CAVCOE

Automated Sidewalk Winter Maintenance

A Research Report Submitted to
the City of Toronto

by

CAVCOE

Executive Summary

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Introduction

CAVCOE (formerly The Canadian Automated Vehicles Centre of Excellence) is pleased to submit to the City of Toronto this research report on *Automated Sidewalk Winter Maintenance* (ASWM).

The City of Toronto is interested in trialling systems for Automated Sidewalk Winter Maintenance (ASWM), and expects that ASWM may, at some point, be able to complement existing snow plowing fleets, as well as offer significant advantages compared to conventional winter maintenance services.

Technical Aspects

The report proposes and defines seven levels of automation for automated snow plows, ranging from ASWM-0 which is basically no automation, to ASWM-6 which is full automation. The ASWM technology developers interviewed described systems that appeared to currently be ASWM-0 and ASWM-1 respectively, i.e., low levels of automation, and that they both had ambitions to achieve ASWM-2 in the foreseeable future, which is still significantly short of full automation.

The developers interviewed have adopted significantly different approaches to the technical design:

- Sensors to detect the machine's surroundings include cameras, LiDAR, radar, and ultrasound. The companies developing ASWM equipment have different strategies for sensors. Two ASWM technology developers were interviewed, one relied primarily on LiDAR technology (Left Hand Robotics - LHR), and the other on cameras (Top Hat Robotics – THR).

- Other technical / design issues include the "software and hardware stack", which refers to the different software systems and sub-systems that provide robot functionality, along with the physical sensors, computing components and actuators to provide physical control of the vehicle. The "full stack" is essentially the equivalent of a human driver and can be referred to as an Automated Driving System (ADS).

- Localization techniques also have various options, and the developers have different approaches. However, all developers are expected to utilize Global Navigation Satellite Systems (GNSS), of which one common system is GPS.

- Obstacle detection. There is an intrinsic link between localization, path planning and obstacle detection and avoidance. In essence, these are all about safe navigation for the robot, which is in-turn intrinsically linked to the decision-making algorithms in the software and hardware stack (the ADS).

- Internal combustion engine or electric: again, one developer chose one and another developer chose the other.

- Plow or rotary brush: again, one developer chose one and another developer chose the other.

- Data collection: currently, data is collected for product development and to provide a record for legal liability. In the future, data may have a commercial value. Privacy, of course, will be a factor.

Overview of Technology Development & Deployment

The Canadian Automated Snow Plow Initiative (CASPI) – a not-for-profit association for the industry – has organized annual automated snow plow competitions for university students.

Two key robotic companies were found that were actively developing and/or marketing ASWM technology in North America:
- Left Hand Robotics (LHR), based in Colorado, and
- Top Hat Robotics (THR), based in Ontario.

The body of this report includes significantly more information on the machines from both companies.

There was only one other company worldwide that emerged from the research that has openly acknowledged that it was developing technology:
- Lumebot, based in Estonia.

There are also examples of technology developers working on large-scale snow plows for use at airports, etc. They may, or may not, be interested in downsizing their vehicle platforms for sidewalk operations.

Industry events in the ASWM ecosystem includes the Western Canadian Snow and Ice Management Summit[1]:
- The 2019 event was held in Calgary and the local headlines highlighted 'Robotic Snow Removal Machines'[2].
- The 2020 event was cancelled.
- The 2021 Summit is likely to demonstrate automated sidewalk maintenance equipment with greater capability than previously seen.

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[1] Western Canadian Snow and Ice Management Summit https://www.snowandice.ca
[2] Global News, 'The future of snow clearing? Robotic snow-removal machines on display in Calgary' https://globalnews.ca/news/5896601/calgary-snow-clearing-robots/

There have been ASWM pilot projects in Grande Prairie AB. There have also been pilots of automated sidewalk equipment for other use cases, such as measuring the condition of sidewalks. Additional pilot projects are planned for locations in Ontario for the 2020-2021 winter season.

Current Municipal Perspectives

The Cities of Toronto, Calgary, Edmonton, and Grand Prairie are particularly aware of the potential of ASWM and were interviewed for this report. There has been significant and sometimes high-profile interest in this topic, including the Grande Prairie pilot, a presentation at the recent *Winter Operations Workshop* organized by the Ontario Good Roads Association (OGRA), and the City of Toronto's Automated Sidewalk Winter Maintenance Challenge.

As might be expected, all the municipalities interviewed had a prior interest in ASWM technology to one degree or other, primarily because of the potential of the technology to improve levels of service to residents in their jurisdictions. Therefore, support was unanimous, and few issues were raised as being likely to prevent the adoption of the technology if, and when, it should become available.

Conventional winter maintenance systems have been shown to have inefficiencies. In some cases, there is room for substantial improvement in improving monitoring systems for payment purposes and reducing the number and severity of incidents resulting in claims. The desire for efficiency gains is a strong driver for innovation in this sector, and GNSS monitoring technology is seen a key part of this solution. Hence, there is even greater interest in emerging ASWM technology as there is the potential for significant efficiency gains and cost savings.

Public Perception

Many of the municipalities interviewed have experiences with autonomous shuttle trials and therefore are aware of the process of communicating novel technologies to the public.

It became clear that a tried and tested path to widespread technology adoption is already recognized that might look like this:
- Stage a short demonstration of the technology and solicit feedback.
- Trial the technology and invite public participation in an appropriate way.
- Plan a phased wider rollout of the technology.

None of the interviewees predicted that that there would be an issue with the public rejecting ASWM innovation. The expectation being that if there is resistance it would be from a minority. If, as predicted, more sidewalks can be maintained for the same budget, then it is reasonable to expect that this will be viewed in an overall positive light by the public.

Municipalities have successfully engaged with the media in the past in communicating the potential of innovative technologies like autonomous shuttles. Similarly, media coverage of the first Canadian ASWM pilots has been favourable. A continued policy of media engagement seems appropriate to help keep the public informed.

Regulations and Standards

The regulatory and standards environment for ASWM is new and still a work in progress. There are numerous existing regulations, standards and guidelines for conventional vehicles, equipment and operations related to sidewalk winter maintenance, but none that specifically cover ASWM.

The following are some of the organizations developing regulations, standards and guidelines that are or will be relevant in varying degrees to future ASWMs. They are organized into three categories:

- International Standards Organization (ISO), which is an independent, non-governmental international organization with a membership of 165 national standards bodies. Based in Geneva, Switzerland, ISO develops voluntary, consensus-based, market relevant international standards. All ISO standards start with "ISO".
- There are other organizations that develop standards, including the CSA Group (formerly known as the Canadian Standards Association).
- Third, all levels of government have regulations that govern both the design and operation of equipment, which we expect will in the future include ASWM equipment.

It should be noted that as these standards and regulations are developed, it is likely that there will be multiple overlapping standards and regulations, rather than a single national or international framework.

The principal organizations setting standards, regulations and best practices are:

- **International Standards Organization** (ISO) Draft Technical Standard (DTS) 4448. The development of this standard is being led by Bern Grush of Toronto-based Hamonize Mobility, with participation from Canadian, US and European stakeholders[3]. ISO DTS 4448 will be a standard for managing curb and sidewalk traffic, including robots crossing the sidewalk (such as delivery robots) and winter maintenance robots that travel along sidewalks.

- **CSA Group** (formerly the Canadian Standards Association) advises that it is not currently working on any specific initiatives related to sidewalks, curbs, and/or automated snow plows.

- **Transport Canada** advises that there are multiple jurisdictions implicated by sidewalk robots, with testing in various locations -- including by retail organizations. Similarly, automated snow plows are attracting some interest from various jurisdictions for possible applications. Transport Canada is watching these developments with some interest, monitoring the evolution of automated sidewalk robots, and identifying potential safety best practices for these vehicles in

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[3] There are a total of 30 stakeholders from some 20 cities advising this development. Barrie Kirk of CAVCOE is a member of this team.

collaboration with its provincial/territorial colleagues.

- The **Ministry of Transportation of Ontario** (MTO) told us that it recognizes the importance of new vehicle technology, especially if it expands economic opportunities and consumer options for Ontarians – but safety is their top priority. Ensuring that new vehicle types can integrate safely with pedestrians and other vehicles is a key consideration for MTO before any new vehicle type will be allowed on-road. Although sidewalk robots for deliveries and snow clearing will primarily be operated on sidewalks, they may likely be required to cross public roads, MTO will need further investigation before expanding the CAV testing regime.

- The **City of Toronto** is actively interested in the opportunities and issues related to ASWM, and the fact that they commissioned this research report is evidence of that. Toronto is also active in automated shuttles, and recently announced both the Transportation Innovation Zone and the Automated Sidewalk Winter Maintenance Challenge.

One particular concern raised during the research was that standards should be inclusive of persons with disabilities, as certain ASWM vehicle safety features should provide sufficient warning to all members of the public.

Possible Pilot and Deployment Timeframes

Interviewees thought that full ASWM automation might be available within 5 years and maybe as early as 2-5 years. But they considered that a 5-year estimate is ambitious for the social issues.

We know that low levels of ASWM automation have already been achieved. Technology developers are already working towards higher levels, but they were unwilling to state a specific timeframe for full automation. Based on what CAVCOE heard and its own thought leadership, here are possible cautious and optimistic timeframes for high levels of automation / full automation:

- Cautious: at least 5 years, and probably in the 5-10 years range. However, mid-range ASWM automation levels can reasonably be expected to be achieved sooner than the higher levels, possibly in less than 5 years.

- Optimistic: if a larger technology developer with deeper pockets than currently exists in the ASWM space enters this market, then mid- to high-levels of automation could be achieved within 2-5 years.

The Path Forward

When municipalities consider the potential benefits of ASWM technology, including developing the policies, and a strategy to move to wide scale deployment, the following factors can be considered:
- Complementary use cases that support the use of ASWM in summer months will add significant value to any investment (e.g. the ability to use appliances for grass mowing or snow plowing allows all-year round use and strengthens the business case).

- Grass mowing is an easier challenge than sidewalk winter maintenance and it may be appropriate for this use case to lead development of a wider municipal sidewalk and parks robot deployment strategy.
- Both external rental of ASWM technology or internal purchase and use of ASWM equipment are almost certain to be options. The advantages and disadvantages for each option need careful evaluation in light of each municipality's characteristics and preferences.
- Future winter maintenance contracts may benefit from clauses that are inclusive of ASWM technology and avoidance of clauses that are exclusive.
- There is significant potential for mature ASWM technology to demonstrate substantial efficiencies over conventional winter maintenance systems because of near real-time data monitoring.
- There is significant potential for mature ASWM technology to demonstrate greater consistency and quality of work (level of service) and safer operations, thereby reducing the risk of incidents and claims. Cost savings on claims could be substantial.
- The environmental and efficiency benefits of electric ASWM systems, if battery technology continues to improve on its current trajectory, makes a strong case for battery electric systems over conventional fossil fuel equipment.
- Wide scale deployment of ASWM technology will probably reduce the labour resources. However, a higher level of labour skills, and/or additional skills will be required, such as additional maintenance and operational skills needed for electric vehicles, route programming, and operation of robots etc.
- Innovative technology like ASWM can develop fast, in multiple directions and take many forms. Well-written municipal policies and strategies will provide room for innovation, whilst ensuring safe operations and not hindering creative solutions.

Conclusions

Automated Sidewalk Winter Management (ASWM) is an approach and technology that holds great promise, but full automation is not here yet and it will take several years. Based on the potential of future mature ASWM systems, the qualitative business case is clear for municipalities, parking lot operators, and developers and potential suppliers. The supply side of this ecosystem can and will leverage the fast-paced developments in the automated passenger and delivery vehicle ecosystems.

CAVCOE forecasts that there will be incremental steps along this path, especially partially-automated machines that will increase in capability and become more popular in the years ahead. CAVCOE also forecasts an accelerating number of pilots and trials, similar to that seen in the autonomous shuttle sector.

An increase in the number of municipalities showing interest at this early stage can be beneficial in signalling a positive interest in the technology, and spurring technology developers to invest resources and realign priorities to develop such solutions for municipalities in North America.