Technical Requirements and Considerations for Automated Snowplow Route Optimization

Decision Support Guide

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CR 19-04: Technical Requirements and Considerations for Automated Snowplow Route Optimization

DECISION SUPPORT GUIDANCE

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Introduction

Planning for snow and ice control (SIC) activities on the roadways before, during, and after winter weather events involves complicated decisions about staging and routing of the winter maintenance vehicles that are responsible for plowing and spreading chemicals and abrasives. DOTs and other transportation agencies are increasingly exploring automated methods for snowplow route optimization as a means for increasing the efficiency of these operations. Route optimization projects have been demonstrated to produce significant savings for transportation agencies when they result in the implementation of new routes.

However, many DOT snowplow route optimization projects have fallen short of implementation. Interviews with DOT staff identified two types of challenges that prevent winter maintenance optimization results from being implemented. These challenges are:

1. Technical/operational issues with the final routes that make them unsafe or infeasible to implement.
2. Institutional barriers to change that prevent routes that are technically feasible from replacing existing routes.

These challenges can be substantially mitigated with improvements to the process of soliciting and selecting a contractor or platform to perform the optimization.

This Guidance Document is intended to provide DOT staff with a clear understanding of the technical requirements that must be met to conduct a route optimization project that produces feasible routes. In addition, it highlights several issues which can result in institutional resistance to route implementation so that DOTs undertaking route optimization projects can be proactive in addressing these concerns. The body of the Guidance Document includes six sections covering the following key topics:

1. **Optimization Purpose:** Is the *primary* purpose of the project to reduce costs or to reduce service time?
2. **Optimization Scope:** What components of winter maintenance operations (e.g., facility locations, service territory boundaries, fleet allocation) can realistically be changed to improve performance, and what components should be considered fixed? Should multiple routing scenarios be considered? Should route optimization be conducted for a pilot region or the entire state?
3. **Data Needs and Sources:** What information is required to conduct a route optimization and where can it be obtained?
4. **SIC Operational Practices:** What winter maintenance practices (vehicle operating speeds, material spreading rates, etc.) need to be included in the route optimization?
5. **Route Review Process:** How are the routes produced by the optimization software reviewed to ensure they are safe and feasible?
6. **Other Key Considerations:** What are the indications that a route optimization project will improve on existing routes and that the results will be successfully implemented? Should the optimization be conducted in-house or by a consultant?

Optimization Purpose

Importance: Essential

Routes can be optimized in different ways to achieve different goals. Establishing the purpose of a route optimization project is essential to its success. Generally, optimizations are either structured to A) minimize operating costs while remaining within the maximum cycle time thresholds set by the DOT ("cost minimization"), or to B) minimize the time required to service all road segments using all existing winter maintenance vehicles ("service time minimization"). These two optimization purposes typically produce different route systems.

Figures 1 and 2 illustrate how the routing solutions produced by A) cost minimization and B) service time minimization differ for two hypothetical road networks. In each case, the road network is maintained by a single garage with two available winter maintenance vehicles (one blue and one red). In the cost minimization scenario for Figure 1, a single vehicle can provide winter maintenance within the maximum cycle time threshold. As a result, only one of the winter maintenance vehicles is utilized, eliminating all deadheading and route overlap, and resulting in the lowest possible vehicle operating time and miles of travel. The second vehicle can potentially be eliminated from the winter maintenance fleet. In the service time minimization scenario for Figure 1, both vehicles are routed. This creates some deadheading as the blue vehicle travels to and from the road segment that it is servicing but also results in the fastest possible winter maintenance for all road segments.

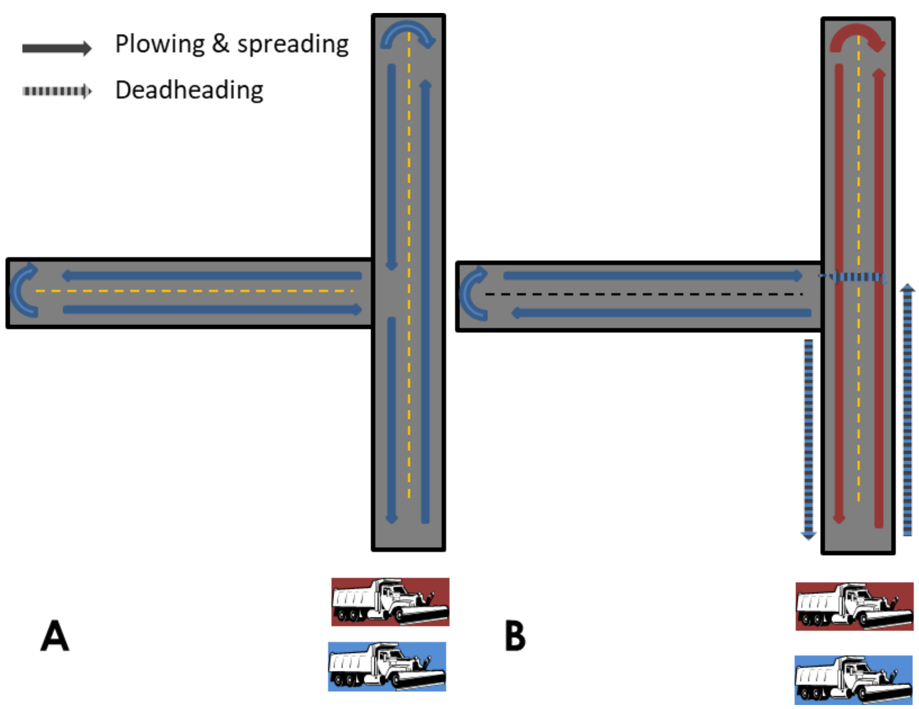

Figure 1. Routes optimized for A) cost minimization (all roads serviced by a single continuous route to minimize miles of travel), and B) service time minimization (all available vehicles are used to get all roads serviced as quickly as possible).

In Figure 2, the road network cannot be traversed by a single winter maintenance vehicle within the cycle time threshold so both vehicles are routed for the cost and service time minimizing optimizations. Once again, the cost-minimizing scenario eliminates all route overlap to minimize the total miles traveled by the winter maintenance vehicles. In contrast, the service time minimization scenario increases vehicle miles traveled in order to more quickly provide winter maintenance service to all road segments.

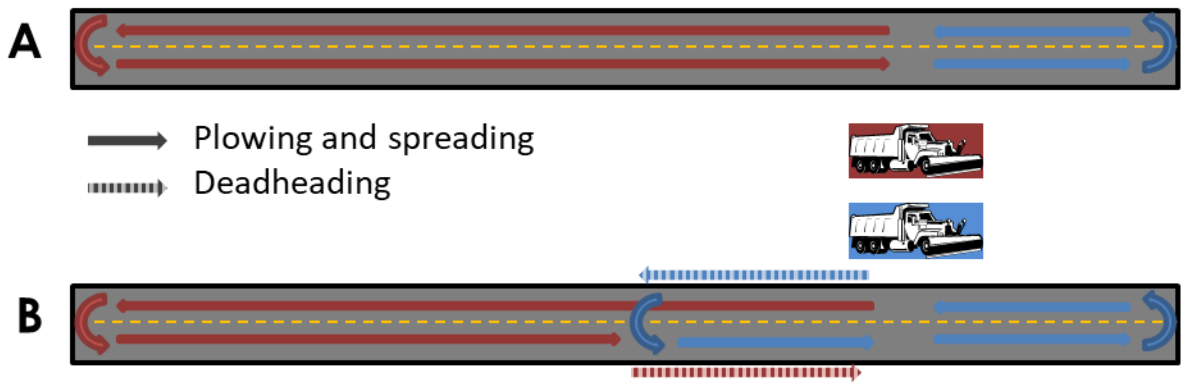

Figure 2. Routes optimized for A) cost minimization (non-overlapping vehicle routes minimize miles of travel), and B) service time minimization (roads serviced as quickly as possible with overlapping routes that are closer to equal in length).

Ultimately, each agency will need to determine which optimization purpose supports their overall route optimization goals, as these approaches make opposite trade-offs between cost and time savings. Cost minimization has the *potential for the largest cost savings,* but also the greatest potential to generate *internal or external pushback* against the proposed routes since they frequently result in a reduction in the number of routes/vehicles providing winter maintenance. Service time minimization has the greatest potential to *increase winter maintenance performance* but may not provide cost savings in comparison to existing routes.

In some cases, a DOT might be interested in a hybrid optimization approach utilizing different optimization purposes for different parts of the state. For example, a DOT might want to minimize service time in parts of the state with higher traffic volumes or elevated safety concerns and minimize costs in less-traveled areas.

When considering an optimization approach, the following questions should be answered:

- **How will stakeholders react if the optimized routes increase the service time for some roadways?**

  Optimization can produce routes that meet a DOT's stated winter maintenance policies but that nonetheless result in slower winter maintenance service relative to existing routes on some roadways. Using the example in Figure 1, if a DOT transitioned from the two winter maintenance routes in scenario B to the single winter maintenance route in scenario A, the new route system would not cover all road segments as quickly as it had when servicing the road network with two winter maintenance vehicles. This has the potential to generate public pushback, even when the new routes are consistent with DOT policy. The DOT may want to consider how to communicate these types of changes to the public (potentially emphasizing cost savings) when undertaking these projects. This occurrence is most common for cost minimization since route consolidation is a significant source of cost savings but can also occur for some road segments for service time minimization.

- **To what extent does the operating speed of your Agency's winter maintenance vehicles vary with storm severity?**

  The time that is required to complete a route is determined by the speed that winter maintenance vehicles travel while deadheading, plowing only, or plowing and spreading materials, each of which can vary with storm intensity. If optimized routes are produced using vehicle speeds from an average storm, it may not be possible to complete the routes within the cycle time thresholds during a more severe storm. To avoid routes that are too long to be completed on time in severe weather, DOTs may want to consider conducting multiple routing scenarios or using the lowest expected vehicle speeds for the optimization.

- **If considering cost minimization, does your Agency have *agreed-upon* cycle time thresholds for winter maintenance?**

  DOTs interested in this cost minimization must have specific cycle time thresholds in their winter maintenance plans. The cycle time thresholds can vary by road classification or other prioritization schemes but must be available for all road segments. DOTs that use other criteria for winter maintenance performance, such as returning to bare pavement within a specific time period after the end of a storm, will need to determine what cycle time thresholds are suitable for achieving these criteria before using this optimization method. Generally speaking, route lengths created using this method will be relatively close to the maximum allowable cycle time, as routes that are significantly shorter than this threshold are candidates for route consolidation (which reduces miles of travel), so there should be broad agreement that hitting the cycle time thresholds is an appropriate standard for determining the suitability of winter maintenance routes. Lack of consensus/support for the cycle time thresholds used in the optimization can undermine support for implementing new routes once the optimization is complete.

- **If considering cost minimization, how will your Agency manage pushback from internal stakeholders about potential reductions in the number of staff and vehicles available for winter maintenance resulting from route consolidation?**

  Winter maintenance is a demanding job and maintenance staff at the operational level may be reluctant to embrace optimized routes that reduce the resources that they have available to conduct winter maintenance activities within their district. Engaging with staff early in the project process may be important to set and manage expectations.

## Optimization Scope	Importance: Essential

Route optimization projects can be narrow in scope, producing new routes for a single jurisdiction using existing facility locations and a fixed number of vehicles, or very wide-ranging, incorporating multiple jurisdictions, considering new facility locations and changes to the winter maintenance vehicle fleet. Optimization projects with broader scopes have the potential to address a wider range of inefficiencies and, therefore, to produce larger cost savings and service time improvements. However, broader projects are likely to be costlier to conduct and to require more extensive changes to existing winter maintenance operations, potentially raising significant implementation barriers. Selecting the appropriate scope for an optimization project is a matter of balancing the potential for greater cost savings that can be achieved by a broader scope against the greater likelihood of implementation that comes from a narrower scope.

When determining the project scope, DOTs must consider which structural components of winter maintenance operations (facility locations, service territory boundaries, and fleet allocation) to include in the project. Facility locations, service territory boundaries, and fleet allocations can be revised as part of the route optimization project or excluded from the scope and held fixed, while only the routes themselves are optimized. Generally speaking, if it is not feasible to make changes to a particular component of winter maintenance operations in practice then that component should be excluded from the optimization process. Optimizing, for example, DOT garage locations without funding dedicated to relocating these facilities will result in routes that are incompatible with real-world conditions. Conducting alternative scenarios to explore the impact of optimizing winter maintenance components that cannot immediately be changed can be valuable for planning purposes but will not result in routes that are implementation-ready.

This section describes the potential benefits and drawbacks of including each of these structural components of winter maintenance operations in the optimization, as well as of using multiple routing scenarios to explore alternative configurations and varying weather conditions. Finally, it discusses whether the geographic extent of the route optimization project should be limited to a pilot region or extend statewide. These project elements help to set the breadth of the project scope.

Facility Locations

The locations of winter maintenance facilities (garages and salt sheds) are one determinant of optimal routes for winter maintenance activities. Facilities that are relatively evenly distributed across the road network tend to promote more equal route lengths and reduce deadheading. Garage locations and salt sheds can be revised as part of the optimization process potentially resulting in recommended new locations for these facilities that improve service territory partitioning and routing efficiency. Potential facility locations can be limited to pre-identified sites provided by the DOT as practical for construction or "blue sky" locations can be selected without pre-screening. The latter approach can identify locations that are superior with respect to routing efficiency but add complexity and cost to the project and may be less likely to be constructed than facilities at pre-identified locations. As a result, the "blue sky" approach is not recommended for projects designed to produce implementation-ready routes. It should be noted that changing garage locations can be costly and time-consuming. If moving a garage is not a realistic, near-term possibility, creating routes that are based on flexible garage locations will more than likely result in routes that cannot be implemented. DOTs interested in simultaneously optimizing garage locations and winter maintenance routes may want to consider conducting multiple optimization scenarios, one with facility locations included in the optimization and one using fixed facility locations. This approach would allow the DOT to assess the potential cost savings that could be achieved by changing garage locations while also ensuring that the project produced routes that could be implemented with the current facilities. Since new salt sheds require less of an investment than new garages, it may be more feasible to optimize salt shed locations than garage locations although the benefit is likely to be smaller as well.

Service Territory Boundaries

Winter maintenance routes often terminate at service territory boundaries that may not have been created with the optimization purpose in mind. Often these service territory boundaries are administrative or political, like town or county boundaries. Adjusting service territory boundaries to further the route optimization provides additional flexibility to improve the efficiency of the routes and/or create more equal route lengths between jurisdictions. Because optimizing service territory boundaries does not require significant changes to infrastructure, including these boundaries in the optimization is generally desirable when there is buy-in among the jurisdictions. Minor adjustments to turnaround points on rural roads may be necessary to adjust service territory boundaries, and these new boundaries may require an initial period of adjustment for winter maintenance vehicle drivers. However, the benefits of optimized service-territory boundaries typically outweigh the costs of this adjustment period.

Fleet Allocation

In some cases, the allocation of winter maintenance vehicles between garages or districts is not compatible with the optimization purpose and the most efficient routing schemes require leaving some winter maintenance vehicles idle or reallocating vehicles between service territories.

Altering the allocation of vehicles between service territories can result in resistance from service territories that are losing vehicles and among drivers whose vehicles are being moved.

Number of Optimization Scenarios

DOTs undertaking route optimizations must also decide how many routing scenarios to model within the optimization project. Conducting multiple routing scenarios can be used to understand the impact of different weather conditions and winter maintenance strategies on the optimal routing as well as to explore the impact of optimizing facility locations, service territory boundaries, and fleet allocations. Since there is significant overlap in the setup required to optimize different scenarios, there are economies of scale associated with running multiple scenarios. While increasing the number of optimization scenarios should be expected to increase the total project cost it should also lower the cost per scenario.

Alternative routing scenarios can create routes that are optimized specifically for plowing, for varying weather conditions, for the application of different material types, or for differing equipment configurations, among other factors. Winter maintenance vehicles can generally travel longer distances before returning to a maintenance facility when plowing without applying materials since material capacity is often a limiting factor in route length. Material spreading rates and vehicle speeds can also vary with winter weather conditions, meaning that the routes produced by the optimization will vary depending on the assumed weather conditions. Conducting scenarios that explore the impact of shifting operational practices will result in routes that may not be implementation-ready but that can be valuable for strategic planning purposes and can help make the case for longer-term changes to the strategic winter maintenance plan. This might include optimizing winter maintenance facility locations or creating routes for the application of different material types since material capacity and spread rates vary depending on the material that is being applied (e.g. with liquids versus solids). Conducting multiple routing scenarios may result in the DOT using different routes in response to different weather conditions or the DOT selecting a single set of routes for general use from among the different scenarios.

One potential drawback to conducting a large number of scenarios is that the process of reviewing routes produced by optimization software to ensure they are safe and do not require alterations (discussed later in this Guidance) can be time consuming. Having too many routing schemes may make it difficult for DOT staff to comprehensively review all of the options. Since winter maintenance vehicle capacities for material spreading are often a critical constraint on route optimization scenarios, we recommend conducting optimization scenarios for material spreading that capture both typical and high demand for material spreading. The assumption then can be made that these routes will also be well suited to storms that require little or no material spreading.

Geographic Extent

The choice between a statewide project and a more geographically limited pilot project poses a trade-off between project risk and project benefit.[1] Statewide projects have the potential to deliver greater savings than projects that cover a smaller geographic area. First, adjustments to service territory boundaries are a source of efficiency improvements that cannot be captured (or are only partially captured) when optimizing a pilot region that may only consist of one or two service territories. Second, potential efficiency improvements from route optimizations will vary from region to region depending on the efficiency of the existing routes. As a result, pilot optimization in regions that are already relatively efficient may underrepresent the potential savings in other parts of the state where existing routes are less efficient. Finally, a statewide project will include all of the state's routes, so the total efficiency savings will be greater than for a single pilot region and achieved more quickly than would be the case with a series of smaller projects.

Conversely, statewide projects are higher in cost and may face greater institutional implementation barriers than smaller pilot projects as they require buy-in from a larger number of supervisors, drivers, and administrators. Pilot projects are lower cost and can build confidence in the optimization process before a statewide application is attempted. Given the limited number of DOT route optimization projects that have resulted in the implementation of new routes to date, we recommend that state DOTs pilot route optimization in a smaller region before attempting to conduct or contract for a statewide optimization project. Pilot projects that include two adjacent regions would allow service territory boundary adjustments to be considered.

If a DOT opts to conduct a pilot route optimization, two factors should be considered when selecting the pilot region(s): the support of the operations staff in the pilot region(s) and the complexity of the road networks. Selecting a pilot region where there is strong support for optimization among winter maintenance supervisors will help to overcome the institutional barriers to change and is strongly advised. Generally speaking, the potential for cost savings is higher in areas where the road network is more complex. Existing routes in regions with a relatively simple road network are less likely to deviate significantly from the optimal routing since the optimal routes are easier to determine through a manual process. Therefore, DOTs should consider prioritizing pilot regions with greater road network complexity

[1] Note that a "statewide project" or "statewide optimization" is used to refer to a project the covers all roads maintained by the DOT. Due to the computational intensity of route optimization, the optimization itself is likely to be conducted sequentially for smaller sub-state regions rather than for the entire state simultaneously.

to achieve greater cost savings and/or performance improvements. For these reasons, the team recommends that a pilot project include a more urbanized region of the state's road network and an adjacent region outside the urban core.

## Data Needs and Sources	Importance: Essential

Three types of data are necessary for route optimization. The first is data about the roads that require winter maintenance, the second is data about the winter maintenance vehicle fleet available to service these roads, and the third is data about DOT garages and service territories. In addition to these required data, information about baseline winter maintenance practices (current vehicle allocations and current routes) is very helpful for making the case for implementation but is not essential for conducting the optimization itself. Providing sample data for the GIS road network, winter maintenance fleet table, facility locations, and services territory boundaries at the time an RFP is issued will allow consultants to better assess the extent of the data preparation required for the project and more narrowly tailor their project budgets.

GIS Road Network

Route optimization software typically requires a GIS representation of the road network, with coded topology (links directions, travel times, capacities, and turn penalties), which comprise a routable road network. A routable road network is a representation of the roads (or a subset of the roads) in a given area that embeds information about how vehicles can travel on the road network. Embedded information includes elements that are necessary to process how a winter maintenance vehicle can navigate the network, such as distinctions between overpasses and intersections, the direction of travel that is possible on a road segment (one-way or bi-directional), and the turning behaviors that are possible where road segments meet. Generally, DOT GIS staff will be able to supply a GIS representation of the road network for the state, but it won't likely be fully coded and routable. In cases where the state does not maintain a routable network, they can often be acquired from commercial mapping companies, open-source providers, or developed as part of the contract.

Regardless of the source of the road network in GIS, some features may need to be corrected, added, or modified to ensure that it is routable for winter maintenance route optimization. Modifications to the GIS road network should be an expected step in the route optimization project. Modifications will likely be necessary to address many of the following road network topology attributes needed for the route optimization:

- **Information about Individual lanes may need to be represented for multilane highways.** Typical GIS road networks use single links to represent the traveled way, regardless of the number of lanes that are present, as shown in column B of Figure 3. The number of travel lanes in each direction is recorded as an attribute of the link. Thus, an undivided highway will generally be represented by a single, bidirectional link and a divided highway will be represented by two opposing links, one for each direction of travel. For winter maintenance routing, the representation of individual travel lanes is critical for developing lane-specific winter maintenance routes and to accurately represent limited-access features like emergency turnarounds and on/off-ramps. This enables different vehicles to be dedicated to different lanes, as is necessary for a dedicated left-side plow vehicle for serving the left lane of travel on a divided freeway. Information about the width of pavement that needs to be cleared, including road shoulders if applicable, is also valuable.

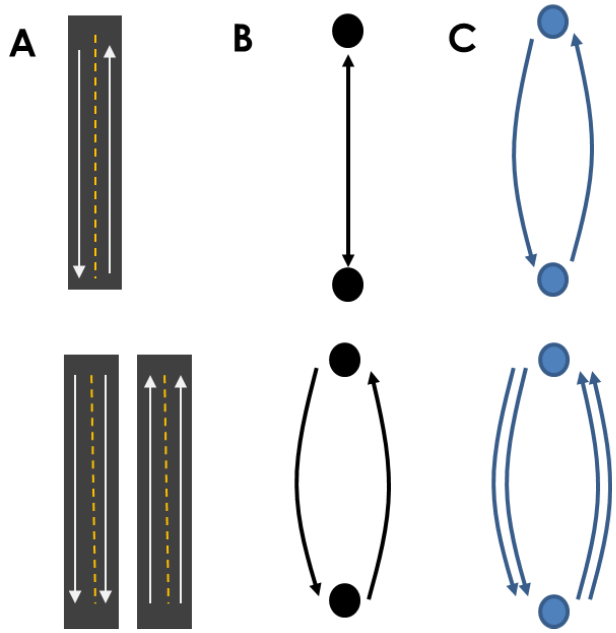

Figure 3. A) Actual road network, B) typical GIS representation, C) ideal representation for SIC routing for undivided (top) and divided multilane highways (bottom).

- **Local roads that may be traversed by winter maintenance vehicles must be included in the network.** State-maintained GIS road networks may exclude local roads and streets that are not maintained by the state. During the project setup phase, local roads that may be traversed by winter maintenance vehicles (for example, the roads between a state-owned garage and a state highway) should be identified and added to the road network if necessary. Even roads that are not provided with winter maintenance service may be critical linkages for efficient winter maintenance routes.
- **Functional classification and winter maintenance priority levels must be included as link attributes of roads to be serviced.** Many DOTs have different winter maintenance performance standards for different road segments depending on attributes like functional classification, or average daily traffic. These data must be included as link attributes for every state-maintained roadway or added to the GIS road network to be considered in the optimization. winter maintenance vehicle travel speeds may also be specific to the functional classification or other attributes of the roadway. In order to establish winter maintenance travel times for vehicles providing service, these speeds will need to be assigned to every serviceable link in the network, while safe travel speeds should be available for traversable local roads and streets where winter maintenance service is not to be provided.
- **Road segments that require special treatment,** such as known hazard areas that require more frequent service or different material application rates, should have this information included as a link attribute.

- **Road-specific restrictions on material spreading must be included as link attributes**. Restrictions on the chemicals or liquids that can be spread on any road segments should also be documented so that these restrictions can be added to the road network.
- **Median crossovers that can be utilized by winter maintenance vehicles should be represented as links in the road network.** These links can be added easily between parallel links for divided highways (bottom center of Figure 3). For median crossovers or U-turn opportunities on undivided highways, a bi-directional link may need to be converted to represent individual lanes (top right in Figure 3) so that the crossover link can be added. Failure to include these features in the road network is likely to result in inefficient routes, especially around on- and off-ramps.
- **Off-network areas that need to be serviced:** If the DOT is responsible for clearing rest areas, driveways for state facilities, or other non-road areas that are not represented on the GIS road network, these areas may also need to be added to the network. Alternatively, these areas can be left out of the route optimization project if there is a non-routable winter maintenance vehicle dedicated to servicing them.

While not required to conduct a route optimization, identification of existing (baseline) winter maintenance routes in GIS is *highly recommended* for DOTs interested in route optimization. Without the baseline routes and travel speeds coded into GIS or replicated in the optimization software, it will be more difficult to make the case for implementing new routes, since their benefit over the existing routes cannot be quantified. Data on existing routes in non-GIS formats can be converted to GIS as part of the optimization project. DOTs are advised to postpone route optimization projects if baseline data is not available.

Winter Maintenance Fleet and Equipment

The second piece of essential information that is required for route optimization is a tabulation of the winter maintenance vehicles available for routing and their attributes. For each vehicle in the winter maintenance fleet, the following information is required:

- The maximum distance the vehicle can travel before refueling
- The vehicle’s capacity for solids, liquids, both, or neither
- The vehicle's compatibility with and access to tow plows or dedicated left-side plows that alter the number of lanes or the type of lane the vehicle can treat in a single pass (if used by the DOT) as well as how many
- The vehicle’s home depot or garage

Generally, DOT’s maintain all of the fleet information required for the routing process though it may be necessary to work with individual jurisdictions to gather, confirm, and tabulate this information. The winter maintenance vehicle’s garage location may be altered by the optimization if the scope of the optimization project includes optimizing the vehicle allocation.

Facility Locations and Service Territory Boundaries

The locations of all DOT winter maintenance facilities (garages and salt sheds) as well as existing district service territory boundaries (if these boundaries are not being optimized) are also required for the optimization. If garage and salt shed locations are available in a GIS format this information can be provided by address or latitude and longitude. If service territory boundaries are available, they can be used to assign links in the network to specific garages, by adding the “servicing garage” as a link attribute in the GIS.

Winter Maintenance Operational Practices

Importance: Essential

New routes must be consistent with the operational practices of the DOT in order to be considered for implementation. A wide range of operational constraints and practices can be built into the optimization process. Failure to include these constraints can lead to optimized routes that are infeasible to implement or that do not improve on existing practices. Optimization project teams should strongly consider engaging operations staff at the supervisor or operator level to ensure that the assumptions used in the optimization reflect on-the-ground practice. Operational practices that should be considered with the optimization team include:

Winter maintenance vehicle operating speeds

Importance: Essential

Vehicle travel speed is an essential optimization criterion. Variations in operating speed based on road classification, whether the vehicle is deadheading or performing winter maintenance activities, or other factors should be reflected in the optimization and should be as accurate as possible. Overstating operating speeds in the optimization risks producing routes that cannot be completed within DOT guidelines while understating operating speeds may eliminate opportunities for cost savings. Historical AVL data is one possible source of speed data.

Material spread rates

Importance: High

Material spreading rates determine how quickly winter maintenance vehicles need to return to a garage or salt shed to resupply with materials. Route optimizations for material spreading require reasonable estimates of the rates at which materials will be applied. Underestimating material spreading rates may result in infeasible routes. DOT guidelines and historical AVL data may be sources of material spreading rates.

Compatibility between roadways and vehicles/equipment

Importance: Variable

Different winter maintenance vehicles and equipment are appropriate for different road types. Trucks with tow plows that are suitable for use on multi-lane interstates are not suitable for narrow state highways and trucks with specific plow configurations may only be able to service left or right lanes. Restrictions on the equipment that is compatible with each road type or road segment should be documented at the start of the optimization process.

Turn restrictions and penalties

Importance: Variable

Many DOTs seek to avoid left-turns and/or U-turns to avoid dropping snow in the roadway as well as to avoid safety issues and reduce the length of time vehicles spend waiting to make a turn. Specific turning actions can be prohibited entirely or may be assigned a time penalty which reduces the frequency with which the turning action occurs. Turn restrictions may be more relevant in high-traffic areas than in more rural regions and do not have to be uniform across the road network.

Cycle time thresholds and roadway prioritization Importance: Variable

For cost minimization cycle time thresholds are essential. DOTs frequently have winter maintenance performance standards that vary by road functional class or other criteria. When this is the case, this prioritization scheme should be conveyed to the project team so that it can be incorporated into the optimization. DOTs should consider whether specific winter maintenance vehicles can treat roads with different priorities or if routes should be limited to a single prioritization level. Allowing winter maintenance routes with mixed prioritization can increase efficiency.

Treatment strategy for multilane highways Importance: Variable

The treatment strategy for multilane highways should be documented for the project team. The use of tow plows, wing plows, and effective treatment width of all vehicles should be included in this documentation. If echelon plowing is used this should also be specifically noted as it can be difficult to incorporate into an optimization and the consultant/software provider should address their capacity to model echelon plowing specifically.

Treatment strategies for intersections, ramps, turn lanes, & roundabouts Importance: Variable

Strategies for road features where lanes must be serviced in a specific order or where the equipment that is used deviates from that being used on adjacent road segments should be detailed at the start of the project. This might include roundabouts where the inner lane is cleared first and wing plows are generally retracted, specific intersection configurations, or exit ramps. These treatment options may differ based on storm intensity. Less critical turn lanes, for example, may be left uncleared during severe storms, but ramps must be kept clear at all times.

Route Review Process

Importance: Essential

The Data Needs and Operational Practices sections of this Guidance Document are intended to ensure that the initial optimization process does not omit or misrepresent major operational considerations. With these operational practices as inputs, optimization software will produce routes that are technically feasible on the road network and winter maintenance vehicle allocations for every garage included in the optimization. Nonetheless, idiosyncrasies in roadway geometry, grade, lines of sight, traffic conditions, equipment capabilities, or other factors may mean that rules that are generally true do not hold in a particular circumstance or location. Consequently, the project team should expect that the optimized routes will require review and at least minor revisions to be safe and feasible in practice, regardless of the rigor that goes into setting up the optimization inputs.

As a result, all route optimization projects should include a route review process to identify any safety concerns or incompatibilities between the initial optimized routes and the DOT's winter maintenance operational practices. Ideally, this review process would include supervisors and/or operations staff riding along on each of the optimized routes to confirm their viability and identify potential problem areas. Any problem areas that are identified in the review process should then be addressed by the optimization team. To ensure that the finalized routes are fully compatible with DOT operational practices, the optimization project should be scoped to include multiple iterations of the review process.

Other Key Considerations

Importance: Variable

Beyond the technical considerations laid out in this guidance document, DOTs should consider certain key non-technical considerations, including:

- support of all winter maintenance operations stakeholders,
- indications that route efficiency can/should be improved,
- ability to demonstrate that the new routes improve upon the existing routes prior to undertaking a route optimization
- whether to conduct the optimization in-house or to have it performed by an external consultant or software vendor.

Strong support for the optimization process at all levels of the DOT, from executive leadership through district supervisors to winter maintenance drivers, and among all external winter maintenance stakeholders can help overcome the resistance that can prevent the implementation of new routes. Open communication between the optimization team and the supervisors and drivers that will be responsible for using the new routes is also helpful from a change management perspective.

The reductions in cost/service that can be achieved through route optimization depend on the efficiency of the existing routes. If the existing routes closely approximate the optimal routes, optimization will not produce large benefits. DOTs can explore several indicators that could suggest opportunities for optimization. Routes with cycle times that are substantially shorter than the DOTs maximum cycle time threshold indicate the potential for route consolidation in a cost-minimizing optimization. Significant variability in cycle times across different routes and garages can also indicate benefits from optimizing routes and vehicle allocations. Significant discrepancies across service territories in the ratio of winter maintenance vehicles to lane miles that must be plowed can be an indication that optimization of the fleet allocation could reduce costs and/or service times. Garages that are not relatively centrally located within their service territories suggest that facility locations and/or service territory boundaries adjustments could be beneficial. Another element to consider is the complexity of the road network. In areas with a relatively simple road network and a limited number of winter maintenance vehicles, careful manual review of winter maintenance routes may be a cheaper, faster, and comparably effective approach to designing winter maintenance routes. Routing in areas with higher numbers of winter maintenance vehicles and greater complexity in the road network is less easily done manually and therefore automated optimization can provide larger benefits.

Subjective indications that route efficiency can and should be improved are also helpful to motivate the route optimization project. For example, if the DOT is experiencing unusually high or inconsistent costs for winter maintenance from year to year as compared to peer states or fails to meet its stated performance targets, then the motivation for trying new routes and service territories may be high. It is also common for drivers and supervisors in a particular district to express concerns about the efficiency or effectiveness of existing routes. In some cases, highly variable route lengths could be causing problems with staffing and overtime costs. Often these motivating factors can help pinpoint regions where a pilot project can be focused.

The ability to clearly demonstrate reductions in cost and/or service time is essential to carry a project through the implementation phase. As mentioned previously, documentation of existing winter maintenance routes is *highly recommended* for DOTs interested in route optimization. Without documentation of the baseline routes and cycle times, it is much more difficult to make the case for implementing new routes as it becomes more difficult to quantify cost savings and performance improvements. It also is worth verifying that actual winter maintenance practices align with stated winter maintenance routes as discrepancies between the theoretical and actual routing also make it more difficult to establish the magnitude of cost savings and performance improvements.

Finally, DOTs interested in route optimization must decide whether to purchase software and contract training services so that optimizations can be conducted in-house or to contract for route optimization services with a consultant. Both approaches offer benefits and drawbacks. Developing the capacity to conduct route optimization in-house enables the DOT's optimization team to bring local knowledge of winter maintenance operations into the optimization process. Staff analysts can work with winter maintenance operators over a longer timeframe to troubleshoot routes and build buy-in. This approach also gives the DOT the capacity to update optimizations as new roads and lanes are added to the network or as the winter maintenance fleet is improved. However, route optimization software packages are highly specialized, and developing and maintaining proficiency with them requires a significant investment of staff time (initially it may be a full-time commitment). Unless multiple staff members are trained and maintain proficiency with the software, there is a risk of losing optimization expertise if a relatively small number of staff positions turn over. For many DOTs, the road network that they maintain is relatively static and there is little benefit to frequently re-optimizing routes. In this case, it may make sense to work with an external consultant with experience conducting snowplow route optimizations.

CLEAR ROADS

research for winter highway maintenance

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