DEPARTMENT OF TRANSPORTATION

Designing and Implementing Maintainable Pedestrian Safety Countermeasures

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16. Abstract (Limit: 250 words)

While pedestrian safety countermeasures contribute to reducing vehicle-pedestrian crashes, their impacts on winter maintenance operations are sometimes overlooked during design. There is a need to investigate the best practice guidance and solutions for the design, installation and maintenance of pedestrian safety features for year-round maintenance. To address this, we conducted a search of literature as well as agency interviews to identify and document current best practices for designing and implementing pedestrian safety countermeasures for year-round maintainability. The countermeasures reviewed included curb ramps, crosswalk markings, corner radii, curb extensions, refuge islands, and speed humps and raised crosswalks. The information collected allowed for the development of conclusions and recommendations for these features. The design dimensions and features of pedestrian curb ramps are established by the Americans with Disabilities Act and should have a slope of greater than 1:12 and a maximum cross slope of 1:50. Durable materials can be used for crosswalk markings, and these can be grooved into the pavement to provide protection from abrasion. Bulb-outs should use a 1:2 or 1:3 upstream taper and a 1:3 downstream taper. When used, tight radii of 15 feet or less should be employed. Refuge islands can range from 6 feet or greater in width, 24 feet to 40 feet in length, with a 4-foot or greater walkway width. Finally speed humps and tables should be between 3-4 inches in height, with lengths of 12-14 feet (humps concave in shape) and up to 22 feet (tables).

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FINAL REPORT

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LIST OF ABBREVIATIONS

American Association of State Highway Transportation Officials (AASHTO)

Americans with Disabilities Act (ADA)

Department of Public Works (DPW)

Federal Highway Administration (FHWA)

Institute for Transportation Engineers' (ITE)

Manual on Traffic Control Devices (MUTCD)

Minnesota Department of Transportation (MnDOT)

Minnesota Pollution Control Agency (PCA)

National Association of City Transportation Officials (NACTO)

National Cooperative Highway Research Program (NCHRP)

National Highway Traffic Safety Administration (NHTSA)

Technical Advisory Panel (TAP)

United States Department of Transportation (U.S. DOT)

EXECUTIVE SUMMARY

Many Minnesota transportation agencies have incorporated safety countermeasures into their pedestrian systems to proactively protect users and address potential crash issues. While these countermeasures contribute to reducing vehicle-pedestrian crashes, their impacts on winter maintenance operations are sometimes overlooked during selection and design. Furthermore, snow and ice are major impediments to winter pedestrian travel; all pedestrians face diminished safety and mobility when snow removal is delayed or deficient. There is a need to investigate the best practice guidance and solutions for the design, installation, and maintenance of pedestrian safety features for year-round maintenance. This research project addresses this need.

To address the existing knowledge gap, the researchers conducted a search of literature as well as agency interviews to identify and document current best practices for designing and implementing pedestrian safety countermeasures for year-round maintainability using existing equipment. The work also reviewed MnDOT and select local agency winter maintenance plans, polices, and procedures, specifically for information on activities related to the safety and accessibility of pedestrians. Collectively, this information was used to develop and recommend options for agencies to deal with winter maintenance of pedestrian infrastructure.

The research tasks included a comprehensive literature and current practice review, a review of state, county, and city winter maintenance plans, policies, and procedures, structured interviews with winter maintenance professionals to obtain feedback on the best and worst design features of pedestrian safety countermeasures, development of best practice case studies of pedestrian infrastructure winter maintenance, and identification of designs and solutions to address winter maintenance of the pedestrian safety treatments of interest. The countermeasures of interest to this work, which were identified and selected by the Technical Advisory Panel, included curb ramps, crosswalk markings, corner radii, curb extensions, refuge islands, speed humps, and raised crosswalks.

The collection and review of information during the various project tasks allowed for the development of a number of conclusions. The primary conclusion of this research was that there is an absence of specific documentation, discussion or common policies for best design practices, guidance, and solutions for pedestrian safety countermeasures with year-round maintenance in mind. Winter maintenance practices for pedestrian treatments tends to vary by jurisdiction. Agency policies and plans largely concentrate on sidewalks and who will conduct winter maintenance (i.e., property owners vs. governments) and the timeline in which it should be completed, as opposed to discussing designs that can assist in encouraging or facilitating that maintenance.

There is discussion both within the United States and internationally as to whether sidewalk snow removal should be the responsibility of property owners or completed as a municipal service. This decision affects the way communities approach winter maintenance of pedestrian facilities. Practitioners in cities where snow removal is delegated to property owners expressed an enforcement orientation, often finding themselves on the receiving end of complaints from citizens dissatisfied by

their neighbors' snow removal efforts. Practitioners in communities where sidewalk snow removal is a municipal service expressed a production/operational orientation and were clearly under pressure to be ready when the next storm occurs.

In most Minnesota municipalities, the responsibility for clearing pedestrian features such as curb ramps and sidewalks of snow and ice is typically delegated to adjacent property owners. Bloomington, Minnesota, is a notable exception, with snow removal for public sidewalks provided as a municipal service. Nevertheless, many municipalities are involved in clearing snow from business districts, either directly using municipal employees or indirectly through contractors. In addition, all municipalities need to arrange for removing snow from sidewalks on bridges and adjacent to public facilities such as parks, cemeteries, schools, and pumping stations.

When an agency does perform snow and ice removal on pedestrian facilities, the approach taken is often a phased one, where certain portions of the sidewalk system are cleared before moving on to other specific facilities like bicycle trails and multi-use paths. The agencies interviewed throughout the course of the project indicated that snow storage is an issue with pedestrian-related infrastructure, and there is often a need to haul snow to disposal sites following most storms because of the lack of storage capacity on the roadside in pedestrian areas.

The design dimensions and features of pedestrian curb ramps are established by the Americans with Disabilities Act (ADA), with detectable surfaces made from a nonslip material incorporated to warn vision-impaired pedestrians that they are entering the motorized traffic area. Curb ramp designs per ADA guidance specify a slope of greater than 1:12 and a maximum cross slope of 1:50. Experience has shown that steel and cast-iron truncated domes are preferable to plastic domes, but they must be properly installed to remain undamaged over time.

For crosswalks, whether comprised of paint or decorative materials, the primary maintenance concern is durability. The winter maintenance impacts on crosswalks include salt/sand and snowplow abrasion that wears markings out at a faster rate and may damage permanent, decorative installations. More durable materials can be used for crosswalk markings, including tapes and thermoplastics, and these can be grooved into the pavement to provide protection from snowplow abrasion and extending marking life. Alternatively, annual repainting with traditional waterborne paints should be budgeted. All crosswalk markings should be retroreflective for nighttime visibility and inspected during the day and at night to determine condition and retroreflective properties.

The use of bulb-outs/curb extensions or channelized right-turn lanes are closely related to the selection of appropriate corner radii during design. The use of extensions is good for pedestrian visibility and creating parking areas, but they can also be difficult for snow removal and street sweeping operations. When selected as a treatment, bulb-outs should be used on lower speed roadways (35 mph or lower). A 1:2 or 1:3 upstream taper and a 1:3 downstream taper is preferred for this feature. An S-style curb design and the use of high-strength concrete should also be considered in future designs for durability.

Tighter radii at intersections presents maintenance tradeoffs, including the need to facilitate sweeping during summer months and maneuverability during snowplowing. The presence of right-turn channelization, combined with a “pork chop” island, can serve as a pedestrian refuge, but from a winter maintenance perspective, it has limited snow storage capacity and must be cleared for pedestrian accessibility. When designing for pedestrians at intersections using tight corner radii and/or channelized right-turn lanes, radii of 15 feet or less should be employed to provide more space for ADA-compliant curb ramps.

Pedestrian refuge islands support pedestrian safety by allowing pedestrians to make two-stage crossings of multilane roadways, which can assist with maintaining two-way traffic progression along signalized arterials. The winter maintenance of this particular feature is often overlooked but is something that would typically fall to agency forces as the feature is within the right-of-way. Median refuge island design parameters can vary greatly, ranging from 6 feet or greater in width and 24 feet to 40 feet in length (including the pedestrian path across the island), and include 3-foot to 5-foot bullnose tapers at either end. Pedestrian passages through median islands less than 48-inches wide can be potentially problematic and should be avoided where feasible.

Speed humps and tables can serve as a pedestrian crossing feature, and the designs of these are largely uniform. The height of these features is between 3-4 inches, with lengths of 12-14 feet for humps (concave in shape) and up to 22 feet for tables.

Where right-of-way constraints do not exist, dedicated storage locations (e.g., grass medians between curb and sidewalk) should be incorporated for snow storage. A recommended minimum width for this feature is 4 feet.

Finally, it is recommended that designers discuss their plans for pedestrian safety features with maintenance personnel early in the design process. Working with maintenance personnel during the design process to modify designs to meet their concerns can prevent future damage to pedestrian features while also allowing winter maintenance activities to be performed efficiently.

CHAPTER 1: INTRODUCTION

Whether it is walking from a car or bus to a school or business, or engaging in exercise (walking or running), at some point during the day, nearly all transportation system users are a pedestrian. Unfortunately, the safety of pedestrians has taken on a negative trend in recent years, with increases in fatalities nationally and in Minnesota. Data from the Minnesota Department of Public Safety underscore this. In 2021, there were 56 pedestrian fatalities and 708 injuries on or at Minnesota roadways (Minnesota Department of Public Safety 2021). The fatality figure represented an increase over the prior year. Over the past 10 years, the number of Minnesota pedestrian fatalities from November through March has fluctuated between 15 and 47 (Figure 1.1). While the long-term trend on average has remained relatively stable, this indicates a lack of progress toward safety goals.

Similar trends have been observed regionally and nationally. According to the National Highway Traffic Safety Administration (NHTSA), there were 6,516 pedestrian fatalities nationally in 2020 (NHTSA 2022). This represented 17 percent of all traffic fatalities and a decrease of 3.9 percent in fatalities from 2019 (NHTSA 2022). Winter pedestrian fatalities have also been trending upward in the upper Midwest, with an average of 127.4 pedestrians killed in the winter months of each year in the Iowa, Minnesota, North Dakota, South Dakota, Wisconsin region, while Minnesota's individual average is 39.3 fatalities (Figure 1.1). Transportation agencies have sought to address these issues by implementing various pedestrian safety countermeasures at crosswalks and other conflict points.

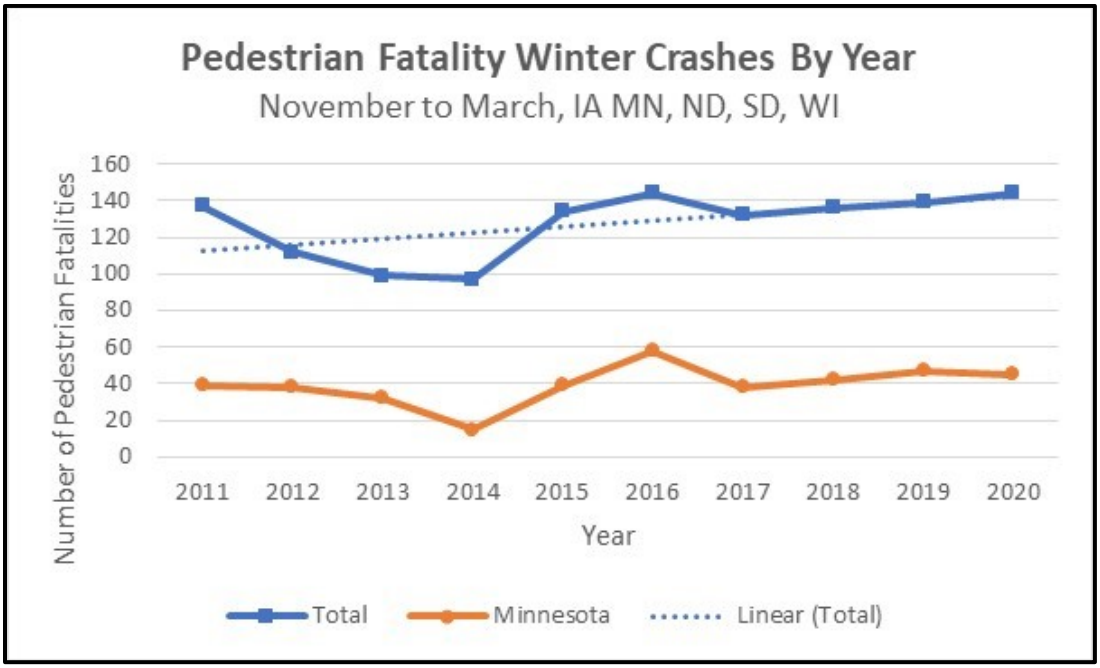

Figure 1.1 Pedestrian-involved fatal winter crashes in Minnesota and the Midwest (created using data from NHTSA's Fatality and Injury Reporting System Tool)

The challenges for pedestrians are especially pronounced at intersections and mid-block crossings, where the pedestrian (sidewalk/trail) and roadway systems interface with one another. In recognition of the need for improved pedestrian safety and mobility, many Minnesota transportation agencies have incorporated safety countermeasures into their pedestrian systems. These safety countermeasures include, but are not limited to, enhanced pavement markings, textured crosswalks, in-street pedestrian signs, curb ramps and truncated domes, curb extensions, smaller corner/curb radii, raised crosswalks, speed humps, narrow lanes, and pedestrian refuge islands/medians. While these countermeasures contribute to reducing vehicle-pedestrian crashes, their impacts on winter maintenance operations are sometimes overlooked during selection and design. Furthermore, snow and ice are major impediments to winter pedestrian travel, as all pedestrians face diminished safety and mobility when snow removal is delayed or deficient.

While the use of pedestrian safety countermeasures can introduce challenges to snow removal and winter maintenance operations, misconceptions also exist. For example, one misconception is that people in the suburbs do not walk, and so keeping locations like median refuges clear of snow and ice is a lower priority for agencies. Unfortunately, research has not helped in addressing these issues. Instead, it has largely focused on the mechanics of snow and ice removal—the equipment to use, material application rates, etc.—and not the impacts of designs on maintainability and pedestrian safety.

Aside from maintenance impacts, pedestrians also have concerns related to safety treatments. Li et al. (2012) studied aging and the use of pedestrian facilities to determine what users considered to be the aspects that decrease accessibility. The survey collected responses from 177 persons from three age groups in Toronto, Ontario: young (18-34), middle age (35-59), and older (60+). Included in the survey sample were users with functional limitations, including mobility, hearing, and sight. When asked what location(s) on the pedestrian user system were of most concern, 8 percent of respondents cited curb ramps. With respect to curb ramps, the primary feedback from users was that puddles, snow, and ice at the bottom of the ramp make the location inaccessible and hazardous. The authors concluded that curb ramp design at present is ineffective and alternative designs are needed to address the pooling of rain, snow, and ice. It was also found that another concern at crossing locations was the presence of snowbanks (Li, et al., 2012). Respondents indicated that the presence of snowbanks obstructed pedestrians and drivers from seeing one another.

Similarly, a Minnesota study found that low-income residents and people with disabilities frequently mentioned snow and ice as mobility obstacles that affected their ability to complete activities of daily living and seek employment (Guthrie et al., 2019).

MacKnight et al. (2021) developed guidelines to prioritize curb ramp retrofits under the Americans with Disabilities ACT (ADA) in Virginia. While this report did not specifically document the design or maintenance aspects of curb ramps, the findings from a survey of pedestrian user groups provided useful insights. For example, vision-impaired survey respondents indicated that high-speed, high-volume roadways should receive priority for curb ramp repairs and upgrades, while this same group, along with mobility-impaired respondents also indicated that low-speed, low-volume locations should also be

prioritized. In a sense, such findings present a consideration from the maintenance perspective, although not expressed or identified by the research, both when considering repair activities and snow removal for existing ramps.

There is a research need to investigate the best practice guidance and solutions for the design, installation, and maintenance of pedestrian safety features for year-round maintenance. The research presented in this report was performed to address this need. The specific objectives of the research included:

- Identify current best practices for designing and implementing pedestrian safety countermeasures for year-round maintainability.
- Document the design characteristics that make pedestrian safety countermeasures easier to maintain in the winter while using existing MnDOT and local agency equipment.
- Review MnDOT and select local agency winter maintenance plans, polices, maintenance agreements, and procedures regarding the safety and accessibility of pedestrians and recommend options for agencies to deal with winter maintenance of pedestrian infrastructure.

In summary, there is a clear knowledge gap regarding information on the design characteristics of pedestrian countermeasures and their maintainability. This information would include the characteristics, dimensions, and practices used both in Minnesota and elsewhere to effectively conduct winter maintenance on such countermeasures to the extent they already exist. In the case of winter maintenance, it is also of interest to determine whether existing winter maintenance plans, policies and agreements are providing safety and accessibility for pedestrian facilities in Minnesota.

1.1 RESEARCH APPROACH

The intent of this research was to address existing knowledge gaps identified in the above text. This was accomplished through the following research tasks:

- Conduct a comprehensive literature and current practice review to determine how various pedestrian safety countermeasures have been designed nationally (and in Minnesota to the extent this information is available) and determine what characteristics of these designs facilitate efficient winter maintenance operations as well as enhance pedestrian safety versus those that present winter maintenance challenges and impact safety.
- Review and compare current state, county, and city winter maintenance plans, policies, agreements, and procedures to determine whether and how they provide pedestrians with year-round safety and accessibility.
- Conduct structured interviews with winter maintenance professionals in Minnesota and nationally to obtain feedback on the best and worst design features of pedestrian safety countermeasures with respect to winter maintenance, and seek input on ways that features could be improved to address current maintenance impacts.

- Identify potential solutions to address snow removal at street-sidewalk interface points, based on the literature review and interviews. For example, could certain design features help to reduce the build-up of ice and snow at critical locations like curb ramps?
- Develop best practice case studies of how different community types (large, medium, and small) have handled pedestrian infrastructure winter maintenance.
- Based on the information collected, identify the design characteristics that would make pedestrian safety countermeasures easier to maintain using existing MnDOT equipment.

Using all the information collected and developed though these task activities, the research identified best practices for winter maintenance of in-road pedestrian safety treatments that agencies can adopt and employ in the future.

1.2 REPORT CONTENT

This report document is organized as follows. Chapter 1 has introduced the project and the problem being addressed, as well as the objectives and research approach. Chapter 2 presents a literature review of past work related to pedestrian safety treatment designs and maintenance, both in winter and in general. Chapter 3 discusses agency practices related to the design and maintenance of pedestrian safety treatments. Chapter 4 reviews a sampling of snow removal policies and procedures in Minnesota, as well as presents best practice case studies for the winter maintenance of pedestrian treatments in Minnesota cities and Milwaukee and Winnipeg. Chapter 5 summarizes pedestrian treatment design and snow removal best practices based on the information collected throughout the project. Finally, Chapter 6 provides conclusions, recommendations, and a summary of the trade-offs between pedestrian safety treatments and their respective maintenance and general costs based on the findings of this work.

CHAPTER 2: LITERATURE REVIEW

To better understand the design characteristics of pedestrian accommodations and document any discussions of feature designs, dimensions or maintainability, a literature review of past research was completed. The review sought information on the characteristics, dimensions, and maintenance practices for pedestrian safety countermeasures of interest to the research project. The countermeasures of interest were identified and selected by the Technical Advisory Panel (TAP) during initial project meetings. Those features included curb ramps, crosswalk markings, corner radii, curb extensions, refuge islands, and speed humps and raised crosswalks. The focus of the review was on how these countermeasures have been designed with respect to dimensions, to document (when applicable) any information on how winter maintenance impacts were factored into and addressed by those designs, and summarize other relevant information of interest. The effectiveness of features in reducing pedestrian-vehicle crashes or reducing vehicle speeds was not summarized by this work. Rather, the focus of the literature review was on past discussions of the maintenance impacts of the countermeasures of interest, with a focus on winter maintenance, as well as any procedures that were employed to keep them safe for pedestrian use.

2.1 DESIGN FEATURES

2.1.1 Curb Ramps

Curb ramps are the transition point where sidewalks and trails interface with the roadway, providing a surface change to accommodate all pedestrians, but especially those who would have trouble stepping up or down from a high curb. Such accessibility on public rights-of-way is required by the 1990 Americans with Disabilities Act (ADA), and curb ramp designs fall under the auspices of this act. With limited exceptions, the ADA states that curb ramps must not have a slope of greater than 1:12 (i.e., one-inch rise per 12 inches of distance, or 8.33 percent), and a maximum cross slope of 1:50 (one-inch rise per 50 inches of distance, or 2 percent). Ramps also must incorporate texture patterns that are detectable by vision-impaired users, typically panels of truncated domes. Some local jurisdictions may decide to produce standards that differ from these to meet the ADA; however, these would require review and approval by the Federal Highway Administration (FHWA) and/or the United States Department of Justice. The following sections highlight past work that has discussed design and maintenance-related aspects of curb ramps.

The United States Department of Transportation (U.S. DOT) published the two-part Designing Sidewalks and Trails for Access guide in 1999 to determine when ADA provisions applied to sidewalks and trails, as well as recommendations on accessible designs (Axelson, et al., 1999a, 1999b). The guide contains discussions on the basic design parameters associated with curb ramps, as well as discussions of the tradeoffs of different configurations. Of interest to the current research was the section covering curb ramp drainage. It noted that water draining can leave debris once the ramp area has dried, or can turn to ice and slush during the winter (Axelson, et al., 1999b). Drainage should focus on channeling water down toward the bottom of and then away from the curb ramp. Grading plans to accomplish this

should specify sidewalk, pavement, ramp and gutter slopes, curb and gutter elevations (ends and center), and dimensional distances and elevations for inlets and catch basins (Axelson, et al., 1999b). Maintenance practices should be established to remove gutter debris in the curb ramp area. Maintenance and repairs should also be performed to address height differentials associated with cracks and expansion joints (Axelson, et al., 1999b).

While it is a city in a warm-weather climate, San Diego, California includes design considerations for curb ramps in its Planning and Designing for Pedestrians model guidelines based on available corner radii (San Diego Association of Governments, 2002). For radii of five feet, perpendicular ramps are recommended. If a landscaped median area is present between the curb and sidewalk, the diagonal ramp is recommended, although this design should be considered as a final option. Finally, for radii greater than fifteen feet, perpendicular or parallel ramps are recommended.

FHWA's PEDSAFE report discusses some of the basic design features of curb ramps (Harkey and Zegeer, 2004). The report also notes that all newly constructed and altered roadways must incorporate curb ramps, and agencies should also be looking across their system for other locations that can be upgraded. The report itself covers only basic design considerations and does not include discussion of on-going maintenance activities or winter maintenance.

The American Association of State Highway Transportation Officials (AASHTO) Guide for the Planning, Design and Operation of Pedestrian Facilities provides items to consider when designing intersection corners and curb ramps (AASHTO, 2004). For example, these areas should be free of obstructions and have enough space for pedestrians to wait to cross. Curb ramps should be designed to the least slope possible that is consistent with curb height and available corner area, while providing a level landing for turning and maneuvering. Detectable warnings, such as truncated domes, also need to be incorporated. The guide notes that ramps for new construction should be a minimum of four feet wide, while retrofits of existing facilities should be a minimum of three feet wide. Drainage grates or inlets should not be located in the ramp/crosswalk area. Finally, the guide presents three different types of ramps that can be considered, depending on site characteristics: perpendicular ramps, parallel ramps, and diagonal ramps. Perpendicular ramps are used where the sidewalk is too narrow to accommodate the length of the curb ramp with the required slope (AASHTO, 2004). Parallel ramps are used where space between the curb and adjacent properties is too tight to allow for the installation of a ramp and landing. A single ramp can also be placed diagonally at the apex of the intersection corner (AASHTO, 2004), but this design is not ideal for visually-impaired users. Examples of each of these ramp types are presented in Figure 2.1, Figure 2.2, and Figure 2.3. The guide does not discuss any maintenance aspects.

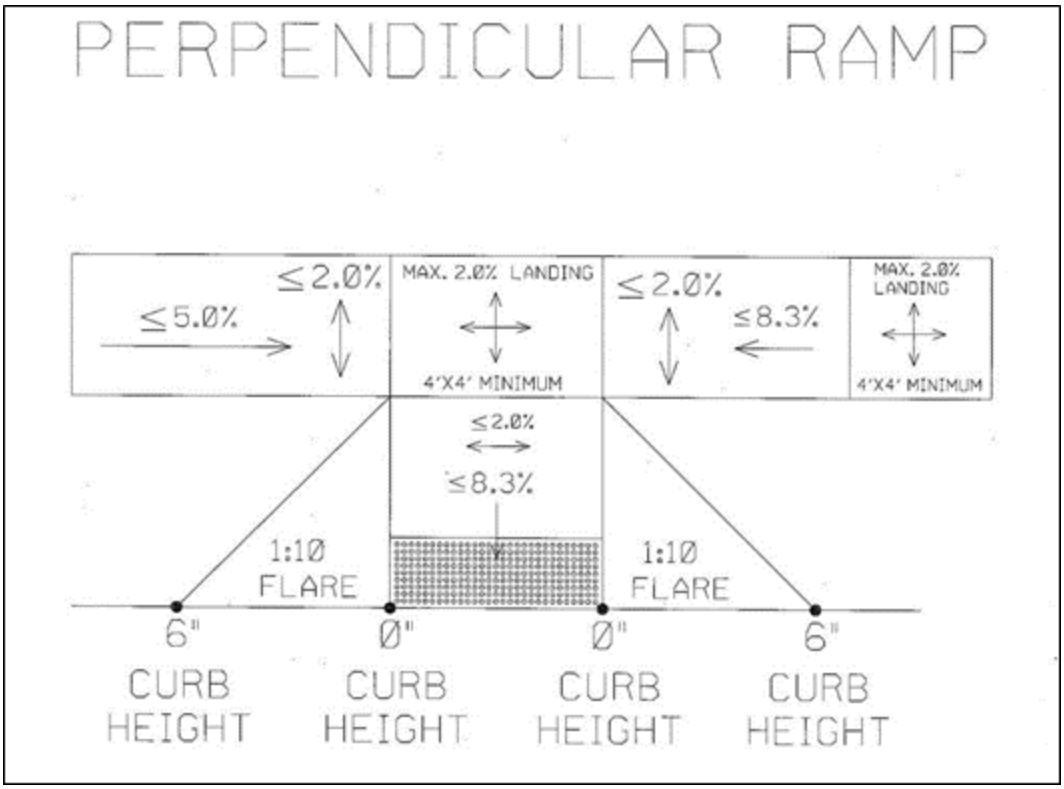

Figure 2.1 Perpendicular ramp design (Source: MnDOT)

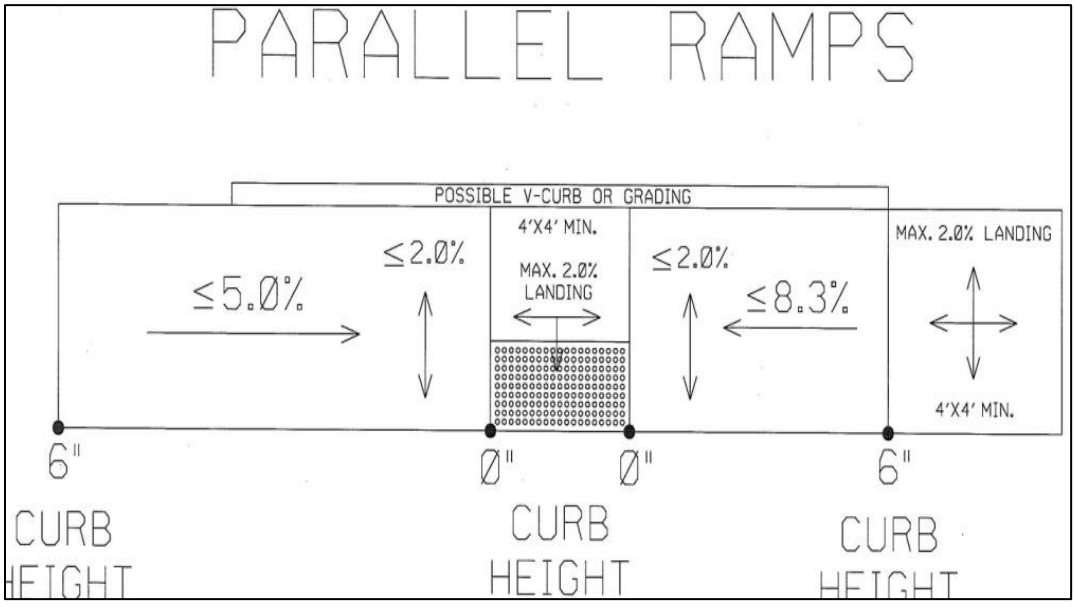

Figure 2.2 Parallel ramp design (Source: MnDOT)

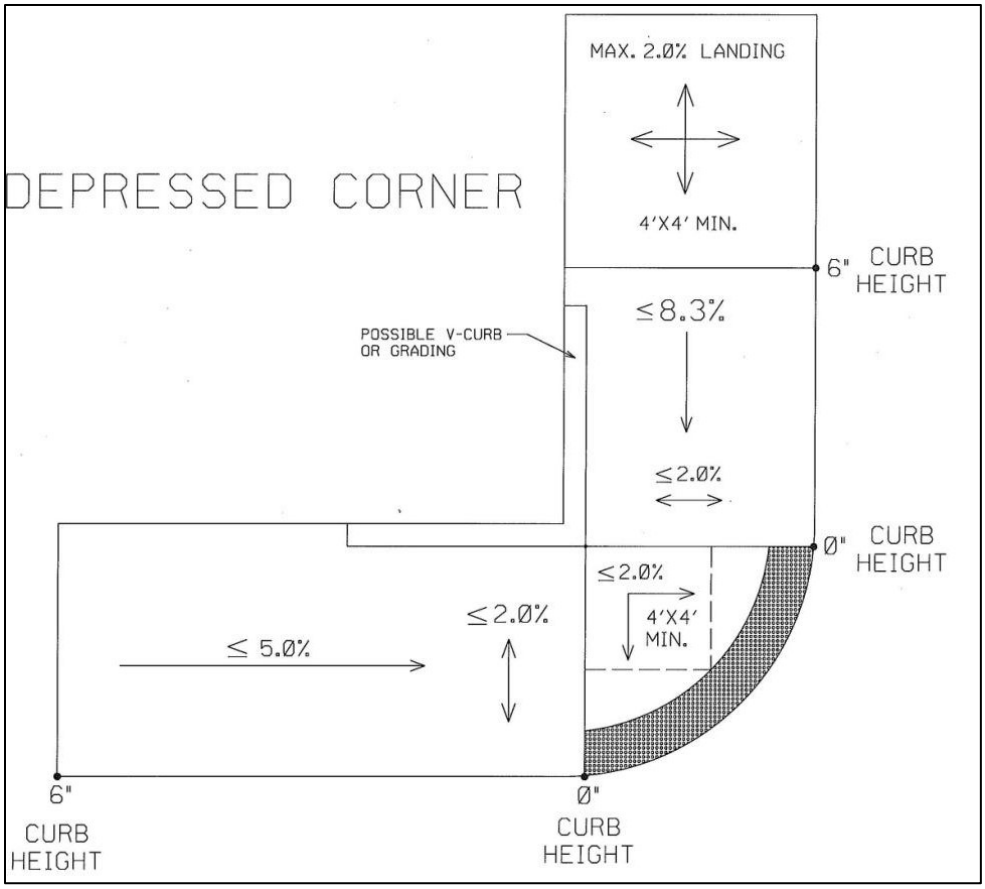

Figure 2.3 Diagonal ramp design (Source: MnDOT)

Scott and Rudd developed a guide for local governments on the winter maintenance of pedestrian facilities in Delaware. The guide notes that the accumulation of snow and ice on curb ramps presents a physical obstacle which limits accessibility for pedestrians, particularly those with disabilities (Scott and Rudd, 2012). To address this, local government standards practices and/or ordinances should be established and snow should be plowed so that it does not block curb ramps (Scott and Rudd, 2012). Additionally, public works departments need to be educated about the problems associated with depositing snow onto curb ramps when plowing. The guide also suggested that residential and commercial property owners could be asked to voluntarily clear snow in these areas (Scott and Rudd, 2012) (Figure 2.4).

Figure 2.4 Curb ramp immediately after snow removal (left) and one day later with refreeze beginning to occur at bottom of ramp. (Source: John Shaw/Iowa State University)

FHWA's 2013 Guide for Maintaining Pedestrian Facilities for Enhanced Safety covers a number of different aspects related to maintenance, including winter maintenance (Huber, et al., 2013). In general, curb ramp maintenance is necessary when displacements, surface issues (cracks, holes, deterioration), grades and cross slopes, and other issues (detectable warning field damaged) are present. The guide stresses the need for seasonal maintenance, namely in winter, noting that plowing operations can push snow and block crosswalks and curb ramps, while blocked or clogged drains can cause pools and refreeze at curb ramps. It is also suggested that shoveling out curb ramps is often the best way to address these items, particularly when these are not easily accessible by other means (skid steer, pick-up truck, etc.) (Huber, et al., 2013). In some communities, clearance of features such as curb ramps is required in ordinances, with successful compliance achieved through specifying clearance expectations and the provision of education materials to the public.

To reduce problems such as ponding at the bottom of curb ramps, the Colorado Department of Transportation developed a guide on the geometric design guide for curb ramps (Colorado DOT, 2019). The guide discusses some of the issues specific to cold climates and includes three-dimensional drawings of typical situations.

2.1.2 Truncated Domes

Truncated domes allow visually impaired pedestrians to identify specific hazards. They have two main applications: at stations on rail lines and busways, they mark the edge of the platform; at curb ramps, they warn pedestrians that they are about to enter a space shared with motor vehicles. The size and shape of the domes is stipulated by ADA, and to assist people with low vision their color should contrast

with the adjacent pavement. Within these constraints, agencies can select from a wide range of materials such as polymers, ceramics, concrete, stainless steel, and cast iron.

Virginia, Montana, New Hampshire Vermont and Oregon all have evaluated the durability of truncated domes for curb ramps in recent decades. O'Leary, et al. evaluated detectable warning surfaces for curb ramps in Virginia (O'Leary, et al., 1995). Seven different warning surfaces were evaluated in terms of detectability and maneuverability for the vision-impaired. These surfaces included black concrete domes, rough exposed concrete aggregate, smaller gradation exposed concrete aggregate, concrete lateral domes, red paver bricks with domes, yellow rubber dome tiles, and composite domed tiles. As part of testing, the researchers concluded that there is a tradeoff between the detectability of a surface for the visually impaired and maneuverability for the mobility impaired. A survey of states to assess the maintenance of surfaces indicated that brushed concrete and grooved finishes accumulated ice in the grooves, while domes tended to break off in some instances (O'Leary, et al., 1995). For example, New Jersey reported that snowplows broke off 50 percent of domes in the course of one winter (material not specified). Aggregate was reported in Virginia as peeling off of some exposed aggregate finished surfaces. When concrete domes were used, some damage occurred over the course of winter as well. The cause of that damage was uncertain however, as the snowblowers used to clear snow had their blades raised to prevent such damage. It was surmised that the damage may have been the result of deficient concrete installation (O'Leary, et al., 1995).

New Hampshire evaluated eight truncated dome systems under winter maintenance conditions (plowing and deicing) in the City of Concord (Boisvert, 2003). A five-foot wide articulated four-wheel drive vehicle with an angled plow blade was used to clear snow and apply deicing material. During the first snowfall test, six of sixteen panels (two panels for each product were tested) experienced damages that included scalping, chipping or completely losing domes (Boisvert, 2003). All of this damage occurred on uphill panels. During a second snowfall test, thirteen panels were damaged, ranging from scuffing to complete dome loss (Boisvert, 2003). Based on the evaluation, it was found that precast polymer concrete panels were highly durable, as were thin pavers and pressed stone blocks (Boisvert, 2003).

Although a Montana evaluation focused on specific commercial products in a pre-winter environment, the findings are still of interest to maintenance. All products tested showed some accumulation of debris occurred within truncated dome mats throughout the year (i.e., small gravel/grit), along with loss of mat adhesion when glues (as opposed to epoxies) were used (Abernathy, 2004).

The Oregon Department of Transportation (ODOT) evaluated the durability of truncated domes on existing curb ramps (Kirk, 2004). Four products, including latex-coated mortar, polyurethane, rubber, and resin/monomer, were evaluated over a two-year period. The author noted that the installations were not subjected to snow removal or freezing conditions, and all precipitation experienced was rain. All products showed minimal to no wear over the evaluation period, with the only problems encountered being related to color deterioration.

Vermont evaluated six different detectable warning panel products that were in place between 2006 and 2013. Installations were inspected for intactness, dome damage and delamination (VTrans, 2013). Products found to be durable over the observation period included cast iron and stainless steel dome panels, although coloring issues (fading and chipping) were encountered in some cases as time went on. Similar to other states, buildup of gravel/grit on some panels was also experienced that could lead to stability problems for some users.

2.1.3 Pedestrian Pavement Markings

Pedestrian crossing pavement markings are one of the most basic treatments that are typically implemented to provide enhanced pedestrian safety and guidance. They guide and delineate the path that pedestrians are to follow when crossing a roadway, whether at an intersection or midblock crossing. Crosswalk markings are discussed in detail in the Minnesota Manual on Traffic Control Devices (MUTCD) in Section 3B.18, with different marking patterns depicted in Figure 3B-19 of the manual. Traditionally, parallel lines have been used at many crossings. The MUTCD also states that crosswalk lines shall consist of solid white lines not less than six inches or greater than 24 inches in width. Aside from this standard, the manual provides room for enhancements to be considered. Those enhancements can consist of different marking patterns or materials. Examples of different marking patterns are shown in Figure 2.5. However, the use of such enhancements comes with maintenance considerations and tradeoffs, particularly when considering the interface between snowplow blades and pavement markings.

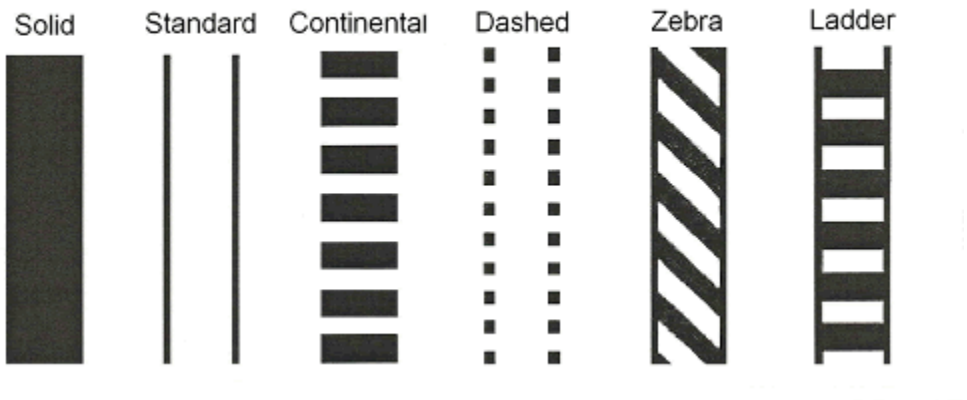

Figure 2.5 Crosswalk pavement marking patterns. (Source: Federal Highway Administration)

National Cooperative Highway Research Program (NCHRP) Report 500 covers different strategies to enhance crosswalks, noting that marked crosswalks are commonly installed at signalized intersections and other high-volume pedestrian areas. Marking enhancements cited by the report include the use of marking patterns different from standard parallel lines (i.e., solid, continental, dashed, zebra or ladder patterns), as well as alternative materials, such as inlay tape or thermoplastic (Zegeer, et al., 2004). Inlay tape is specifically cited as being highly reflective, long-lasting, slip resistant, and low maintenance, and should be considered for new and resurfaced pavements (Zegeer, et al., 2004). Thermoplastic is

recommended for existing, rough-surfaced pavements. The use of these durable materials can also extend to other crosswalk-related markings, such as advanced stop or yield lines. The impacts of winter maintenance on these designs and materials is not discussed.

FHWA's PEDSAFE report discusses pedestrian crossing pavement markings and enhancements (Harkey and Zegeer, 2004). The report notes that crosswalk markings alone are unlikely to benefit pedestrian safety and should be used in conjunction with other countermeasures, such as curb extensions, parking restrictions, etc. to enhance safety. While the report does not specifically speak to winter maintenance impacts on crosswalk markings, it does address marking materials and their impacts on pedestrians in wet conditions. The report notes that crosswalk marking materials should not be slippery when wet, and the best materials to avoid this potential are inlay tapes and thermoplastics. Both materials, while more expensive, are long-lasting, slip resistant, and low-maintenance.

While focused on determining driver detection distances for different crosswalk marking patterns, Fitzpatrick, et al. touch on some maintenance-related considerations for crosswalk markings. The spacing of crosswalk ladder or longitudinal markings in the wheel path of vehicles can lead to wear. As a result, the cost of repainting crosswalk markings (material and labor) because of wheel path wear is a consideration when selecting a marking pattern and placing it on the roadway (Fitzpatrick, et al., 2010; Fitzpatrick, et al., 2011). For example, some agencies attempt to align the black bands of the continental pattern with the wheel tracks.

AASHTO's Guide for the Development of Bicycle Facilities highlights some of the considerations associated with pavement markings at and in the vicinity of marked crosswalks (AASHTO, 2012). At a basic level, the guide notes that pavement markings should be retroreflective, not slippery, and rise no more than 0.16 inches above the pavement (AASHTO, 2012). Further maintenance considerations presented in the guide are the use of high visibility markings (i.e., ladder or zebra patterns) at crosswalks when necessary, and the conduct of annual inspection of marking conditions and repainting as needed. Winter maintenance is also touched on in the guide, and while considerations specific to pavement markings are not offered, basic considerations are presented. This includes removing snow from all travel lanes (including bike lanes) and shoulders, which would include clearing the crosswalk area, and not storing snow in areas where pedestrian traffic is expected.

Scott and Rudd discussed the maintenance of pedestrian facilities, including crosswalks, in a guide developed for use Delaware (Scott and Rudd, 2012). Specific to crosswalks, the guide noted that a frequently observed problem in the state was access to the crosswalk from the sidewalk being blocked by snow. The roadways have been cleared by plowing, but the curb ramp/sidewalk area has not been cleared. Instead, snow piles deposited in the curb ramp area block access to crosswalks by pedestrians. The authors provided one example of how this situation might be addressed, where the city of Bend, Oregon's downtown association funded contractor sidewalk snow removal, including at curb ramps and crosswalks (Scott and Rudd, 2012). The cities of Dover, Delaware and of Toronto, Ontario were also cited as using a similar approach, only with crosswalk snow removal carried out by the city (Scott and

Rudd, 2012). Other locales were identified which provided guidance to residents to not cover crosswalks with snow when clearing sidewalks.

McGrane and Mitman, when providing an overview of high visibility crosswalk marking styles, note that decorative pavers used to create crosswalks can create a slippery condition for pedestrians (McGrane and Mitman, 2013). These paver materials can include brick, granite and cobblestone. The authors note that crossing striping should always be applied in addition to decorative treatments (McGrane and Mitman, 2013).

Huber, et al. developed a guide for maintaining pedestrian facilities, which includes discussions of crosswalk maintenance as well as snow and ice removal (Huber, et al., 2013). The authors begin the discussion of crosswalk maintenance by stating that not only do crosswalk markings need to be maintained, but also the roadway surface where the crosswalk is located, on account of the need of pedestrians to have a surface free of defects (e.g., potholes, excessive cracking).

In terms of marking materials, agencies need to weigh cost, durability, retroreflectivity, friction/slipperiness, and agency capabilities to apply the material (labor and equipment) (Huber, et al., 2013). Thermoplastics and epoxies are more durable than paint, but are more expensive and perhaps more difficult to work with during installation. These materials (and some tapes) can become slippery when wet, presenting a problem for pedestrian safety. Thermoplastics and epoxies also require clean, dry surfaces for application, adding cost to the process. However, the benefit of these materials are increased lifespans (24 to 48 months for epoxies, 48 to 72 months for thermoplastics) (Huber, et al., 2013).

The primary maintenance problem associated with crosswalk markings is durability, where higher traffic roadways with crosswalks require more frequent repainting (Huber, et al., 2013). Traffic impacts can be addressed when feasible by spacing bars to be between wheel paths when alternative designs are used (i.e., continental or ladder designs). In winter-weather climates, the abrasiveness of salt and sand, as well as plows, can also result in more rapid deterioration of markings (Huber, et al., 2013). The authors report that some agencies use recessed/grooved thermoplastic markings to address abrasion from plows, but this can be costly. Retroreflectivity is another maintenance issue, and wear over time results in a loss of retroreflective materials (i.e., glass beads) (Huber, et al., 2013). The authors point toward the need for frequent retroreflectivity inspections to monitor this.

Huber, et al. provide several recommendations based on the maintenance issued associated with crosswalk markings, and these recommendations include:

- When using paint, use a high build grade with glass beads for retroreflectivity.
- Inlay tape is most durable and suited for new or reconstructed pavements, while providing retroreflective and slip-resistant properties.
- Thermoplastic is a better option for rough pavement surfaces.

- Long-lasting markings should be installed at the time of new construction or reconstruction to make use of project budgets (Huber, et al., 2013). Conversely, future maintenance budgets may not have funding for refreshing more costly materials.

Noyce, et al. developed guidance for at-grade trail crossing treatments for the Minnesota Department of Transportation (MnDOT), including decision trees to assist in the selection of treatments (Noyce, et al., 2013). Among the treatments presented are crosswalk markings and materials. The authors note that the use of alternative paving materials for crosswalks (bricks, pavers, etc.), while showing a path is to be used by pedestrians, can be problematic for some pedestrians, such as wheelchair users, to traverse (Noyce, et al., 2013). Difficulties for snowplows are also noted, but not elaborated upon. Concerns over alternative materials creating unwanted noise for road users, pedestrians and area residents, are also listed as drawbacks to use (Noyce, et al., 2013). Similar to other documents, the authors note that crosswalk lines should be used with textured materials to enhance visibility to drivers, also highlighting the MnDOT recommendation that when textured materials are used, they should be used outside of the area that pedestrians travel (Noyce, et al., 2013). Finally, the need for retroreflectivity is presented, along with recognition that markings should not result in a loss of traction for pedestrians when wet. Raised thermoplastic markings are cited as being difficult for some pedestrians to negotiate.

Ashur and Alhassan, as part of developing guidelines for the selection of pedestrian crossing treatments, presented feedback from agencies on considerations related to crosswalks (Ashur and Alhassan, 2015). When advance stop lines are used at a crosswalk, agency concerns included that the markings are not visible in snow conditions. The cost to maintain all markings was another concern that was cited to the authors.

MnDOT's Facility Design Guide, while not discussing crosswalk markings, does provide guidance to consider (MnDOT, 2021). The guide indicates that crosswalks should be tabled to a two percent cross slope when feasible, and should not have a running slope (i.e., across the roadway) of greater than five percent.

2.1.4 Intersection Corner Radii

The appropriate radius of curvature for street corners has been debated by engineers and urban designers for decades. The wide corner radii typical of 1950s-1980s design practice have the advantage of reducing overtracking by buses and heavy trucks that are making right turns. This allows buses and trucks to turn more easily, reduces encroachments into adjacent lanes and space allocated to opposing-direction traffic (see Figure 2.6), and helps prevent damage to curbs and the terrace area. A major disadvantage of wide corner radii is that they allow cars, light trucks, and (especially) motorcycles to complete right turns at relatively high speeds (Suzuki and Ito 2017). Wide radii tend to make pedestrians less visible to motorists by moving the curb ramp away from the travelled way. They also increase the pedestrian crossing distance, which in turn can affect traffic signal timing and intersection capacity. Where the space is constrained by terrain or structures, wide radii can also impact the available pedestrian storage, limit the space available for landings at the top of curb ramps, and make it more

difficult to assure that at least 4 feet of clear sidewalk width is available during winter conditions (cf. section 8C.7.5.3 of the Minnesota Facility Design Guide) (MnDOT, 2021).

Figure 2.6 Right-turning truck encroaching adjacent lanes. (Source: National Association of City Transportation Officials)

Since the mid-1980s, a number of designers have advocated tight corner radii to reduce vehicle speeds, improve pedestrian safety, provide more space for ADA-compliant curb ramps, and allow the curb ramps to be better aligned with adjacent pedestrian paths (see Figure 2.7). For example, the National Association of City Transportation Officials (NACTO) Urban Street Design Guide advises, “while standard curb radii are 10–15 feet, many cities use corner radii as small as 2 feet. In urban settings, smaller corner radii are preferred and actual corner radii exceeding 15 feet should be the exception” (NACTO, 2013). In contrast, the 2018 AASHTO Green Book recommends corner radii ranging from 15 feet on residential streets to 40 feet or more for truck freight corridors (AASHTO, 2018); the upper limit in MnDOT guidance is 35 feet (MnDOT, 2021). AASHTO also notes that the effective radius for right turns is affected by special-purpose areas adjacent to the right edge of the roadway, such as parking lanes, bike lanes, bus stops, or loading zones (see Figure 2.8).

Figure 2.7 Tight corner radius combined with use of bollards and stamped concrete crosswalk. (Source: David Veneziano/Iowa State University)

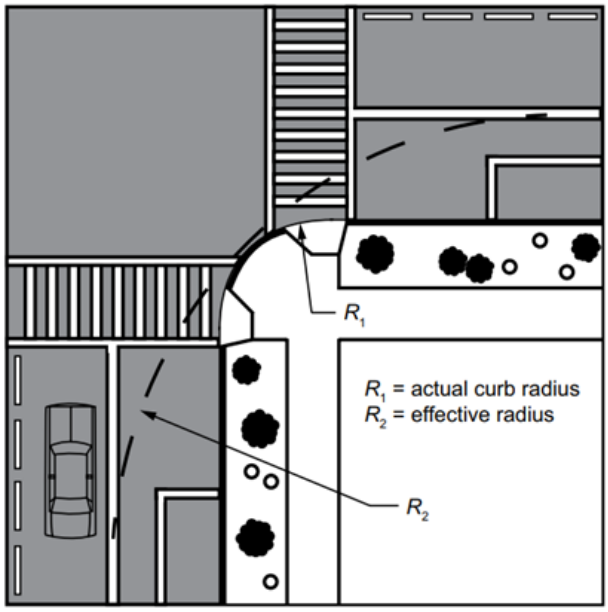

Figure 2.8 Parking lanes, bike lanes, bus stops, and loading zones can affect effective corner radius. (Source: AASHTO)

Corner radius is likely to have several effects on winter maintenance. Wide corner radii usually increase the overall paved area of an intersection, increasing the number of square feet to be cleared of snow and decreasing the square footage available for snow storage. Conversely, tight corner radii can make it more difficult for snowplows to maneuver, when turning movements are performed, resulting in a greater need for multiple passes or backing maneuvers to achieve complete snow removal. Summer

maintenance is also affected: to facilitate street sweeping, AASHTO recommends a minimum radius of 5 feet at corners where turns are prohibited (AASHTO, 2018).

There is a strong interaction between corner radius and curb ramp design. Tighter radii allow more precise alignment of curb ramps with adjacent pedestrian accommodations (Colorado DOT, 2019). Conversely, very wide corner radii can result in the need for the ramp to be placed diagonally (a design some visually-impaired people find confusing, and not recommended by MnDOT), or require the use of a blended transition - a curving curb ramp that wraps around at the street corner - which is termed a fan ramp in the Minnesota Facility Design Guide (see Figure 7).

Although a Colorado Department of Transportation (CDOT) publication suggests that blended transitions may be easier for winter maintenance than parallel and perpendicular ramps (Colorado DOT, 2019), the lack of a distinct grade difference between the sidewalk and the street could also make it more difficult for maintenance crews to distinguish the sidewalk from the street. Blended transitions increase the total surface area requiring snow removal, and seldom offer a distinct location for snow storage. Blended transitions often include bollards to prevent motor vehicles from encroaching on the pedestrian space, and snowplow operators are likely to shy away from the bollards, increasing the number of square feet where manual snow removal is required (cf. sections 8C.9.3.G. and 8C.9.4.1.1.2 of the Minnesota Facility Design Guide) (MnDOT, 2021).

In retrofit situations, wide corner radii can make it more challenging to achieve appropriate drainage slopes while also assuring that wheelchair users are not confronted with excessive cross-slope or geometrics that result in loss of wheel contact or bottoming-out for wheelchair users (Colorado DOT, 2019). Section 8C.7.5.3 of the MnDOT Facility Design Guide notes the importance of avoiding ponding at the bottom of the ramp in these situations (MnDOT, 2021). To avoid slush ponding and re-freeze, specialized hardware such as slot drains or trench drains (Figure 11) is sometimes required, and these devices have their own maintenance considerations.

Figure 2.9 Trench drain. (Source: Mississippi Watershed Management Organization/Flickr)

2.1.5 Channelized Right Turns (Slip Lanes)

Channelized right turn lanes (slip lanes) are typically used to increase right turn capacity at major intersections (see Figure 2.10). In most cases a triangular island (also called a "pork chop") is provided to separate the right turn lane(s) from the adjacent lanes serving through traffic. As a result, the design of the separator island is often intertwined with corner radius decisions. Pedestrian crosswalks often extend through the pork chop island, resulting in multiple curb ramps at each corner of the intersection.

Suzuki and Ito (2017) found that at large signalized intersections, the geometric design of slip lanes affects the speed of turning vehicles and the level of risk taken by pedestrians. The further the crosswalk is set back from the parallel curbline the more pedestrians attempt to cross the street during the "DON'T WALK" phase of the signal cycle.

While snow can be piled freely on pork chop islands that do not serve pedestrians, the snow discharged by plows can be problematic in pedestrian areas. Crosswalks and curb ramps on the pork chop island typically need to be cleared of snow manually, and the snow storage capacity of the pork chop is often very limited. In heavier snow events, crews could have difficulty gauging the exact location of the island.

Figure 2.10 Typical slip lane and porkchop island, Arboretum Blvd/78th Street (MN 5) at Eden Prairie Road, Eden Prairie, MN. (Source: Google StreetView)

2.1.6 Curb Extensions (Bulb-Outs)

Curb extensions (also called bulb-outs or bulb-outs) extend intersection corners toward the center of an intersection, usually by the width of the adjacent parking lane (see Figure 2.11). When used mid-block, this treatment is sometimes referred to as a choker. In either case, the extension reduces pedestrian crossing distances, makes pedestrians more visible to motorized traffic, provides more space for

pedestrian queuing, and offers space for sidewalk amenities and plantings (SANDAG, 2002). Curb extensions are often used in combination with tighter corner radii, and are sometimes combined with raised crosswalks or other safety treatments. They are mainly used on streets with speed limits of 35 mph or less (Ashur and Alhassan, 2015).

In a qualitative survey of 21 state DOT design practitioners, curb extensions were identified as a preferred and frequently-used pedestrian safety device (Ashur and Alhassan, 2015). Quantifying the safety effects of curb extensions has proven more elusive. For example, a small Oregon study found that the addition of a curb extension resulted in a statistically-significant reduction in the number of vehicles passing before a pedestrian was able to cross the street, but the effect on the number of motorists who yielded to the pedestrian was not statistically significant (Johnson, 2005). Nevertheless, curb extensions are often included as one element of a streetscaping project or "environmental street" intended to reduce speeding and encourage pedestrian activity. A meta-analysis of the effects of several European "environmental street" projects identified a 35% reduction in injury crashes (95 percent confidence interval 26 percent to 43 percent) and a 27 percent reduction in property damage crashes (95 percent confidence interval 18 percent to 36 percent) (Elvik et al., 2009). Similarly, a study of safety improvements at intersections in New York City found that against a background of declining crash rates throughout the city, projects that included curb extensions had larger vehicle-pedestrian collision reductions than control sites (Kang, 2019). Since the individual sites included up to 14 other design elements, it was difficult to isolate the effects of curb extensions.

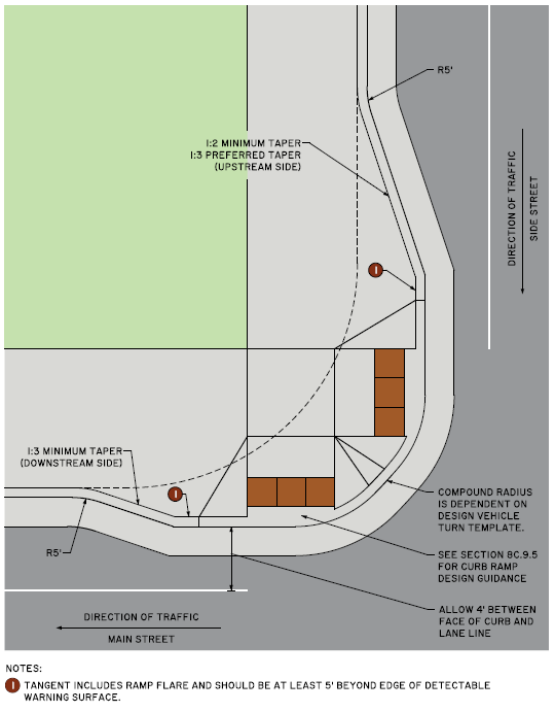

Figure 2.11 Minnesota design guidance for curb extensions. (Source: MnDOT Facility Design Guide section 8C.9.7.4.)

The addition of a curb extension can affect drainage, street cleaning, and winter maintenance operations (Ashur and Alhassan, 2015). As a survey respondent from in Connecticut noted in Ashur and Alhassan's practitioner survey, they are "not popular with plow drivers." To address drainage, stormwater is sometimes channeled through a gap in the curb extension, which is bridged by plates or grates. In many designs the upstream and downstream approaches to a curb extension meet the adjoining curb at right angles. In contrast, the Minnesota design guidance recommends a 1:2 to 1:3 horizontal taper on the upstream side and a 1:3 taper on the downstream side (see Figure 2.11), which should facilitate street sweeping and snow removal.

2.1.7 Median Refuge Islands

Median refuges islands (also referred to as center islands, refuge islands, or pedestrian islands) are islands located in the center of a roadway that serve as a place for pedestrians to safely wait while crossing multiple lanes. These features are typically raised, although sometimes they are simply a painted area. Depending on the setting, these features can serve to reduce vehicle speeds, providing secondary traffic calming benefits. Refuges may be used at uncontrolled as well as controlled (i.e., signalized) crossings. While this type of feature provides pedestrians with a safe waiting point while crossing a roadway, it does have the potential drawbacks of stranding pedestrians when heavy traffic in one direction does not allow a crossing to be completed, and may also lead some drivers to not yield to pedestrians. Examples of refuge islands are shown in Figure 15.

Figure 2.12 Median refuge island. (Source: David Veneziano/Iowa State University)

AASHTO's Guide for the Planning, Design, and Operation of Pedestrian Facilities provides design dimensions for median refuge islands (AASHTO, 2004). The guide suggests that islands should be six feet wide or wider (eight feet when practical) to provide space for a wheelchair users or multiple pedestrians to wait. Existing medians with a width of four feet may be retained, but should be widened to six feet or greater during reconstruction projects (AASHTO, 2004). Where right-of-way is limited, the guide indicates that lanes may be narrowed to 10 or 11 feet to provide adequate space for the island. Detectable warnings (truncated domes) must be provided at two feet from the street edge on each side of the island, as well as a curb ramp for accessibility. Approach noses offset from the edge of the traffic lane(s) should also be incorporated along with a treatment to warn drivers of the island's presence. Regarding maintenance, the guide notes that if a cut through ramp is used with the island, it must be graded to drain properly, and cut throughs may also require additional sweeping.

NCHRP Report 500 provides basic design considerations for the use of refuge islands (Zegeer, et al., 2004). This includes noting that painted islands do not provide the same benefits as raised islands, and raised islands need to be accessible for all users via cut throughs or curb ramps. The report also notes that raised medians are not recommended for high-speed rural roadways. Finally, the report indicates that crossing islands are appropriate at many signalized intersections.

AASHTO's Guide for the Development of Bicycle Facilities highlights several conditions where refuge islands are beneficial for pedestrians (AASHTO, 2012). These include high-volume roadways which present difficult crossing conditions for pedestrians, where roadway width is excessive given the available crossing time, or the roadway cross section is three or more lanes in width. The guide also provides general dimensions for islands, including a minimum six-foot median width, and a length from the nose of the median to the crossing area of a minimum of six feet (AASHTO, 2012).

Noyce, et al. discuss refuge islands as part of a larger discussion of the selection of at-grade trail crossing treatments in Minnesota (Noyce, et al., 2013). Written in 2013, the guidance in this document points to the then-current MnDOT Bikeway Facility Design Manual for designs of refuges. This included a width of at least eight feet if used by bicycles and an outward extension from the cut through portion of 6.5 feet upstream and downstream (Noyce, et al., 2013). If the pathway is angled through the median so that users face oncoming traffic, that angle should be approximately 75 degrees, with a median refuge width of 12 feet minimum (Noyce, et al., 2013). A refuge island size of 50 square feet for urban areas and 70 square feet for rural areas is also provided, noting that ideally, 100 square feet is preferred (Noyce, et al., 2013).

Ashur and Alhassan conducted a survey of agency experiences to develop guidance for the selection of pedestrian crossing treatments (Ashur and Alhassan, 2015). Feedback from the survey indicated that these treatments were not typically built on high-speed roadways, becoming unfeasible above 40 mph or 45 mph. Comments provided by one agency included a concern with maintenance and snowplowing, although these were not elaborated upon.

Zegeer, et al, offer several considerations for the installation of refuge islands, including the design consideration that if large groups of pedestrians are expected to cross, adequate storage should be

provided (i.e., a larger island) (Zegeer, et al., 2017). The addition of stop or yield lines, as well as signing, should also be considered.

MnDOT's Facility Design Guide Chapter 8 covers non-motorized facilities, including refuge islands (MnDOT, 2021). Crossing refuges are typically a raised area, curbed island or median between lanes, although a painted median area flush with the roadway surface can also informally serve the same purpose. The guide notes that crossing islands should typically have a length of 24 feet to 40 feet, with a 3- foot to 5-foot-long taper nose, a 6- to 10-foot-long raised curb area, and a 6- to 10-foot-long pedestrian access route (i.e., the crosswalk width on the island) (MnDOT, 2021). On higher speed roadways, the extended curb area of the island could be extended to 40 feet on either side of the crossing. Raised features need to use either a curb ramp or a cut through flush with the pavement surface, with either of these approaches incorporating detectable warning surfaces at the curblines. Finally, the guide specifically states that designers should "[c]onsider the width of maintenance equipment being used to clear snow from the refuge when establishing this width" (MnDOT, 2021).

Furth et al. discussed the designs of median islands for speed control on two lane collectors and arterials (Furth, et al., 2021). The authors developed a method to determine the chicane length needed prior to a refuge island based on lane width, island width, and target speed (based on models of the relationship between roadway geometry, vehicle path radius and speed). Analysis of different geometric combinations determined that roadways with right-of-way widths of as little as 60 feet and curb-to-curb widths as narrow as 40 feet could still accommodate school buses and bike facilities while still providing a median refuge (Furth, et al., 2021). The impacts of designs on maintenance activities were not examined.

2.1.8 Speed Humps, Speed Tables and Raised Crosswalks

A speed hump is an elongated hump with a circular-arc or flat top shape, with flat topped humps also referred to as speed tables (Zegeer, et al., 2004). They are intended to reduce vehicle speeds, including when used as a pedestrian crossing. The reduction of vehicle speeds because of the roadway surface change decreases the risk of a crash and its severity for pedestrians. Application is generally on low-speed, residential streets or in traditional storefront commercial zones, and it is recommended that they be applied area-wide as opposed to individual or spot locations (Zegeer, et al., 2004). An example of these features is presented in Figure 16.

When a crosswalk is painted on the flat top of a speed table, it is a raised crosswalk. The San Diego Association of Governments' Planning and Designing for Pedestrians model guidelines point out that in this manner, raised crosswalks function as both a pedestrian crossing and a traffic calming device (SANDAG, 2002). The purpose of raising the crosswalk is to elevate pedestrians above the roadway surface to increase their visibility to approaching drivers. Typically, the height of the crosswalk is at the same level as the sidewalk to eliminate the need for curb ramps (Huang and Cynecki, 2001).

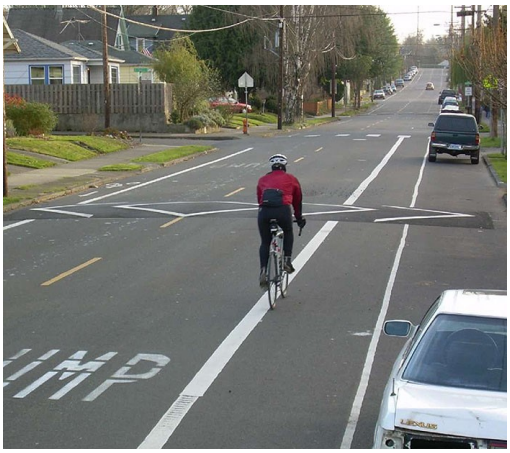

Figure 2.13 Speed hump. (Source: FHWA)

While speed humps, speed tables and raised crosswalks have been evaluated in different cities for their impacts on vehicle speeds and crashes, limited information has been documented discussing maintenance concerns, either during clement weather or during the winter months. For example, while discussing the speed reduction impacts of raised crosswalks in different cities across the U.S., the only maintenance item noted by Huang and Cynecki was that agencies in areas that receive snow found a need to monitor the condition of the raised crosswalk's pavement markings (Huang and Cynecki, 2001).

MnDOT research into effective traffic calming applications and implementation included speed humps and tables (Saffel, 1999). The design parameters of speed humps cited by the author included a height of three to four inches and a length of eight feet, with installations made on local streets of 40 feet width or less. From a maintenance perspective, speed humps may interfere with drainage, but were stated as not affecting snow removal. [Interestingly, a summary table of Minnesota installations did indicate that speed humps made access for snow removal vehicles and snow storage more difficult in two communities.] Speed table dimensions were cited as three to four inches in height, with a length of 12 feet to allow speeds of 15 to 25 mph. Some designs allow an open space to let bicyclists pass alongside the table without having to cross it (Saffel, 1999). When used, this bicycle gap provides for continuous drainage at the curbline. Similar to speed humps, speed tables are cited as not interfering with snow removal.

The San Diego Association of Governments' Planning and Designing for Pedestrians model guidelines indicate that the use of speed tables can be considered for residential, residential collector and main street/central business district roadways with low to moderate traffic volumes (up to 9,999 vehicles per day) (San Diego Association of Governments, 2002). A three to four-inch height and 22-foot length are specified, as is the use of six-foot ramps at each end and a 10-foot-long flat table at the top. The need for drainage to be addressed on account of this raised feature is noted, but this is the only maintenance consideration that is presented.

FHWA's PEDSAFE report discusses different design parameters for speed humps and tables (Harkey and Zegeer, 2004). Speed hump dimensions were stated to be three to four inches high and 12 feet long (for

speed ranges of 15 mph to 20 mph), up to 22 feet long (for speed ranges of 25 mph to 30 mph). The feature spans the roadway itself from edge/curb to edge/curb. The guide notes that these features may create drainage issues if not properly designed. Aside from this issue, no additional maintenance considerations or concerns were provided.

Parkhill, et al., in updating the Institute for Transportation Engineers' (ITE) recommended practice, presented updated guidelines for the design and application of speed humps (Parkhill, et al., 2007). The paper offered a compete framework based on the experience of dozens of agencies that were interviewed. That framework included 1) develop and follow a formal public consultation process, 2) determine needs, 3) construct and maintain speed humps, and 4) monitor and evaluate effectiveness (Parkhill, et al., 2007). The guidelines also suggested consultation with roadway maintenance workers and snowplow operators to solicit input and feedback. Of interest to this research is the discussion of construction and maintenance. Design dimensions for were 3 to 3.5 inches in height and a length of 12 to 14 feet. Speed table dimensions cited were three to three and half inches in height ad 22 feet in length (6-inch ramps and 10-foot flat table top). Standard designs and construction procedures should be used in constructing speed humps and tables. Agencies interviewed found that parabolic or sinusoidal shapes were more difficult to construct than circular speed humps or tables. Those same interviews found that speed humps and tables were not generally damaged by snowplowing activities (although some damage from plows was experienced with parabolic shapes). Most agencies reported that their plow operators do not plow down to the pavement on local streets with speed humps, but any impacts on pedestrians crossing at or near such features as the result of such practices was not reported.

Berthod discussed different aspects considered in the use of speed humps in Quebec, Canada (Berthod, 2011). In Quebec, speed humps are recommended for urban streets, local streets, residential streets, school and playground zones, and other areas where low speeds are desired. The height of speed humps is three inches, while the length is 11 to 13 feet (22 feet for a speed table) (Berthod, 2011). Relevant to the current research, the author discusses maintenance of these features in winter conditions. The author noted that whether winter maintenance is completed by an agency or contracted out, snow removal methods will need to be adjusted. This includes using smaller or modified equipment, as well as specific removal procedures and the use of operators who are familiar with the locations of speed hump or table features (Berthod, 2011). Operators may need to properly position the blade on their equipment, including having it slightly raised, and take the time to remove the snow on and around the speed hump where it may accumulate. Winter maintenance operations may take longer as a result of these treatments, but agencies that the author interviewed indicated that they did not cause any specific problems.

A MnDOT best practices synthesis and guidance for at grade trail-crossing treatments, included a discussion of the use of speed humps and tables (Noyce, et al., 2013). While the section of the guide discussing speed humps and tables mainly focused on the effectiveness of these installations in reducing vehicle speeds, design parameters were summarized. The authors noted that speed humps generally are three to four inches high at center, with lengths of 12 to 14 feet and design speeds ranging from 15

mph to 30 mph. Speed tables are a bit longer, commonly built at 22 feet long, with an entire crosswalk serving as the center of the table. The authors concluded from a review of existing literature that the use of speed tables is only recommended when the 85th percentile speed is less than or equal to 25 mph, and average daily traffic less than 2,000 vehicles per day (Noyce, et al., 2013). The maintenance aspects associated with speed humps and tables, regardless of time-of-year, were not discussed.

The Minnesota DOT's Facility Design Guide, calls for the raised area at a raised crosswalk to be 10 feet or wider (MnDOT, 2021). It also indicates that the crosswalk should be raised between three and six inches above the roadway surface.

2.2 CHAPTER SUMMARY

Based on the information presented in this chapter, several conclusions can be made. Generally stated, there is an absence of specific discussion that summarizes the best practices for guidance and solutions in the design and installation of pedestrian safety countermeasures with year-round maintenance in mind. Winter maintenance for different pedestrian safety countermeasures does appear in literature, but it is often presented as something that should be kept in mind when considering the selection of a feature as opposed to providing any design guidance to facilitate maintenance itself.

Occasionally, state or national guidelines encourage designers to discuss their plans with maintenance personnel, but little advice on the scope and content of such a consultation is offered. Nevertheless, some current design guides appear to reflect maintenance experience. For example, the Minnesota Facility Design Guide specifies the use of tapered upstream and downstream approaches to curb extensions, a feature that can facilitate snow removal and street sweeping. Similarly, the Colorado curb ramp design guidance mentions "drainage" and "flow line" frequently, perhaps in response to past problems with ponding and refreeze at the bottoms of curb ramps.

The information identified and summarized in this chapter largely leaves the question unanswered: how can pedestrian safety countermeasures (aside from those that are part of sidewalks, such as curb ramps) be designed with winter maintenance in mind? No specifically documented designs for or maintenance practices related to pedestrian safety countermeasures were identified. Rather, general information has been documented that can be on in developing guidance on such designs and recommended maintenance practices. A summary of the general design and maintenance findings from the literature review is presented in APPENDIX A General Design and Maintenance Findings, located at the end of this report.

Curb ramp designs are currently driven by the ADA guidance, which specifies a slope of greater than 1:12 and a maximum cross slope of 1:50. Detectable surfaces that are made from a nonslip material need to be incorporated to warn vision-impaired pedestrians that they are entering the motorized traffic area. The use of durable panel materials for detectable warnings when using mechanized snow removal is something an agency should also consider. Finally, for general maintenance, agencies should perform periodic sweeping operations to remove debris build up which could otherwise present stability concerns for some users.

Only limited discussion of winter maintenance operations and responsibilities for curb ramps came up in literature, mainly that shoveling should be performed by adjacent property owners. As shown earlier in Figure 2.4, property owners typically shovel over the tops of the truncated domes, leaving a smooth (non-detectable) snowpack approximately 0.5 inches thick. This snowpack sometimes remains in place long after a storm.

When considering crosswalks, the primary maintenance concern is durability. The winter maintenance impacts on crosswalks, salt/sand and snowplow abrasion wear the markings out at a faster rate. More durable materials are available for crosswalk markings to address this and include tapes and thermoplastics. These materials are more costly than traditional paints. Additionally, durable materials and paints can be grooved into the pavement, with the recess providing some protection from snowplow abrasion. Alternative marking patterns can be employed to enhance driver detectability of the crosswalk from a distance, but these will require the use of additional material. All crosswalk markings should be retroreflective for nighttime visibility. Inspection of markings during the day and at night should be performed to determine condition and retroreflective properties.

Curb extensions, channelized right turn lanes, and the selection of appropriate corner radii are closely-related from a design perspective. All involve important trade-offs between vehicle speed/pedestrian safety considerations and the potential for curb and terrace damage due to overtracking of buses and heavy trucks.

Considerations for corner radii and channelized right turn lanes at intersections include the use of radii of 15 feet or less. This provides more space for ADA-compliant curb ramps, and allows curb ramps to be better aligned with adjacent pedestrian paths. Wider radii corners should only be considered for routes with heavy freight traffic (i.e., heavy trucks) that do not have large volumes of crossing pedestrian traffic. The maintenance tradeoffs when using tighter radii include the need to facilitate sweeping during summer months, as well as maneuverability during snowplowing operations. The tighter radii combined with blended curb ramp transitions could also make it difficult for plow operators to distinguish the roadway from sidewalk when plowing. The presence of right turn channelization, combined with a “pork chop” island can also produce benefits and challenges. The island can serve as a pedestrian refuge, but from a winter maintenance perspective, it has limited snow storage capacity and represents another feature that must be cleared for pedestrian accessibility.

Curb extension literature indicated that this feature should be used on lower speed roadways (35 mph or lower). A 1:2 or 1:3 upstream taper and a 1:3 downstream taper is preferred for curb extensions. For maintenance, curb extensions have an impact on street sweeping and snowplowing operations, and drainage is also a concern.

The design parameters of median refuge islands were generally reported as being six feet or greater in width, 24 feet to 40 feet in length (including the pedestrian path across the island, and three feet to five feet nose tapers at either end. Refuge islands are generally used on lower speed roadways, with applications not being made on roadways above the 40 mph to 45 mph range. Existing literature included only a limited discussion of general maintenance considerations, and this consisted solely of a

mention of the need to sweep curb ramps. Limited discussion of winter maintenance also occurred in literature, and that only touched on designing with the width of snow removal equipment in mind. This limited discussion is concerning for a pair of reasons. First, there is a need to clear the pedestrian pathway through the median itself, and this is something that would typically fall to agency forces as the feature is within the right-of-way. Second, the location of islands makes them susceptible to snow buildup as snowplows pass by, once again underscoring the need for an agency to clear the pedestrian path.

The literature review of speed humps and tables found that the designs reported are largely uniform. The height of these features is between three to four inches, with lengths of 12 to 14 feet for humps (concave in shape) and up to 22 feet for tables. The primary maintenance issue identified is the accommodation of drainage, which can be accommodated by proper inlet placement or a channel incorporated through the feature at the curbline. Additionally, some have reported problems with winter maintenance vehicle access at these features, as well as snow storage being more difficult. Most reported that speed humps and tables are not significant challenges to plowing. Of note is that no discussions of the impacts of winter maintenance on pedestrians for these features appeared in literature.

CHAPTER 3: AGENCY PRACTICES

The maintenance of pedestrian safety countermeasures can be a challenge to winter maintenance operations. The challenges these features present from a design and maintenance perspective may lead to some agencies not employing these treatments. For example, some features, such as curb extensions, can present challenges to plowing operations based on that the increased need for the plow vehicle to maneuver to clear snow. Other features, such as refuge islands, are located within the roadway environment, but given their raised designs, do not lend themselves to plowing in order to keep pedestrian pathways clear.

To better understand the impacts of design characteristics on winter maintenance (and year-round maintenance in general), interviews with local and state agency maintenance professionals were completed. These consisted of structured questions with professionals in Minnesota and nationally to solicit feedback on the best and worst design features of pedestrian accommodations with respect to winter maintenance, as well as other aspects of maintenance and their performance in general. Additionally, input on ways that features could be improved to address maintenance impacts was sought. The interviews documented past experiences with the winter maintenance of pedestrian safety countermeasures, and what agencies may have done to address specific issues. The form used to guide each interview is presented in Appendix B. The questions posed to agency contacts were developed in consultation with the Technical Advisory Panel. Interviews were conducted via telephone/videoconference with contacts identified by the TAP, as well as through different email lists (Snow Ice Listserv and similar channels).

Aside from conducting agency interviews, published snow removal plans, policies and procedures for pedestrian infrastructure and features from agencies in Minnesota, as well as in other states and internationally were identified and reviewed. An online search was conducted to identify relevant websites and documents that present such plans, policies and procedures. In Minnesota, the team sought to identify a mix of cities of varying size throughout the state, while all county plans/policies were reviewed. These are the agencies whose winter maintenance operations typically include and intersect with pedestrian facilities (sidewalks and trails). The team relied on past experience to identify plan and policy information from other states and internationally. Note that collectively, the information provided in this chapter is only a sample of what may be available.

This chapter first provides the results of interviews with Minnesota agencies and their winter maintenance experience with pedestrian safety features. Next, the results of interviews with agency contacts in other states are summarized. Minnesota, as well as other state and international snow removal plan, policy and procedure information is then reviewed. Finally, general conclusions based on the information obtained from the different agencies and texts are provided.

3.1 MINNESOTA AGENCY INTERVIEWS

3.1.1 City of Alexandria

Contact: Dane Bosl

Date: May 2, 2022

Pedestrian Features of Interest:

- Curb ramps with cast-in iron dome panels
- Curb extensions along five-block commercial area (with flower boxes)
- Pedestrian refuge islands (one)

The pedestrian features in Alexandria are approximately 7 to 8 years old. Winter maintenance for pedestrian features is done by the city and includes clearing the sidewalks. The cost for this is paid through a special assessment to the business owners. Previously snow removal was done privately, but now it's better to have the city do it so that all snow removal is done concurrently. The city has to haul out all of the snow, which was true before the pedestrian improvements were built as well. General sidewalk clearance is done in multiple passes during the storm, but this clearance is not performed during the night. Haul-out is completed the next night after a storm, depending on storm timing. Snow hauling is generally done starting around 3:00 AM. The city uses a Bobcat to push snow into the street (Broadway), then pulls the snow into a windrow with a road grader, and then uses a large snowblower to load it into trucks. This is done after every storm with more than 1.5 to 2 inches of snow. Otherwise the parking lanes get filled up with snow.

MnDOT generally avoids plowing until the city has done their pass. MnDOT typically plows snow into the parking lanes, then city will load out again. MnDOT pays the city to haul away the snow from the state highway.

There have been no major problems with damage to the bulb-outs aside from occasionally getting nicked by plows. The amount of time required for clearance is about the same as it was before the bulb-outs were installed. Other landscape features within the bulb-outs, such as flower planters, are concrete and holding up well.

The curbs are holding up well. The concrete that was used has a high granite content and a clear sealant is applied every two years. For general, year-round maintenance, the corners of the bulb-out tapers are a little difficult to get into with the street sweeper. These small corners require hand-sweeping depending on the machine being used, as the city's newer machine is better. The flower boxes placed on the curb extensions are maintained by the Parks Department. This landscaping includes wood chips, flowers, and trees and is considered a good attraction for the business district.

Additional Pedestrian Features:

- Mini roundabouts/traffic calming circles (seven) installed seasonally between spring and Labor Day.
- Lighted bollards

The population of Alexandria triples during the summer due to proximity to lakes, so there are more kids playing, and the need for traffic calming, which includes the use of traffic calming circles. The circles are made using segments of Bio Log (erosion control product consisting of wood chips in black netting), with additional wood chips and plastic planters placed in the center of the circle. An example of this feature is presented in Figure 1. These traffic circles are used mainly in residential areas, and flower planter watering is the only maintenance. The circles are not damaged by vehicles overrunning. Initially, people laughed at the idea, but now more and more residential areas want them. They are easy to install in the spring and remove in the fall when school resumes.

Lighted bollards that were installed inside the curbs are rusting due to salt exposure and will need replacement or major overhaul. These were installed in 2014. From a maintenance perspective, a non-corrosive material would have been better. The bollards are still functional, but they are starting to look shabby. One bollard was hit by a car and did not break away since the features are 8 feet steel pipe sections below grade and 4 feet above grade.

Figure 3.1 Bio-Log roundabout. (Source: Jacob Reuter/MnDOT)

3.1.2 City of Grand Marais

Contact: Lenny Bloomquist

Date: April 18, 2022

Pedestrian Feature of Interest:

- Curb ramps

- Curb extensions
- Crosswalk markings
- Tight radii

Grand Marais is a tourism-driven community located on the north shore of Lake Superior. It is 110 miles northeast of Duluth, and 80 miles southwest of Thunder Bay, Ontario. The city experiences both heavy snowfall and a long snow season. The evening before being interviewed (April 18), there had been a 6-inch snowfall overnight. Although activity in the community has been traditionally limited to the summer season, there are more and more year-round homes, and tourists are visiting during the winter now.

Most of the community's pedestrian features are located along MN 61, and the reconstruction of this route, including pedestrian features, was completed in the fall of 2021 (construction was completed over two seasons – 2020 and 2021). There are some additional pedestrian accommodations in the downtown. MN 61 was rebuilt with bulb-outs and lane widths of 12 feet (11-foot lanes were considered but eliminated early in design due to the inclusion of bulb-outs and MnDOT plow widths). Bulb-outs were constructed at street crossings, while other locations on MN 61 are square corners. Since the rebuild was completed, a few issues have been observed. There has been overtracking at the bulb-outs by large trucks due to the tight corner radii. Similarly, the use of 11-foot-wide lanes has made right turns difficult for large trucks unless they first swing to the left. The 11-foot lanes have also presented problems for wide loads coming through town, which create conflicts with opposing traffic. Another issue has been the tendency for pedestrians to stand too close to the traffic lanes while waiting on corners.

Although the MN 61 right-of-way is owned by MnDOT, and the roadway mainline is maintained by MnDOT with the city handling snow removal for the parking lanes, bike lane, and sidewalks. Experience has shown that it is hard to clear snow from the bulb-outs, and the trees and planters on the back side of the sidewalk make visibility difficult during snow removal. The city is using a skid steer to blow snow from the sidewalks, and it can be hard to find the curb ramps in deep snow (there have been 6-foot tall snowbanks during the 2021-2022 winter). MnDOT plows up to the roadway edgeline, while they city plows the parking lanes. The cost to haul snow away is shared between the state and the city at a 75/25 percent split. It is difficult to find places to dispose of the snow, and a backhoe and loader are used to push it as far away from the roadway as possible until it can be hauled out.

With respect to pedestrian features, there has been some damage to curbs and bulb-outs from the snow removal equipment (a 16-foot ProTec snow pusher on a loader is used). MnDOT plows would be able to clear the whole highway if the bulb-outs were not in place. Some of the older bulb-outs in the downtown area, which are about 15 years old, have damage from loaders and experienced subsidence from base failure. The subsidence may be due to changes in the water table from changes in lake level. Sand plowed off the highway has accumulated on the bulb-outs at times, and this requires hand clearing. Chipping of truncated domes in concrete panels is also a problem, especially when using the pick-up truck plow.

In addition to damage from equipment, the pedestrian features in use do not allow for enough snow storage. Bike trails and sidewalks are on the curb of the road, and snow from the mainline ends up on these facilities. As a result, the city has to re-plow and/or re-blow to get the snow over the fence and into the available storage area.

There is a need to plow the downtown sidewalks overnight because there is too much traffic during business hours to do removal with city equipment. The city has a three-person street department and pulls in other city employees if needed. The city works with the county highway department to complete snow removal operations. The county plows residential streets and the city plows the downtown area to benefit the businesses (although the county also owns the roadways downtown). The city does most of the sidewalk snow removal, with property owners doing minor cleanup. Finally, the city also clears safe-routes-to-school sidewalks.

Aside from winter maintenance, residential areas receive street sweeping once in the spring, while the downtown and MN 61 are swept every Thursday or Friday, with extra cleanings before and after street festivals. Maintenance forces have found it harder to sweep around the bulb-outs. The areas with subsidence are not swept because they are too uneven. There have been no problems with pedestrian features being vandalized.

Crosswalk pavement markings generally preform alright. There are some high spots on the roadway where the markings are getting worn quickly. The city repaints lines annually, though new thermoplastic markings might not require painting this year. Painted lines typically get worn off over the winter.

As mentioned above, pedestrians (mostly tourists) stand too close traffic on corners while looking for businesses. Two crashes occurred in the fall of 2021 that were related to parking/visibility from the side streets. Illegal parking on the bulb-outs has also impacted pedestrian visibility.

Additional Pedestrian Features:

- Planter boxes

3.1.3 City of St. Peter

Contact: Joel Schmidt

Date: April 27, 2022

Pedestrian Feature of Interest:

- Curb ramps
- Curb extensions
- Tight radii
- Pedestrian refuge islands
- Crosswalk markings

The pedestrian features in the city are in the downtown area along the US 169 corridor. This area was redone in 2009, so the pedestrian features are relatively new. The bulb-outs are good for creating parking, but can be difficult for snow removal depending on light poles, signal bases, bike racks, decorative fences, and other features. Under a cooperative agreement, MnDOT plows US 169 and gets the snow to the side of the roadway, and then the city does the final cleanup. There is usually a one to two-night delay in getting the snow removed from the sidewalks, etc. The city will broom or snowblow the sidewalks into the street and then load the snow into trucks to haul to the snow dump. This is labor intensive. Snow removal is performed between midnight and 5:00 AM to avoid traffic impacts.

Snow is moved twice following a storm; once off the roadway to clear the pavement and then back onto the roadway to facilitate loading into truck. Toolcat™ utility work machines are used for sidewalk snow removal, along with snow blowers or brooms. That equipment kicks the snow to the edge of the sidewalks, and then a motor grader is used to move the snow into the traffic lanes. From there, a loader-mounted blower (6-foot wide) is used to load snow into the dump truck. There is not much space for snow storage next to the sidewalk due to limited right-of-way (storefront commercial area). Decorative features get in the way a bit, but traffic is the main hindrance to snow removal.

Downtown snow removal is scheduled to occur at night and is not reactive like street snow removal. The city tries to keep pedestrian ramps as clean as possible without doing snow removal for the entire sidewalk in the interval between the snowfall and the major removal efforts during a following night. Businesses shovel and remove the snow on the sidewalk, piling it up where they can until the major removal by the city occurs. Experience has shown that the type and timing of the snowfall will affect the extent of curb-ramps filling in and subsequent citizen complaints.

The city is a bit more proactive with downtown snow removals during the December shopping season. Snow is removed after every snowfall of an inch or two. In January/February, the city will do removal less often based on the buildup of snow. If snow is becoming hazardous, then this is a trigger for a removal effort.

For general maintenance, a water truck is used to flush the medians to remove sand/debris onto the road at night during the summer. This moves all sand into the curbline. Then a street sweeper is used to remove the debris from the curbline the next night. Experience has shown that gradual tapers are better than 90-degree corners for street sweeping, with a 45 to 60 degree taper easier to deal with.

The bulb-out curbs are prone to getting chipped and damaged during snow removal operations. Colored concrete requires frequent sealing to avoid spalling. The city performs curb repairs every year, and US 169 always has some sites on the list for repair. Decorative fencing pillars along the corridor are prone to damage from vehicles overrunning the curb or hit during parking maneuvers. These features are easily damaged and expensive to repair.

The city tries to use directional pedestrian ramps, rather than the fan or modified fan types. There are very few signals in the city except on US 169, which has made it easier to move light poles and get private easements to improve the curb ramps at intersections.

The city offered several considerations for design improvements based on past experience. The type of curb for parking bulb-outs could be improved, with the S-style curb (drive-over/roll curb) being more forgiving than the B style 6-inch curb. The S-style curb will help deflect some of the damage from snow removal equipment. This is a trade-off with using the curb to keep vehicles off the sidewalk. The 6-inch B-style curb has worked fine along the sides of the bulb-outs. Vertical and horizontal tapers make everything more forgiving for maintenance. Otherwise, other communities could consider using different features besides bulb-outs if that is feasible.

The transitions from zero-height to full-height curb for curb ramps are always a problem. The more gradual the transition, the better to reduce damage. This is not easy at bi-directional curb ramps. A 3 to 4-foot transition length is too short to do these tapers nicely, so the flat section should be extended if possible. If starting over, more focus on tapers in the design plans would be given, especially to maintainability. The trade-off between visual appeal, standardization, and maintainability needs to be considered, along with how the ramps will hold up over 5 to 10 years, how they will be maintained and how much manpower will be required with that maintenance. Plastic truncated domes for detectability have been a problem, with the steel and cast iron working fine as long as they are properly installed.

Additional Pedestrian Features:

- Pedestrian signals - RRFBs/PHBs
- Planter boxes
- Special landscaping

The city maintains all of the plantings, landscaping, etc. through the US 169 historic district.

3.2 U.S. AGENCY INTERVIEWS

An email was sent via the Snow-Ice Listserve to identify agencies that were willing to be interviewed regarding their experiences with pedestrian safety features and winter maintenance. During May and June, 2022, the research team conducted interviews with five agencies across the U.S. to obtain information on their maintenance practices with respect to pedestrian infrastructure.

3.2.1 City of Davenport, Iowa

Contact: Mike Vance

Date: June 17, 2022

Pedestrian Feature of Interest:

- Curb ramps
- Curb extensions
- Tight corner radii
- Speed humps (parabolic)

- Pedestrian refuge islands
- Pedestrian signals, Rectangular Rapid Flashing Beacons, Pedestrian Hybrid Beacons
- Raised crosswalks (midblock)

Most of the pedestrian safety features identified above are in downtown Davenport, with some in redevelopment areas. Major downtown streets are 60 to70 feet wide. Wing plows and maintainers (motor graders) are used for winter maintenance operations. For tighter radius intersection corners, a plow pushes snow into the intersection past the adjacent gutter line. The plow blade is then lifted, the plow turns the corner, and then resumes pushing the snow along. Plow vehicles equipped with wing plows can swing around the corner.

The downtown plowing crew does special cleanup. This includes pulling windrows off the edge of the street, and for larger storms, the downtown crew will load the snow out. This involves a large crew pushing snow into the street, mostly done with Bobcats with broom attachments. Plow crews push snow from middle of the road to the curb during normal snow removal operations. They will leave wider windrows when they know they will be hauling snow out. If four inches or more of snow accumulation has occurred, the city will do a load out; if less than four inches is received, they mainly use the Bobcats to move snow. These are equipped with Tenco 600s brooms that stick out beyond the tires, are easy to turn, and can maneuver around the bulb-outs. Crews also pile snow up on corners and load out with end loader. The city has a downtown snow dump, which saves on hauling. Outside of the downtown, the city uses motor graders for residential street snow removal. The priority for snow removal is emergency routes, then residential streets, and then downtown cleanup.

The challenges to winter maintenance operations include curb damage from strikes by motor graders that result in cracking/spalling. It is hard for operators to know where curbs are with appreciable snowfall. The city does use curb guards on many plows which consists of a two-inch solid carbide strip bolted onto edge of snowplow. Finding catch basins during the winter is also difficult. Curbs, bulb-outs, pavement markings, raised intersections and anything that sticks up and can be caught or gouged by a plow (or a car) presents a problem. Curb ramps in the city are easy roll (curbing), with rubber ramps placed out of the gutter line. Planters are also getting hit/scraped/gouged (90% of damage is due to maintenance operations, 10% due to being struck by cars). Stamped and painted brick is starting to chip and fade.

Operator experience helps with avoiding features when plowing, and most staff has five-plus years of experience. The city also does pre-storm training for new hires. All crews are city employees, but they do have a few contractors for snow hauling. A special pick-up is used to plow pedestrian features during downtown clean-up. Occasionally there have been problems with sod damage, roadside sign strikes, and over tracking during snow removal. There is also some damage to hydraulic lines from striking/dragging over features. The primary advice the city would offer to others is to make features smooth or use easy transitions. In other words, nothing should be raised above the road to avoid plow damage. Additionally, pedestrian features should be designed considering maintainability; straight and parallel is easier for snow removal.

Additional Pedestrian Features:

- Planter boxes
- Bioswale

The city has one bioswale, located in a hospital area (and maintained mainly by hospital).

3.2.2 City of Iowa City, Iowa

Contact: Brock Holub

Date: June 10, 2022

Pedestrian Feature of Interest:

- Curb ramps
- Curb extensions
- Tight corner radii
- Speed humps
- Mini roundabouts
- Pedestrian refuge islands
- Pedestrian signals, Rectangular Rapid Flashing Beacons, Pedestrian Hybrid Beacons
- Raised crosswalks

For winter maintenance activities, the city plows the streets, the Parks Department clears city-owned sidewalks and bridges, and Transportation Services clears the pedestrian mall and downtown parking in metered parking areas. Street staff will plow streets, and then parking staff will try to clear the parking spaces. There is a push to keep crosswalks and pedestrian ramps clear of snow, and the city tries aggressively to keep the downtown area cleaned. Each November the group have an internal coordination meeting to cover roles and responsibilities.

In downtown area, six inches of snow is hard to deal with. Snow is windrowed to middle of street, then blown into trucks for hauling. A skid steer or tractor with a broom is then used to clear the crosswalks. There are continual issues with curb ramps outside of the downtown being kept clear. Parking and transportation staff cannot respond to every intersection in the city that has a crosswalk. The city would need to triple staff to keep all of the pedestrian areas outside of downtown clear. The curb ramp locations that are bad are on arterial streets; on residential streets, asking property owner to keep curb ramps clear is fairly reasonable. Some pedestrian refuge islands on undivided cross-sections get cleared by the Parks Department, but some are ignored and do not get cleared.

In downtown and on wide streets, there is a shortage of snow storage. The city will initially push snow to the right, then try to remove snow at the corners, but there is some snow left over. Snow is loaded with either an end loader or a snow blower. The snow blower is preferable for larger events, as it takes less than one minute to fully load a truck. However, if looking at the forecast, it is determined that they can

pile it and let it melt, that is a significant cost savings and hauling will not be done. Businesses may find this inconvenient, though.

In terms of general maintenance, raised crosswalks have been not caused problems, as long as the drainage at these locations is proper. There has been some damage to domes and structure at curb ramps, depending on the materials used. Cast iron domes hold up well and should be the default. Plastic and concrete domes tend to get damaged from mechanical snow removal equipment. Water retention on the dome plates and at the base of the curb ramp area is also a problem, especially with refreeze. This occurs because the slope is too flat. Keeping snow out of curb ramps and crosswalks is difficult and there don't seem to be any good solutions.

Plowing tight corner radii is generally not a problem. Tandem plowing is done for long stretches on arterials with the plows continuing forward and not turning at intersections. In other words, the radiuses are not getting plowed. On residential streets there is more turning, but the tighter corner radius also means there is less snow to plow. Iowa City has 13 plow routes, and truck(s) and an end loader are assigned to each route. The city tries to make operators aware of the need for radius clearing.

Feedback from maintenance staff has provided different insights. Traffic calming features tend to be viewed as "fighting" maintenance operations, especially features like offsets that are hard to plow. The curbs on the downstream end of bulb outs tend to take a beating. They are hard to see from the truck and various types of equipment are used, all with different visibility. The city tries to keep same operators on the same routes, so they know the features and where they are located. Still, once enough snow has accumulated, it is hard to avoid things like curbing.

Speed humps are difficult to plow, but they are better to plow than narrowed streets. The city council wants narrow streets and on-street parking, but in a bad winter the width of the street narrows, and the on-street parking takes up more space. The end result is situations that are hard to plow, filling up driveway aprons with the windrows. The other problem with narrowing streets is that plow blade are 12 feet wide, but sometimes roadway designers want to build 11-foot lanes. Traffic calming circles are difficult also for refuse collection trucks year-round. Trees planted in small traffic calming circles do not survive, they either get hit or don't have enough root space.

Paint at crosswalks is being upgraded to high build in an attempt to get two years of life between repainting. Doing this for crosswalks and other special markings presents a stronger business case for durable materials than standard lane lines. You can save in terms of labor costs and the need to close a lane if you only have to paint specialized markings every other year.

3.2.3 New York State Department of Transportation

Contact: Kristina (Tina) Crowley

Date: June 9, 2022

<u>Pedestrian Feature of Interest:</u>

- Curb ramps
- Bus bulb outs
- Pedestrian refuge islands
- Pedestrian signals, Rectangular Rapid Flashing Beacons, Pedestrian Hybrid Beacons
- Raised intersection (one)
- Pavement markings

This interview was with the Snow and Ice Program Manager for New York State, and so the discussion covers pedestrian features and maintenance activities in a more general sense. It was not possible to estimate the number of specific pedestrian features that are in use nor their age. Winter maintenance in New York State is organized between state-maintained roadways and municipal/city roadways. State roadways do not include those within the borders of a city. The NYSDOT maintains state roadways, and maintenance activities stop at the jurisdictional border.

The pedestrian features that are in use throughout the state on DOT roadways are those which work in conjunction with high speeds. The DOTs primary object is to move traffic, and so features that slow traffic down are not used. The Pedestrian Safety Action Plan is what the state is using to guide selection of pedestrian safety countermeasures. It guides what type of crossing gets which treatments. From the winter maintenance side of things, operators make do and adjust to things when a feature is built. The state is under pressure to reduce salt use, but the municipalities and residents/businesses that are clearing pedestrian features (curb ramps) are still using it. There is no incentive for those parties to not use salt.

While they do get built, the use of bus bulb outs has been discouraged from installation from a maintenance standpoint. These features have received complaints from maintenance forces, as they require additional plowing, which slows down operations. In general, whenever improvements are proposed or designed that move from a cross section that is free of curbing to one that has a curb, that generates complaints from maintenance crews. The state uses granite curbing to prevent plowing damage. Municipalities may change the equipment they use on a plow route based on the pedestrian features they have in place.

A raised intersection was installed by the DOT in 2021, but there has been no feedback received to date on any winter maintenance issues. The state has been working systematically to bring curb ramps on its system up to ADA compliance. The state also has bike paths along its roadways. These can be established on the shoulder using pavement markings, delineated on the shoulder using white tube markers, or built separately off the roadway. The DOT also allows parking on the shoulders of their roadways, and they plow the shoulders, although the roadway gets cleared first. If they don't get to the shoulders quickly enough, municipalities will plow the them, particularly if local business parking is affected.

No feedback related to summer maintenance could be provided, as street sweeping generally falls to municipalities, and the state doesn't roster street sweeper equipment. One consideration that

sometimes is overlooked is that lighting is often needed in conjunction with the pedestrian features that are being built in the state.

3.2.4 City of Delafield, Wisconsin

Contact: Paul Zellner

Date: June 21, 2022

Pedestrian Feature of Interest:

- Curb ramps
- Curb extensions
- Tight corner radii
- Pedestrian signals, Rectangular Rapid Flashing Beacons, Pedestrian Hybrid Beacons
- Pavement markings

The city's approach to winter maintenance is to plow streets as early as possible. Generally, operations will start at 4:00 a.m. and finish before traffic begins to increase at 6:30 a.m. Clearing city-owned sidewalks are a top priority following a storm as well. A couple of plows will be sent out the next morning to do clean-up operations as needed (plowing parking lanes, etc.). After three or four storms, the city will come in and haul snow out of the downtown area. This consists of back-dragging snow to the center of the streets and loading it starting at 3:00 a.m. This continues until traffic begins to increase (between 6:30 a.m. and 7:00 a.m.). The experience of the city has been that pedestrian features do not necessarily present a challenge to winter maintenance, although the truncated domes and curb ramps in general can be a problem. These typically require manual cleaning. Similar to other communities, there is always a need for more equipment and staff for winter maintenance.

The age of Delafield's pedestrian features varies, with some dating back to the early 2000's or earlier. The downtown area was redone in 2002, and many pedestrian features were incorporated in that rebuild. Aside from the challenges presented by truncated domes and curb ramps citied above, the city has not had any general maintenance issues with pedestrian features. Sidewalks are washed in the spring, and then street sweepers come through the area. Their current sweepers have been able to maneuver around features like bulb-outs without any problem, since more tapered transitions have been used with these features. The only other challenge is that downtown area is so traffic heavy it is hard to get maintenance equipment in and out year-round. Over the years the city has updated its equipment fleet to have an arsenal that is capable of dealing with the different pedestrian features that have been installed. Equipment flexibility is a key with pedestrian features.

Experience has found that most pedestrian features are not prone to excessive damage from winter maintenance operations. There is occasional curb damage from plows, but this has been reduced through the use of rubber curb guards at the edge of plows that the city has found wears pretty well. (These rubber guards are similar to the steel ones mentioned and used by other cities in other sections

of this document). Aside from general curb damage, the decorative brick that was added between the curbline and sidewalks during the 2002 downtown reconstruction needed to have poly edges added later to prevent plow edges from dragging.

Some epoxy is used for crosswalk pavement markings, but most are done with waterborne paint and repainted annually. The city also has brick crosswalks with concrete ribbon borders (18 in the downtown area). These are more maintenance intensive, as they receive damage from plows in the winter and other heavy vehicles throughout the year. Use of an alternative, such as stamped concrete or asphalt, would be preferable for these types of installations.

One other problem the city has encountered with its features has been with lighted bollards. These have had corrosion issues with their internal electrical components. Salt is causing this corrosion, and it is not clear what can be done to prevent it. In some cases, the city has removed the electrical components and filled the bollards with cement. Perhaps an LED lighting package with components that are better sealed would address this problem, but the city has not found such a product to date.

Additional Pedestrian Features:

- Blended transitions
- Bollards
- Bus bulbs
- Planter boxes
- Special landscaping

3.2.5 City of Cheyenne, Wyoming

Contacts: Randy Hickman

Tom Coonts

Bill Gonzales

Alton Cross

Mike Schlabs

Date: May 31, 2022

Pedestrian Feature of Interest:

- Curb ramps
- Curb extensions
- Pedestrian refuge islands
- Crosswalk markings

The interviewees indicated that they do not like bulb outs, as they make snow removal and street sweeping difficult. There is not a lot of pedestrian traffic in Cheyenne, and there is some question of whether bulb outs are needed. Bulb outs were mostly placed by the Wyoming Department of Transportation, not the city.

From a winter maintenance perspective, the inside corner of the bulb out is hard to reach, especially those that are at 90-degree angles. The feature is troublesome for snow removal, and once a snowfall of greater than 6 inches occurs, the snow has to be hauled, as mentioned above. From a plowing point of view, the sharp corner is a problem with mid-blade equipment like motor graders. The equipment basically has to mount the curb to get the snow out.

In the downtown area of Cheyenne (the traditional storefront commercial area), the business association funds "Downtown Clean and Save". This funds contractor and city forces to do snow removal on downtown sidewalks and parking lanes with light equipment. Snow from the parking lanes is pushed into the end of the bulb outs, and then the Streets & Alleys Department hauls it out periodically through the winter.

Typically, damage to curbs occurs every winter from plows hitting the curbs. The inside corner of bulb outs catch most of the damage since this spot is hard to find when hidden by snow. Designs used in the city vary; some are sharper, while others are more tapered. Inconsistency of design is a bit of a problem, equipment operators don't know what to expect. Some bulb outs are 45-degree tapers that were designed by the DOT. The variation in designs is the result of changes made during different construction projects.

The city does snow removal by mutual agreement, no state plows operate within the city. The city plows everything to the outside of the roadway, and then the Downtown Clean & Save group pushes the snow from the parking lanes into the bulb outs. Then the city comes back in, pulls the snow back to the middle of the roadway, and loads it out. A snow blower and truck cannot fit between the bulb outs, which is why snow has to be moved back out onto the roadway for loading. The Downtown Clean & Save group has not had any problems with ADA curb ramps, and businesses also try to keep them open.

The city also has three pedestrian refuge islands. Winter maintenance for these features involves plowing to the outside of the feature and going slowly to avoid catching the island. Refuge islands are not as much trouble for winter maintenance as the bulb outs. The ADA ramps on the refuge islands might not get cleaned out however. The snow is plowed away when passing the ramps, but no one goes back to clean them out.

Aside from winter maintenance, general maintenance with the bulb outs depends on the level of dirt that is present. Sometimes staff has to do hand work to get all of the dirt out of the corners. The sweeping machine can get caught with the tighter radius bulb outs, and gradual tapers are easier clean. The city uses two types of street sweepers/brooms; the Elgin Pelican with rear-wheel steering and Dulevo sweepers with four-wheel steering. The Dulevo sweepers are easier to maneuver around bulb outs.

Storm drains in the corners of bulb outs are hard to reach for cleaning, especially when it is necessary to get in with a vacuum truck. During redesigns, the inlet is moved into the corner, and the 45-degree pipe bend buried underground. So far there have been no major clogs, but there are not a lot of deciduous trees in the downtown. The bend is difficult to locate for construction purposes.

Aside from maintenance issues, the city has observed that delivery trucks run over the bulb outs. There are planters close to edge of bulb outs, which help to protect pedestrians. The Downtown Development Authority pays for planter maintenance through special taxing district funding. About a year ago (2021), Bird scooters start to be deployed within the bulb outs. There has been a need to consider where to park them. The local contractor puts them in the bulb outs where they are visible.

3.3 AGENCY SNOW REMOVAL POLICIES AND PROCEDURES

The conduct of winter maintenance, and maintenance in general, for pedestrian facilities can vary greatly, as the prior sections have shown. Typical 20th Century street designs established distinct zones for pedestrians and motor vehicles. In most cities, maintenance responsibilities were divided accordingly, with adjoining property owners responsible for sidewalk snow removal and public-sector crews or contractors handling snow removal for the roadway. When roadways are converted to shared-space designs, the delineation of winter maintenance responsibilities not as clear (NACTO, 2013a). For example, when the Harvard Square commercial district in Cambridge, Massachusetts was converted to a woonerf[1], the adjoining businesses shouldered the additional snow removal responsibilities, but shared residential streets could prove more challenging.

In some cases, maintenance responsibilities have been split between public agencies. For example, when the City of Chicago installed buffered bike lanes on Dearborn Street, the two-way cycle track was designed to be wide enough for a street sweeper or snowplow (NACTO, 2013b). The Chicago Department of Sanitation is responsible for street sweeping in both the cycle track and the traffic lanes, but winter snow removal in the cycle track is delegated to the city's Department of Transportation (DOT).

The following sections present information obtained through a review of published snow removal policies and procedures. Information from Minnesota cities and counties is presented, first, followed by other information from in-state agencies. The section concludes with coverage of a sample of information from other U.S. states and internationally.

3.3.1 Minnesota Cities

The City of Albert Lea assigns the responsibility of removing snow and ice on sidewalks to individual property owners (City of Albert Lea, 2007). The city does not explicitly state that sidewalks and curb ramps at intersections or midblock crossings are the responsibility of property owners, but it can be

[1] A woonerf is a living street that includes shared space, traffic calming, and low speed limits.

surmised that this is the case. Property owners are instructed that snow and ice cannot be cleared onto streets or sidewalks.

The City of Duluth does not specifically indicate that property owners are responsible for snow and ice removal on pedestrian facilities adjoining their property (City of Duluth, Undated). However, the city's snow and ice control policy does explicitly state that "snow removal operations shall be performed on streets, alleys and sidewalks maintained by the city." Nevertheless, sidewalk snow removal conducted by the city is limited to only selected routes, such as those near schools, high pedestrian traffic areas, and so forth. Aside from city-designated routes, one could conclude that maintenance of sidewalks and similar pedestrian features falls to property owners.

The City of Faribault's snow and ice control guidelines explicitly state that the city is responsible for the clearing of curb cuts and crosswalks (City of Faribault, 2022). Property owners are responsible for the clearing of sidewalks in the city. City-owned trails are also plowed by the city, but these are not necessarily cleared of all snow and ice.

The City of Mankato requires property owners to remove snow and ice of any accumulation within 24 hours of the end of a storm (City of Mankato, Undated). If snow is not removed, the city will complete snow removal and the property owner charged for this cost.

The City of Bloomington, in its presentation of snow removal and snow emergency information, states that the city is responsible for snow removal on over 260 miles of sidewalks. Ten snow removal units are used to accomplish this maintenance, which is conducted by park maintenance staff. Sidewalks in the city are divided into three priorities:

- First priority – school walking areas, wheelchair accessible areas and high use areas on main roads.
- Second priority – sidewalks extending out from school areas and along major roads.
- Third priority – residential and industrial areas.

It is presumed that property owners can clear sidewalks adjoining their property prior to city plowing if desired. The City of Bloomington states that the total cost of snow removal (streets and sidewalks combined) averages approximately $43.20 per household per year (City of Bloomington, Undated).

The City of Cloquet snow and ice control policy explicitly states that property owners are responsible for clearing their sidewalks. Aside from this, city-owned sidewalks and trails are the final areas that are cleared by city staff following a storm. The operations performed on these facilities include sweeping, plowing and snow blowing.

The City of St. Cloud's snow and ice removal policy points out to property owners that they are required to clear snow and ice from sidewalks on all sides of their property within 24 hours of the end of a snowfall. The city also explicitly states that if a property owner is on a corner, it is their responsibility to clear curb cuts and crosswalks to the street gutter in order to facilitate accessibility for people with

disabilities. Property owners that fail to comply with these requirements will have snow or ice removed by city staff and be billed accordingly.

The City of Thief River Falls sidewalk snow removal policy assigns the responsibility for snow and ice removal on residential sidewalks to adjacent property owners, with removal being completed within 48 hours of the end of a storm. Property owners within the central business district of the city are also responsible for snow and ice removal, but these properties are required to have sidewalks cleared within 24 hours of the end of a storm.

3.3.2 Minnesota Counties

A review of the plan and policy information posted online by Minnesota's 87 counties was performed to determine what, if any winter maintenance is performed for pedestrian infrastructure. Given the primarily rural nature of most counties in the state, it is not surprising that the majority of county roadway department snow and ice policies speak only to the plowing of roadways. Only one instance, that of Ramsey County which encompasses St. Paul and the northern suburbs, was found where a county performs snow removal at some pedestrian facilities. Specifically, Phase Two of snow removal operations in the county after a storm includes removal of snow and ice from pedestrian ramps at signalized intersections.

Aside from this, a few county policies state that sidewalks on the county or county state aid system that are within municipalities fall under the snow policy of the municipality. In such cases, snow removal may fall to property owner or municipality, depending on the municipal snow policy. The counties that state this in their policies include Lake County, Itasca County, Chippewa County, Lac Qui Parle County, and Dodge County.

3.3.3 Additional Minnesota Guidance

The Minnesota Pollution Control Agency's (PCA) Model Snow and Ice Policy Advisory Committee has developed a model snow and ice management policy (Minnesota PCA, 2016). This policy is designed to serve as a template for Minnesota cities and counties to adopt for their winter maintenance operations. The model policy includes text indicating that an agency is not responsible for managing snow and ice on sidewalks, while leaving the option for the agency to add their own specific policy statement regarding whether snow and ice removal is delegated to property owners. Further information provided in the model policy indicates that target clearance time for sidewalks and trails following a storm may range from 9 to 36 hours, depending on the size of the entity.

The Minnesota PCA and Mississippi Watershed Management Organization have also developed public information materials encouraging property owners and snow removal contractors to follow best practices for snow removal. To protect water quality in Minnesota's lakes and rivers, the materials emphasize the importance of avoiding over-salting.

In addition to individual agency information, a Minnesota Transportation Research Synthesis summarized snow removal best practices and lessons learned from survey responses of seven different

agencies throughout the U.S. (Minnesota DOT, 2013). At the time (2013), only Delaware and Wisconsin reported having a snow and ice policy for pedestrian facilities, and all responding agencies indicated that they plow less than 25 percent of their pedestrian facilities. Five respondents indicated that bare pavement is acceptable for bikes and pedestrians, even after only a trace of snow has accumulated, and they rely on adjacent property owners to help clear sidewalks and trails. All seven respondents indicated that they did not plow roadways differently in the vicinity of sidewalks and trails. To summarize, the information in the synthesis underscores that while agencies recognize that winter maintenance of pedestrian facilities is necessary, their agencies largely did not take that responsibility upon themselves.

3.3.4 State Plans and Policies

In addition to Minnesota municipal and county policies, snow removal information from various local agencies throughout the U.S. was also identified. While only a sample has been reviewed as part of this project, the documents provide a snapshot of how the winter maintenance of pedestrian facilities is handled elsewhere. As the review of policies in Minnesota found only minimal county mentions of winter maintenance for pedestrian facilities, the search completed for other states focused on municipal policies.

The City of Bismarck, North Dakota's snow and ice control plan calls for abutting property owners to clear sidewalks within 24 hours of the end of a storm (City of Bismarck, Undated). If the property owner does not remove snow, the city directs removal and the property owner is assessed the cost. The plan does not speak to the clearing of specific pedestrian features, aside from sidewalks.

The City of Ames, Iowa assigns the responsibility for clearing sidewalks to adjacent property owners in its snow and ice control policy (City of Ames, 2019). The policy goes on to state that owners of lots that have pedestrian crossing ramps are required to remove snow and ice from those ramps. Aside from this, the policy assigns the clearing of snow and ice on trails and shared use paths to parks and recreation maintenance staff. The policy does not discuss other pedestrian features.

The City of Madison, Wisconsin assigns the winter maintenance of sidewalks to adjacent property owners (City of Madison, Undated). Property owners are also responsible for the clearing of curb ramps. If snow and ice is not removed, crews will complete this task and the property owner billed accordingly. The policy does not discuss other pedestrian features.

The City of Omaha, Nebraska directs that property owners are responsible for sidewalk snow removal (City of Omaha, Undated). Aside from this requirement, the city does not speak of responsibilities related to other pedestrian features, including curb ramps.

The City of La Crosse, Wisconsin, while assigning sidewalk snow removal to abutting property owners, also instructs owners of corner lots that curb ramps should also be kept free of snow and ice extending past the curb and gutter to the pavement (City of La Crosse, Undated). The city does not discuss other pedestrian features.

In the winter maintenance of pedestrian facilities guide developed for local governments in Delaware, Scott and Rudd suggest that agencies clarify who is responsible for winter maintenance responsibilities for pedestrian facilities (Scott and Rudd, 2012). For example, this could include specifying in agency policies who is responsible for clearing curb ramps. Although not discussed, this recommendation would also extend to specifying who is responsible for the clearing of additional pedestrian infrastructure that is not near/adjacent to sidewalks, such as median refuge islands.

3.3.5 International Plans and Policies

Snow removal for pedestrian facilities is a universal concern in cold climates (PIARC 2022). Bus stops, schools, and commercial districts are often mentioned as the highest-priority areas. Particular trouble spots include steep hills, ramps, bridges, and entrances to pedestrian underpasses. Practitioners in Europe and Japan are particularly concerned about the potential for pedestrian falls when snow removal is inadequate, as well as reductions in the width of the available pedestrian space due to snow build-up. There is also universal concern about sidewalks becoming impassible due to windrows from mechanical plowing of streets. Japanese cities such as Sapporo and Aomori have worked to encourage residents to help one another with sidewalk snow removal, with particular emphasis on assisting elderly or disabled people; Sapporo has established volunteer programs for this purpose. In a few cities such as Oslo, heated sidewalks have been installed in commercial districts.

In discussing the trial of new, smaller sidewalk snowplowing equipment, a report to the city of Toronto Infrastructure and Environment Committee stated that the city is responsible for mechanically clearing snow from sidewalks in most areas of the city (City of Toronto, 2021). This is accomplished by 15 contracts with contractors that clear approximately 6,070 kilometers (3,771 miles) of the city's 7,300 kilometers of sidewalks using 237 machines. Locations where sidewalks are not cleared generally have a sidewalk too narrow for exiting equipment, obstacles, or limited adjacent snow storage. While the document does not indicate whether pedestrian safety features such as curb ramps, median refuge islands and others also are cleared of snow, it is reasonable to conclude that these do receive winter maintenance, given the extensive coverage of the sidewalk program.

The City of Calgary, Alberta requires property owners to complete snow and ice removal within 24 hours of the end of a storm (City of Calgary, Undated). Interestingly, the city takes responsibility for "reducing windrows at 500 crosswalks and wheelchair curb ramps".

The City of Winnipeg, Manitoba is responsible for the removal of snow and ice on 3,000 kilometers (1,864 miles) of sidewalks (City of Winnipeg, Manitoba, Undated). Snow removal operations on sidewalks are divided by priority routes. Priority 1 and 2 routes begin snow removal following 5 centimeters of snowfall and are targeted for completion 36 hours after the end of a storm. Priority 3 routes begin snow removal following 8 centimeters of snowfall and are targeted for completion within five working days after the end of a storm. While the document does not indicate whether pedestrian safety features such as curb ramps and others also are cleared of snow, it is reasonable to conclude that these do receive winter maintenance given the extensive sidewalk network coverage.

In 2016, the City of Winnipeg's devoted 10% of its CAD $39 million overall snow removal budget to sidewalk snow removal. The sidewalk snow removal budget of CAD $3.9 million works out to approximately CAD $5.15 per resident (approximately USD $3.1 million total, or $4.00 per resident) (Santin, 2017).

In Northern Europe, snow removal for public walkways is often treated as a public service. For example, the Highland Council, a consolidated city-county government in the Inverness area of northern Scotland, takes responsibility for snow removal on public streets (Highland Council, 2016). The main shopping areas are cleared first, followed by sidewalks serving schools, hospitals and other commercial areas. Residential sidewalks are generally treated last. Snow removal on private property is the owner's responsibility.

In Greater London, the City of Westminster describes a similar policy: "Cold weather in winter can mean ice, frost and snow, which are dangerous for cars on our roads and for people walking on our [sidewalks]…we mechanically treat a network of our busiest [sidewalks], using small…vehicles. Additionally, our [staff] manually grit over 500 other [sidewalk] locations across the city, such as pedestrian crossing points and subway steps… [Priority is given to] steep gradients, bus routes, areas outside transport hubs, outside fire and police stations, hospitals, schools, and nursing homes..." (City of Westminster, 2020).

In some British cities and counties, volunteers assist public employees with sidewalk snow removal. For example, predominantly rural Cumbria County in northwest England recruits hundreds of "Snow Champions" who agree to maintain a specific sidewalk section (Cumbria County Council, 2018). In exchange, the volunteers receive snow shovels, salt, and high-visibility winter coats from the county. A notable aspect of this approach is the potential to train volunteers on proper body mechanics, snow placement, and deicer application.

According to a press report, about 60% of municipal councils in Sweden delegate responsibility for snow removal to property owners (usually sidewalks, but in some cases also streets) (The Local, 2019). In 2019, Villaägarnas Riksförbund, a national organization representing homeowners, called for repeal of the 1868 law that authorizes municipalities to delegate these duties. The organization argued that the law was obsolete "due to the invention of snowplows" and argued that delegating the responsibility to homeowners results in inconsistencies and safety risks, and puts an undue burden on the elderly.

In Stockholm, Sweden's largest city, snow removal for both sidewalks and streets is a municipal service. In 2016 the municipal government announced a policy prioritizing snow removal on sidewalks, bus lanes, and bicycle paths, and near bus stops, daycare centers, and schools (CBC Ottawa, 2018). Snow removal at these locations begins when the snow depth is 2 to 4 centimeters (0.75 to 1.5 inches), while the trigger for street clearing is 6 to 8 centimeters (2.25 to 3 inches). Municipal leaders argued the policy is more equitable to children, elderly people, and women (who are less likely to drive than Swedish men), and encourages year-round use of non-motorized transportation and public transit. They suggested that while it is possible to drive through 10 cm (4 inches) of snow, it is very difficult to walk through snow that deep.

3.4 CHAPTER SUMMARY

Based on the interviews that were conducted, as well as the winter maintenance plans and policies reviewed, a number of conclusions can be drawn that will help guide the development of feature design and snow removal best practices. These are summarized in the following text.

Different communities mentioned damage to various areas of concrete, but most specifically, curbing. This damage comes primarily from snow removal equipment (i.e., plow blade strikes and scrapes). Communities that have specified high-strength concrete in the construction of pedestrian-related infrastructure have found that it has held up well and experienced less damage. As a result, the use of high-strength concrete is a recommendation as a design consideration in this report. Repairs to damaged curbs should also be scheduled annually to prevent further deterioration.

Agencies interviewed indicated that snow storage is an issue with pedestrian-related infrastructure, and roadways in general. Agencies frequently haul snow away to disposal sites following most storms because of the lack of storage capacity on the roadside in pedestrian areas. While right-of-way constraints often impact storage capacity, where such constraints do not exist, dedicated storage locations (e.g., grass medians between curb and sidewalk) could be incorporated into designs when possible. Otherwise, where storage capacity does not exist, highway agencies will need to develop snow removal and haulage plans to assist in keeping pedestrian areas free of snow build-up, if they do not already have such plans in place.

One agency interviewed had considered narrow lanes (11 foot) and tight intersection corner radii as a design option during the development of overall reconstruction plans. The use of narrow lanes was removed from consideration in that case early in design due to the inclusion of bump-outs and plow widths. If an agency is looking at incorporating narrow lanes into a design, aspects such as winter maintenance equipment width, opposing vehicle passing needs (especially for wide loads) and turning challenges for heavy vehicles should be considered in decision-making. Narrow lanes and tight corner radii should be employed only when low heavy vehicle traffic volumes are present.

One agency interviewed had experienced soil subsidence following the completion of their pedestrian infrastructure project. This occurrence underscores the need during the planning and design stages to determine soil types and composition, as well as determining what remedial measures may be needed during construction to prevent future problems.

Agencies expressed that bulb-outs are good for creating parking areas, but they can also be difficult for snow removal. This is especially the case when combined with the presence of other support infrastructure, such as light poles, signal bases, bike racks, decorative fences, etc. The use of such features should be incorporated in such a way that these elements do not hinder snow removal operations or other maintenance in general. The use of a more gradual taper for bulb-outs, between 45 and 60 degrees, was found to work well by one city. The S-style curb design (drive-over/roll curb) is more forgiving to plowing activities compared to the B style curb and should also be considered in future designs. One agency also stressed that designing all pedestrian features to be “smoother”

whether in terms of transitions or in-roadway (i.e., raised crosswalks) is something that should be considered.

The trade-offs between visual appeal, standardization, and maintainability need to be considered during design. Decorative features such as fencing, bike racks, etc., are useful, but these can sometimes be easily damaged, particularly during snowplowing. These features can also be expensive to repair, and their use should be carefully considered in light of benefits versus costs.

Curb ramp transitions, while from a design perspective are guided by the Americans with Disabilities Act (ADA), should use gradual transitions whenever possible. The gradual transition appears to reduce damage from snow removal activities. Additionally, experience has shown that steel and cast-iron truncated domes are preferable to plastic domes, but they must be properly installed to remain undamaged over time.

While often overlooked, training for operators both when they are newly hired and before the winter season (refresher discussions) on snow removal techniques on and around pedestrian features should also be considered. Most agencies interviewed indicated that assigning operators to set routes helps with familiarization (i.e., drivers know where features are and avoid striking them with plow blades). In other cases, using tall markers during the winter months could also help in identifying certain features.

The intensity of staff resources that will be required for maintenance, both winter and year-round, should be considered when selecting pedestrian safety features. This can be as basic as the need to manually sweep debris from inaccessible areas of bulb-outs, to the need to repair damage to roadside decorative/safety features like fencing.

The majority of the policies reviewed from Minnesota, as well as nationally and internationally point out that keeping pedestrian features (besides sidewalks) such as curb ramps clear of snow and ice are typically the responsibility of adjacent property owners. Features like bulb-outs and curb extensions are part of the sidewalk system and clearing of such features would also, presumably, fall to property owners. Not surprisingly, no plan or policy that was reviewed stated who would be responsible for clearing snow and ice from other dedicated pedestrian safety features like median refuge islands. In some cases, such as speed tables, the feature falls within the travelled way and is cleared by the owner-agency as part of normal plowing operations. In other cases however (median refuges), this clearance may be overlooked and not performed by anyone.

Minnesota municipalities vary in the extent to which snow removal is performed as a municipal service. When policies mention city removal of snow and ice from pedestrian facilities, the approach taken was often a phased one, where certain portions of the sidewalk system were cleared before moving on to others. In limited cases, such as the cities of Cloquet and Duluth, the city claimed responsibility for snow removal on a portion of the sidewalk system. In the case of Bloomington, the city took on a wider role in clearing pedestrian facilities. Plans from cities in other states assigned snow removal primarily to adjacent property owners, excluding specific facilities like bicycle trails and multi-use paths.

Canadian cities vary in the extent to which snow removal is performed as a municipal service, with Toronto and Winnipeg exemplifying cities where nearly all public sidewalks are cleared by the municipality or its contractors. Sidewalk snow removal is often treated as a municipal service in Northern Europe. All of these operations appear to be heavily mechanized. Proponents claim municipal snow removal service is efficient, reduces physical burdens on property owners (especially the elderly), supports the mobility of children and public transit users, and encourages year-round use of active transportation. Municipal removal also gives public agencies a high degree of control over the quality and timing of sidewalk snow removal and the opportunity to influence surface water quality by specifying the type and quantity of deicer applied to sidewalks. However, agency snow removal comes with costs, including labor and equipment, which must be factored into agency plans when designing any municipal snow removal operation for its overall pedestrian network.

CHAPTER 4: BEST PRACTICES CASE STUDIES

Snow and ice result in mobility challenges and physical hazards for pedestrians, especially in the Upper Midwest/Great Plains region. For example, inadequate winter maintenance can render some walkways impassable, while snow pack and meltwater refreeze can create slip-and-fall hazards. Curb ramps are subject to icing, access to pedestrian signal pushbuttons can be blocked by snow piles, and clogged storm drains can result in slippery ponds of meltwater.

These mobility and safety issues can be particularly acute for children, people with disabilities, and the elderly. In addition, people with disabilities and the elderly often have difficulty removing snow from their properties, resulting in physical hazards to themselves and other pedestrians.

Actual and perceived pedestrian snow removal inadequacies can generate complaints from residents, adversely impact retail sales for community businesses, and make it more difficult for employees to reach their jobs. Falls and other pedestrian injuries can result in financial claims against public agencies and property owners. Pedestrian injuries also have direct financial impacts on publicly funded healthcare programs.

More than any other state, Minnesota is known for the lakes and rivers that are among its most prized natural, cultural, and tourism resources. Winter deicing operations require judicious use of salt and other de-icing chemicals to assure the quality of these waters and the good health of their wildlife.

Communities in the Upper Midwest/Great Plains region have adopted a variety of strategies for addressing pedestrian facilities winter maintenance challenges. To learn more about the range of approaches currently in use and their advantages and disadvantages, interviews were conducted with four communities: Wilmar, Minnesota; Bloomington, Minnesota; Milwaukee, Wisconsin; and Winnipeg, Manitoba (see Figure 4.1). This chapter summarizes the main points from these interviews, with detailed descriptions of the information gathered through discussions with officials from Willmar, Bloomington, Milwaukee, and Winnipeg being presented. The four cities are presented in order of increasing population.

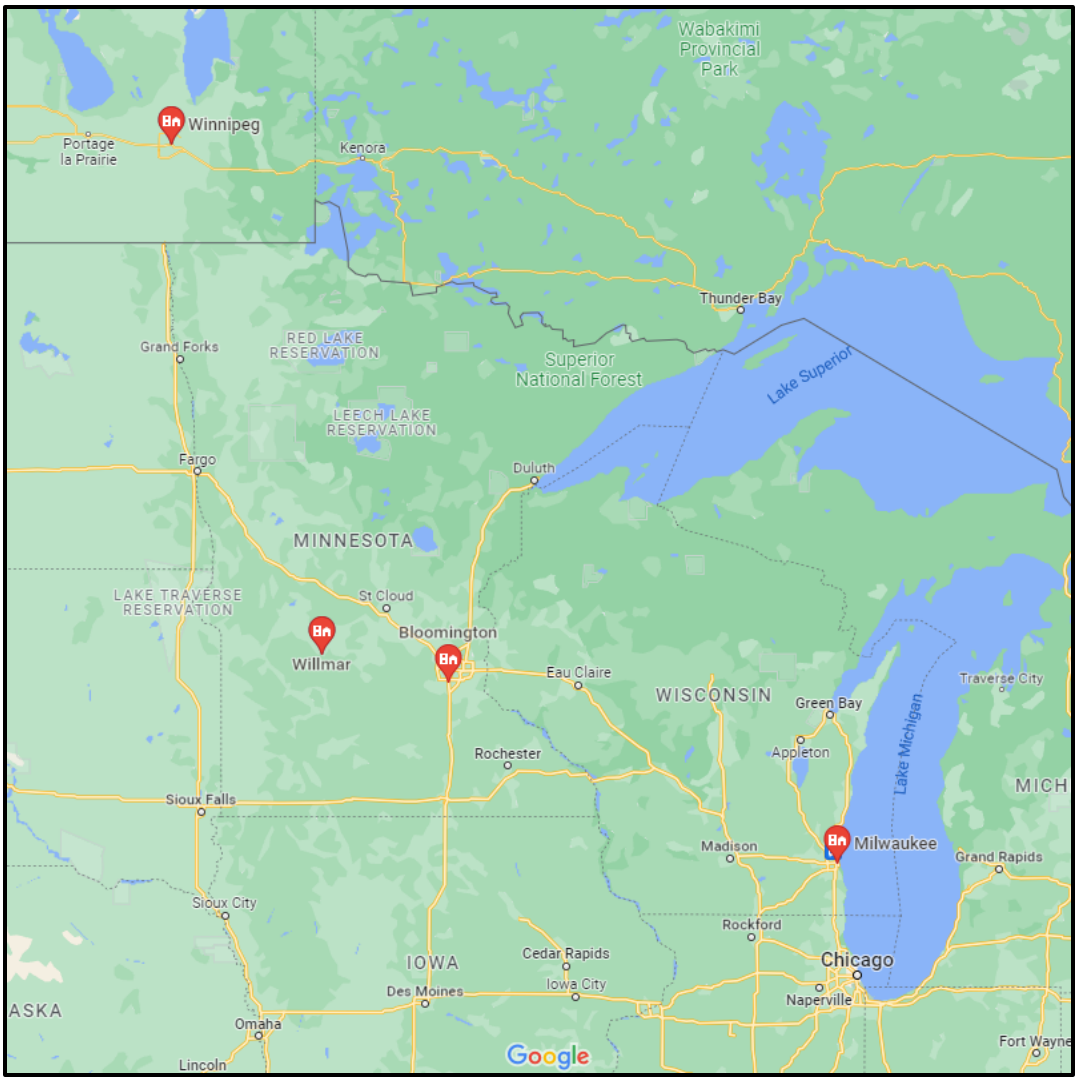

Figure 4.1 Location of agencies interviewed. (Source: Google Maps)

4.1 BEST PRACTICE CASE STUDIES

4.1.1 City of Willmar, Minnesota

Willmar, the county seat of Kandiyohi County, is located about 100 miles west of the Twin Cities. As of the 2020 Census, the population was 21,015. According to the United States Census Bureau, the city has an area of 16.0 square miles, of which 14.2 is land and 1.8 consists of lakes and waterways. US 12 runs east-west through the city and Business US 71 runs north-south through the city. U.S. 71 skirts the southern and eastern edges of the city and parts of MN 23 and MN 40 enter the city limits. The average annual snowfall is 46.1 inches, and the daily mean temperature in January is 11.7° F.

Gary Manzer, the city's Public Works Director reported that the city has approximately 135 miles of streets and 25 miles of city-maintained sidewalks and bike paths and multi-use trails. Most of the paths

and trails are paved with asphalt or concrete; a few are more rustic nature trails surfaced with crushed granite. The city typically experiences 10 to 15 snow events per year that require plowing.

4.1.1.1 Business District

Willmar's main business district extends about 10 blocks along U.S. 12 and about 10 blocks along Business U.S. 73, plus some streets adjacent to the two trunk highways. Each property owner in the business district is responsible for moving snow to the curb. City employees use specialized tractors to push the snow from the curb into the street. The city then hauls out the snow from the curbline as an overnight operation, typically the second night after a storm.

Much of the business district adjoins four-lane trunk highways without medians (see Figure 4.2). Due to the wide expanse of pavement and sidewalks, hauling out snow is a major operation. The absence of a median has both advantages and disadvantages: although there is no snow storage in the middle of the roadway, the city does not have to deal with plowing median pedestrian crossings as a separate operation.

Figure 4.2 Willmar business district along Business US 71. (Source: Google Street View)

Coordination of snow removal between property owners, city crews, and Minnesota DOT crews is challenging, especially due to the lack snow storage space. For example, when MnDOT crews plow U.S. 12, they often throw snow onto the sidewalk. Similarly, when city crews plow Business U.S. 71, to avoid throwing snow onto the sidewalk they have to be careful not to proceed too quickly. This problem would be less acute if the roadways had a terrace (grass strip) between the sidewalk and the traffic lanes.

4.1.1.2 Residential Areas

By ordinance, snow removal from sidewalks adjoining residential properties is the responsibility of property owners. After a storm, owners have 48 hours to remove the snow. Enforcing the ordinance requires a significant amount of administrative effort, and handling violations often takes at least as much staff time as it would take to remove the snow.

The city typically learns of violations through complaint calls, and a member of the city staff is sent to the location to verify and photograph the violation. The city then sends a compliance notice by mail directing the snow to be removed within 24 hours. If necessary, this is followed by a second notice sent by registered mail. If an owner still fails to remove the snow, city crews clear the sidewalk and a charge is added to the owner's property tax bill. The charge is proportionate to the number of linear feet cleared.

One of the main problems with the current compliance process is that it often results in considerable delay. By the time city crews arrive to remove the snow, it is usually densely packed and hard to remove. To make the process timelier, the Public Works Department is studying the possibility of switching to notifying residents using a door hanger instead of sending compliance letters by mail. This would require amending the city ordinance.

4.1.1.3 Public Facilities

Several areas in Willmar require snow removal by city forces. For example, the downtown includes various city-owned parking lots, and in these areas the city clears the snow from the sidewalks. The city also assumes responsibility for clearing snow from bike paths and multi-use trails.

For sidewalk snow removal, the city has acquired several Trackless model MT tractors, which can be equipped with a five-foot blade or snow blower depending on the depth and type of snow to be removed.

Since the city's bike paths and trails are 10 feet wide, the crews typically use Bobcat Toolcat™ vehicles equipped with a wide plow (Figure 4.3). They have also used skid-steer loaders with snow blowers for this purpose. To prevent snow compaction, the city tries to discourage snowmobiles from using the paths and trails.

Figure 4.3 Bobcat Toolcat™ with snowplow and salt spreader. (Source: Doosan Group)

Wind has a major effect on the timing of snow removal for the paths and trails near Willmar's lakes. Snowfalls are often followed by high wind, causing snow to drift across the lakes, so it is often necessary to delay trail plowing until the wind subsides. In some instances, it has been necessary to close a trail for the rest of the winter; this has usually been for recreational facilities, and the city attempts to keep more utilitarian trails in service year-round.

The Public Works Department currently has a staff of 22 people for snow and ice removal. While most of these personnel are needed for plowing streets, one person is dedicated to sidewalks and paths. About four others contribute half to two-thirds of their shift to clearing snow from sidewalks. With this staffing level, after a storm it typically requires about 10 hours to remove the snow from the sidewalks adjacent to public facilities, and another 10 hours to remove the snow from bike paths and multi-use trails.

The speed of the sidewalk snow removal operation is about 1 mile per hour. The city has developed a planned route that covers all the trunk highways as a continuous operation. In contrast, a considerable amount of jumping around and deadheading is required to cover parks, city buildings, parking lots, and other public facilities. Overall, about half of the time is spent for snow removal along the two trunk highways, the other half for spot removal at city-owned sites.

As part of these operations, curb ramps adjoining public facilities are typically cleared using the Trackless machine. Old areas of the city not yet equipped with curb cuts are difficult; the presence of curb ramps makes mechanical snow removal easier.

Sidewalks are usually salted lightly by hand. On bike paths and trails, the city uses the Toolcat to spread salt-sand mixture. Liquid deicers are used on streets, but not on pedestrian facilities.

4.1.1.4 Other Observations

Keeping pedestrian pushbuttons accessible in winter is sometimes a challenge in Willmar. Crews need to plow carefully to avoid burying pedestrian pushbutton poles in snow piles. If a pole gets buried in the snow, labor-intensive manual shoveling is required.

Similarly, when plowing side streets and intersections, extra effort is required to avoid filling the curb ramps with snow. During these operations, the movements made by plow drivers often conflict with turning traffic, and there have been a few instances when a plow has been struck by another vehicle. To minimize this problem, the city tries to begin street snowplowing early in the morning when traffic is light.

As noted by other communities interviewed for this project, street snowplowing sometimes results in curb damage. In Willmar, this rarely occurs as a result of plowing along the edge of the curb – most of the damage is caused by loader buckets striking a curb while picking up snow for haul-out. The broken concrete pieces are often lost—until they jam a snow blower.

Roadway geometric design certainly affects winter maintainability. For example, the city has some square-cornered cul-de-sacs where the corners require hand-clearing. Gradually rounded and tapered vertical and horizontal geometrics are much easier to clean.

Another design issue that affects winter maintenance is utility access boxes. With multiple utility companies operating in Willmar, some intersections have up to six utility access boxes. These can get in the way of snow removal and are cumbersome to clean around. In addition, there is always a chance of striking a utility box with the snowplow.

Manzar feels it is important for designers to consider the needs of people with disabilities – not just wheelchairs users, but also people who use walkers or other mobility assistance devices.

4.1.2 City of Bloomington, Minnesota

Bloomington is a suburb of the Twin Cities, located in Hennepin County. It is Minnesota's fourth-largest municipality, with a population of 89,987 as of the 2020 Census. In addition to residential properties the city has extensive commercial areas including numerous office parks, retail destinations including the Mall of America, numerous hotels, and several industrial and warehousing areas. Most of the development occurred between the 1970s and 1990s. Nearly a third of the city is parkland, with numerous lakes, ponds, rivers, and creeks throughout the city. The total land area is 38.4 square miles of which 34.7 is land and 3.7 is water. Snowfall averages 51.2 inches per year and the mean daily temperature in January is 16° F.

4.1.2.1 Municipal Snow Removal Service

Mike Kalis, the Street Maintenance Supervisor explained that Bloomington's approach to winter pedestrian facilities maintenance began decades ago as part of efforts to market the city as a walkable

community. Nearly all streets have sidewalks on both sides. The city takes responsibility for maintaining this pedestrian infrastructure, including snow removal. On paper, an ordinance delegates responsibility for sidewalk snow removal to the adjoining property owners, but in practice the city plows all sidewalks that run parallel to public streets, along with various public trails. Bloomington residents value the municipal snow removal service, as evidenced by the fact that it has survived many attempts to cut the maintenance budget.

In all, there are approximately 260 miles of public sidewalks in Bloomington. All but about 10 miles are plowed by the city, and these unplowed areas are disused cut-throughs that are candidates for sidewalk removal.

Property owners are responsible for clearing minor sidewalks that branch off to their doors. Some volunteer programs are in place to assist elderly residents and people with disabilities with removing the snow from these private sidewalks. As elsewhere, private driveways and parking areas are the property owner's responsibility.

Given the number of miles to be covered, plowing the public sidewalks is a big undertaking. The Parks Department maintenance crew is the primary staff for the sidewalk snow removal operation. A total of nine sidewalk plow machines are used. To avoid a "battle" with spillover and windrows from street snowplowing, the sidewalk plowing normally begins 2 hours after any snow event that requires street plowing. Thus, the streets have already been plowed when the sidewalk snow removal machines arrive.

The city has a well-defined hierarchy of sidewalk snow removal priorities, which is supported by the city council. Sidewalks near schools and along bus routes are the top priorities, and will be plowed whenever there is a snowfall of about ½ inch or more. Plowing of residential streets follows. The sequence is as follows:

- P**riority 1: Removal of the bulk of the snow near schools and along bus routes.** This usually takes about 4 hours. For an overnight storm, the majority of Priority 1 areas usually clear by noon after the storm.
- **Priority 2: Collector streets and the first side of residential streets.** For an overnight storm, this usually begins the afternoon after the storm, and continues through most of the second day after the storm.
- **Priority 3: Second side of residential streets.** For an overnight storm, this usually takes most of the third day after the storm. In addition, hauling out snow from areas with limited storage typically occurs on the third day.

Occasionally there are consecutive snowfalls on two or more days. In these cases, Priority 1 restarts. Although some residents complain that Priority 2 and Priority 3 walkways have not been cleared, most are understanding of the situation.

Sidewalk snowplow routes are mapped out to minimize deadheading, with a few exceptions such as some outlying elementary schools. The plows follow continuous routes, so areas that might be

troublesome in other communities (such as sidewalks across roadway medians) are covered routinely. Since comprehensive sidewalk snow removal is undertaken by municipal employees, the city does not have to devote any resources to snow removal ordinance enforcement.

Bloomington has very few storefront commercial areas—most of the retail space consists of malls and big-box stores. Nevertheless, there are some areas where it is necessary to haul out snow, especially on narrow bridge decks, places where retaining walls impede snow storage, and areas with extensive streetscaping. Additionally, there are some locations where haul out is necessary to prevent snowbanks from obstructing sight distance. In all cases, city crews push the snow to the gutter and then load it out with a large snow blower. This is usually a Priority 3 operation.

Snow removal is financed from the city's general fund. The annual budget is currently $1.4 million for streets and sidewalks combined. Since much of the city's tax base consists of commercial property, the cost per residential dwelling unit is low, about $36 per residential unit per year.

4.1.2.2 Equipment and Operational Considerations

Similar to Willmar, Bloomington mainly uses tractor-type snow removal units. These can be equipped with V-plows or snow blowers, depending on the circumstances. V-plows are much faster than blowers, but the feasible equipment depends on the snow depth:

- V-plows can be used for ½ to 3 inches of snowfall. Nine machines can remove snow from all sidewalks in the city in a 12-hour extended shift.
- Heavier snowfalls of 4 to 8 inches slow down the operation, and it is often necessary to attach the snow blowers for removal in higher-density areas of the city. With 9 machines in operation, the required working time increases to at least 16 hours, and in some cases it is not possible to complete all of the Priority 3 areas within that time.
- For very heavy snowfalls of 9 inches or more, snow blowers need to be used everywhere. With 9 machines in operation this requires around 31 hours.

After heavy snowfall events the city issues messages to the public explaining that extra time will be required for snow blowing and haul-out. Individual crew members typically work 8 to 12 hours per shift, with some of the labor provided by part-time employees.

Bloomington has tried sidewalk snowplows from various manufacturers. Currently the Trackless brand of tractors are the most prevalent in the city's fleet, mainly because the company has strong dealer support in the Twin Cities area. The machines require a considerable amount of maintenance and have to be replaced about every 5 years.

Operator training and daily maintenance make a big difference in the effectiveness of the sidewalk snow removal operations. Sidewalk imperfections can result in operator injuries, so safety measures have been implemented, including shoes for the V-plows to avoid snagging on uneven surfaces. Snow blowers make the machine lean forward, so the city added extra caster wheels to help support the weight of the

blower. The machines are rough and bouncy; operating a sidewalk snowplow for 12 hours is not a desirable job.

Out of concern for the city's lakes and rivers, Bloomington does not use de-icing chemicals on sidewalks. Some light applications of grit (sand) are done at selected areas on request from Metro Transit, the area's public transit agency.

4.1.2.3 Design Considerations

As noted by some of the other communities, gradual curb extensions are easier for plow operators to maneuver. The city installs markers on the ends of traffic islands to help operators locate the island when it is snow-covered. They prefer a bullnose style island tip to avoid plow blade snagging and consequent curb and equipment damage.

Since city crews plow the entire sidewalk system, median islands are covered by the plow routes. Nevertheless, median islands are challenging due to lack of snow storage. Operators try to note locations where excess snow needs to be hauled out with a front-end loader or skid loader. In addition to snow storage space, space is required to turn the snowplow machine.

Passages narrower than 48 inches are problematic for the snow removal equipment. There are some sites where the pedestals for pedestrian signal actuation pushbuttons are barely wide enough for the machine to squeeze through. Hand snow removal is sometimes required around the pedestrian pushbuttons; the machine operator usually carries a scoop shovel for this purpose.

Cast iron truncated dome plates are the best choice for curb ramps in communities that plow sidewalks mechanically. Plastics and ceramics don't hold up.

Drainage around curb ramps is sometimes an issue. In Bloomington, operators are encouraged to plow all the way to the curb to facilitate drainage. Raised markers would be useful to help locate the curb.

4.1.3 City of Milwaukee, Wisconsin

Milwaukee is the largest city in Wisconsin, with an estimated population of 569,330 as of July 2021. It anchors the Milwaukee Urbanized Area with a population of approximately 1.6 million. The daily mean temperature in January is 24.0° F. Milwaukee's average annual snowfall is 48.7 inches, substantially more than suburbs such as Waukesha which typically receives only 36.0 inches of snow. The difference is due to Milwaukee's location on the western shore of Lake Michigan. Although the prevailing wind direction is from west to east, after a storm passes out onto the lake, backdrafts can pick up moisture and deposit heavy, wet snow within about a mile of the shore.

Danielle Rodriguez, the Director of Operations for the Milwaukee Department of Public Works (DPW), James Washington the DPW Coordination Manager, Kate Riordan the Senior Multimodal Transportation Planner, and Erin Stoekl the Property Maintenance & Compliance Manager provided details about Milwaukee's approach to pedestrian facilities winter maintenance.

In recent years, Milwaukee has been making extensive use of Geographic Information Systems (GIS) mapping to create a comprehensive inventory of winter maintenance needs, including those related to pedestrian facilities. The GIS is also used to plan efficient snow/ice control routes. Specialized pedestrian installations such as walkways across bridges and traffic islands have been a major focus of these mapping efforts, helping assure that crews are aware of the need to remove snow from these areas. The mapping has also helped improve coordination with Milwaukee County which owns numerous parks and other facilities within the city limits, and is responsible for snow removal at the county-owned facilities.

4.1.3.1 Snow Ordinance Enforcement

Milwaukee City Ordinance #116-8 codifies the requirement for property owners to complete snow and ice removal on public sidewalks adjacent to privately-owned properties, and establishes penalties and procedures for non-compliance. The DPW Forestry Division is responsible for enforcement. The main features of the ordinance and associated business procedures are as follows:

1- Property owners are required to remove all snow and ice from the public sidewalk adjacent to their property within 24 hours after a snow/ice event has ended.
2- If a property owner fails to have the sidewalks cleared within the 24-hour time-frame, they can be cited for a violation. Currently, the Forestry Division does not look for sidewalk snow violations proactively, but responds to all complaints, which are typically received through the city services hotline/website or calls to alderperson offices. When a property is cited:
    a. A notice is applied to the front door (if there is a building present) and photos are taken of the property.
    b. The property is referred to the City's abatement contractor the same day.
    c. The abatement contractor has 24 hours to clear the sidewalk. The contractor provides before and after photos of their work to the City.
    d. The photos are reviewed and if work was satisfactorily completed by the contractor, the property owner is fined and sent a bill.
    e. Any unpaid fines are assessed to the property's tax roll at the end of the year.
3- Fee structure (there are few different scenarios):
    a. If the property owner was cited, but completed work before the City's abatement contractor arrived, a $50 posting fee is charged. This fee applies regardless of how many times the property has already been cited in the same season.
    b. First violation of the season if the City's abatement contractor completed work:
        - Total fee = $50 posting fee + $75 administrative fee + contractor charges + sales tax
        - As of November 2022, the contractor charging rate was $68 per 60 feet of sidewalk cleared. Under Wisconsin law the contractor charges and administrative fee are subject to 5.5% sales tax, bringing the minimum charge to $200.87.
    c. For any subsequent violations in the same season, the administrative fee rises to $100. With tax, this brings the minimum charge to $227.24.

Owners of corner lots are responsible to for clearing curb ramps and around pedestrian pushbuttons. The city takes responsibility for sidewalk snow removal on corner areas only when this poses an undue hardship for the property owner.

4.1.3.2 Commercial Districts

In contrast to the other cities interviewed for this project, Milwaukee performs snow haul-out from commercial districts only on an as-needed basis. As in the other cities, this work is done at night (third shift) to minimize traffic disruptions, except in emergencies. Removal of snow piles around parking meters is a particular concern.

The most intensive haul-out operations are required along the city's streetcar (light rail) route. If this snow is not removed, it can impede the streetcar track and adjacent parking areas.

Business owners in many of Milwaukee's neighborhood commercial districts have expressed interest in installing curb extensions (known locally as bulb-outs). The city has created a rapid implementation program for bulb-outs, using a combination of pavement markings and plastic delineator posts attached to the pavement surface. Typically, a local business association or Business Improvement District agrees to maintain the temporary bulb-outs, including removing snow from the area inside the delineators. This works to the mutual benefit of the city and the business owners; without this arrangement there would be several days of delay because these areas are a low priority for city crews.

4.1.3.3 Residential Areas

A notable feature of Milwaukee's approach to snow removal for residential streets is the odd-even overnight parking system used in most neighborhoods. In these areas, residents and visitors must park on the odd-numbered side of the street on odd-numbered days, and on the even-numbered side of the street on even-numbered days. This facilitates snow removal from the entire street over a period of two consecutive nights.

The odd-even restriction does not apply in some of the city's higher-density neighborhoods. The non-use of odd-even parking makes snow removal more complicated, as crews have to avoid creating windrows around parked vehicles. Moreover, these areas tend to have the narrowest streets in the city. Snow haul-out is occasionally required; this is done on a case-by-case basis at the request of the district alderperson (city council member).

As noted earlier, property owners throughout the city are responsible for sidewalk snow removal.

4.1.3.4 Public Facilities

- When winter storms occur, Milwaukee takes an all-hands-on-deck approach to staffing the snow and ice removal operations:

- Staff from various DPW sections including Forestry, Sanitation, Streets Maintenance, Sewerage, and Electrical Services all collaborate to remove the snow from streets, bridges, and specialized pedestrian installations.
- The city's Facilities Management group oversees custodial groups that perform snow removal at facilities such as city-owned parking lots.
- City-owned facilities that have on-site staff, such as police and fire stations, are responsible for performing their own sidewalk snow removal, much like any private property owner.
- Some snow removal operations are contracted out, such as hauling out snow from bus stops, which tend to become windrowed from street plowing operations. Haul-out from the bus stops is done overnight (6:00 PM to 6:00 AM), allowing end loaders to be positioned perpendicular to the street to simplify scooping out snow.

In spite of this multifaceted approach, as of November 2022 plow operator vacancies are currently a major concern due to an overall shortage of commercial drivers in Southeast Wisconsin. As a result, for the winter of 2022-23 the DPW is experimenting with reducing the initial post-storm level of snow removal service for major streets to "safe and passible" instead of "curb to curb" so they can begin working on residential streets earlier. For both types of streets, the traffic lanes will be cleared first, with parking lanes to follow in the days after the storm.

4.1.3.5 Special Areas

Milwaukee DPW refers to pedestrian walkways that cross features like traffic islands as "non-accessibles" (that is to say, "not accessible with a snowplow truck"). The GIS mapping process has been used to identify these features comprehensively and add them to the maps provided to snow removal crews. Maintaining these maps requires ongoing effort because the number of non-accessibles continues to increase as a result of street reconstruction. Non-accessibles, curb extensions (bulb-outs), and other unique pedestrian installations are cleared "faithfully" after 4-inch snowfall, but typically are not cleared for smaller snowfalls. There are occasional complaints due to snow buildup. Street clearing is performed first, followed by sidewalks, bike paths, and non-accessibles as secondary work.

Non-accessibles are typically plowed using sidewalk tractors or Trackless machines. A few are too narrow for a trackless tractor and must be cleared by hand. Milwaukee uses the same deicing chemicals and strategies for all facilities: streets, bike paths, sidewalks, and non-accessibles.

4.1.4 City of Winnipeg, Manitoba

Winnipeg is the capital of Manitoba and the province's largest city. It is located approximately 70 miles north of the Minnesota border at the confluence of the Red and Assiniboine Rivers. As of 2021, Winnipeg had a population of 749,607, making it the sixth-largest city in Canada. The average annual snowfall is 44.8 inches. Winnipeg considerably colder than Willmar, Bloomington, and Milwaukee, with a January daily mean temperature of 2.5° F.

4.1.4.1 Municipal Snow Removal Service

Jean-Luc Lambert, the Support Services Engineer for Winnipeg's Department of Public Works, reported that sidewalk snow removal is provided as a municipal service in Winnipeg, as is the case in several Canadian cities. A hierarchal approach has been adopted, with regional roadways (arterials) as Priority 1, collectors as Priority 2, and residential streets and back lanes as Priority 3. As in Bloomington, the priorities reset if a second storm occurs before cleanup can be completed. The scale municipal snow removal operations is considerably larger than in Bloomington, comprising around 3000 km (1800 miles) of sidewalks, bike paths, and park pathways.

Prior to 2019, due to resource limitations the sidewalks were plowed after completion of street snowplowing. In 2019, the city council voted to raise the priority of sidewalk snow removal services to support pedestrian mobility and better align with resident expectations. As a result, Priority 1 sidewalks are now cleared with the same urgency as Priority 1 streets, with the goal of completing plowing on all Priority 1 sidewalks within 24 hours after a storm.

During snow events, crews focus on keeping streets passable. Sidewalk plowing begins as soon as the storm has passed and wind has subsided. Residents are responsible for removing snow from driveways, driveway aprons, and from their front door to the public sidewalk. Residents also need to remove any windrows left along public sidewalks.

Operationally, the snow is first cleared from the street, and then the sidewalks are plowed. This sequence minimizes problems with over-throw and windrowing. Snow blowers are required in locations prone to drifting. At some locations, especially near intersections, it is necessary to load out snow. In addition, Winnipeg has storefront commercial areas where it is necessary to haul out snow at night. Skid steer loaders are used to push snow into the street; it is then blown into trucks and hauled out. The city does not haul out snow from residential streets.

Winnipeg does not apply salt or chemicals to sidewalks, but grit (sand) is applied. In the spring, a separate sweeping operation is conducted to remove excess grit.

Administratively, sidewalk snow removal is completed by a combination of contractors and city crews. Currently about one-third of the sidewalk snow removal is contracted out, and city personnel handle the remainder. Having a mixed approach provides backup in case of a strike by municipal employees, or if contractors can't handle the workload. Currently, the snow removal industry in the Winnipeg area is not large enough for sidewalk snow removal to be entirely outsourced. Provincial highway crews do not remove snow from major highways that pass-through Manitoba's large cities, but this does occur in small towns.

Ideally the city would like to contract out about half of their overall snow removal effort, but it has been difficult to find contractors willing to invest in sidewalk plowing equipment. City officials prefer to award one contract covering both types of snow removal service in a designated geographical area. This avoids

disputes over who cleans up windrows, which have sometimes been problematic in locations where a where contractor is responsible for plowing streets and the city handles sidewalks.

Figure 4.4 Sidewalk snow removal in Winnipeg (Source: City of Winnipeg/Twitter)

Perhaps because of the city council initiative, sidewalk snow clearing in Winnipeg is more political than street clearing. Once new expectations were set, residents wanted to see the street snow removal happen. The city occasionally receives complaints about the promptness of snow removal service, mainly from visually impaired people, people with physical disabilities, and bus passengers. In addition, during the covid-19 lockdowns there was an uptick in complaints related to residential snow removal, evidently due to more pedestrian activity on residential streets. To help clarify expectations, the city posted the snow clearing policy, time frames, and snow depth trigger (5 centimeters, about 2 inches) on its website. During post-storm cleanup, the website also provides twice-daily updates on the status of snow removal operations (see Figure 4.5).

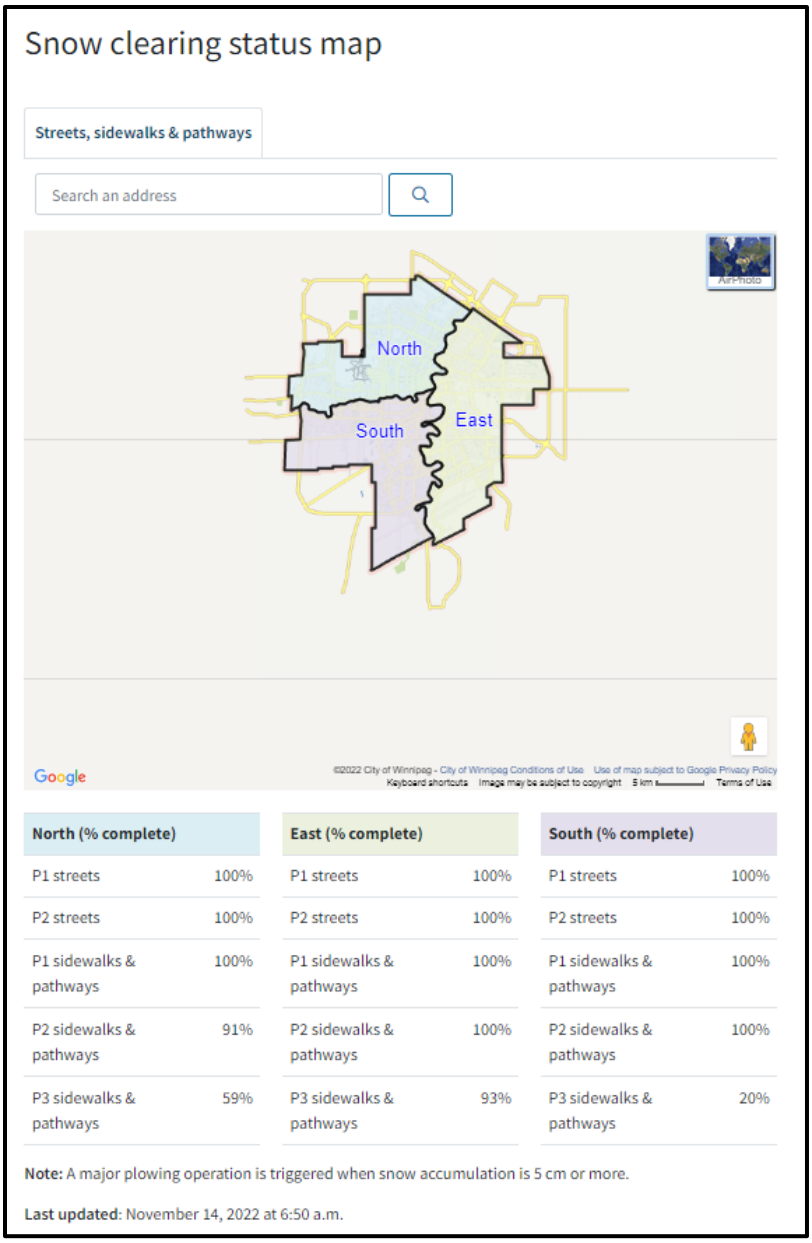

Figure 4.5 Winnipeg snow clearing status website. (Source: City of Winnipeg)

The layout of sidewalk snow removal routes remains fairly constant from year-to-year, but changes occasionally need to be made as a result of new development. To assure route familiarity, the Public Works Department attempts to assign the same personnel to each route, year after year. Due to employee turnover this is not always possible, particularly in light of the current labor shortage.

The city's overall budget for snow removal is around $35 million Canadian dollars (CAD) per year ($26.3 million U.S. dollars (USD) at the November 2022 exchange rate of 0.75 USD per CAD) . This can reach CAD $50 to $60 million if extreme snowfall occurs. Of this, sidewalk snow removal requires CAD $2

million to $3 million (USD $1.5 million to 2.3 million) annually. Taking the middle of this range, the annual cost of sidewalk snow removal is around CAD $3.30 (USD $2.25) per resident.

These costs exclude the capital expenditure required to expand the city's fleet of sidewalk snow removal machines in response to the 2019 city council initiative. Before 2019, about 32 sidewalk snowplows were used. In 2019, an additional 21 units were added at a capital cost of CAD $3 million (USD $2.3 million).

4.1.4.2 Equipment

Lambert says it is necessary to "gear up" for sidewalk clearing, which is "a different beast" than street snow removal. Each sidewalk snow removal machine is equipped with a plow or snow blower and a salt/sand spreader. The size of the fleet needs is governed by the distance to be covered in each shift. This is based on a typical operating speed of 1 km/h (0.6 mph), and needs to account for the time required to mobilize from the maintenance yard to the plowing location. Sidewalk snow removal units are not as reliable as regular snowplows, so the fleet is sized to allow 30 percent of plows to be out of service at any given time.

4.1.4.3 Design Considerations

In recent years Winnipeg has modified roadway design standards with snow removal in mind. Curbs take a lot of abuse. The most common problem is gouging when a street is plowed with a motor grader. On regional streets and collectors, the city's new standards call for a 6-inch curb with a slight batter for the curb face. Curb transitions at intersections have been lengthened to reduce the risk of snagging the plow. A mountable roll curb design is used on local streets to help prevent curb damage when plow operators shy onto driveway aprons to minimize windrows. The standards are available on the city's website.

4.2 CHAPTER SUMMARY

The officials interviewed for the case studies described a relatively wide range of operational and policy approaches for pedestrian facilities winter maintenance. The variations reflect differences in community size, community values, land use, and roadway design. Some officials also spoke candidly about historical practices that have been carried forward from year to year, in spite of results that are not entirely satisfactory.

The physical requirements for winter pedestrian facilities maintenance vary within, as well as between communities. Most of those interviewed made distinctions between four main area types:

- Commercial districts, especially traditional storefront commercial areas
- Residential areas, notably single-family residential subdivisions
- Public facilities, such as locations where a public walkway adjoins or crosses a public building, parking lot, park, or the like

- Special areas, notably locations where the legal responsibility for snow removal is ambiguous, such as pedestrian walkways crossing alleys, roadway medians, or traffic channelization islands

Street snow removal can throw snow onto sidewalks. As a result, those interviewed favored plowing streets first, followed by sidewalks. With the exception of Milwaukee, most of the communities interviewed for this project do not apply chemical de-icers on sidewalks, but some lightly apply salt or grit (sand), especially near high-use areas such as bus stops. In the spring, a separate sidewalk sweeping operation may be required to remove excess grit.

Storm timing and the type and depth of snowfall have major impacts on the level of effort required for pedestrian facilities snow removal and the perceived quality and timeliness of the snow removal operations. In addition, storm timing can exacerbate difficulties with operational coordination between various levels of government, and between public agencies and private land owners or their contractors.

Electronic mapping tools can help cities keep track of the pedestrian facilities that require maintenance. In addition, these tools can facilitate the coordination of snow removal amongst various levels of government and neighboring municipalities.

Although cost was not the major focus of this research, it appears that sidewalk snow removal has considerable economies of scale. That is to say, the greater the number of contiguous properties that can be handled by a single snow removal service provider, the easier it is to mechanize the operation, and the lower the cost per foot of sidewalk. Conversely, efficiency declines when a service provider must travel to various geographically dispersed properties, with considerable amounts of labor and fuel consumed by deadheading. The diseconomy of working dispersed sites is particularly notable for ordinance enforcement actions, where it appears to take the better part of an hour to travel to a site, remove the snow from a few dozen feet of frontage, and prepare documentation such as site photos and an invoice.

CHAPTER 5: DESIGN AND SNOW REMOVAL BEST PRACTICES

Design of pedestrian facilities should consider functional performance for pedestrians while providing winter maintenance-friendly options, as possible. Considerations include snowplow damage to curbs and curb extensions, snow removal damage to truncated domes, decorative crosswalks, bollards, drainage, snow storage, and pedestrian crossings of all types of traffic islands. These types of damage can have an impact on pedestrians using facilities, and can also result in maintenance repair costs that an agency did not expect or plan for. This chapter presents the design best practice considerations that Minnesota agencies should consider when implementing various pedestrian safety treatments throughout the state to provide for pedestrian accessibility while also preventing (or minimizing) infrastructure damage from winter maintenance and other operations. .

5.1 DESIGN BEST PRACTICE CONSIDERATIONS

5.1.1 Snowplow Damage and Maintainability of Curbs and Curb Extensions

When designing curbs and curb extensions for pedestrian facilities, two key considerations for winter maintenance are the potential damage caused by snowplows and the potential for buildup of ice or other debris in hard-to-clean areas such as tight inside corners (see Figure 5.1). Potential design considerations to prevent or reduce snowplow damage and improve maintainability include:

- Use a horizontal curb extension angle about 45° to help redirect the energy from snowplow impacts and make it easier for plow operators to maneuver around the curb extension. (Current MnDOT guidance is consistent with this recommendation, calling for a 1:2 to 1:3 horizontal taper, i.e., 18° to 26°.)
- Using a wide radius for the minor corners of curb extensions can help reduce ice and debris accumulation at the inside corner, and reduce the likelihood of maintenance equipment (or other vehicles) snagging the outside corner. (Current MnDOT guidance calls for a 5-foot radius on the inside corner and a sharp outside corner, but this could probably be increased to improve maintainability.)
- Specify high-strength concrete for curbing in bulb-outs and other vulnerable areas.
- Consider cast iron curb guards (e.g., Neenah Foundry R-4985 series)[2] for vulnerable areas such as the outside corners of bulb-outs.
- Provide marker rods at back of curb (similar to fire hydrant flags) – with a built-in holder allowing flags to be removed during the warmer months.
- Operationalize wider use of rubber curb guards for snowplows.

[2] The inclusion of manufacturer and product listings here and elsewhere in this document is for reference purposes only and is not an endorsement of a particular product or manufacturer.

While the use of rubber curb guards is more of an operational than a design consideration, it could be a valuable solution in cases where redesign and construction of pedestrian facilities are not feasible or where the design constraints for new or redesigned pedestrian facilities cannot reasonably use other options. The rubber curb guards could also be beneficial in reducing damage, regardless of the curb and curb extension design, for the cases when the blade still strikes the curbing.

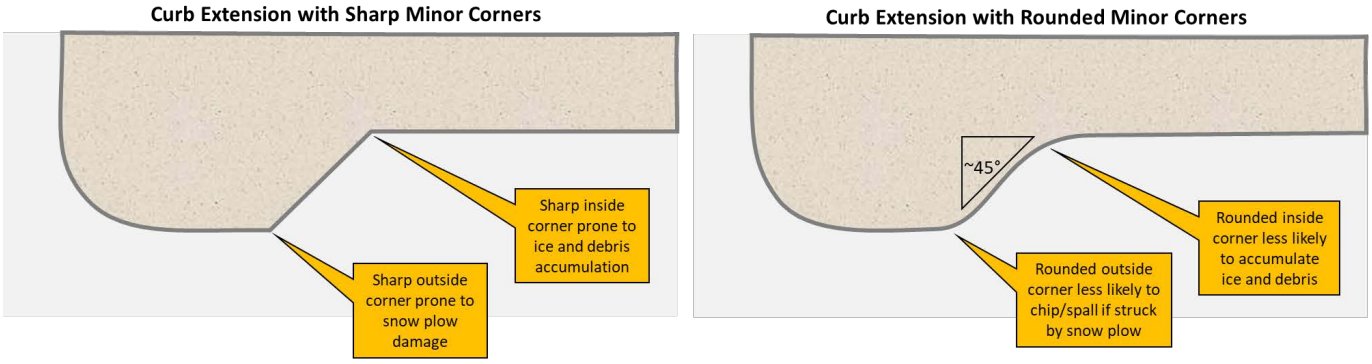

Figure 5.1 Comparison of sharp and rounded minor corners for curb extension (diagram by John Shaw/Iowa State University)

5.1.2 Snow Removal Damage to Truncated Domes

ADA and MnDOT standards require truncated dome plates to be provided at the lower end of curb ramps. The bumpy surface notifies visually impaired pedestrians that they are entering a space shared with motorized traffic. With truncated domes, snow removal can sometimes damage the surface of the dome. A couple options for protecting the surface of the dome during winter operations include:

- Field experience indicates cast iron truncated dome panels (e.g., East Jordan Iron Works product numbers 00700561, 00700571) are more durable than other options such as concrete, plastics, or pressed steel. Cast iron resists damage from snowplows, snow blowers, and manual shoveling.
- Optionally, the panels can be powder coated in yellow, black, or brick red.

The cast iron truncated panels can reduce damage from snowplows and the powder coatings can provide additional delineation and protection. As a note of caution, if the use of less durable materials, such as plastic domes, is pursued for permanent outdoor installations, an entity should be prepared to budget for ongoing repair/replacement.

5.1.3 Decorative Crosswalks

Decorative crosswalks are often desired in town centers and neighborhoods. However, if not designed for winter maintenance, they often do not maintain the desired function for quality pedestrian crossing surface. Deteriorated decorative crosswalks can detract from an otherwise well-maintained and welcoming appearance. Designers should consider the following principles and options:

- Avoid surface texture patterns that will result in poor aesthetics if spalling or plow damage occurs
- If colored concrete will be used, specify full-depth color to reduce the visual impact of chipping/spalling
- Consider stamped concrete with full-depth color
- Hard brick or granite might be permissible
- Avoid soft brick, limestone, and other friable, porous materials.
- Evaluate proprietary products, e.g., decorative thermoplastic panels, colored anti-skid coatings to determine performance with winter maintenance, including functional and aesthetic performance
- With further testing, Minnesota red granite chips bonded with epoxy resin might be considered as a functional alternative to proprietary products

When in doubt regarding the materials for decorative crosswalks, full-depth colored concrete (with or without stamping) should be considered as an option.

5.1.4 Bollards

Bollards help distinguish pedestrian areas from motorized traffic areas at locations such as blended transitions, and are also used to discourage vehicles from parking on sidewalks. With bollard use, a concern in winter maintenance is that the materials could be damaged by the chemicals used to prevent ice buildup on the roadway and sidewalk surfaces. Some bollards are developed using materials that are resistant to chloride damage (for example, see https://simmonsigns.co.uk/road-safety-solutions/bollards/simbol/). Thus, if bollards are used, it is recommended that the design specifies the bollards be made using materials resistant to chloride damage. Often the bollards made from thick, soft plastic are the most satisfactory choice: they are corrosion resistant, yield if struck by an errant vehicle, and spring back into position if a vehicle runs over them deliberately.

Corrosion of internally illuminated bollards can result in electrical hazards. Some vendors have addressed this problem by placing the electrical components in a hermetically sealed underground module that projects light into the body of the bollard, which then reflects it outward (for example, see https://simmonsigns.co.uk/road-safety-solutions/bollards/simbol/).

5.1.5 Drainage

Drainage is a common consideration in any transportation project. However, it becomes essential in preventing ice buildup and other issues for pedestrian facilities. One of the most common problems is meltwater ponding at the bottom of curb ramps or other low points during the daylight hours, followed by refreeze to solid ice at night. Such ice can be a slip-and-fall hazard for pedestrians, and is often very difficult to remove. A few design considerations that should be used to improve drainage include:

- Avoid bends in the inlet pipe when retrofitting existing sites.
- Plates over a surface channel to allow pedestrians to avoid water in the channel.

- Consider adopting the existing Colorado DOT guidance on slope selection, especially around curb ramps (Colorado DOT, 2019)
- Consider the relationship between corner radius and drainage, particularly as it relates to maintaining a uniform slope along the flow line. Tightening the corner radius typically reduces the impervious surface area and usually makes it easier to maintain satisfactory spacing between inlets and curb ramps.
- When curb extensions are retrofitted to an existing site, consider converting the old gutter into a drainageway that can be bridged with grates (Figure 5.2). In this application, cast iron grates are usually more satisfactory than steel plates.
- When other types of inlets are not feasible, consider the use of trench drains or slot drains (see Figure 2.9, presented in Chapter 2).
- Carefully consider inlet grate patterns with regard to ADA and PROWAG requirements, resistance to clogging, and ease of replacement in the event the cover is damaged or stolen.
- To prevent winter clogging and ponding, plan for maintaining inlets/outlets, including removal of accumulated autumn leaves and other debris.

The goal of drainage related to pedestrian facilities is to remove any water quickly and prevent any standing water, particularly in winter when it may refreeze. Using the above design and maintenance considerations should result in maintainable, functional pedestrian facilities.

Figure 5.2 Drainage channel through a curb extension, bridged by drain grates. (Source: San Diego Association of Governments)

5.1.6 Snow Storage

Snow storage is sometimes overlooked in transportation facilities design. In some areas, pedestrian facilities become the default storage location for snow that is plowed off the road. This results in the pedestrian facilities not being functional for their intended use (i.e., by pedestrians). In recent years Minnesota and other Midwestern states have experienced increases in total winter precipitation coupled with somewhat milder temperatures. If this trend continues, heavy-wet snowfall is likely to

occur more frequently in the future, potentially increasing the amount of space required for snow storage. Thus, design and maintenance plans should consider snow storage areas that allow the pedestrian facilities to remain usable by pedestrians during winter months whenever possible. Options could include:

- Pre-designate snow storage areas, e.g., specific parking spots
- Co-locate winter snow storage with summer sidewalk cafes or grass areas between curblines and sidewalks

Specific widths of the snow storage area between the curbline and sidewalk will be determined, in part, by the right-of-way that is available. While no guidance exists that establishes a recommended width of this storage area based on snowfall totals and storage needs, there is some design guidance that can be considered. The AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities provides guidance on buffer widths (also referred to as a planting strip). This guidance is the use of a strip 2- to 4-feet wide on local and collector streets, and 5- to 6-feet wide on arterial and major streets (AASHTO, 2004). The Iowa Statewide Urban Design and Specifications (SUDAS) Design Manual provides a more general figure of 4-feet minimum for this space (also to as "parking" in the manual) in Chapter 12 (Iowa SUDAS, 2013). This minimum width appears to work well in communities that experience similar winter conditions as Minnesota, albeit with lower snowfall totals.

The plan for snow storage areas should then be communicated with winter maintenance personnel (and property owners) and plans made to ensure that these areas are used, particularly when it is more convenient to simply plow the snow onto the pedestrian facilities. If hauling snow off site is currently performed, this should also continue. If this is not currently being done, it is another strategy an agency can consider adding to its process.

5.1.7 Pedestrian Crossings of Median Islands, Splitter Islands, and "Porkchop" Islands

Pedestrian pathways that cross traffic channelization islands (such as median islands, roundabout splitter islands, or "porkchop" islands for free-flow turn lanes) are sometimes overlooked when designing for winter maintainability. Although drainage is usually straightforward when the walkway is above the adjoining road surface, avoiding ponding and refreeze can be challenging when a walkway cuts through an island, as in Figure 5.3. To provide sufficient hydraulic capacity at the correct elevation, it is sometimes necessary to install an inlet on the pedestrian walkway or to use a trench drain or slot drain. In other cases, a small gutter can be installed parallel to the walkway to intercept meltwater.

Figure 5.3 Cut-through design for pedestrian walkway across a roundabout splitter island in Ames, IA. (Source: David Veneziano/Iowa State University)

As with curb extensions, all minor corners should be rounded to minimize the risk of damage from snow removal equipment and other vehicles. To avoid creating locations where ice and debris can accumulate, curvilinear longitudinal layouts are preferable to sharp corners and abrupt angles.

Pedestrian crossings of small traffic islands are prone to accumulation of windrowed snow from maintenance operations. Where possible, an island width of 4 feet or more can provide some snow storage, though haul-out may be required for heavier snowfalls.

In locations where the pedestrian traffic is highly seasonal or related to occasional events, the use of removable islands built up from timber, sandbags, or erosion control booms can potentially simplify winter maintenance in comparison to permanent islands. Typically this involves creating a perimeter of timbers/sandbags/booms and then filling the center of the temporary island with material that can be removed easily, such as wood chips. Another possibility is to delineate the temporary islands using prefabricated fencing panels or similar materials (see Figure 5.4).

Figure 5.4 Pedestrian walkway delineated by prefabricated fence panels. (Source: Ingolfson/Wikimedia Commons)

5.2 BEST PRACTICES FOR SNOW REMOVAL AT PEDESTRIAN-ROADWAY INTERFACES

One of the challenges that repeatedly comes up in literature as well as in discussions with winter maintenance practitioners is that of clearing snow and ice from pedestrian and roadway interface points. Most notably, curb ramp areas at intersections can be a grey area in terms of who is responsible for clearing these features during and after a storm. Most agencies rely on adjacent property owners (voluntarily or through policy/ordinance) to clear these features, while other agencies maintain a portion or all of the pedestrian system, including interface points, using agency staff and equipment or a contractor. When pedestrian safety features are going to be incorporated into new or reconstruction projects, the question of snow and ice removal should be considered in advance, particularly at roadway interface points. The following sections outline considerations and best practices for snow and ice removal for agencies to consider when planning and designing, as well as after constructing pedestrian safety infrastructure.

5.2.1 Property Owner Removal

Historically, most governmental entities have relied on adjacent property owners to maintain pedestrian infrastructure, including sidewalks and curb ramp areas. This remains a common approach employed throughout the United States. This approach is also employed where there might be interest by an agency in maintaining pedestrian facilities but budgets and staffing are limited, precluding performing that portion of winter maintenance.

Regardless of the reason why property owners are tasked with winter maintenance of pedestrian features, the conduct of that maintenance is best outlined through the use of an ordinance, policy or regulation. The use of an ordinance, policy or other regulation helps specify the duties and responsibilities required of the property owner, establishes timelines that clearance should be completed by, and so forth. This eliminates ambiguity as to what may or may not be required of property owners, particularly those whose property is located on a corner that may be required to clear curb ramps to the curbline. Included in the outline of what is expected should be a specification of the

amount of time following the end of a storm that a property owner has for completing maintenance, as well as what the penalties are for non-compliance. For example, will the property owner by fined, will a hired contractor be brought in to clear the area and the property owner charged, or some other approach and/or penalties adopted.

For communities or agencies that do not have a policy in place, the Minnesota Pollution Control Agency (MPCA) has developed a model snow and ice control policy (MPCA, 2016). Specific to pedestrian facilities, namely sidewalks, that policy states that "The City/County is not responsible for managing snow and ice on streets, sidewalks, or other areas not within City/County jurisdiction" (MPCA, 2016).

Some agencies also provide property owners located on corners with sand, salt or other deicing or abrasive materials to spread in the curb ramp area to prevent or address post-storm ice buildup. Other agencies have provided educational materials to the public regarding responsibilities and snow/ice removal techniques. These types of assistance for property owners can increase compliance and provide pedestrians with a safer path at roadway-pedestrian interface points.

As indicated above, when a property owner does not complete maintenance following a storm, so agencies either perform the maintenance themselves or use a contractor to complete the maintenance. In most cases, the property owner is fined in some way to cover the cost of the maintenance that has to be performed. This passes the financial burden of the additional maintenance activities from taxpayers to the property owner and helps to build future compliance.

5.2.2 Public Agency/Contractor Removal

In the cases where an agency performs winter maintenance pedestrian facilities (or uses a contractor to do so), this work can range from priority locations like downtown business areas, school zones, bus stops, etc., to the entire pedestrian system. Regardless of whether the agency or a contractor performs the work, the different approaches taken to removing snow from pedestrian areas and the extent they are completed can depend on various factors. For example, available budget, equipment and staffing are all considerations that determine whether there is a focus on specific points on the pedestrian system (e.g., curb ramps, downtown business district, etc.), or if work is completed across the entire system (e.g., all residential/business sidewalks, trails, etc.). The former approach tends to be the one employed in the United States, while the latter approach is more common internationally.

Systemwide maintenance comes with a cost, and from a review of literature and interviews with practitioners, this approach appears to be infrequent in the United States. Some agencies employ special levies or similar mechanisms to cover the cost of removal, such as in downtown districts. When this approach is employed, there is typically buy-in (or demand) from stakeholders (i.e., businesses) before it is pursued.

More typical is the clearance of specific locations or points on the pedestrian system, as this is less budget, equipment and staffing intensive. When this is done, there may or may not be a dedicated funding mechanism in place (i.e., downtown business association funding). In some cases, clearance of

specific locations consists of clearing sidewalks in front of city hall. Regardless of the form that site-specific clearance takes on, the locations themselves should be specified within an agency's snow removal policy or plan.

Equipment is another consideration that influences agency decisions on the extent that pedestrian features receive winter maintenance. Most agency winter maintenance equipment consists of a snowplow fleet, along with a few pieces of specialized machines, such as four-wheeled all-terrain vehicles, skid steers, Toolcat™ utility work machines, snow blowers, and the like. If available budget limits the agency fleet to snowplows, then expanding snow removal activities to pedestrian facilities will not likely happen, absent a new/dedicated funding stream. Similarly, staff constraints may limit agency winter maintenance to the roadway network, with staff additions possible only with an increase in funding.

To address equipment and/or staffing issues, some agencies may use a contractor to clear all or specific portions of the pedestrian system. This may be for dedicated maintenance activities, such as the clearance of specific locations (e.g., downtowns), hauling snow (e.g., dump truck operators), or addressing code violations (e.g., contracted to clear snow from sidewalks when residents do not do so when required by ordinance). The use of a contractor addresses equipment and staff limitations, as the agency is delegating the work to an outside entity, but funding is still required. This funding may come from fines (in the case of residential noncompliance), assessments, levies or other mechanisms.

Regardless of whether an agency, contractor, or combination of the two performs winter maintenance for pedestrian facilities, a snow policy or ordinance should be created/adopted. This can establish not only roles and responsibilities, but also priorities for maintenance activities completed on the pedestrian system. For example, the policy could establish that sidewalks, curb ramp areas and median refuge islands in downtown areas are cleared first, followed by bike trail crossings, and so on. Establishing prioritization can also help in determining staffing needs, as well as identify equipment that will be necessary to complete maintenance activities.

5.3 CHAPTER SUMMARY

The design of various pedestrian features should take winter maintenance operations into account to improve the maintainability of the feature and minimize damage to it. To this end, several general points have been emphasized throughout this chapter.

Designers should select materials and configurations that prevent or reduce snowplow damage. At the same time, features that account for these factors should also seek to ease maintainability and avoid the potential for snow and ice build-up. For example, the use of a wide radius on the minor corners of curb extensions, combined with the use of high strength concrete will help to reduce plow strikes and subsequent damage. Markers could also be utilized to delineate the location of features that may become hidden by snow. If the redesign/reconstruction of an existing feature is not an option, then the use of rubber curb guards on plow blades can help to reduce damage.

Decorative crosswalks should be designed with maintenance in mind using materials and construction techniques that will reduce damage from plowing. Traditional crosswalk pavement markings will still require annual repainting, unless durable materials (i.e., thermoplastics) are used and laid in milled-in grooves.

Fixed features, like bollards, should use chloride-resistant materials or coatings to prevent corrosion. If lighting features are incorporated in any feature or design, these should also be sealed to prevent corrosion.

The formation of ice from snowmelt around features like curb ramps is a drainage concern for pedestrian facilities. Drainage around these features can be improved by avoiding the use of bends in inlet pipes during retrofits or reconstruction activities. Similarly, planned maintenance to prevent inlet clogging, particularly removal of leaves during the autumn, can also reduce or prevent clogged inlets. Bridge plates across channels at locations like speed tables can allow pedestrians to cross while maintaining drainage flow. At intersections, a tighter corner radius reduces impervious surface area while maintaining satisfactory spacing between drain inlets and curb ramps.

Snow storage should be incorporated into designs whenever possible. In a pedestrian setting, this consists primarily of grass areas between the curbline and the sidewalk. A minimum width fr this tupe of feature would be 4-feet. Alternatively, if storage cannot be included in a design, then an agency should plan for snow removal and haulage to storage sites. If snow storage is incorporated into a design, its use should be communicated to maintenance staff and property owners.

Pedestrian refuge islands and similar features also should be designed to avoid ponding in curb ramp areas. These features should also avoid design aspects that lead to the accumulation of snow and ice, as these can lead to the need for additional maintenance efforts. Rounded corners should be used for curbing, while bullnoses should be used at the ends of medians, etc.

Snow removal responsibilities by property owners should be outlined through an ordinance, policy or regulation. This includes what the owner is responsible for, clearance expectations, and compliance timelines. Some communities provide materials (i.e., sand or salt) for use by property owners who clear curb ramps at locations like intersections. The provision of these materials can help with compliance in clearing these features. Regardless of location, noncompliance is addressed snow removal performed by agency or contractor staff, with the property owner assessed a fine to cover costs.

Budget, equipment and staffing all play a role in determining the extent of the pedestrian system that an agency or their contractor can perform winter maintenance on. Systemwide clearance in the U.S. is not common, as it requires a substantial funding mechanism to be in place. Many agencies do perform at least some winter maintenance on pedestrian facilities, albeit at specific locations, such as in front of government offices. Regardless of the approach taken, a snow policy or ordinance should be followed to prioritize agency activities.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Pedestrian safety treatments can present a challenge to winter maintenance operations and general maintenance during the remainder of the year based on their designs and characteristics. While these countermeasures help to reduce vehicle-pedestrian conflicts and crashes, their impacts on winter maintenance operations can be overlooked during the selection and design process. Furthermore, snow and ice themselves are major impediments to winter pedestrian travel, so their effective removal is essential to encouraging and facilitating pedestrian activity.

The research in this report was conducted to identify the design characteristics of different pedestrian safety countermeasures that could make them easier to maintain in winter months as well as year-round. The present absence of such a summary represents a knowledge gap that may hinder the selection and construction of pedestrian safety treatments. To address this gap, this project collected and evaluated information on the design characteristics of pedestrian safety countermeasures with respect to maintainability in winter months as well as throughout the year. This information was collected from literature as well as through direct interviews with local agencies within Minnesota and in other states and Canada. With a better understanding of the tradeoffs and impacts of various features and their elements, agencies should be in a better position to select and appropriately design pedestrian treatments with maintenance in mind.

The information collected during the various project tasks is used to develop various conclusions and recommendations presented in this chapter. The intent of this information is to provide entities with items to consider when selecting and designing pedestrian safety treatments. The chapter concludes with a summary of the trade-offs between the safety benefits of pedestrian treatments and their respective maintenance and general costs.

6.1 CONCLUSIONS

A primary conclusion of this research is that there is an absence of specific documentation, discussion, or common policies for best design practices, guidance, and solutions for pedestrian safety countermeasures with year-round maintenance in mind. Winter maintenance practices for pedestrian treatments tend to vary by jurisdiction, although these practices are frequently recognized as aspects that should be kept in mind during the selection of a feature. Beyond this recognition, though, there is little specific information that provides design guidance to facilitate maintenance itself.

Typically, agency policies and plans largely concentrate on sidewalks and who will conduct winter maintenance (i.e., property owners vs. governments) and the timeline in which it should be completed as opposed to discussing designs that can assist in encouraging or facilitating that maintenance. In most Minnesota communities, clearing pedestrian features such as curb ramps and sidewalks of snow and ice is typically the responsibility of adjacent property owners. Features like bulb-outs and curb extensions are part of the sidewalk system and clearing of such features presumably falls to property owners. This does not account for other dedicated pedestrian infrastructure, like median refuge islands, and the

clearance of these features may be overlooked and not performed by anyone. In other cases, such as speed tables, the feature falls within the travelled way and is cleared by the owner-agency.

In communities that delegate sidewalk snow removal to property owners, there are often ambiguities about who is responsible for clearing median refuges, porkchop islands, bridges, and other walkways that are not clearly associated with a specific abutting owner. This can lead to snow accumulation and ice pack that impact pedestrian mobility and become difficult to remove.

When an agency does perform snow and ice removal on pedestrian facilities, the approach taken is often a phased one, where certain portions of the sidewalk system are cleared before moving on to other specific facilities like bicycle trails and multi-use paths. Pedestrian facilities are cleared by the municipality or its contractor(s), and these operations are heavily mechanized. This approach gives public agencies a high degree of control over the quality and timing of sidewalk snow removal and the opportunity to specify the type and quantity of deicer applied to sidewalks. However, agency snow removal comes with costs, including labor and equipment, which must be budgeted and funded accordingly.

The agencies interviewed throughout the course of the project indicated that snow storage is an issue with pedestrian-related infrastructure (as well as roadways themselves in some cases). Typically, there is a need to haul snow away to disposal sites following most storms because of the lack of storage capacity on the roadside in pedestrian areas.

The design dimensions and features of pedestrian curb ramps are established by ADA requirements. Detectable surfaces that are made from a nonslip material need to be incorporated to warn vision-impaired pedestrians that they are entering the motorized traffic area. Winter maintenance operations and responsibilities for curb ramps vary by locale, but in the majority of cases identified and in the interviews conducted during this project, these responsibilities are assigned to adjacent property owners. Property owners typically shovel over the tops of the truncated domes, leaving a smooth (non-detectable) snowpack approximately 0.5-inches thick, which sometimes remains in place long after a storm. This may result in an unsafe walking surface for pedestrians.

For crosswalks, whether comprised of paint or decorative materials, the primary maintenance concern is durability. The winter maintenance impacts on crosswalks include salt/sand and snowplow abrasion that wear pavement markings out at a faster rate and may also damage more permanent, decorative installations. More durable materials are available for crosswalk markings to add durability and include tapes and thermoplastics, but these materials are more costly than traditional paints. Additionally, durable materials and paints can be grooved into the pavement, with the recess providing some protection from snowplow abrasion. Alternative marking patterns can be employed to enhance driver detectability of the crosswalk from a distance, but these will require the use of additional marking materials. All crosswalk markings should be retroreflective for nighttime visibility. Inspection of markings during the day and at night should be performed to determine condition and retroreflective properties.

The use of bulb-outs/curb extensions or channelized right-turn lanes are closely related to the selection of appropriate corner radii during design. This results in trade-offs between vehicle speed/pedestrian safety considerations and the potential for curb and terrace damage due to over tracking of buses and heavy trucks. Agencies that were interviewed expressed that bulb-outs/curb extensions are good for creating parking areas, but they can also be difficult for snow removal and street sweeping operations. This is especially the case when combined with the presence of other support infrastructure, such as light poles, signal bases, bike racks, decorative fences, etc. The use of such features should be incorporated in such a way that these elements do not hinder snow removal operations or other maintenance in general. Drainage around these features is also a concern, as the nonlinear curbline can affect flow and must be designed appropriately. Different communities mentioned damage to various areas of concrete, but most specifically, curbing. This damage comes primarily from snow removal equipment (i.e., plow blade strikes and scrapes). Communities that have specified high-strength concrete in the construction of pedestrian-related infrastructure have found that it has held up well and experienced less damage.

Tighter radii at intersections presents maintenance tradeoffs, including the need to facilitate sweeping in summer months, as well as maneuverability during snowplowing operations. The tighter radii combined with blended curb ramp transitions can also make it difficult for plow operators to distinguish the roadway from sidewalk and curb ramp when plowing. Conversely, wide radii often increase the total sidewalk area and reduce the available snow storage space. The presence of right-turn channelization, combined with a “pork chop” island can also produce challenges. The island can serve as a pedestrian refuge, but from a winter maintenance perspective, it has limited snow storage capacity and represents another feature that must be cleared for pedestrian accessibility.

Pedestrian refuge islands support pedestrian safety by allowing two-stage crossings of multilane roadways; their use makes it easier to maintain two-way progression along signalized arterials, which can decrease motorist and pedestrian delays. The winter maintenance of this particular feature is often overlooked, which is concerning from a pedestrian safety perspective for a pair of reasons. First, there is a need to clear the pedestrian pathway through the median itself, and this is something that would typically fall to agency forces as the feature is within the right-of-way. Second, the location of islands makes them susceptible to snow buildup as snowplows pass by, once again, underscoring the need for an agency to clear the pedestrian path. Both concerns need to be recognized and addressed by agencies that choose to adopt this particular pedestrian safety countermeasure.

Speed humps and tables can serve as a pedestrian crossing feature, and the designs of these are largely uniform. The primary maintenance issue identified is the accommodation of drainage through the feature along the curbline. Additionally, problems with winter maintenance vehicle access at these features has been observed, and snow storage can also be more difficult. While maintenance vehicle access can be difficult, speed humps and tables generally are not significant challenges to plowing operations themselves. Rather, the challenge presented by these features is in terms of total roadway width, which sometimes is narrowed in the vicinity of the speed hump or table itself.

6.2 RECOMMENDATIONS

At a high level, it is recommended that designers discuss their plans for pedestrian safety features with maintenance personnel early in the design process. Some current design guides appear to reflect maintenance experience, such as the *Minnesota Facility Design Guide*, which specifies the use of tapered upstream and downstream approaches to curb extensions to facilitate snow removal and street sweeping. Similarly, curb ramp design guidance from Colorado mentions "drainage" and "flow line" frequently, perhaps in response to past problems with ponding and refreeze at the bottoms of curb ramps. Working with maintenance forces during the design process to modify designs to meet their concerns can prevent future damage to pedestrian features while also allowing winter maintenance activities to be performed efficiently.

While right-of-way constraints often impact storage capacity, where such constraints do not exist, dedicated storage locations (e.g., grass medians between curb and sidewalk) should be incorporated into pedestrian-related designs when possible. Aside from providing storage, these features can reduce the amount of snow plowed from the roadway from reaching the sidewalk. A recommended minimum width for this feature is 4 feet, although this will depend on available right-of-way. Where storage capacity does not exist, highway agencies will need to develop snow removal and haulage plans to assist in keeping pedestrian areas free of snow build-up, if such plans are not already in place.

Curb ramp designs must continue to follow ADA requirements to ensure compliance and support accessibility for all users. Curb ramp designs per that guidance specify a slope of greater than 1:12 and a maximum cross slope of 1:50. Curb ramp transitions should always use gradual transitions whenever possible. The gradual transition appears to reduce damage from snow removal activities. The use of durable panel materials for detectable warnings, such as cast-iron dome panels, should be considered by agencies, particularly when mechanized snow removal is employed. Experience has shown that steel and cast-iron truncated domes are preferable to plastic domes, but they must be properly installed to remain undamaged over time. Drainage around these features can be improved by avoiding the use of bends in inlet pipes during retrofits or reconstruction activities. Agencies should also perform periodic sweeping operations outside of winter months to remove debris build-up, which could otherwise block drainage and present stability concerns for some users.

More durable materials are available that can be used for crosswalk pavement markings. These include tapes and thermoplastics, although these materials are more costly than traditional paints. Durable materials and paints can be grooved into the pavement, with the recess providing some protection from snowplow abrasion and extending marking life. Alternative marking patterns can be employed to enhance driver detectability of the crosswalk from a distance, but these will require the use of additional material at added cost. All crosswalk markings should be retroreflective for nighttime visibility and inspected during the day and at night to determine condition and retroreflective properties. If agencies continue to use waterborne paints directly on the pavement surface, they should budget accordingly to renew those markings on an annual basis.

When selected as a pedestrian treatment, bulb-outs/curb extensions should be used on lower-speed roadways (35 mph or lower). A 1:2 or 1:3 upstream taper and a 1:3 downstream taper is preferred for curb extensions. Within this range, a gradual taper between 45 and 60 degrees is found to work well by one city interviewed during this project. Shallower tapers allow for maintenance equipment to maneuver past the feature, with less difficulty while reducing potential damage from plow strikes during winter maintenance. The S-style curb design (drive-over/roll curb) is more forgiving to plowing activities compared to the B-style curb and should also be considered in future designs. The use of high-strength concrete is also recommended to address durability concerns. Repairs to damaged curbs should be scheduled annually to prevent further deterioration. Designs that account for these factors should result in easier maintainability and reduced potential for snow and ice build-up. For example, the use of a wide radius on the minor corners of curb extensions, combined with the use of high strength concrete will help reduce plow strikes and subsequent damage.

When designing for pedestrians at intersections using tight corner radii and/or channelized right-turn lanes, radii of 15 feet or less should be employed. This provides more space for ADA-compliant curb ramps and allows curb ramps to be better aligned with adjacent pedestrian sidewalks or paths. Tight corner radii should be employed only when low heavy vehicle traffic volumes are present or features such as upstream parking lanes allow trucks and buses to make a wide turn. Wider radii corners should only be considered for routes with heavy freight traffic (i.e., heavy trucks) that do not have large volumes of crossing pedestrian traffic.

Median refuge island design parameters can vary greatly, ranging from 6 feet or greater in width, 24 feet to 40 feet in length (including the pedestrian path across the island), and include 3-foot to 5-foot bullnose tapers at either end. Pedestrian passages through median islands less than 48 inches wide can be problematic and should not be designed or used. These and similar features also should be designed to avoid ponding in curb ramp areas.

The design of speed humps and tables found in this project was largely uniform across agencies and throughout literature. The height of these features is 3-4 inches, with lengths of 12-14 feet for humps (concave in shape) and up to 22 feet for tables. The recommendation for this project is that these dimensions be employed by Minnesota agencies, and if already employed, that their use continue. Drainage can be accommodated through proper inlet placement, or the use of a channel crossed by bridge plates incorporated through the feature at the curbline. Note that these features do not appear to be used on high-speed and/or high-traffic volume roadways such as state highways in northern states.

Aside from the specifics related to the features covered above, visual appeal, standardization, and maintainability need to be considered during design. Decorative features such as fencing, bike racks, etc., are useful, but these can sometimes be easily damaged, particularly during snowplowing. These features can also be expensive to repair, and their use should be carefully considered in light of benefits versus costs. Fixed features, like bollards, should use chloride-resistant materials or coatings to prevent

corrosion. If lighting features are incorporated in any feature or design, these should also be sealed to prevent corrosion.

At intersections, snow removal must be performed for pads to pedestrian push buttons (at signals). When designing push button access, the location of the button should consider snow removal needs. The location of utility boxes should also be considered during design to minimize interference with snow removal. Agencies should monitor all these features to ensure they do not become buried in snow piles, regardless of who is responsible for snow removal.

The intensity of staff resources required for maintenance, both winter and year-round, should be considered when selecting pedestrian safety features. This can be as basic as the need to manually sweep debris from inaccessible areas to the need to repair damage. While often overlooked, training for operators (both newly hired and before the winter season) on snow removal techniques on and around pedestrian features should be considered. Assigning operators to set routes also helps with familiarization (i.e., drivers know where features are and avoid striking them with plow blades).

The use of markers to delineate the ends of features, like bulb-outs or refuge islands, can also be pursued to reduce plow strikes and damage. The use of rubber curb guards on plow blades is another approach that can reduce damage.

Whether an agency performs winter maintenance on a portion of or the entire pedestrian network, a hierarchy of removal priorities should be established. This will make it clear to staff, as well as the general public, what facilities will be cleared in what order. Agencies can use tools like Geographic Information Systems to inventory and prioritize winter maintenance for pedestrian facilities that may be overlooked, such as bridge walkways or median refuge islands.

The equipment selected by an agency to perform winter maintenance for pedestrian facilities should be appropriate to the features being cleared, while also recognizing that some equipment will be down for repairs. This means that additional equipment may need to be purchased, adding to costs. That equipment also tends to have a shorter lifespan, and this should be budgeted for accordingly.

Snow removal responsibilities by property owners should be outlined through an ordinance, policy or regulation. If snow removal is delegated to property owners, there may be a need to ensure compliance with any applicable ordinances or policies. Enforcement should be conducted in a timely manner, and property owners assessed fines or fees to cover any cost incurred by an agency in ensuring compliance.

6.3 TRADE-OFFS BETWEEN SAFETY AND MAINTAINABILITY

Regardless of the overall design characteristics, maintenance requirements, and responsibilities for snow and ice removal for pedestrian safety features, agencies will still need to consider the trade-offs that can arise between keeping pedestrians safe using those features and their impact on maintenance. To assist agencies and decision-makers in selecting appropriate pedestrian safety countermeasures, Table 6.1 has been created. This table summarizes the tradeoffs between keeping pedestrians safe while

maintaining the infrastructure itself. It is based on information identified during the literature review and in the various interviews conducted with maintenance practitioners.

Table 6.1 Benefits and costs of pedestrian safety treatments

Feature	Safety Benefit	Winter Maintenance Costs	General Costs
Curb Ramps	• Accessibility for people with disabilities • Gradual transition for all pedestrians • Visual/tactile cue for crossing area	• Responsibility for clearing (agency, property owner) • Plowed snow, ice, snowmelt accumulation	• Require sweeping to remove grit/debris • Difficult to design at curbline to prevent water accumulation • Durable truncated domes can be expensive
Pavement Markings	• Delineate crossing for pedestrians • Alternative/enhanced patterns more visible to drivers	• Markings prone to wear from plowing	• Cost for durable/decorative materials or groove insets • Cost to annually repaint waterborne
Tighten Intersection Corner Radii	• Reduces distance for pedestrians to cross • Pedestrians cross at near-right angle to cross traffic, allowing better view of approaching vehicles • Easier to obtain 1:12 curb ramp slope	• Corner may be difficult to navigate with plows • Plowed snow accumulation may remain in curb ramps	• Difficult to navigate for large vehicles (semis)
Curb Extensions	• Provides pedestrians with better view of approaching traffic and drivers of pedestrians • Shortens crossing distance for pedestrians	• Difficult to maneuver plows around • May impact snow storage capacity on roadside	• May require specific street-sweeping equipment to "reach" into corners • If street sweepers not used, may require manual clearing
Refuge Islands	• Provides pedestrians with safe stopping point when crossing busy traffic streams • Provides pedestrians with view of approaching traffic	• Pedestrian path through island will need to be cleared • Difficult for some operators to identify when plowing if not marked • Likely to require specialized snow removal equipment	• Pedestrian path may require periodic sweeping, maintenance of curb ramps • May need to repair curb damage from plow strikes

Speed Humps/ Raised Crosswalks	• Slow traffic approaching and within pedestrian crossing area • Raised crosswalk provides delineated pedestrian crossing	• May require plows to slow through area • Some plows may damage raised features	• Need to address curb drainage through the raised feature • May impact street sweeping operations • Should install advance warning signage for features • Not necessarily applicable on high speed/high volume roadways like state highways

As the table illustrates, the safety benefits of different pedestrian treatments can vary based on the particular design. In some cases, the benefits are reduced crossing distances, while in others, pedestrians are afforded a better view of approaching traffic with which crossing decisions can be made. For other treatments, pedestrian safety is enhanced by clearly delineating the area where a pedestrian should be crossing, both for pedestrians and approaching drivers.

On the cost side, impacts to agencies have been separated into two categories: those specific to winter maintenance, and those which more generally occur throughout the year. Winter maintenance costs and challenges center around the ability of certain equipment to operate around the pedestrian infrastructure when clearing snow and responsibilities for clearance (i.e., property owner versus maintenance forces). Aside from this, there are also the costs presented by plow damage (chipped concrete, worn pavement markings) and drainage of snowmelt (particularly at curb ramps). General maintenance costs include addressing physical damage (concrete repairs, pavement marking repainting), drainage (curb ramps, speed humps/tables), general design (curb ramp compliance), and debris clearance (street sweeping and manual cleaning as needed). While none of the winter or general maintenance costs for the pedestrian features of interest present significant obstacles to implementation, they do represent items for consideration when planning and designing future installations or retrofits. Advanced planning and an understanding of the costs of a feature can help to potentially address issues through alternative designs, equipment purchases, or budgeting prior to construction.

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APPENDIX A GENERAL DESIGN AND MAINTENANCE FINDINGS

Treatment	Design Guidance	General Maintenance Considerations	Winter Maintenance Considerations
Curb Ramps	• 1:12 slope max • 1:50 cross slope max • 3-4 foot width • Use min. slope as possible • Incorporate texture for detection • No grates or inlets in ramp area	• Maint. needed to address displacement, deterioration, grade and cross slope • Debris accumulated within detection surfaces needs removal • Detection panels can lose adhesion (when glued versus pressed), deteriorated color	• Brushed concrete and grooves accumulate snow/ice • Domes of some materials (rubber, concrete, etc.) can shear with snow removal • Puddles, ice and snow can accumulate at bottom of ramp
Pedestrian Pavement Markings	• 6 - 24+ inch widths • Basic material - paint • Durable materials - thermoplastic, epoxy, tapes	• Markings should be retroreflective • Markings should be nonslip • Inspect annual, repaint/reinstall when needed • Use different patterns to enhance visibility • Space enhanced markings to avoid wheelpaths • Include parallel lines on edges of alternative materials (pavers, etc.)	• Remove snow from all lanes to uncover crosswalk • Snowbanks in crosswalk area can affect sight distances for drivers and pedestrians • Salt, sand and plowing abrasiveness wear markings
Intersection Radii	• Employ radii less than 15 feet for urban ints. • Larger radii may be considered on freight corridors	• Consider need to facilitate street sweeping tight radii • Wide radii a challenge in achieving drainage slopes, consider slot drains	• Large radii increase plowing area • Small radii harder to maneuver when plowing • Blended transitions difficult to distinguish when plowing

Curb Extensions and Lane Narrowing	• Use on streets 35 mph or less • 1:2 to 1:3 horizontal taper preferred on upstream • 1:3 preferred downstream	• Can affect drainage and street sweeping	• Feature not popular with plow drivers
Median Refuge Island	• 6-10 feet wide • 24-40 feet long • 3-5 foot nose • Include detectable surface at edges • Not for high speed roadways	• Ped. pathway sweeping • Consider stop/yield lines, warning signs	• Consider width of maintenance equipment used for snow removal
Speed Humps, Tables, and Raised Crosswalks	• Speed humps - 3-4 inches high, 8-22 feet long • Speed tables - 3-4 inches high, 22 feet long, 6 foot ramps, 10 foot top	• Drainage needs to be accommodated at curbline	• Adjust plowing operations with modified equipment, procedures • Snow storage can be difficult • Monitor crosswalk pavement markings for plow damage

APPENDIX B PEDESTRIAN FACILITIES OPERATION & MAINTENANCE QUESTIONNAIRE

Agency	**Interviewed By**	**Interview Date**
X	X	X
Respondent Name and Job Title	**Respondent Phone and Email**	
X	X	

1. Which types of pedestrian accommodations are currently in use in your community?

Frequently-used items (read list during interview)

- ☐ Curb ramps
- ☐ Curb extensions (bulb-outs, bulb-outs, chokers, or pinchpoints)
- ☐ Tight corner radii
- ☐ Speed humps – flat top
- ☐ Speed humps – parabolic
- ☐ Speed humps – don't know which type
- ☐ Mini-roundabouts (neighborhood traffic circles)
- ☐ Pedestrian refuge islands on divided cross-sections
- ☐ Pedestrian signals / RRFBs/ PHBs
- ☐ Raised crosswalks on mid-block pedestrian crossings
- ☐ Raised intersections/speed tables with crosswalks

Less frequently-used items (mark if mentioned by respondent)

- ☐ Blended transitions at street corners
- ☐ Bollards
- ☐ Bus bulbs
- ☐ Chicanes
- ☐ Gateways
- ☐ Parklets
- ☐ Pedestrianized alleys
- ☐ Pedestrianized streets
- ☐ Planter boxes

  Where? X
- ☐ Residential shared streets (woonerfs)
- ☐ Special landscaping
- ☐ Speed cushions
- ☐ Speed tables without crosswalks

Other

X

2. In general, how old are the features and are they under local jurisdiction or on trunk highways?

3. Which features, if any, have been difficult for snow removal and other winter maintenance? X
4. Which features, if any, have been difficult for street sweeping and other summer/year-round maintenance? X
5. Have you made changes in summer or winter maintenance operations or the sequencing of operations to address the issues encountered? X
6. Which features, if any, have been prone to weathering, chipping, spalling, or other gradual deterioration? X
7. Which features, if any, have been prone to unintentional damage? X
8. Which features, if any, have been prone to vandalism or misuse? X
9. Have there been other operational or safety problems? X

10. Do you think the troublesome features could be improved through changes in design standards? If so, how? X
11. What would you do differently if you were starting again? X
12. What else do practitioners and designers need to know? X

Other items to discuss when applicable:

Winter Maintenance order of operations (Mainline then cross streets, corners, sidewalks? Timeline for completion?)

During and after an event, plows will repeatedly plow a route. Do they do the same for sidewalks & corners.

Do they ever hear of complaints from pedestrians regarding S&I?

Question about pavement markings: Policy or practice on refreshing