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Autonomous Vehicles in Canada

With the growing popularity of Autonomous Vehicles (AVs), more nations are preparing for their widespread use, including Canada. This goal is not without distinctive challenges, however. Harsh winter, changing road conditions, and outdated liability laws create conditions for AVs that differ significantly from those for which they were initially designed to thrive in [1]. While manufacturers have demonstrated promising results in dry and controlled environments, these results do not translate well to Canadian roads. The following explains that Canada is not yet ready for the widespread use of AVs because (i) current sensors do not work well in winter conditions and (ii) there are no laws specifically for AV-related liability [6]. To successfully enable widespread adoption of AVs, Canadian regulators must create winter-ready sensors and pass legislation that clarifies responsibility in mixed-control crashes.

To understand why Canada would struggle to adopt AVs, it is essential to examine how the vehicles operate and why Canada differs from other deployment environments. AVs rely on three central sensing systems to interpret their surroundings: LiDAR to create three-dimensional maps using laser pulses, radar to measure distance and motion and cameras to analyze visual information such as lane markings and traffic signals. Together, these systems enable the perception that forms the basis of all automated decision-making. The Society of Automotive

Engineers ("SAE") defines automation levels from Level 0 (no automation to Level 5 (fully driverless) [1]. In Canada, most testing currently focuses on Level 3, where the human driver must take control if the system fails [2]. Even in ideal weather conditions, the need for sudden human intervention is risky, and Canadian weather can amplify the risk. The harsh winters significantly affect sensor performance as snow conceals road markings, salt forms on camera lenses, black ice removes visual clues, and fog limits LiDAR range [3]. These conditions could last for almost half the year in Canada. As many of these systems are trained on American or European roads where the road conditions often significantly differ from Canadian roads in the winter, they do not perform well in Canadian environments, leading to unexpected failures [3].

The potential issues are better evidenced when considering sensor failures in Canadian winter conditions. LiDAR, for instance, is very sensitive to airborne particles. Snowflakes reflect LiDAR pulses randomly, creating "ghost objects" and messy point clouds [4]. Heavy snowfall can generate thousands of false positives every second [5], which can overload the perception system and lead to emergency braking or disengagements. These false detections are not merely an inconvenience; they are dangerous, unpredictable malfunctions that can cause collisions. In the winter, cameras do not guarantee safety because roads can lose lane markings, snowbanks may blend into road surfaces, and headlights reflect unpredictably off ice. Learning models trained on clear, high-contrast road images do not recognize these patterns.

Further, camera lenses can often be covered with salt, snow or slush, which severely impairs image clarity. Human drivers can use their intuition, experience, and, most importantly, active visual scanning, to handle these conditions; AVs cannot. Radar works adequately in winter weather, but it does not provide the clarity required for detailed decisions, such as lane centring, pedestrian detection, and traffic sign recognition [5]. Radar alone cannot ensure safe operation, as AVs continue to rely primarily on cameras and LiDAR for these tasks. Most training datasets for AVs are developed and/or tested in California, Arizona, or European highways, where the weather is consistent, and road markings are clear [3]. Without extensive training data in weather conditions akin to Canadian winters, sensor fusion algorithms can act unpredictably in slow or sleet. This issue is crucial because autonomous vehicles trained in different areas must effectively learn to operate when used in Canada.

In addition to technical limitations, Canada's lack of legislation creates a separate set of obstacles for autonomous vehicles. For most car accidents, Canadian law still assumes that the human driver is responsible [6]. This approach works for vehicles Level 0 to 2, which are classified as driver-support systems rather than fully autonomous vehicles. Still, it causes significant problems for vehicles that operate at Level 3 and higher. If an autonomous vehicle makes an error while the human driver is technically "in control" but has been told to disengage, there are no laws and/or regulations to determine who is liable. Here, it is unclear whether the driver, the manufacturer, or the software provider is at fault. Presently, due to the lack of legislation and regulation to account for the widespread use of AVs, Canadian courts often hold the driver responsible, even if the driver may not have been able to reasonably prevent the failure [6]. Level 3 automation requires a human to regain control during system failures, but winter failures can be unpredictable and sudden. If a camera loses visibility due to snow spray, slush, or any other obstruction caused by winter conditions, the AV may require immediate driver intervention with little notice. This is an unrealistic legal and practical expectation. Without laws that outline liability in these situations, drivers, manufacturers and software providers are left without clear guidance. Manufacturers are likely to hesitate to test or deploy AVs in Canada if liability is unclear. Additionally, governments cannot effectively regulate safety without a precise legal test that outlines the distribution of fault. This legal uncertainty has a chilling effect on innovation and keeps Canada behind countries with more established frameworks.

These problems highlight the importance of considering both engineering and legal solutions. Engineers must train sensor fusion algorithms on Canadian winter datasets and include weather-adaptive weighting. For example, radar should be prioritized in snow, while LiDAR and cameras should automatically adjust their confidence thresholds. Distinguishing real objects from snow clutter requires machine-learning filtering layers trained on large, annotated winter datasets from different provinces. Manufacturers must also gather training data from Ontario, Quebec, Alberta, and the northern territories to ensure all conditions, such as wet snow, dry snow, slush, black ice, and salt mist, are accounted for. Canada should further establish a standard winter testing protocol to assess AV performance across different snow types, temperatures, and visibility conditions. Legally, Canada must define who is responsible when automated systems are engaged and how liability may shift between the AV and the human driver in Level 3 driving events, whether it be the driver, manufacturer, software provider, or sensor supplier. Last, regulators must mandate that manufacturers report weather-related disengagements.

Some may argue that AVs are not ready anywhere and that focusing on Canada is premature. However, other nations have clear regulations and environments that are better suited for AV deployment. While Canada's unique weather conditions are uncontrollable and raise risks beyond those seen in places like California or Germany, testing for those conditions and defining liability frameworks is within governmental control [7], [8]. Addressing Canadian-specific issues early will help avoid larger deployment failures down the road. Others claim companies will solve winter issues independently. Still, without regulatory pressure, companies have little reason to invest in expensive winter datasets or sensor research, mainly since Canada represents a smaller market than the U.S. One of the major concerns here is cost. Historically, large vehicle manufacturing companies, such as General Motors, have prematurely released vehicles that were inadequately tested, causing a disproportionate number of accidents, injuries, and deaths. Ironically, testing for winter conditions would reduce costs in the long run, as the costs of collisions, injuries, and legal disputes are far higher. Investing in safety engineering and legal clarity early reduces long-term risks for the drivers, industry leaders and governments.

Autonomous vehicles have significant potential, but Canada is not yet prepared for the crucible of Canadian winters. Current AV sensors have difficulty accurately detecting winter road conditions. Additionally, Canada's legal system fails to clearly determine who is responsible in mixed-control accidents. These problems raise serious safety concerns and create uncertainty in regulations. To safely deploy AVs, Canada needs to develop standards for winter-adaptive sensors and enact liability laws specific to AVs. Achieving these two requirements is the key to moving toward a future in which autonomous vehicles are both safe and practical.

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