Development of Snow Removal Machinery for Optimizing Sidewalk Snow Removal

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ABSTRACT

National and local governments conduct snow removal in Japan. Even in winter many people use sidewalks for commuting to work and school. Therefore, we have high residential demand for sidewalk snow removal and so need removal from sidewalks as well as roads.
Due to recent severe financial conditions we are facing a problem in how to conduct sidewalk snow removal efficiently in order to match increasing demand. Accordingly we have developed sidewalk snow removal equipment to streamline removal.
We currently use two types of equipment. First, a small, riding, snow removal vehicle, and second a walk behind type snow removal machine. The riding vehicle is efficient but difficult to maneuver, while the walk behind type machine is easy to use but less efficient.
However, there are problems with our conventional snow-removing equipment relating to safety, operational efficiency and operational costs. Therefore, we have employed enhanced technologies to solve these problems.

KEY WORDS

SNOW REMOVAL MACHINERY / TECHNOLOGY DEVELOPMENT / SIDEWALK SNOW REMOVAL

1. Introduction

Organized deployment of snow removal machinery in Japan began in 1956 after the Japanese government established an organized budget for road snow removal. 20 years later, in 1977, sidewalk snow removal on National Roads began, initially being conducted only experimentally in certain intervals.
Up until 1956, snow removal was mainly conducted with earthmoving machinery such as bulldozers and wheel loaders, however, after the establishment of an organized budget for road snow removal, the development and adoption of machinery special for snow removal began to increase. Today, 55 years later, the length of snow removed has increased dramatically, with the number of snow removal vehicles deployed for National Roads alone ranging at over 4200 vehicles. The overall efficiency, size, speed, automation, and safety of snow removal machinery have also improved significantly.
In 2003, the Japanese government declared to maintain a present status standard for the deployment of snow removal machinery, resulting in a decrease in the annual budget assigned to

snow removal machinery each year. This decrease in funds, has reached its peak, currently at 57%. Under such budgetary constraints, technical improvements such as optimized quality, lifecycle, and cost performance, have been heavily promoted. For example, by reducing the time of each job cycle, increasing the range of functions to lower the number of deployed vehicles, and improving the safety of machinery, the capability of snow removal machinery has been greatly improved.
Notably, in the past few years, there has been a raising demand from citizens for sidewalk snow removal. Under the budgetary constraints, the efficiently of the growing sidewalk snow removal industry has become a major issue. In this paper, the current condition of the development of effective and efficient machinery for sidewalk snow removal will be reported and the deployment of such machinery will be looked into.

2. The current condition and issues concerning sidewalk snow removal in Japan

2.1 Summery of the sidewalk snow removal industry

60% of the national area of Japan consists of snow-falling cold regions, with approximately 20% of the Japanese population (~28 million) living in these regions. Additionally, there are cities ranging in population from several hundred thousand to over a million in regions with an accumulated snow depth of over 5 meters. Despite such harsh conditions during the winter season, these regions occupy an important position in Japan, supporting a stable supply of food and utilizing the rich natural environment. On the other hand, it is often the case that in comparison to other regions, public transportation is not very advanced, and automobile dependence is high in snow-falling cold regions. For this reason, it is crucial that road transportation is maintained in order to support the livelihood of citizens and the economy during the winter season. During the winter, snow removal is generally conducted with snow removal machinery, and it is inevitable that the snow removed from the roadway accumulates onto the snowdrift region by the sidewalks.
However, when the capacity of the snow drift region is exceeded, snow accumulates onto the sidewalks themselves. This, in addition to the snow which naturally accumulates onto the sidewalks and the snow which falls from the roofs of houses, creates an increased snow drift region.
In such conditions, when there is not much snow, pedestrians on the sidewalks tread down the snow with their feet, creating a narrow path as they walk. However, when large amounts of snow accumulate and walking on the sidewalks becomes difficult, pedestrians are forced to walk on the roadways, thus increasing the risk of traffic accidents.
For the above reason, sidewalk snow removal is crucial in ensuring the safety of pedestrians and smoother traffic. Sidewalk snow removal in Japan began in 1977, centered on highly utilized areas such as city centers, school roads, and welfare facilities. The length of snow removed from sidewalks in Japan is approximately 20000km, which constitutes 4% of the total annual cost for snow removal.
The goals of sidewalk snow removal are as follows.

ⅰ. To ensure safe passage for pedestrians (to the degree that pedestrians can easily walk the sidewalks in boots).

ⅱ. To create a wide enough area of snow cleared sidewalk to support the number of pedestrians.

ⅲ. To ensure that snow drifts formed though natural accumulation of snow and road snow removal do not cause difficulty to pedestrians.

ⅳ. To utilize snow hauling in areas where there is no snow drift zone or the amount of snow exceeds the capacity of the drift zone.

ⅴ. To complete snow removal operations prior to the morning rush hour.

2.2. Deployment and technical management of sidewalk snow removal machinery

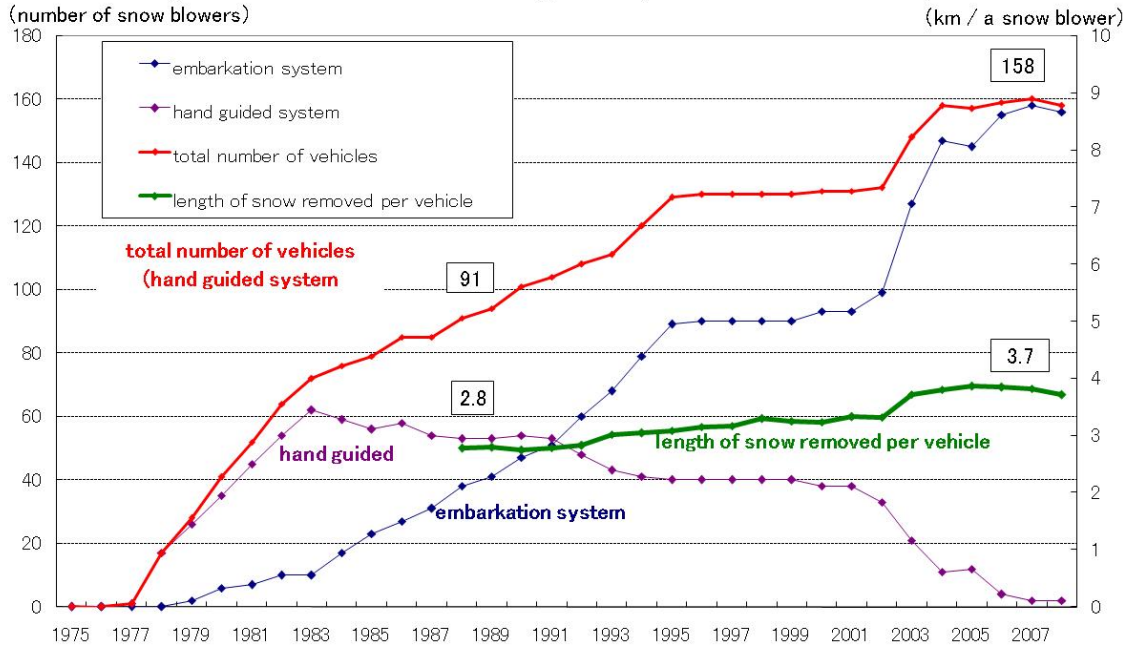
2.2.1. Snow removal procedures

There are two coinciding varieties of sidewalk structure: there is the mounded type, in which a curbstone, rising 15-20cm from the roadway, protects pedestrians from traffic; and there is the semi-flat type, which attempts to convert the sidewalk into a barrier-free structure. Mounded type sidewalks are most dominant in urban areas. However, this type of sidewalk is not only narrow in width, but the structures that have also slopes declining into the roadway at terminal areas for vehicles and pedestrian crosswalks. In addition, there are many sections of sidewalk which are not adequate in width due to adjunct structures such as pedestrian bridges and private properties on the sidewalk. These areas obstruct walking and hinder the efficiency of sidewalk management.

In these kinds of circumstances, measures to control sidewalk snow are classified into snow removal measures and snow protection measures. Snow removal measures are classified into machine or human powered snow removal, snow melting machinery, and snow-flowing gutters, but due to the aspect of cost, as mentioned before, machinery is currently the main measure for snow removal. In mechanized snow removal, it is most economical to utilize the same machinery that is used in roadway snow removal in sidewalk snow removal as well. However, due to the narrow width and shape of the sidewalk, obstructions such as delineator poles, private properties on the sidewalk, and the close proximity of civilian residences, it is very difficult to utilize roadway snow machinery on sidewalks. For these reasons, the development of snow removal machinery solely for sidewalks has become the general method.

The machines used for sidewalk snow removal are mainly constructed using a rotary system, and due to sidewalk structure and roadside conditions, either hurling snow outside of the road or hauling the snow to another location. The width of the machinery is adjusted according to the sidewalk width, ranging from approximately 0.8-1.5m. The decision of whether to use a hand guided system or embarkation system is made with consideration to economic aspects and the overall length of snow removed in the area. The cost of a hand guided system is low; however, the operating speed is only around 0.5km/h. On the other hand, the cost of an embarkation system is high, but the operation speed is about 1km/h, so the longer the time of operation is, the more economic it becomes to use an embarkation system. In this way, sidewalk snow removal machinery is deployed in the most appropriate way possible, with consideration to economical efficiency.

Figure 1: Annual shift from hand guided system to embarkation system



2.2.2. Retention of machinery

The total number of sidewalk snow removal vehicles in Japan is 2500, and when the status of deployment is observed from territorial authorities, for example, it can be seen there has been a general progression from hand guided machinery to disembarkation machinery in accordance with the length of snow removed. Due to this shift in machinery, the amount of snow removed by a single vehicle has increased by approximately 1km over the past 20 years. This increased productivity shows how the adoption of better machinery is directly correlated with the reduction of snow removal cost. (Figure 1)
Furthermore, due to the amount of snow removal changes according to the amount of snowfall each year, the amount of operation for sidewalk snow removal is not fixed from year to year. In addition, operation can only be anticipated during the winter season, which is about four months long. For this reason, when private contractors hold sidewalk snow removal machinery, it is difficult to collect investments for the cost of the machinery. Therefore, the government often holds the machinery and lends it out to private contractors.

2.2.3. Management of operations quality

The control level of sidewalk snow removal is determined by taking into considerations of factors such as the sidewalk traffic, snowfall conditions, roadside environments, and structural restrictions of roadside. The deployment of machinery is efficiently calculated to account for the operation time necessary in each snow removal section. Under the limited budget, it has become important to ensure the level of service when conducting road management. (Figure 2)

Figure 2: Level of control for sidewalk snow removal

Objective rank conditions	A	B	C	D
Level of sidewalk use	number of pedestrians: more than 100/day or more than 40 school children/day		daycare and school commuting routes	intervals crucial to traffic safety
Meteorological conditions	2m above the total accumulated snowfall over the past 5 years			
Roadside conditions	drift zone present no obstacles to snow removal	drift zone present obstacles to snow removal present	no drift zone obstacles to snow removal present	mechanized snow removal is possible
Sidewalk structure	sidewalk width above 1.5m no complicated shifts in sidewalk height	sidewalk width above 1.5m small amount of complicated shifts in sidewalk height		mechanized snow removal is possible
Local relations	cooperative towards snow removal demanding sidewalk snow removal			
Snow removal time period	snow removal executed prior to the school rush hour	snow removal executed during the daytime	snow removal executed after continual snowfall	snow removal executed during the melting period

2.3. Issues concerning sidewalk snow removal

In the past, traffic was often stopped for long periods of time during the winter due to snow accumulation. This lack of traffic caused industrial economic activity to stop and brought insecurities to livelihood. Nowadays, in order to promote industry in snow falling cold regions, improvements to road conditions, such as an enhanced implementation structure of snow removal operations and secured snow drift zone have been promoted, making the condition of roads much more adequate for the winter season. At the same time, due to social changes such as aging and a rising interest from residents for better road conditions, there is an escalating demand for both improved snow removal and an increase in the length of snow to be removed. However, when the public financial circumstances of Japan are taken into consideration, it is difficult to make any investment which

would greatly exceed the present government standard for snow removal. Therefore, various measures are required to ensure winter traffic conditions.
The following points are taken into consideration for sidewalk snow removal.
ⅰ. More efficient snow removal operations to reduce operational costs.
ⅱ. An increasing public dependence on snow removal due to the dwindling birthrate and
ⅲ. A shift to barrier-free sidewalks to reduce slip and fall accidents caused by narrowing sidewalk widths and frozen sidewalks.
ⅳ. Safety assurance for machine operators and citizens during the time of snow removal.

2.3.1. Issues concerning sidewalk snow removal machinery

In the past few years, the public demand for sidewalk snow removal is escalating. However, due to the fiscal condition, there has been a continuing decrease in the budget for the purchase and maintenance of snow removal machinery. The compensation for snow removal expenses is, for the most part, calculated according to the number of operational hours. Therefore, it is of high importance that operational efficiency is optimized to reduce operational cost and that the number of deployed vehicles is constricted in order to minimize machinery investments. Furthermore, adequate safety measures for the operation of sidewalk snow removal machinery are also of high importance.
In recent years, accidents involving snow removal machinery have not only claimed operators as victims, but pedestrians as well. Measures against such accidents have become urgent business. (Figure 3) Clogging of snow removal machinery, in particular, is the largest factor in the occurrence of accidents, and it has become a major hindrance in the optimization of job efficiency as well. The demand for snow removal is expected to increase in the coming years. With such a limited budget, it is of high importance to advance the development of snow removal machinery, in order to guarantee safety, reduce cost, and increase the efficiently of snow removal.

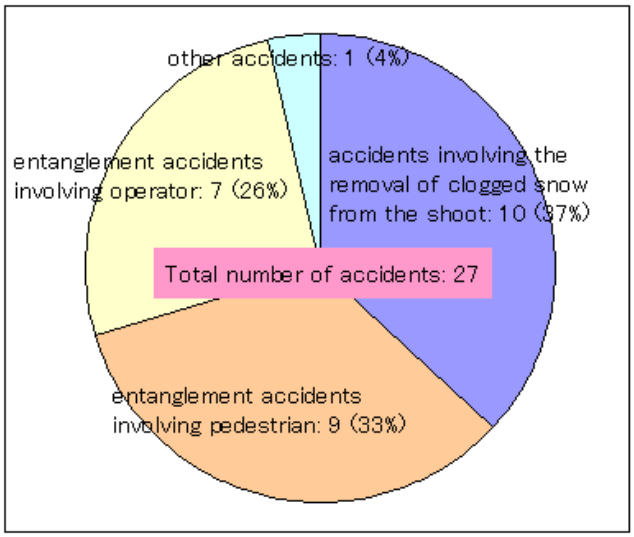


Figure 3: Comparison of accident types(2003-2004)

2.3.2. Sidewalk structure

The reexamination of sidewalk structure in order to create a more suitable structure for snow removal is also of high importance. While sidewalk width has been increased from year to year, in areas where there are lots of private residences close to the sidewalks, it has been difficult in increase sidewalk width. Furthermore, because varying widths of sidewalk occur due to obstacles such as utility poles and signs, efficient removal of snow is difficult. Since mechanized snow removal on sidewalks is complicated, it becomes necessary to rely on human powered snow removal, which is both highly inefficient and expensive.
Additionally, in residential areas where cars frequently move in and out of driveways, the height of the sidewalk is often unlevel in sections where driveways meet the roadway, making it necessary to constantly adjust the angle of the machinery to comply with the differences in sidewalk level. These adjustments cause decreases in operational time, and are a major setback for snow removal. When improving sidewalks, both large investments and cooperation from roadside inhabitants become

necessary, causing any reconstruction work to require a long period of time. Therefore, it is crucial to utilize the most efficient measures possible when developing snow removal machinery.

3. Appropriate deployment and management of sidewalk snow removal machinery

3.1. Obstacles for sidewalk snow removal, and ways to make operations more efficient

3.1.1. Factors concerning the technical proficiency of machine operators

Currently, due to factors such as rippling sidewalk structures and low operability and workability of snow removal machinery, snow removal is dependent on highly skilled machine operators. This is a large problem for sidewalk snow removal. The cost concerning the operation of small-sized snow removal vehicles is currently compensational with job time; however, the amount of work possible per operation (the length of removable snow) is greatly influenced by the degree of skill of the operator.

3.1.2. Obstacles concerning machinery

Small-sized snow removal vehicles are capable of exerting a specific amount of power by adjusting the operational speed. However, in order to set the snow throwing direction, one must operate five separate levers. (Image 1) Such vehicles are difficult to control for inexperienced operators, and problems such as snow clogging and sections missed due to unlevel sidewalks cause inefficient operations, resulting in higher cost. (Image 2)

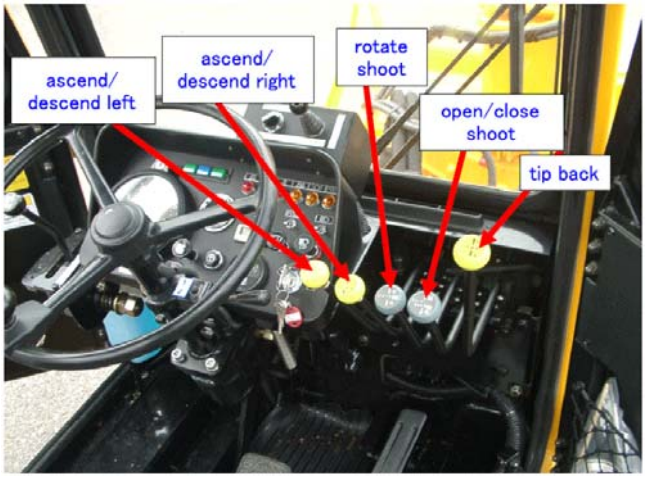


Image1:Operational lever in older machines

Image2:Unleveled sidewalks resulting in leftover snow

Snow clogging occurs when the balance between the amount of snow taken into the machine and the operational speed (snow removing ability) is disrupted. The snow removal device becomes unable to expulse the snow within, and stops working. In addition, the snow clogged within the machine must be removed manually, which interrupts snow removal operations. Therefore, much unnecessary time is spent during snow removal, creating an obstacle for pedestrian commuters.

3.1.3. Factors which hinder job performance

During snow removal, operators must adjust the snow removal machine accordingly to the differences in level of the sidewalk; however, since fine tuning of the machinery is necessary, the number of required operations is high, thus resulting in an uneven finish. In order to accommodate for differences in sidewalk level, operators must lower the speed of the machinery, but walking

across different levels is extremely difficult and often results in 10cm or more of leftover snow. This leftover snow then gets treaded down by pedestrians and turns into ice, becoming a major walking hazard.

3.1.4. Developmental goals for improving the efficiency of sidewalk snow removal

In the case of small-sized snow removal vehicles, the operator must both steer the vehicle itself and operate the controls for snow removal at the same time. This causes difficulties in operations, requiring a highly experienced operator.
Because of the following difficulties, high experience is required to operate snow removal machinery.
ⅰ. The speed of snow removal cannot keep up with the level of snow accumulation.
ⅱ. Snow removal machinery cannot comply with driveway entrances and other differences in level or asperity in sidewalks.
ⅲ. The control lever of machinery often malfunctions.
Due to the above reasons, snow clogging and mechanic malfunctions often interrupt snow removal, causing inefficient operations.
The simplification and semi-automation of control systems is a major goal of equipment development in order to simplify operations and improve the efficiency and constructively of equipment. More precisely, the simplification and semi-automation of equipment has resulted in an operational speed increase of 30%, a deduction in operational cost of 20%, and has lowered the amount of left over snow to 2cm.

3.2. Enhancing the safety of sidewalk snow removal operations and the various safety hazards

3.2.1. Structural factors

Sidewalk snow removal machinery is equipped with a high speed ribbon-screw auger which throws the snow. For this reason, if one were to get caught in the machine, this could lead to a major accident. In addition, since sidewalk snow removal takes place on the sidewalk, the danger of harming passing pedestrians is also present. Due to the increasing need of sidewalk snow removal and an increase in accidents involving hand guided sidewalk snow removal machinery, in 1988, the Ministry of Land, Infrastructure, Transport and Tourism established a new safety guideline for hand guided sidewalk snow removal machinery.
According to these new guidelines, there must be equipped an automatic stopping mechanism, which stops the snow removal device when the operator moves away from the controls of the machine. Also being required is a device which will automatically stop the machine if the operator falls down during backwards movement, however, at the current time, not all snow removal machines on the market are equipped which such a device yet.
Furthermore, as a measure to prevent pedestrians from getting caught in the ribbon-screw auger, a single button emergency stopping blade is also required; however, such a blade does not physically stop such entanglement accidents.

3.2.2. Operational factors

During the operation of sidewalk snow removal machinery, it is necessary to adjust the running speed and running direction while controlling the snow removal mechanism. The snow removal controls consist of individual levers to adjust the direction in which the snow is thrown, the distance it is thrown, and the amount of snow that is thrown. Machine operators must control all of these mechanisms while surveying their surroundings to ensure safety. However, with such a large number of levers to control, it becomes easy to make erroneous operations. In addition, in order to

check the position of a certain level, the operator must briefly take his or her eyes off the surroundings, thus not being able to ensure the surrounding safety, which can lead to accidents. The risk of accidents is especially high for operators who are low in experience and not used to the controls yet.

3.2.3. Developmental goals to improve safety

In order to prevent accidents involving sidewalk snow removal machinery, it is necessary to use safety devices such as an auger protector. However, when attaching the protector to the front of a machine, it is necessary that the protector is designed so that it does not obstruct snow removal. Another way that safety has been improved is by integrating multiple control levers into one, in order to simplify operation for inexperienced operators.
By utilizing the above design improvements with the safety guidelines of the Ministry of Land, Infrastructure, Transport and Tourism, other than collisions with motor vehicles, it is possible to prevent nearly all types of accidents involving sidewalk snow removal machinery.

4. Developmental projects in recent years

4.1. Improving operational efficiency

4.1.1. Snow clogging prevention mechanism

In order to prevent snow clogging due to work speed over, it is necessary to adjust the load of snow removal with the speed. The newly developed snow clogging prevention mechanism consists of an overload capacity stopping device, which stops the machine when the load of snow taken into the machine surpasses the machines snow removal capability and starts the machine back up when the load of snow is reduced. There is also a snow depth specific speed control device, capable of automatically adjusting the speed of the machine according to the amount of snow.

ⅰ. Overload capacity stopping device

The overload capacity stopping device monitors the load of removed snow by checking the rotation rate of the blower with a sensor, and stops the machine when it overloads its capacity. (Figure 4)

ⅱ. Automatic work speed control device

The automatic work speed control device allows the operator to set the depth of snowfall with a dial, which automatically adjusts the speed limit of the machine appropriately to the snow load.

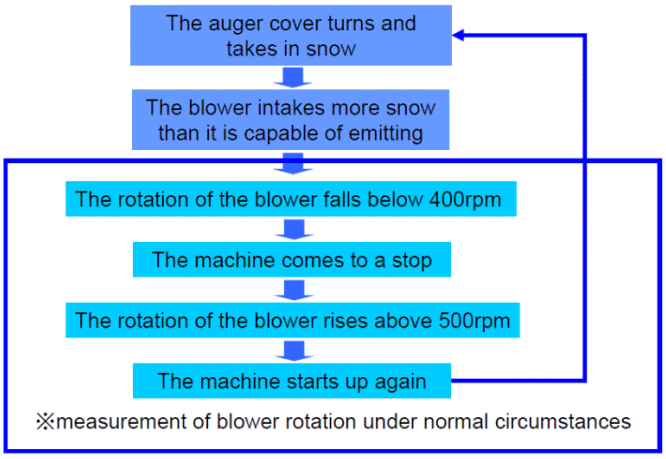


Figure 4: The flow of stopping the machine

4.1.2. Automatic surface adjustment mechanism

The newly developed automatic surface adjustment mechanism controls the oil pressure of the oil hydraulic circuit supporting the work device. The mechanism automatically adjusts the height of the machine within an 8% angle and a 2cm gap from the sidewalk at unlevel areas between roadways and sidewalks. Such a mechanism eliminates the need for the operator to manually adjust the angle of the machine up and down, left and right, or forwards and backwards in order to accommodate with differences in sidewalk level. With the induction of this new mechanism, it has become possible to lower the number of control levers from 5 levers to a single lever.

4.1.3. Evaluation of developmental techniques

Up until now, the operational speed of snow removal machinery was approximately 1.0km/h; however, with the induction of these various new developments, this speed has risen 50% in top scenarios and 30% on average. (Figure 5)
A cost-benefit analysis shows that for an annual average operation time of 100 hours, the cost-benefit is 1.14, and for an annual average operation time of 250 hours, the cost-benefit is 2.31. This shows that cost is comparatively lower over an increased operation time. (Figure 6)

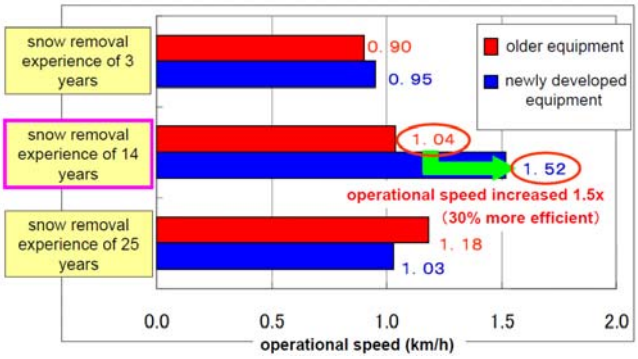


Figure 5: Comparison of operational speed

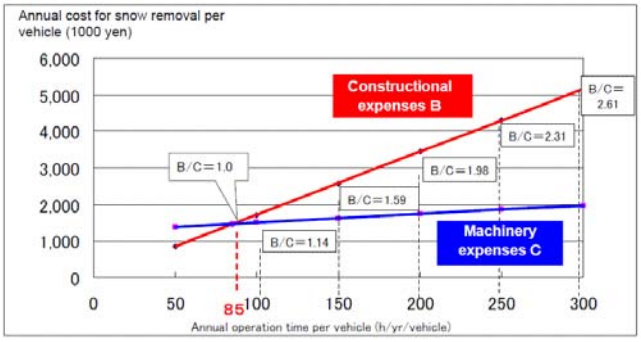


Figure 6: Cost benefit analysis

The automatic surface adjustment mechanism is capable of keeping the amount of leftover snow under 2cm, and can adjust the machine within a 5% angle from the sidewalk, regardless of the operator's skill level. (Figure 7)
This eliminates the need to delicately adjust the machine to accommodate with surface level, thus reducing the number of required lever operations by approximately 97%.(Figure 8)

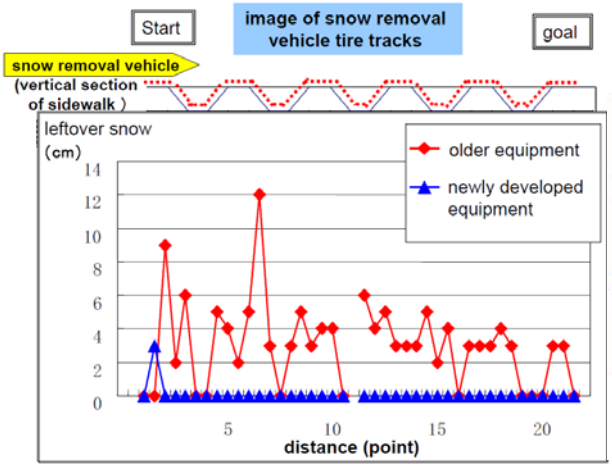


Figure 7: Amount of leftover snow after snow removal

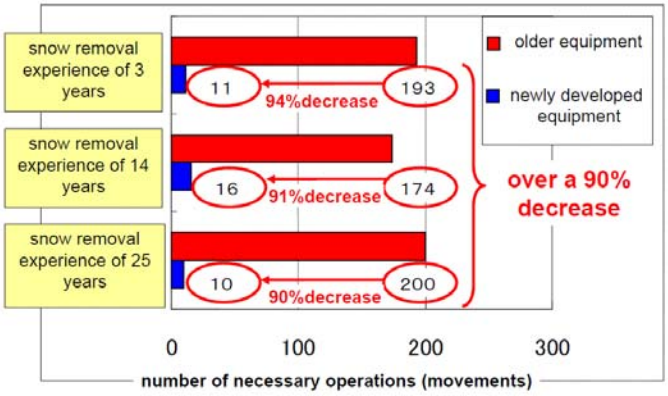


Figure 8: Comparison of number of necessary lever operations

4.1.4. Results fro m the developed technology

Due to the induction of the new technology outlined in this paper, the operational time for removing snow has decreased dramatically, and it has become possible to complete snow removing operations prior to the morning rush hour.
Through the induction of simplified controls, job interruptions and leftover snow have become a thing of the past, and snow removal is no longer dependent on the operator skill.

For example, in a Hokuriku regional road authority, before the induction of new machinery, the amount of deployed vehicles necessary was 27; however, through the induction of simple control sidewalk snow removal vehicles, it has become possible to lower the number of required vehicles 20% (22 vehicles), thus greatly reducing infrastructural cost.

4.2. Safety improvements

4.2.1. Auger safety protector

When developing an auger safety protector, it is required to prevent entanglement accidents. However, at the same time, it is also necessary to make sure that the device does not interrupt snow removal operations or affect the lateral weight of the machine.
For the above reasons, the auger safety protector was constructed using a link mechanism. This allows the protector to open and close automatically, without drawing power to adapt to the depth of snow under the float. (Image 4,Figure 9)

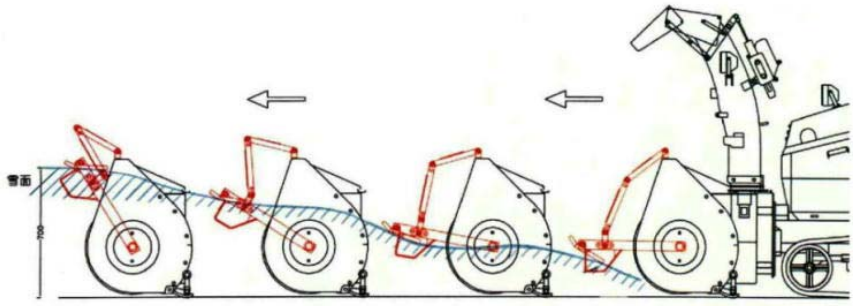


Figure 9: Movement of the auger safety protector

Image 4: Auger safety protector

4.2.2. Simplification of control levels

In order to simplify the control levers, a joystick mechanism was recently adopted. Along with the newly installed overload capacity stopping device, it has become possible to easily operate snow removal machinery. (Image 5)

Image 5: Simplification of levels

4.2.3. Evaluation of developed technology

The auger safety protector is capable of covering 70% of the anterior opening of the machine, with the largest dimension of the uncovered section measuring about 140mm. Unless one were to deliberately insert his or her hand into the float, there is nearly no physical risk of entanglement accidents. The only problem remaining is that when the protector is raised in a deep snowfall area, it

is possible for a pedestrian to get caught in the bottom section of the float. However, since the protector is only raised in deep areas of snow, the chance of a pedestrian being in front of the vehicle is very low. Even if one were to get entangled in the float, as long as the operator used the emergency stopping device within about a second, physical injury could be avoided. With the simplification of control levers, it also becomes easier for the operator to ensure his or her surroundings for safety, making it possible to avoid accidents involving sidewalk snow removal machinery.

4.2.4. Results from the new technology

The newly developed mechanisms were put through a field adaptability test in 2007, and as of 2008, 7 vehicles have been officially adopted into the field and are currently operating. (Image 6) The safety auger protector is capable of preventing entanglement accidents without drawing power, and does not lower the performance of snow removal. Along with the simplified control levers, the auger safety protector has received a high appraisal for improving the safety of the work field. In areas where the safety protector has been adopted, there have been zero accidents related to sidewalk snow removal machinery.

Image 6: Operational conditions

4.3. Future outlook

From the high evaluation of field adaptability tests, it can be confirmed that the new technology developed over the past few years has established a new standard for snow removal. This new technology has contributed to higher working efficiency, decreases in cost, and improvements in safety. In addition, the newly developed technology can be utilized in both hand guided systems and embarkation systems. Therefore, in the future, we plan to make positive efforts to introduce this new technology as the standard for sidewalk snow removal machineries.

5. Current plan for optimizing the deployment of snow removal machinery

In Japan, the total length of snow removed has reached 250,000km. Out of this total length, the length of snow removed in intervals designated for federal snow removal assistance by law is approximately 100,000km. These intervals span from directly controlled national highways to city, town, and village roads.

Approximately 23,000 snow removal machineries are in use in the designated intervals for snow removal. Half of these machineries belong to the federal and local government, with the other half belonging to private enterprises.

It could be said that the snow removal system in Japan is maintained through the cooperation of the government and the private sectors. Private enterprises mainly use earth moving machinery for snow removal, which contributes to an improved utilization rate of machinery, since construction jobs are sparse in the winter season. However, compared to machinery specifically designed for snow removal, the performance of earth moving machinery is inferior, therefore causing a larger number of deployed machineries to become necessary.

Snow removal machinery possessed by the federal/local government is designed specifically for snow removal, and therefore has a high level of snow removal performance. The government has endorsed the technical development and propagation of such machinery. The rotary type snow blower, snow removal grader, and snow plow truck developed in Japan, have all been specially designed to conform to the distinctive characteristics of snowfall in Japan.
All of the new technology covered in this paper is suitable for the complicated sidewalk structure and operational conditions of snow removal in Japan. This new technology has shown satisfactory results in actual road tests and is expected to contribute to optimizing the cost of snow removal.
In the future, it is anticipated that the length of snow removed through sidewalk snow removal in Japan will increase, thus causing the cost of snow removal to increase dramatically as well. Therefore, it is necessary to improve the operational efficiency of snow removal as fast as possible. Currently, out of the 4500 sidewalk snow removal machineries in use in Japan, 1900 of these are government provided machineries. In the future, the government plans to promote the induction of the various new technological developments discussed in this paper into these machineries.

6. Conclusion

The Japanese government is promoting a decrease in public affair expenditures based on a thorough revision of cost. The number of snow removal machineries provided with federal funds in Japan has reached 10,000; however, since the budget for snow removal machinery has been continually suppressed over the past ten years, the current standard is at 50% of what it was during the peak time period.
The technological advances outlined in this paper have already been induced in multiple areas throughout the country, and have shown significant results in lowering cost. Road administrators, machinery operators, snow removal machinery manufacturers, and volunteers all cooperated in the process of development, resulting in a high level of appraisal from the work field.
In the future, we wish to continue to promote the maintenance of snow removal machinery with the following goals: 1.) Create a barrier free environment in snowy regions, which is suitable for the aging population; 2.) Diversify socioeconomic activity; 3.) Deduct the cost of snow removal to gain better understanding from sidewalk users; 4.) Cooperate with local inhabitants. Such goals as these will help contribute to an effective snow removal system, which is adapt to the many changes of society.

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