AUTONOMOUS TRUCKING: INTEGRATION POSSIBLITIES FOR THE FOREST INDUSTRY

A. Manderson, Ing., M.Eng.
FPInnovations. Senior Research Engineer, Transportation and Infrastructure

Abstract

Canada's natural resource sector relies heavily on transportation systems to move raw materials from operating sites to processing mills, and ultimately to markets. However, the ongoing shortage of truck drivers threatens to cause unscheduled mill shutdowns, mill shift curtailment, and major industry production losses. There are several autonomous transportation solutions that can be adapted for the forest industry to address this problem. Although semi-autonomous platooning and single vehicle autonomy are the most attractive, selection of the appropriate option will depend on several factors, some of which include the road class / topography, existing infrastructure on the road network, infrastructure requirements of the technology, and regulatory limitations. This paper will discuss how these factors affect the selection of the appropriate autonomous solution and will highlight ideal first adoption sites and strategies for eco-system creation that will support widespread adoption of autonomous transportation.

Keywords: Autonomous, autonomy, transportation, platooning, forest, eco-system, adoption

1. Introduction

Transportation plays a vital role in the success of the forest industry and Canada's natural resource sector relies heavily on transportation systems to move raw materials from operating sites to processing mills, and ultimately to markets. The industry in total contributed around 33 billion dollars to Canadian GDP in 2022, which is approximately 2 % of the overall Canadian GDP.

The ongoing shortage of truck drivers is causing industry production losses of around $450 million. The average age of drivers in the forest industry is 14% higher than the age of drivers in general transport, creating an urgent need to find solutions to avoiding mill shutdowns due to lack of drivers. By 2030, there will be a requirement of 5,500 drivers to fill the gap in the forestry industry, and the driver shortage is expected to increase exponentially every five years after 2030 as mentioned in RH Camionnage Canada (2024).

FPInnovations believes that autonomous transportation can serve as a viable solution for the transport challenges faced by the forestry industry and is interested in adapting available autonomous transportation technologies to Canada's natural resource environment. During winter 2023, FPInnovations oversaw Phase 1 testing of two autonomous capable platooning class 8 trucks with the goal of identifying technological gaps that must be addressed prior to adapting the autonomous trucks to unpaved, medium-to-long distances roads, which are ideal environments for first adoption (see Figure 1).

Figure 1- FPInnovations' platooning trials on forest roads

While these road tests aimed at identifying technical challenges, the current paper will focus on how these heavy autonomous vehicles can be realistically integrated into day-to-day operational environments. A brief overview of the different autonomous technology under consideration will be given along with the anticipated benefits they may offer the industry. This paper will highlight forest operational scenarios in which the technology may be best suited and will identify the existing challenges present in first adoption sites, focusing on the impact on infrastructure and required support staff. The goal of this study is to begin proactively designing realistic eco-systems now so that operational resource environments will be ready to support the needs of autonomous class 8 trucks when this technology becomes available in the future.

2. Overview of Autonomous Technologies

Highly automated vehicles employ the use of complex and specialized software and hardware to execute driving functions. Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) are sometimes confused and erroneously used interchangeably. The main difference between the two is the level of autonomy and the required involvement from the driver. Where an ADAS will help the driver perform their tasks (i.e. adaptive cruise control and crash avoidance), an ADS will use sensors, and other advanced technologies and algorithms to ultimately perform the entire driving function. Highly automated systems may use machine learning and AI (artificial intelligence) in a way that all driving functions could be executed without the presence of a human driver, under specific conditions. The Society of Automotive Engineers (SAE) has defined six levels of autonomous driving in its SAE J3016 (2021) standard ranging from SAE Level 0 where a human driver performs all driving tasks and no driving automation is used, to SAE Level 5 where all driving functions are executed by the autonomous system in any condition.

Highly automated vehicles use inputs from their perception systems, which may consist of a combination of LiDARs, Radars, and Cameras, to view their environment. These sensors are crucial for obstacle detection and avoidance.

A typical autonomous vehicle may use positioning and heading inputs from GNSS (Global Navigation Satellite System) such as GPS (Global Positioning System) and from IMUs (inertial measurement units) as part of its navigational system allowing the vehicle to be aware of its location in the world.

These environmental and navigational inputs allow for situational awareness, which can then be combined with analytical processes to execute decision making tasks. To then carry out the appropriate driving functions, the vehicles are equipped with specialized hardware components, such as actuators, that interface with the vehicle to control braking, throttle and steering.

Some of these highly automated vehicles can use radiofrequency signals to communicate and exchange information with other vehicles (i.e. V2V: vehicle-to-vehicle communication), and in some cases, with surrounding infrastructure (V2I: vehicle-to-infrastructure communication).

It is FPInnovations' intention to introduce ADS, or highly automated vehicle systems, to the industry. Such systems would operate from the harvesting site to the forest product manufacturing plants using a mixed network of paved and unpaved forest roads. The target system would operate under SAE Level 4 autonomy as defined in SAE J3016 (2024), where the vehicle can perform all driving functions under limited conditions and in a well-defined ODD (Operational Design Domain), and would cease to operate unless all conditions are met.

Two types of automated vehicle concepts are currently under consideration, namely, platooning and single vehicle autonomy, both of which will be discussed in the following sections.

2.1 Platooning

The concept of platooning technology was originally developed for on-highway use with fuel-saving opportunities in mind. A convoy, or platoon, of two or more vehicles (see Figure 2) traveling at high speeds and in close proximity has been proven to reduce drag during transport and therefore reduce the energy (or fuel) required to get from point A to B.

Figure 2 – Platooning concept

This original platooning concept employed a driver in each vehicle. Converting this concept to a semi-autonomous solution would involve using highly automated vehicles, where the lead truck could be manually driven by one driver and the follower truck(s) would be driverless, replicating the path set by the lead vehicle. When the automated system is engaged, all follower vehicles in the convoy will attempt to mimic the leader's speed, position and heading while maintaining a set longitudinal distances between one another. The exchange of information between vehicles is accomplished in real-time (on-the-fly during transport) through V2V communication. Some technology providers may opt to use real-time V2V communication combined with a pre-map where the haul itinerary is uploaded to the follower vehicles prior to departure. Regardless of the method used, the driverless follower vehicle(s) would still need to react appropriately in the event of an unplanned scenario (i.e. a vehicle intruding in the convoy).

The semi-autonomous platooning concept is attractive for numerous reasons, primarily for its ability to use one driver to conduct a convoy of multiple trucks, therefore increasing the productivity of raw material hauling operations. Other benefits include having a person on-site to monitor the convoy and execute troubleshooting tasks as required, as well as directing the convoy to new destinations or through detours along the route. Furthermore, the presence of a human driver in the loop is ideal for public acceptance.

A potential con for platooning is that the human driver would have the increased responsibility of securing the payload for all vehicles in the convoy and monitoring multiple trucks during transport. Additionally, as mentioned previously, it is becoming increasingly difficult to find qualified and experienced drivers, one of which would be required to lead the convoy.

2.2 Single Vehicle Autonomy

In the case of single vehicle autonomy operating under SAE Level 4, a highly automated vehicle would conduct all driving functions in a well-defined ODD under certain conditions without the presence of a driver onboard. If the vehicle encounters a condition outside of the acceptable ODD, the vehicle will perform the appropriate pre-programmed response, such as coming to a stop, and would remain stopped until the desired conditions have been met.

The autonomous vehicle would most likely require pre-mapping, where the hauling route is first driven manually by a driver with the system's sensors acquiring information about the itinerary such as positioning, trajectory and behavioral driving techniques appropriate to the road topographical (i.e. ideal speeds for hills and tight turns). Once the map is available, it would be uploaded to the vehicle and the trajectory could be repeated in autonomous mode. This autonomous transportation solution is ideal for repetitive hauling routes; however, the system must be able to respond to changes in the environment that differ from the pre-map. The system must also be able to interact appropriately with other road users.

Although labor costs are expected to decrease with respect to driver costs, personnel would be required to facilitate tasks such as load securement and inspections. Additionally, without a driver in the loop, alternative forms of troubleshooting / interventions may be required in the event of system malfunction, or changes to the planned trajectory. Potentially remote monitoring and / or control may be an added support mechanism, but would require appropriate network infrastructure and monitoring / inspection stations.

3. Benefits of Autonomous Technologies

The implementation of autonomous transportation in a forest environment is expected to bring forth numerous benefits, one of which is an overall reduction in operational costs. The distribution of transportation cost in the forest industry is illustrated in Figure 3, where labour cost constitutes 28%, fuel cost constitutes 43%, repair and maintenance constitute 16%, and insurance constitutes 6%. This creates an opportunity for automation to reduce some of these costs and decrease the overall status quo transportation cost.

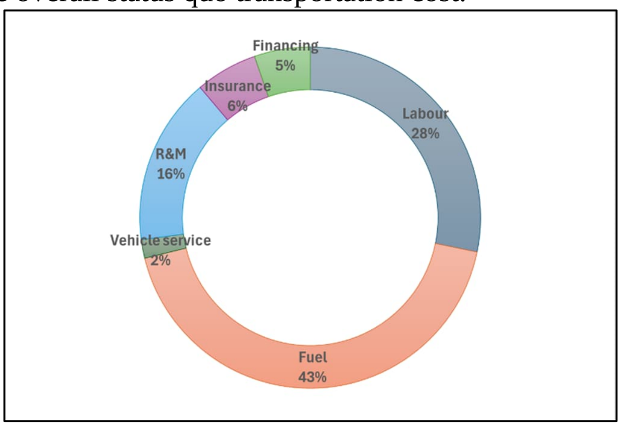

Figure 3 - Log transportation cost distribution

There are numerous studies proving that driving techniques have a significant influence on fuel consumption. The J. Nader (1991) study, where two driving techniques were compared, showed that the driver's response to grades and curves can positively or negatively affect fuel consumption. This study revealed that strategic braking, avoidance of full power usage, consistent speed and progressive gear shifting resulted in an 11% reduction in fuel consumption when compared to aggressive driving techniques with variable speeds, sharp acceleration and frequent brake tapping. In the case of platooning, it can be hypothesized that a driver using optimal driving techniques for the lead vehicle may result in the follower vehicles mimicking this behavior, therefore producing fuel savings for the entire convoy. In the case of a single autonomous vehicle, the system can be configured to replace aggressive driving tendencies with ideal driving techniques and use predictive itinerary planning to optimize fuel savings, and in turn, cost savings. These assumptions would have to be verified by testing the autonomous trucks on forest roads and may be done during future pilot projects.

Autonomous transportation solutions may also lead to overall reduction in transportation cost by lowering direct labour costs, as well as facilitating double shifting and higher equipment utilization rates. Furthermore, by securing the constant flow of materials, the industry can avoid production slowdown as sited by R. Marowits (2018), or plant shutdowns due to driver availability problems and avoid lost profits.

An additional benefit of autonomous transportation is that it presents the opportunity to improve safety and reduce insurance costs in the long term. Majority of road accidents are attributed to human error. The Workplace Safety and Insurance Board (2015) in Ontario reported that forest road vehicle related incidences registered by forest management companies were classified as being extreme in terms of fatality. The adoption of autonomous vehicles, and the appropriate eco-system to support them, has the potential to drastically reduce accidents caused by human error. It will also make it possible to safely support transport operations 24 hours a day, 7 days a week.

4. Forest Operational Scenarios

Resource roads in Quebec are generally categorized into 6 classes (1 to 6). Roads with higher numbers (3 to 5) are generally closer to harvesting sites and typically feature lower travel speeds, narrower widths, and lower construction quality. Class 6 roads, and in some cases class 5 roads, may not be accessible by logging trucks due to their poor quality and narrow widths. Conversely, lower-numbered roads (1 and 2) are usually well-graded and maintained, with wider running surfaces and higher travel speeds. Vehicles often transition from paved and surface-treated public roads to unpaved road networks starting with primary roads that branch into secondary and tertiary roads, eventually reaching harvesting blocks (forming a dendritic network). Primary roads (class 1) typically have dual lanes (one in each direction), while branch roads are typical single lane due to a smaller road width. Besides paved highways, truck automation is most feasible on primary and secondary roads (classes 1 and 2, respectively), where road surfaces are wider and smoother.

Canada has more than one million kilometres of road networks, of which 60% are unpaved roads that are shared between industrial and public traffic. Approximately 20% of forest roads do not encounter highways and lead directly to processing mills.

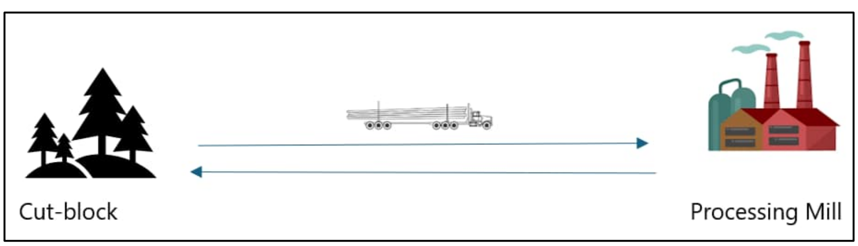

Figure 4 – Traditional haul itinerary (cut-block to mill)

Typically, operations temporarily shut down during spring, and sometimes fall. Reload yards, which serve as temporary storage sites along the route, can be integrated into operations to avoid, or minimize, this shutdown disruption and extend the fiber access period. FPInnovations sees autonomous truck hauling on low-volume, off-road networks as being a practical steppingstone into bringing autonomy to the Canadian resource sector, and reload sites are foreseen to be an integral part of autonomous transportation's first adoption eco-system.

In general, a given haul route could be separated into two different segments when considering reload sites. These segments are listed below.

1. Cut-block (or harvesting site) to reload yard.
2. Reload yard to processing mill.

Logistic details for both these haul segments will be discussed in the following sections. This information is used to determine which autonomy concept is best suited for a given haul segment.

4.1 Cut-block (or Harvesting Site) to Reload Yard

The cut-block is located in the forest and is normally accessible via lower class 2 or 3 roads. Harvesting on winter roads is usually preferred because road surfaces are sturdier. In contrast, these roads are avoided during the thaw season (end of March to June) because of the poor road surface conditions.

Locations of these harvesting sites may vary and are scheduled by the forest management company. Once harvested at the cut-block, the harvested trees are loaded onto tractor-trailers and transported to the reload yard (see Figure 5). In typical operations, the location of the reload yard may also vary depending on forest management planning. Because both the cut-block and/or reload locations may change, the platooning concept is thought to be the most appropriate for this type of itinerary, allowing a driver to direct the convoy between variable locations.

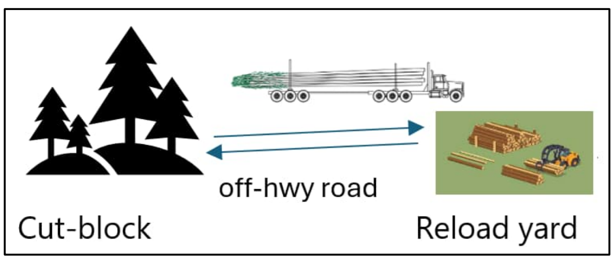

Figure 5 – Cut-block to reload yard itinerary

4.2 Reload Yard to Processing Mill

As mentioned previously, the reload location may vary depending on forest management planning, however the processing mill location remains unchanged. The reload yard to processing mill itinerary normally consists of good quality paved roads, which may or may not be designated as a highway. This itinerary may be well suited for platooning, but even more so for single vehicle autonomous solutions. This is especially true if a reload site with a permanent location was established. By fixing both the reload site and mill locations, a truly repetitive route would be established, therefore create the ideal trajectory for either of the autonomous transportation concepts.

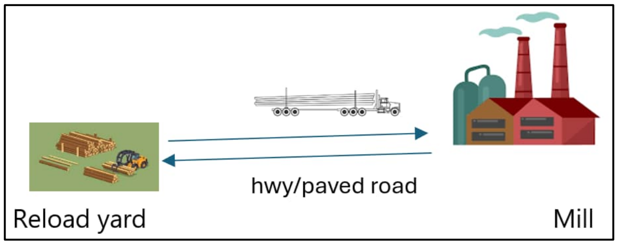

Figure 6 – Reload yard to processing mill itinerary

5. Challenges to be Considered for First-Adoption Sites

There are numerous technology providers currently in the market focused on creating autonomous solutions for specific use-cases such as paved, deliminated roads, or geofenced controlled access sites. Adapting their technology to a forest environment with unstructured roads and varying topography would require both software and hardware modifications and FPInnovations is currently working with various technology providers in the pursuit of solutions to these technical challenges.

Successful platooning trials conducted with various technology providers in 2023 and 2024 highlighted the importance of fine-tuning autonomous technology for specific routes. While the technology is rapidly advancing, it is not yet ready for deployment in all off-road environments. Site-specific challenges, such as transitioning from GPS coverage to GPS-denied areas, adjusting driving reactions when encountering sudden changes in topography (e.g., steep hills transitioning into tight turns), and moving from class 1 to higher-class roads, have sometimes resulted in lateral deviation of the follower vehicle during platooning. To address these issues, FPInnovations sees value in collaborating with regulators to establish autonomous truck corridors on select forest roads throughout Canada. This work, which is planned to commence in 2025, will enable developers to showcase and fine-tune their technology on specific, repeatable routes of interest to the Canadian forest sector.

In parallel, FPInnovations has begun assessing existing operational parameters that may need to be modified to ensure appropriate support is available for the autonomous transportation technology. Parameters that will be discussed in the sections that follow include current infrastructure on haul routes, as well as driver job functions that cannot be performed by autonomous systems. FPInnovations' approach to tackling regulatory hurdles will also be discussed as that it is a key step for ensuring widespread adoption of the technology.

5.1 Operational - Infrastructure

The existing infrastructure must be considered on a given haul route, whether it be from cut-block to reload site or from reload site to mill. Some key considerations are highlighted below.

Bridges:
Most natural resource access road bridges are one lane and usually quite narrow. They are all required to have delineator signs. It is mandatory for trucks to slow down at a bridge approach (typical speeds are limited to 30 km/h), and loaded trucks always have the right-of-way. Even if variations exist between the Canadian provinces, a typical bridge presents the following characteristics:

- Deck width: Single-lane bridge measuring between 4.3 and 5.2 m.
- Average running surface: 4.5 m.

At no point should two trucks be present on a given bridge at the same time. Therefore, in the case of the platooning concept, it is necessary to be able to vary the distance between the leader and follower vehicles to avoid damaging bridges.

Figure 7 – Platooning vehicles over single-laned bridge during platooning trials

Opinions on the ideal truck spacing varies. To maintain bridge structure fidelity, a minimum of 30 m is normally recommended. However, some forest management companies recommend a 1000m distance between loaded trucks as a safety precaution on any hauling route, regardless of if a bridge is present. FPInnovations' recent tests with various technology providers have found that excessive spacing between platooning trucks will cause V2V communication loss, therefore preventing the follower vehicle(s) from receiving trajectory information from the lead vehicle. Although tests are still on-going, FPInnovations and their technology partners have found that anywhere between 100m and 200m results in acceptable V2V communication and comfortable stopping distances at the posted speed limits in unloaded trailer conditions. This gap may increase in adverse weather conditions and if trailers are loaded.

Road surface quality and degradation:
A great majority of resource roads are surfaced with materials that deteriorate quickly with use or due to weather. Although regular maintenance of the road surface is undertaken, the frequency of intervention is never high enough to keep road surfaces in top condition. Depending on the forest management companies scheduling and agreement with contractors, current hauling may be single or double shifts. In the event that autonomous vehicles are integrated into operations and are permitted to run 24/7, this could theoretically increase the number of hauling trips, and the load exerted on the road, which may cause damage requiring increased road maintenance. These speculations will need to be validated through analysis and possible on-road pilots projects, which FPInnovations aims at executing in Phase 2 of the project.

Network and connectivity:
The automated system must not require access to Cellular or WiFi networks either in normal, degraded or emergency modes of operation because these networks are not readily available or reliable in a forest environment. The platooning concept has a self-contained and encrypted V2V communication system where the leader and follower are communicating with each other

via radiofrequency and therefore no outside communication networks are required. Furthermore, the lead driver is on-site to execute troubleshooting tasks if need be. For the single vehicle autonomous concept, if troubleshooting is required, a remote operator can only be used if a viable low latency network option is available. Starlink, which is increasingly used in the natural resource environment, may be a viable option for such troubleshooting requirements but this must be verified by on-road testing during future pilot projects.

5.2 Operational – Support Staff

Incorporating autonomous transportation into day-to-day operations will result in changes to the job profile of operational staff. In the case of a driverless tractor-trailer hauling raw material, we must consider the regular driver job functions and if these functions can be replaced by autonomy or modified by transference to support staff. Some typical driver job functions have been sited by The Urban Institute (2017), and are listed below.

1. Maintain a safe vehicle in good operating order and in compliance with legal and regulatory requirements.
2. Properly and safely prepare vehicle, including loading.
3. Safely travel and transport goods (if loaded) to correct location, meeting or exceeding deadlines.
4. Pick up and deliver cargo on time and in good condition.
5. Utilize appropriate vehicle communication devices; communicate with others regarding vehicle operation and maintenance, safe driving protocols, and cargo transportation and delivery.
6. Maintain accurate and complete records related to travel times, distances, expenses, and delivery of products.
7. Drive truck during the day and at night, in a variety of weather situations and road conditions.
8. Operate according to health, safety and environmental standards, best practices, and requirements.

Each job function listed above has subtasks that should be evaluated individually to determine how they could be handled without the presence of a driver. If the autonomous system is incapable of performing the job function subtasks, an alternative support system must be identified. For example, the subtasks for job function 2 "Properly and safely prepare vehicle, including loading" are illustrated below in Table 1.

Table 1 – Subtask for driver job function #2 - "Properly and safely prepare vehicle"

Subtask description		Can be automated?
a	Conduct pre-trip inspection of critical vehicle components and complete Driver Vehicle Inspection Report (360 deg check).	Partially
b	Perform en-route inspections to ensure proper and safe operation of vehicle.	Partially
c	Perform post-trip inspection and make notes of actual or suspected abnormalities or malfunctions.	Partially
d	Couple tractor and trailer safely and properly.	No
e	Uncouple tractor and trailer safely and properly.	No

f	Make efficient trip plans considering fueling, fuel use, ease of transport, hazards mitigation, and state regulations.	No

If the autonomous system has access to the vehicle's CAN Bus, it is reasonable to think that the pre-trip, en-route and post-trip inspection may be performed partially by an autonomous system. However, visual inspection to identify problems with physical attributes such as hubcaps, turn signals, structural damage and leakage will still need to be performed by a human. Going through the list of subtasks for each job function will be an essential part of designing the eco-system required to support autonomous transportation and is planned for execution in Phase 2 of the project.

5.3 Regulatory Framework

So far, platooning trials overseen by FPInnovations have been solely based in Quebec. However, FPInnovations is interested in autonomous solutions that can be applied throughout Canada. It will therefore be essential to work with each province since the regulatory framework may vary from province to province. In addition to Quebec, FPInnovations is currently in communication with the department of transportation in Alberta, Ontario and Saskatchewan to acquire, or establish, permitting procedures that would allow for the creation of autonomous transportation corridors across Canada.

Preliminary communications has revealed that testing and deployment of autonomous trucks may be easier on private or restricted access roads providing early adaptors the opportunity to deploy driverless trucks on roads with less stringent regulatory requirements. However, such roads with active hauling are not abundant and controlling access is not always possible. FPInnovations will continue its work on corridor identification throughout Canada and regulatory communications into 2025.

6. Conclusion

The goal of FPInnovations' autonomous transportation initiative is to adapt existing platooning or single vehicle autonomy concepts to a Canadian natural resource environment as a solution to the truck driver labour shortage. As FPInnovations works with various technology providers to identify and solve technology gaps, the organization has taken steps to prepare the landscape by first identifying the highlevel characteristics of an ideal first adoption environment, namely, low traffic, off-highway, class 1 to class 2 roads.

This paper has revealed that the most attractive forest operational scenarios for either platooning or single vehicle autonomy would include repetitive hauling routes starting at a permanent reload site and going to a processing mill. However, the platooning concept, which has a human driver leading a convoy of driverless trucks, could potentially be used on a haul route with variable start and end points. Because the platooning concept has a human driver in the loop, which is beneficial for public acceptance, it may be a logical first step to bringing autonomy to the industry.

As highlighted in this paper, FPInnovations has begun assessing the technology's impact on infrastructure, and identifying modifications required to job functions to support autonomous transportation. The organization has also begun working with the forest industry on identifying ideal corridors across Canada that may serve as first adoption sites for platooning and single vehicle autonomy. Next steps will involve assessing these potential sites for safety and logistic feasibility and ramping up engagements with provincial and federal regulators in pursuit of officially establishing the selected corridors as first adoption deployment sites.

7. References

- RH Camionnage Canada (2024), Stimuler le progrès : La nouvelle voie à suivre, mars 2024. Ottawa : RH Camionnage Canada.
- SAE J3016 (2021), Taxonomy and Definitions for Terms Related to Driving Automoation Systems for On-Road Motor Vehicles, J3016_202104.
- J. Nader (1991), Measure of the impact of driving technique on fuel consumption: Preliminary results.
- R. Marowits (2018), Truck driver shortages hitting Canada's forest products sector, Campion Shavings Corporation (https://championshavings.com/truck-driver-shortages-hitting-canadas-forest-products-sector/).
- Workplace Safety North (2015), "WSN Forestry Sector – Key Observations", (https://www.workplacesafetynorth.ca/sites/default/files/Forestry_Sector_Key_Observations_2015-WSN.pdf).
- Urban Institute (2017), "Competency-based occupational framework for registered apprenticeship: Heavy and Tractor Trailer Truck Driver".