can be added in either a conventional (level 0) or automated case.

Another difference is that trucks are subject to a variety of regulations that do not apply to light duty vehicles. Notably, hours-of-service regulations limit the length of time that a driver can operate a truck. This brings up a number of important policy issues. If a truck is level 3, meaning that the driver is fallback ready but does not have sustained responsibility for driving, should the hours of service regulations apply in the same way that they currently do, or should that “ready but not driving time” be counted differently? It is evident from the literature that there are different expectations on how this issue will be resolved.

Of particular interest to our topic is the distinction between level 4 and level 5, which lies exclusively in limitations on the ODD. There are, in fact, numerous current applications of level 4 automation for trucks under extremely limited ODDs. The most frequently cited cases are in the mining industry, where trucks and other large vehicles are used on private property to move minerals from the mine to on-site processing or shipping facilities. Automated agricultural equipment is another example, although these vehicles are not commonly thought of as trucks. Because of these application, there is actually a large base of experience on the operation of heavy trucks without a driver on board. There are, however, no current and relatively few envisioned cases of level 5 automated heavy trucks. For example, the “exit to exit” trucking service described above is clearly a case of level 4 automation because of its limited ODD. Despite this, one often finds reference to level 5 trucks, even in the technical literature.[3]

One important function of automated vehicles that SAE does not address explicitly is “platooning” whereby several vehicles follow a lead vehicle at gaps that would normally be too short for safe operation. This is possible because the lead vehicle controls the movements of the following vehicles and wireless communications among all vehicles synchronized systems so that, for example, they brake simultaneously. The vehicles in the platoon must have at least level 3 automation. There are two benefits to platooning. First, it allows drivers of all but the lead vehicle to relinquish control and rest, although they might serve some DDT fallback function. The second is that by reducing wind resistance it leads to an overall improvement in fuel economy. Because they have generally poor aerodynamics, the latter benefit is especially important for large trucks.

[3] For example Witte (2017).

The benefits of platooning can be extended by eliminating the drivers of one or more trucks in the platoon. Without a human driver, naturally, the level of automation must be at least level 4. An important consideration for our topic, however, is that a platoon that has eliminated one or more drivers may not be able to navigate and maneuver through a typical POE inspection plaza. (Here "navigate" refers to the necessary perception and communications capability, while maneuver" refers to executing complex DDT tasks.)

Another important possibility that does not fit clearly into the SAE levels is that a remote driver can serve the DDT fallback function. Such a driver could be located in a control centre, where a group of drivers would each handle several trucks simultaneously.[4] The use of remote drivers might also extend the ODD of a truck, as in the case when a level 4 truck capable of "exit-to-exit" service uses a remote driver to handle last mile delivery. This would also be a viable option for handling complex navigation and processing in border POEs.

Technology systems

The technology systems in highly automated vehicles can be separated into three categories: perception, planning and execution[5]. These align with the SAE functions defined above, with perception and planning supporting the OEDR aspect of DDT and execution supporting the lateral and longitudinal control aspect. While the system elements are the same for automated trucks as for automated light vehicles, they face some different challenges. For example, trucks have to cope with trailers of a number of different dimensions for different shipments.[6]

Typically, an automated truck will have a number of different installed perception devices based on different technologies. In most cases this will include some combination of LIDAR (light detection and ranging), radar, ultrasonic sensors, cameras, and Global Positioning Systems (GPS). The LIDAR unit is generally the most powerful and most expensive device used for perception. It is similar to sonar in the sense that it sends out laser signals and uses the time it takes them to reflect back to calculate distances, upon which a precise mapping of distances to all objects within line-of-sight in the environment is based. LIDAR is very fast – taking more than a million measurements per second – which is a great advantage for a moving vehicle, whose position relative to other objects is constantly changing. However, its performance is affected by atmospheric conditions. Radar serves a similar function but is based on radio waves. Different radar devices are placed in most vehicles for short and long range detection. Ultrasonic sensors use high frequency sound waves to detect objects. These are typically available on even low level automated vehicles to prevent collisions with objects in the vehicle's path, especially when backing up. Unlike other perception technologies, cameras can detect colours and boundaries, which is important for following lane markers, reading signs, etc. Since cameras don't range distances they must be used in combination with the other technologies. Another important

[4] ITF (2017), page 16.
[5] The foregoing description draws on McGehee *et al* (2016).
[6] Witte (2017).

perception technology is dedicated short range communication (DSRC), which makes it possible to pass information from vehicles to vehicle (V2V) so that each knows the location of other vehicles in its immediate environment, even if it outside the line of sight. Platooning also relies on DSRC to maintain constant distances between vehicles. More generally, some observers argue that the future utility of automated vehicles lies in the ability to coordinate vehicles systems based on DSRC and other forms of wireless technology.[7] DSRC is used for other forms of data transfer, including communication with infrastructure (V2I) and downloading various forms of information. The need for DSRC implies that automated vehicles are necessarily also connected vehicles. (There is currently a debate over whether short range communication via DSRC, 5G cellular or some combination of the two will eventually be dominant in connected and automated vehicles.)

Data fusion software is necessary to make the various elements work as a system. Simultaneous Location and Mapping (SLAM) software provides precise information on the vehicle's location and maps everything in its environment with rapid updating. Object detection is needed to prevent the vehicle from colliding with unexpected vehicles, pedestrian and other objects. While the fused data from these perception technologies gives a detailed and rapidly updated picture of the environment that the automated vehicle is passing through, they all have the limitations and are subject to occasional failure. Thus, externally provided, 3D maps are a necessary supplement. A few major companies, including HERE, TomTom and Google, generate these maps from specially instrumented vehicles and update them continuously from various data sources. Since updates are often minute to minute, these maps can also provide advanced information on traffic jams and other factors that will affect the driving environment into which the vehicle is heading[8].

The planning technology is embodied in software that operates at the broad geographical scale by planning optimal routes to destinations and at a finer level of spatial detail to plan maneuvers such as lane changes, acceleration, deceleration and navigation around complex geometries, such as one might find in an urban environment or in a border inspection plaza. Naturally the more complex the driving environment, the greater is the challenge for the planning technology. This is especially true for tractor-trailer type trucks whose navigation is complicated by their length, relatively slow acceleration, long braking distances and two-piece design.[9]

While systems for perception and planning comprise mainly electronic devices and software, executions systems require mechanical component that do the work that would normally be done by a person, such as turning the steering wheel or depressing the brakes. Devices called actuators receive instructions from the perception and planning systems and provide the mechanical power to exert lateral and longitudinal control over the vehicle. The human strength normally required for these functions is replaced by electric motors, pneumatic devices or other mechanical systems. Up to level 3 in the SAE system, it must be possible for an on-board person

[7] Shaladover (2017).
[8] Demattia (2016.)
[9] Janz and Schob (2018).

to take over control of the actuators. Since the vehicle's actuators are operated via electronic instructions, they are also amenable to remote control by a person located in a control centre where they can access the perception and perhaps also planning systems of the vehicle. (For this reason, they may also be vulnerable to cyber-attack.)

Since the technology system that automates a vehicle comprises a number of smaller devices that are integrated via communications technology and software, it is possible to create a highly-automated vehicle by retrofitting a conventional vehicle. An example is the use by Waymo of FCAs Pacifica minivans as platforms for automated passenger vehicles. In the case of trucking, Uber (though its recent purchase of OTTO) is building level 4 tractor-trailer trucks by retrofitting Volvo trucks. On the other hand, the long-term direction of the industry may be to build highly automated vehicles from the ground up, as in the case of Waymo's electric Firefly and the Tesla Semi truck.

Drivers and impacts

While it is beyond the scope of this report to fully review all the factors that are driving and retarding the development of highly automated trucks, we briefly review four important classes under the headings of safety, environment, economy, and cybersecurity.

Safety: Since driver error is the main cause of fatal accidents, automated vehicles have an enormous potential to reduce highway deaths. This is true of level 1 through 3 automation systems, which either provide additional information to the driver, such as a warning when they veer out of lane, or assume certain aspects of the DDT in order to prevent and mitigate collisions and other accidents. Levels 4 and 5 take full responsibility for the DDT and thus effectively eliminate human error.

These assessments are subject to certain *caveats* however. The first is that safety benefits are only realized if the automated driving systems function correctly. A second is that level 3 systems, which rely on the person in the vehicle to remain ready for DDT fallback, are inherently dangerous as it may be difficult for that person to maintain focus or even stay awake. Furthermore, in recent surveys some drivers say the availability of automated vehicle functionality might make them more likely to take risks, such as operating while drowsy or intoxicated.[10]

In the case of automated truck, level 1-3 features that prevent swerving out of lanes and provide stability control to prevent "fishtailing" are especially valuable for improving safety. Platooning, however, may have detrimental impacts as cars have difficulty merging from on ramps and changing lanes around long lines of closely spaced trucks.

Economy: The economic impacts of highly automated trucking without onboard drivers can be viewed from the perspective of shippers and carriers on one hand and labour on the other. For individual carriers, the ability to move goods without paying drivers has obvious appeal. Not only

[10] Insurance Institute of Canada (2016).

does it reduce costs, but it circumvents the long-established problem of finding and retaining drivers in the trucking industry. Even under scenarios where a human driver is onboard, a single driver may do the work of two, because there are long periods when the driver does not have to be available for DDT fallback; and a single remote driver can take responsibility for more than one truck. In either case there are major labour savings.

Reduction in the number of accidents should lead to much lower insurance rates, although this will be partially offset by the fact that accidents involving highly automated trucks will be costlier because of the higher cost of replacing or repairing the more expensive equipment.[11] Savings in labour, insurance and other costs taken together has been estimated to provide a reduction in the operating costs of trucking of about 30%.[12]

Since trucking is a relatively competitive industry, a substantial proportion of the savings will be returned to the shipper in the form of reduced rates. This will allow producers to expand sales into more distant markets, which in turn will allow then to increase productivity due to scale economies. It will also increase the cost competitiveness of trucking relative to other freight modes, notably rail.

The economic impact from the perspective of labour, however, could be negative. According to the Senate of Canada's recent *Driving Change* report, sectors that employ 1.1 million people in Canada – including truck and taxi drivers – will be subject to significant job losses. According to a recent US study, almost 3% of the US labour force works in driving occupations, all of which are threatened with job loss due to market penetration by highly automated vehicles.[13] However, Uber has recently argued that the net effect on truck driving jobs will be negligible or even positive. They argue that, for the foreseeable future, trucking without an onboard driver will only occur between transfer hubs near highway exits, and human drivers will still take goods to their final destinations. Since the cost of long distance trucking will decrease dramatically, they argue, the demand for trucking services will increase and the corresponding growth in the demand for final delivery drivers will offset the loss on long haul drivers.[14]

Environment: The general argument for environmental benefits from automated vehicles is that they have the potential to optimise their driving cycle and reduce congestion, leading to lower emissions per kilometre. Also, since they can be used around the clock, they reduce the total stock of vehicles, eliminating production activities that create emissions and the need to recycle or dispose of as many retired vehicles. There is considerable controversy, however, about these claims. In particular, some observers see automation as leading to substitution of cars and trucks for transit and rail, which are less energy intensive modes.[15] In the case of trucks, the ability to

[11] Insurance Institute of Canada (2016).
[12] ITF (2017) page 22.
[13] Center for Global Policy Solutions (2017).
[14] UberATG(2017, 2018); see also Madrigal (2018).
[15] Litman (2018); see several testimonies in The Standing Senate Committee on Transport and Communications (2018)

form platoons (sometimes called “convoys”), which reduces energy consumption between 5 and 15% is often cited. However, similar or greater reductions in the greenhouse gas emissions of trucks could be achieved by other means, such as conversion to alternative fuels.

Cyber security: Because highly automated trucks are controlled by information systems and wireless communications, they are highly vulnerable to GPS spoofing, whereby an attacker can take control of the truck and its load. They make attractive targets because cyber thieves can hijack valuable cargoes and either sell the goods or hold them for ransom. They are also attractive targets for terrorists. As the attack in Marseilles in the summer of 2017 illustrate, a large truck can be used by a terrorist to devastating effect.[16] For reasons we discuss below, the threat of cyber-attack is exacerbated when the truck passes through a border POE.

Likely timelines

Opinions vary widely as to how soon highly automated trucks without onboard drivers will become a significant component of the North American freight system.[17] Some journalistic[18] and industry[19] sources see them as a reality that will soon be upon us, with significant adoption in as little as 5 to 10 years[20]. Others are more skeptical, suggesting these unstaffed trucks will appear much later, if at all[21]. Some skeptics even note that optimistic projections generally come from people with financial interests in the automated vehicle industry.[22]

There is far more research and commentary about the likely future of highly automated passenger cars than about trucks, so it is worth considering whether trucks are likely to lead or lag light duty vehicles in automation. There are some ways in which trucking has the advantage in terms of technology development and market penetration. As we have noted, there is already extensive commercial application of highly automated trucks without drivers on board in the mining industry. Also, there are generally more opportunities to transition from private property to public roads by way of dedicated roadway for trucks than there are for passenger vehicles. For example, a detailed study on the Port of Rotterdam examines a scenario whereby trucks without drivers on board that are already operating on container terminal sites will shortly begin moving containers among terminals on a private road. They are then expected to start moving containers to distributions centres as far as 30 km away on public roads in 2025, and over much longer distances by about 2030.[23] Finally, there is a clear financial incentive for carriers to make investments in highly automated trucks that do not need to carry an employee, especially in an environment of labour shortage.

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[16] Carpenter (2017).
[17] See Walker (2017) for an of industry opinions.
[18] Dougherty (2017).
[19] UberATG (2017, 2018).
[20] Freedman (2017).
[21] Mulero (2017 a,b).
[22] Litman (2018).
[23] Spruijt, van Duin and Rieck (2017).

On the negative side, however, there is likely to be reluctance by the public to accept the argument that trucks without a person in the cab are safer or even as safe as conventional trucks. There will also be pushback from labour organizations trying to protect truck drivers' jobs. Finally, trucks operate in a complex regulatory environment that varies between Canada and the US and between states and provinces, as challenges around harmonization of size and weight regulations have demonstrated. Not only is the regulatory process time consuming, there is currently so much uncertainty about the configuration and use of automated vehicles at this time that any regulations adopted might have to be changed as the technology and applications evolve.

A recent study by OECD's International Transport Forum titled *Managing the Transition to Driverless Road Freight Transport*[24] reviewed predictions of timelines for adoption of highly automated trucks without human drivers and arrived at its own predictions under a number of scenarios. They define three scenarios: conservative, regulated and disruptive, plus a baseline scenario in which trucks without drivers on board are never allowed on public roads. (Graphs of their projections are provided in Appendix 2.) For each scenario, they define separate timelines for long-distance and urban driving. This is essentially consistent with the "exit-to-exit" vs. "dock-to-dock" distinction described above. Under the conservative scenario, market penetration does not begin until about 2030 for long-distance trucking, and a few years later for urban, and only reaches a market penetration of about 25% for long distance and less than 20% for urban by the end of the timeline prediction limit in 2040. The disruptive scenario envisions an early introduction in about 2020 for both long distance and urban service, and rapid market penetration accounting for 80% of long-distance and 40% of urban goods movement by 2030. In the regulated scenario, a stricter regulatory regime delays introduction until the late 2020's, but market penetration is assumed to be rapid, jumping to over 90% for long distance and 50% or urban goods movement in just a few years.

While the language in the report is vague, we assume that the rate of adoption refers to new truck purchases. Thus, while the predicted adoption rate in 2030 for highly automated trucks without onboard drivers is around 80% for long distance trucks in both the disruptive and regulated scenario, their share in total goods movement would be much lower as the stock of trucks turns over slowly. Nevertheless, the predictions imply that government agencies – including CBSA, Transport Canada, and other federal and provincial agencies – should be prepared to accommodate substantial numbers of these trucks by 2030. We should note however, that there are credible sources who envision a slower rate of adoption, generally seeing highly autonomous trucks without onboard drivers playing a significant role by 2040[25].

[24] ITF (2017), pages 25-28.
[25] Clevanger (2017).

Part 2: The border crossing process for trucks

Border agencies have three main areas of responsibility: customs, immigration and security. Customs regulates the importation of goods to make sure that illegal goods do not come into the national space and that all required taxes and duties are paid. Immigration is the regulation of people entering the country to makes sure that only those who are admissible under Canadian laws and regulation are allowed entry and that appropriate visas and other credentials are in place. Security is a broad term that refers to protecting the Canadian population from military or terrorist threats or from cross-border criminal activity. It also extends to making sure that any food entering the country complies with Canadian regulations and does not carry pathogens, pests or pesticide residues. Since our focus is on the movement of freight in trucks, our primary interest is in customs administration, but immigration as it relates to the driver and security as it relates to the goods or contraband the truck carries are also concerns.

To address the potential challenges of moving highly automated trucks without onboard drivers through Canada's POEs, we start with a description of the importation process. The key players in the process are the importer who brings the goods into Canada, the supplier/vendor who sells the goods to the importer, the carrier who provides the truck transportation, the freight forwarder who brokers or otherwise arranges freight services, the customs broker or other service provider who handles necessary requirements for the release of the goods into Canada, the Canada Border Service Agency (CBSA), and other "participating government agencies" (PGA) with authority at the border. The PGA and their areas of responsibility are listed in Appendix 3.

Importation of goods into Canada involves 5 steps

1. Advance commercial information
2. Report
3. Examination
4. Release
5. Accounting and payment

Figure 1, which is a process mapping of the movement of trucks to and through a Canadian POE, explains where and how the first 4 steps are completed for conventional trucks with drivers. (Step 5, accounting and payment are post-release steps that take place after the goods have entered Canada. Since we do not anticipate any effects of automated trucking on this step, we have not included it in our review.) To keep the diagram simple, we exclude the freight forwarder and assume the importer or supplier contracts directly with the carrier.

Advance commercial information: Under Canada's eManifest program, highway carriers transporting goods into Canada must electronically transfer information about the truck, driver and cargo to the CBSA a minimum of one hour before the shipment arrives at the border. This can be done either via the eManifest Portal (Internet) or Electronic Data Interchange (EDI). This information is used for risk assessment purposes and is meant to identify high risk shipments. (In

Figure 1, the eManifest is abbreviated as EM and is shown as an electronic transfer between the carrier and CBSA.)

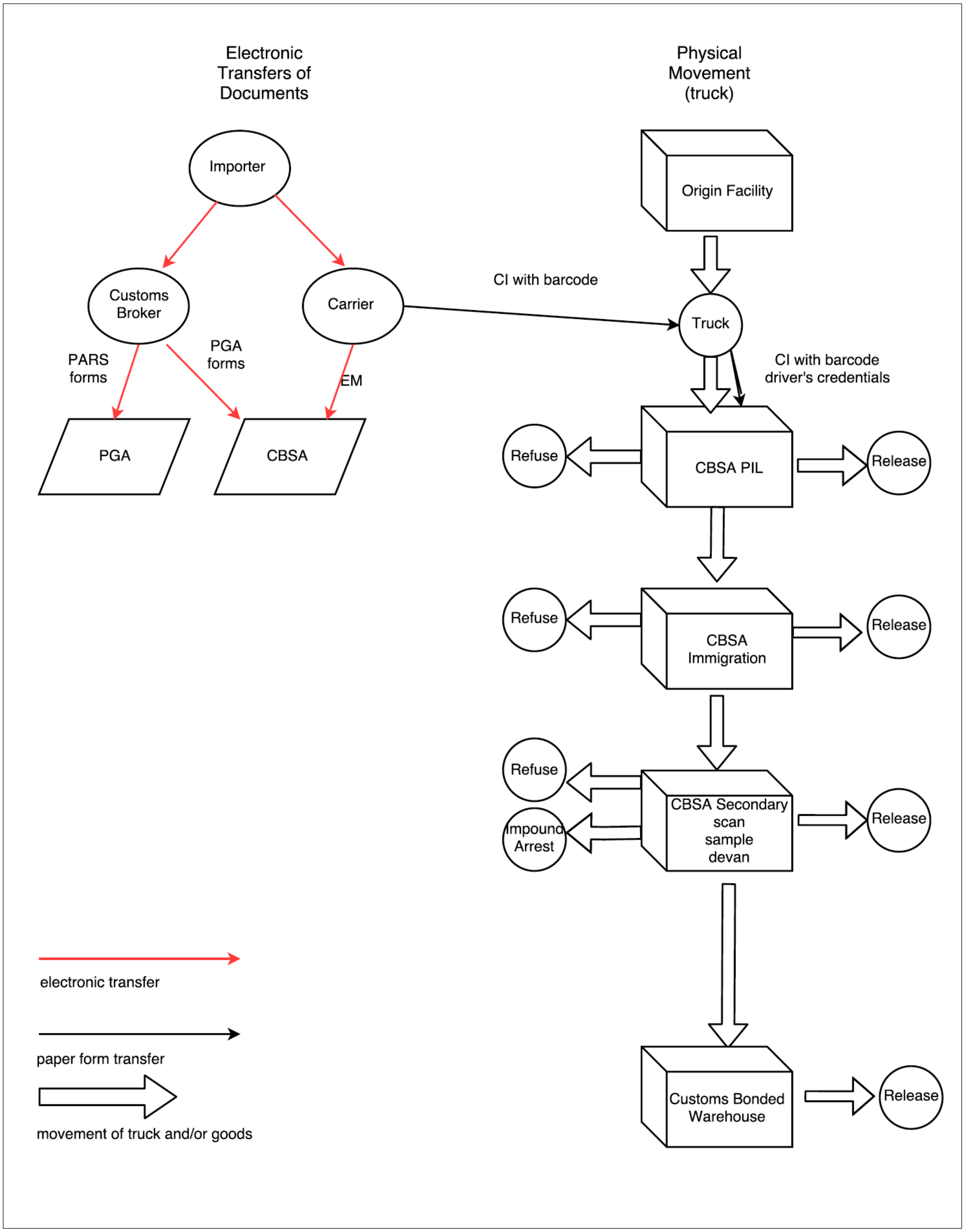

Figure 1. Process Map for Trucks at Canada's POE (excluding accounting and payment)

Report: This step is to provide the information needed for customs administration. All goods imported into or transiting through Canada must be reported at their first point of arrival. Specifically, the importer's customs broker submits the proper documentation on its behalf via EDI in compliance with Canada's Pre-Arrival Release System (PARS). CBSA then provides an approval of release request from which a bar code may be extracted. The bar code is attached to Commercial Invoice (CI) and given to the truck driver before the goods are dispatched from their point of origin. When the driver reaches the primary inspection line (PIL) he or she passes a copy of the CI with the bar code attached to the border service officer(BSO). As shown on Figure 1, as long as the information in the CI is complete to the satisfaction of the BSO it is the only paper form used in the processing of most trucks at the border, aside from the truck driver's ID. Sometimes good are approved to be transported inland to a customs bonded warehouse, in which case an approved seal must be attached to the truck doors. Members of the Partners in Protection (PIP) trusted trader program are required to use high security seals on all shipments.

Examination: Truck drivers are examined to ensure that they are admissible to Canada. If there are concerns with their credentials, they may be referred from the PIL for further examination by CBSA immigration officers at the POE. CBSA may examine the goods carried in the truck for several reasons:

- confirm information regarding the shipment
- establish compliance with the laws and regulations administered by CBSA and ther Government Departments (OGDs)
- ensure accurate documentation used to report for goods
- take samples of goods to assist compliance verification after release
- verify identified shipments, such as those selected by commercial or enforcement systems or deemed as possibly suspect by an alert or lookout, and
- confirm or negate risks or non-compliance.
- commercial goods must meet the import requirements of many Other Government Departments including Transport Canada, Health Canada, Canadian Food Inspection Agency, Environment and Climate Change Canada and Natural Resources;

Not all trucks are examined. The selection of trucks for examination may be based on the BSO's discretion, random or targeted selection, information in the eManifest, or the compliance record of the importer, supplier and carrier. Other than brief examination that occurs at the PIL, all further inspections take place in the secondary inspection facility located at or nearby the POE.

Sometimes the truck is only subjected to VACIS[26] scanning, while other times the doors are opened to examine or sample the content or even to completely devan the goods. In the latter case the truck must be backed to a loading dock at the inspection facility. If contraband or misreported goods are found during the examination, they may be impounded and in some cases the driver may be arrested.

Release occurs when the truck, driver and cargo are allowed to proceed into the national territory. The process is not finished however, as payment of duties and taxes must still be made electronically to the CRA.

Part 3: Challenges for highly automated trucks in cross-border freight movements

Based on the foregoing review of relevant issues, we identify three categories of challenges for the movement of highly autonomous trucks without drivers onboard through Canada's highway POE's:

- Challenges of managing the importing process
- Challenges of navigating and maneuvering through the inspection plazas
- Cybersecurity issues

In the importing process as mapped out in Figure 1, the great majority of information transfers that are necessary to comply with customs regulations and satisfy immigration and security concerns are achieved electronically. This limits the first category of challenges because the driver plays a relatively minor role in the importing process under normal circumstances. The main responsibility for the driver is to hand over the CI with attached barcodes to the BSO at the PIL. If all is in order, this is a trivial task that can be easily automated. However, when there are questions or irregularities with the CI, or if the truck has an elevated risk rating because of targeting information or suspicions of the BSO, the driver sometimes answers questions or acts in the role of go-between with the various players in the importation project (importer, supplier, carrier, freight forwarder, etc.) Remote communication with employees can substitute, but this will not be completely satisfactory for BSOs who have been trained to detect suspicious behaviour through face-to-face contact.

Overall, however, Canada's importing procedures are well placed to adapt to an increased role for trucks without drivers onboard. The immediate impediments may be legal in nature, such as provisions in the Canada Customs Act that make specific reference to an individual requesting release along with their truck and load into the Canadian territory. Legislative changes that are

[26] Vehicle and Cargo Inspection System (VACIS) is a non-intrusive inspection system that uses gamma rays.

necessary to accommodate trucks without drivers will need to be made soon to be ready for a these highly autonomous trucks by the mid to late 2020s, in line with the more optimistic projections.

Problems of POE navigation present a greater challenge. Based on expectations among even the most optimistic industry source, freight service in highly automated trucks without drivers onboard will be of the exit-to-exit rather than gate-to-gate variety, with transfer of goods to conventional trucks and drivers at transfer hubs located adjacent to limited access highways. These trucks will not have the capability to drive through the complex geometry of urban areas without a driver onboard. The question is whether they can handle the complex geometry of a typical POE.

Figures 2 and 3 are images of the truck plazas at two of the most important Canada-US highway border crossings. Figure 2 shows the Canadian POE of the Peace Bridge in Fort Erie. Figure 3 shows the American POE of the Ambassador Bridge in Detroit. Both plazas require entering trucks to make 180 degree reversals of direction between leaving the bridge span and queuing for the PIL. The Peace Bridge plaza also requires the trucks to make two 90 degree turns, one before reaching the PIL and one after being released from it and headed back to the Queen Elizabeth Way limited access highway.

While these are demanding manoeuvers, they are made at very low speeds, and it is not clear that they are significantly more challenging than the most complex highway interchanges. There are, however, two clear problems. The first is with platoons. One of the anticipated intermediate steps to truck freight with the complete absence of onboard drivers is a system whereby a human driver handles the lead truck of a platoon with two or more unstaffed trucks following behind. It is doubtful whether a platoon functioning as one very long, articulated vehicle could negotiate such tight turns without crossing lane markers and interfering with other trucks in the plaza. In the case of a platoon in which all trucks have a driver onboard, they could split up and drive through the plaza separately. This would not be an option, however, if there are one or more trucks in the platoon that have no driver onboard.

The second, and most difficult, problem will come when trucks are sent for secondary inspection. It may be possible to direct the trucks to secondary areas where they can pass through a VACIS scanner, but if trucks are to be opened and unloaded, they would have to back up to loading docks. (This can be seen in both of the truck plaza images.) If these trucks are equipped for exit-to-exit rather than dock-to-dock service, they would not have that capability.

There are two likely solutions. The first is that a staff of drivers is provided at the secondary inspection facility to take control of trucks without accompanying drivers. This would represent an additional cost for accommodating such trucks, which the border agency would probably pass on to the carrier. The second is that the trucks have the capability to be driven by a remote driver.

Figure 2. Peace Bridge Canada Truck Plaza

Figure 3. Ambassador Bridge US Truck Plaza

Cybersecurity is an issue for all trucks with automated systems that are capable of taking full control of the DDT, including levels 2 and 3. A criminal or terrorist could hack the automated system and take control of the truck. As long as there is a person in the cab, however, they would be in a position to override the automated system to prevent this from happening. If there is no driver onboard the truck is therefore much more vulnerable.

Trucks crossing the border are in an especially vulnerable position. Because they must make transfers of electronic documents that provide the list of goods on the truck (the eManifest) and the commercial value of the load (PARS documentation), prospective thieves who intercept the information can target the most valuable loads to hijack, such as pharmaceuticals or electronics equipment. (These products are seldom mentioned on the trucks signage to discourage theft.) Also, a terrorist could identify hazardous cargoes to be used in an attack.

Part 4: Steps toward accommodating highly autonomous trucks without drivers at border POEs

As we noted at the start of this report, there is an strong economic impetus for the Government of Canada to accommodate highly automated trucks without onboard drivers at its highway border POEs. The widespread adoption of such trucks will ultimately occur because they are able to provide freight movements at lower cost than conventional trucking. If such trucks become the standard for domestic intercity goods movement but are unable to provide cross-border service because they cannot pass through POEs, the cost of cross-border freight service will be higher than the cost of domestic service. This will constitute a significant new border cost, with negative implications for firms participating in the cross-border supply chains that account for a large share of Canada's trade with the United States.

Since there is a good probability that highly automated trucks without drivers will play a major role in the North American freight system by 2030, and possibly sooner, a number of steps will be needed to prepare for their appearance at border crossings. Some of them relate to physical challenges, while other relate to regulatory challenges. To address the physical challenges a number of steps are advisable:

- Technical review of the geometry of all POEs to determine whether the path to, through and from the PIL is within the ODD of anticipated level 4 automated trucks;
- Technical review of secondary inspection areas at POEs to determine whether they are within the ODD of anticipated level 4 automated trucks;
- In the event that primary and secondary areas in POEs are beyond the capability of anticipated level 4 trucks, consideration of:
    - Adjustments to inspection routines (short of major infrastructure changes) that can accommodate the ODD of such trucks;

- Programs by which human drivers contracted by the infrastructure owner or CBSA can take control of the truck, with the cost passed via fees to the carrier.

As for regulatory challenges, In order to accurately assess the ability of highly automated trucks without human drivers to complete a cross-border commercial entry, a test phase would need to be implemented. Prior to testing a number of legislative and regulatory exemptions would need to be introduced to make the testing legal.

- Legislation and regulations outlining Canada Border Services Agency (CBSA) and Participating Government Agencies' (PGA) requirements and procedures for reporting and control of commercial goods arriving in Canada would need to be reviewed and amended accordingly.
- Additionally policies and procedures for the reporting of Customs Self-Assessment (CSA) Program; consolidated cargo reporting requirements and processes for freight forwarders and all permits related to PGA will need to be reviewed and edited.
- An extensive review of the requirements pertaining to the commercial importation/in-transit movements of regulated goods found within (Memorandum D3-1-1, *Policy Respecting the Importation and Transportation of Goods*), the reporting and transportation of goods being exported from Canada (Memorandum D3-1-8, *Cargo – Export Movements*) and the release of commercial goods, (Memorandum D17-1-4, *Release of Commercial Goods*) should be undertaken.

Once all relevant sections have been revised to allow the for the testing exemption, participants in the test phase would be required have a CBSA / law enforcement interaction plan for secondary examinations and vehicle communication with a remote operator to ensure for proper notifications of missing documentary requirements.

Transport Canada's Role: The Minister of Transport Canada has been proactive in establishing the need to have a comprehensive response to the use of automated vehicles and the quickly changing technology associated with it. He requested the Senate Standing Committee on Transportation and Communications to study the topic. In January of 2018 the Committee delivered a report addressing various regulatory and technical aspects related to automated vehicles including among other things, looking at impacts to current infrastructure and future infrastructure. In order to address needs related to highway border infrastructure and POE infrastructure we anticipate further, coordinated and interdepartmental discussions, involving private sector users, to be engaged by Transport Canada. As the regulator of federal bridges, we anticipate that Transport Canada will lead discussions with highway border users and coordinate the results of these discussions with CBSA to determine the requirements for automated trucks of POE infrastructure and how they will fit into customs processes.[27]

While it is unlikely that major infrastructure changes will be justified in the early phases of market penetration by highly automated trucks, targeted infrastructure improvements may be needed to avoid total their exclusion from border crossings. CBSA, from a customs process perspective would likely have requirements for specific infrastructure investments. More data and analysis are needed to asses these requirements, based in part on focused discussions with highway border users, in order to make changes and/or adaptations to existing border infrastructure. New highway border infrastructure, which is not something that occurs often, must consider the needs of automated trucks and passenger vehicles.

[27] TC appears to have the necessary requirements to initiate what will be needed on federal bridges (International Bridges and Tunnels Act) **16:** *The owner of an international bridge or tunnel shall inform the Minister, in writing, of any of the following events within 30 days of its occurrence:*

*- **16(b)** a change in the types of vehicles permitted to use the international bridge or tunnel and, in the case of a newly permitted type of vehicle, the conditions or restrictions under which that type of vehicle is permitted to use the bridge or tunnel;*

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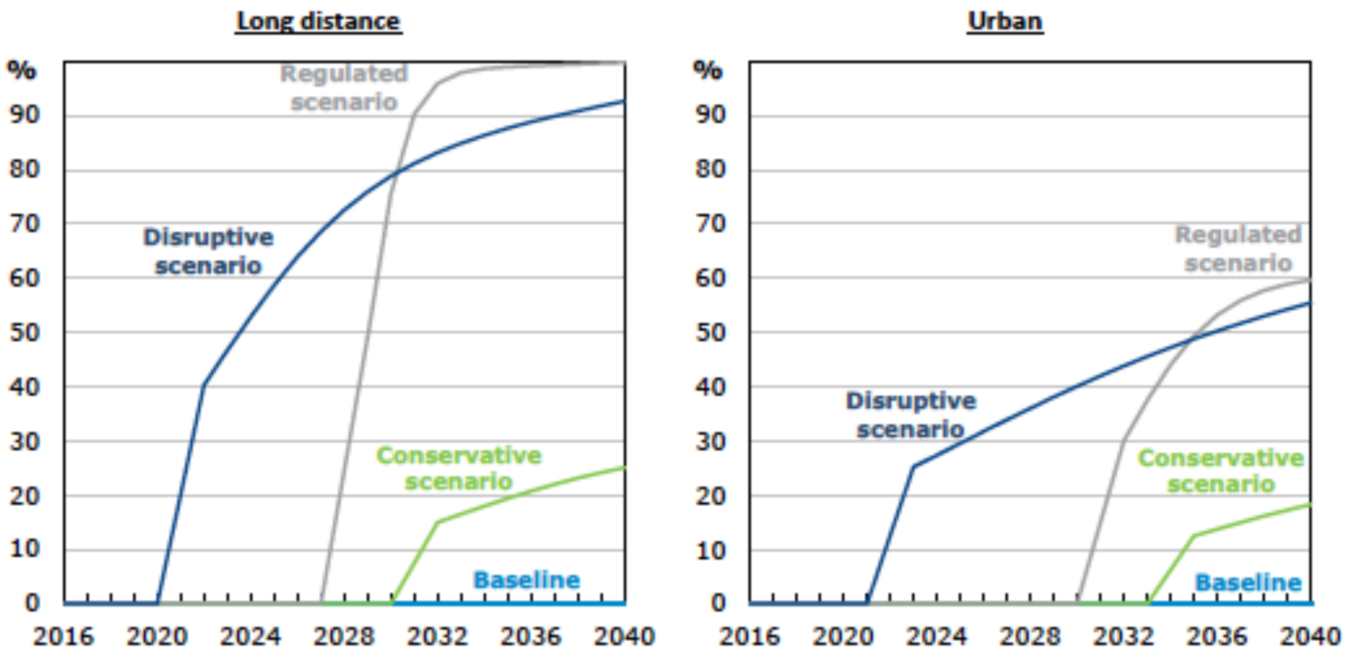
Appendix 1: SAE levels of automation.[28]

Level	Name	Narrative definition	*DDT*		*DDT fallback*	*ODD*
			Sustained lateral and longitudinal vehicle motion control	***OEDR***		
Driver* performs part or all of the *DDT						
0	**No Driving Automation**	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	**Driver Assistance**	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
2	**Partial Driving Automation**	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system*.	***System***	*Driver*	*Driver*	Limited
***ADS* (“*System*”) performs the entire *DDT* (while engaged)**						
3	**Conditional Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.	*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
4	**High Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	**Full Driving Automation**	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

[28] This is a reproduction of Table 1 in SAE International (2016).

Appendix 2: International Transport Forum 2017 timelines for roll-out and adoption of driverless trucks.[29]



[29] This is a reproduction of Figure 7 in ITS (2017)

Appendix 3: Participating Government Agencies and their areas of responsibility

Canadian Food Inspection Agency (CFIA)	• Animals, feed, seeds, fertilizers, food and plants
Canadian Nuclear Safety Commission (CNSC)	• Import Program (Nuclear substances and equipment)
Environment and Climate Change Canada (ECCC)	• Hazardous Waste and Hazardous Recyclable Material • Vehicle & engine emissions, ozone depleting substances and halocarbon alternatives, wildlife enforcement
Fisheries and Oceans Canada (FOC)	• Commercial importation of aquatic species under the Aquatic Biotechnology • Aquatic Invasive Species and Trade Tracking (Fisheries Resource Management) Program
Global Affairs Canada (GAC)	• Import Controls of Agricultural, Steel, and Textiles and Clothing Products
Health Canada (HC)	• Importation of Consumer Products, Cosmetics, Radiation Emitting Devices and Pest Control Products • Importation of Human Drugs, Natural Health Products and Medical Devices Regulated by the Food and Drugs Act • Importation of Controlled Substances and Precursors
Natural Resources Canada (NRC)	• Importation of Energy-Using Products • Kimberley Process (Import of Rough Diamonds) • Explosives
Public Health Agency of Canada (PHAC)	• Importation of Human and Terrestrial Animal Pathogens and Biological Toxins
Transport Canada (TC)	• Importation of Vehicles & Tires