# MANAGING INFORMATION FOR OPTIMAL WINTER SERVICE ACTIVITIES

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**1. Abstract**

Information is a critical part of the efficient and effective provision of winter service to the road-using public. Many actions taken during a winter storm are critically dependent upon good information. Yet often, information flow is barely considered at all as part of the winter service process. The aim of this paper is to examine how information can improve winter service activities, and especially to indicate how a lack of information can cause significant difficulties.

The information needed during a winter storm is a function of who will be using the information. For example, a truck operator needs different information than a supervisor. In considering information flows, it is critical that the end-user be a key factor, both in the type of information provided, and in the manner in which it is displayed.

Four different end users of information will be considered in the paper: supervisors, equipment operators, systems, and road-users. For each end user, the type of information needed will be discussed, the format in which the information should be supplied will be considered, and the sensitivity of the information will be reviewed.

Sensitivity will be considered further as being a defining characteristic of the data supplied. Some information must be supplied to a substantial level of accuracy, whereas other data can be much more approximate and may indeed be qualitative rather than quantitative in nature. Again, the degree of sensitivity depends on the end user.

Finally, a methodology will be presented to evaluate information sources and determine the extent to which the sources satisfy the needs of the end user. Appropriate information should be tailored to meet specific needs.

**2. Introduction**

A classic, and somewhat idealistic, approach to managing a winter storm has two decision points. When snow starts to settle on the roadway (perhaps to a specified depth) snow plows are dispatched to plow the roads and apply chemicals and/or abrasives. This is the first decision point. The second point occurs after precipitation has ended. Once plow operators are convinced that their route or area of responsibility is clear, they stop plowing and return to the maintenance garage.

It should be stressed that this approach is not “bad.” It gets roads clear of ice and snow in a timely manner. Further a broad range of agencies has used it successfully over many winter seasons. There is much experience with this approach, and thus a high comfort level (and generally a high level of performance as a result) among operators. However, this approach is not optimal. It does not make the best use of available resources and does not make the road system safe in the most efficient and effective way.

The purpose of this paper is to explore the role of information in achieving an optimal approach to winter service activities. Four steps will be taken in this exploration. The types of information needed in winter maintenance will be presented and discussed. Four different end users of information will be considered. Each end user requires different types of information presented in different ways. The sensitivity of information will be discussed with particular reference to required levels of accuracy. Finally, a preliminary methodology for evaluating sources of information will be presented.

## 3. Information Types

Managing an agency's response to a winter storm requires that a number of decisions be made at a variety of levels. As noted in the introduction, the number of decisions made can be quite small. Such an approach has two drawbacks. It is unlikely to be optimal, and because decisions are few, the costs for incorrect decisions are likely to be high.

In general, as an agency attempts to respond to winter storms in a more optimal manner, more decisions will be required. Each decision will be based on information, and the value of the decision rests both upon the accuracy and timeliness of the information, and upon its relevance. The determination of these three factors (accuracy, timeliness, and relevance) will be considered later.

### 3.1 Static and Dynamic Information

The information used in decision-making can be categorized in a number of ways. The first categorization determines whether the information is essentially fixed during a storm, or may change as the storm progresses. This categorization may be termed "static-dynamic." Thus the location of the roads in a district is static information, while the amount of snow cover on a road at a given time is dynamic information.

This categorization is not meant to imply that all static information is unchangeable. For example, the average daily traffic on a road is not likely to change during a storm, but may well change from year to year. However, the benefit of classifying information as static or dynamic is that static information generally impacts strategic level decisions (e.g. how many plows should I assign to that stretch of road?) while dynamic information impacts tactical level decisions (e.g. because plow # 37 has broken down, should I reassign plow # 42 to that route?). Table 1 lists examples of static and dynamic information.

| **Static Information Types** | **Dynamic Information Types** |
|---|---|
| Location of Roads and Maintenance Garages | Number of Trucks Currently Operational |
| Average Traffic Levels on Roads in District | Accident Location Information |
| Average Winter Climate Conditions | Current Road Surface Condition |
| Locations for Snow Haulage and Disposal | Quantity of Snow to be Hauled |
| Areas of Road Prone to Snowdrifts | Current Visibility on Road System |

**Table 1: Examples of Static and Dynamic Information**

The benefit of the static-dynamic categorization is that static information is typically not time sensitive, and thus can be collected and developed whenever convenient. Dynamic information is typically required in real-time (or close to real-time). This has implications in terms of data collection and data presentation. A district manager will likely know most of the static information relevant to their district. The implication of this is that such information does not need to be displayed actively on (for example) computer screens in an operations center, although it would be helpful if it were available in the background of such systems. Dynamic information must be displayed more actively in such systems.

### 3.2 Defined versus Algorithmic Information

A second categorization of information is that of defined versus algorithmic information. Information is termed "defined" if a given piece of information is set to a given value regardless of any other piece of information. Information is termed "algorithmic" if other pieces of information are used to develop the information. Thus for example, the level of service on a particular stretch of highway could be either defined or algorithmic. If defined, it would simply be set at a level. If algorithmic, the level of service would be set as a function of the average daily traffic and the type of highway (e.g. divided or two lane). The level of service may then define how soon after the end of a storm the highway should be cleared of snow. That defined time may determine (algorithmically) how many plows are assigned to the particular stretch of highway.

In general, algorithmic information is superior to defined information, but involves more processing. However, sometimes defining information algorithmically requires tackling difficult issues. A relevant example is the issue of road condition. The condition of the roadway may be defined as a measure of how safe that roadway is for the traveling public. It may be observed directly, by a supervisor traveling the route and making a judgment based upon visual observations. Or, the condition of the road may be computed algorithmically, based upon some combination of road surface friction, road surface temperature, and other factors. The first method, using a well-trained observer, is straightforward, but requires a sufficient supply of well-trained observers, and their presence over the whole road network. The second, algorithmic approach also requires observations, but these are made by sensors (and are thus potentially more objective, and may also be greater in number). However, the observations must then be processed according to an algorithm the details of which are not currently clear (Nixon, 1998).

It should be noted that not all information fits into a "defined-algorithmic" distinction. A third distinction may be added of "measured." Thus a measurement of road surface temperature is neither defined nor algorithmic (although strictly the voltage from the sensor must be converted into a temperature). Thus a more complete representation of the second distinction is "defined-algorithmic-measured."

Clearly, other distinctions in information type may be made. However, as a preliminary step the distinctions of "static-dynamic" and "defined-algorithmic-measured" allow for helpful distinctions to be made. Knowing the type of information allows the value of the information to be determined, as discussed below.

## 4. Users Of Information

The information needed in a severe weather situation is highly dependent upon the individual who will receive the information. Obviously, individual needs can be infinitely variable, but four specific examples may help to illustrate the varying requirements. The vehicle operator (in a winter storm, the snow plow driver) has need of information that allows her or him to apply the correct amount of chemicals to the road segment for which they have responsibility. The road system manager (the supervisor at a DOT garage or equivalent) needs to know the status of the whole road system for which she or he is responsible, so that assets can be deployed in real time to address problem areas. The road user has different needs depending on the nature of their road use. A trucker might need to know of delays ahead due to inclement weather. Someone considering a family trip needs to know whether conditions are sufficiently severe to warrant delaying or canceling the trip. Finally, various automated decision systems need information from sensors in order to function effectively. Each of these user needs is considered in some detail below.

### 4.1 Maintenance Truck Operator

The maintenance truck operator primarily needs to know that they are doing what needs to be done while they traverse their maintenance route. For example, they need to know that their chemical application unit is delivering chemicals at the specified rate to the road surface. Chemicals need to be delivered to the road surface when there is a likelihood of precipitation freezing to the road surface. This likelihood is a function both of current conditions (especially, of road surface temperature) and of how those conditions will develop over the next three to four hours (a typical cycle time for a maintenance vehicle route). The import of road surface temperature is very apparent from the popularity among vehicle operators of vehicle mounted infrared thermometers. These devices, which provide a not very accurate (generally they are good to within a couple of degrees at best) measure of the road surface temperature appear to be popular because they provide operators with a sense of the temperature trends. A rising surface temperature may indicate that, given the chemical already on the road, no further application is required. Conversely, a forecast drop in temperature in a few hours may indicate a need for additional chemicals now (because the truck may not revisit that spot until after the drop has occurred).

### 4.2 Road System Manager

The knowledge needs for the road system manager are somewhat broader and less location specific. The manager needs to know (among other things) when a storm will start, how severe it will be, what sort of precipitation it will involve and what will happen immediately afterwards. This information is often not available to a sufficient degree of accuracy.

For purposes of assigning shifts for snow plow operators, a road system manager would ideally like to know (at least twelve hours ahead of a storm) when that storm would begin to an accuracy of ±15 minutes. This allows the manager to get plow operators to the right place at the right time. A typical manager may have responsibility for an area of 400 square miles or more. Clearly, a storm is not going to start at the same time across that whole area, so there is a significant need to know how a storm will move through the area of interest.

But while specific sorts of information are very important for road system managers, equally important is presenting weather information in an appropriate manner. Road system managers are not meteorologists, and do not have the expertise to interpret much of the weather data that are supplied to them. There is substantial need for systems that tailor the information in levels, providing the most critical information at the upper level, with easy methods of “digging below” to find additional information if the manager feels it is needed. Too much, unfiltered information can be as disabling as too little.

### 4.3 Road Users

The road user is primarily concerned with reaching their destination in a safe and timely manner. For some road users, trips may be optional (a family visit, for example) but for most the trip is driven by necessity. Road users need to know when their trip will be delayed by weather, how serious that delay will be, and how hazardous driving might be as a result of the weather.

Some of this information is already available on the web. However, in developing and presenting this information, considerable care is needed. For example, current winter storm information in the United States is often provided by Highway Patrols, who may warn of roads being 25%, 50% or 100% snow and ice covered. Unfortunately, there is some evidence that road users feel these warnings are unduly conservative. If overly conservative information is provided, road users may ignore it. Conversely, if information is provided that does not adequately warn of hazardous conditions, a lawsuit may follow. It is perhaps impossible to satisfy all users, but ways must be found of presenting the relevant information in easily accessible form, so that road users can factor it into their decision-making. These issues have already received considerable study (Kajiya et al., 1998)

The nature of the information to be provided also presents a challenge. If I plan to drive from Chicago to Omaha, I do not need to know road conditions in Omaha now, but in seven or eight hours time. Tailoring information to road users along specific routes with specific travel times included will be an interesting challenge.

### 4.4 Automated Systems

There is increasing use of automated systems on highways that provide information about road conditions to road users without the intervention of humans. Typically such systems take data from a variety of sensors, use that information in some sort of decision algorithm, and if certain conditions are met, display a warning on a message board. Examples include warnings of high winds (Nelson, 1998) and of hazardous winter weather (Pilli-Sihvola, 1996). Part of such systems must include methods for evaluating the reliability and accuracy of the data, and ensuring appropriate fail-safe systems.

## 5. Sensitivity Of Information

Information needs to be evaluated from three viewpoints: timeliness, accuracy, and relevance. Every type of information will have differing requirements for each viewpoint. These three viewpoints are considered below.

### 5.1 Timeliness

This aspect of information is most critical for dynamic information. As noted above, static information is typically not time sensitive and thus timeliness is less of an issue. However, issues of timeliness critically affect dynamic information. In certain cases, information becomes useless if not presented in a timely manner. For example, a forecast of an impending severe winter storm may be very valuable twelve hours before that storm begins. Twenty minutes before the storm starts the information is much less useful. The decisions that needed the information (such as when to call in snow plow crews) have already been made by that time. Thus it is recommended that all dynamic information be assigned a measure of timeliness.

The above example (of the start of a storm) addresses one aspect of timeliness, that is appropriate when the information will be used at only one point during a storm (in this case, prior to the start of the storm). However, other dynamic information may be used repeatedly during a storm. For example, reports and forecasts of pavement temperature may be referenced almost continuously during a storm. Therefore, any measure of timeliness should be applicable to both singular instances of information retrieval and multiple retrievals of the same (albeit changing) information.

It is thus proposed that timeliness be measured in two ways. For singular events (such as the forecast of the start or the end of the storm) timeliness should be related to the start of the storm. Thus a timely storm onset warning would be delivered twelve hours prior to the start of the storm. For multiple events, timeliness should be expressed as an update rate. Thus for example timely pavement temperatures and forecasts should be updated every fifteen minutes. Determining the appropriate timeliness for given information requires a clear understanding of how the information will be used.

### 5.2 Accuracy

Clearly the accuracy of information has a critical effect on the value of that information. And again, each type of information will have its own requirements for accuracy, and those requirements may change depending on the information itself. As an example of the latter, the accuracy of the road surface temperature forecast needs to be much higher when temperatures are close to freezing than when they are ten degrees below the freezing point. In the latter case, any precipitation will clearly freeze to the road, while in the former case, the situation is much less clear, and changes of a tenth of a degree may have a significant impact.

Considering various sources of information, it is readily apparent that each source of information will require its own standards with respect to accuracy. The issue here is not to set standards for accuracy of information, but to ensure that each source of information is appropriately monitored to ensure that the appropriate level of accuracy is achieved.

### 5.3 Relevance

Relevance is an extremely important factor to consider in information management, especially in time critical operations such as managing a winter storm. A manager in such a situation has only a limited time in which to review and process information, and then make a decision. If too much information is presented, without a clear ranking of importance, then decisions will be delayed, or possibly, wrong decisions will be made because critical pieces of information could not be found in time.

One example area where this can be a problem is weather information. Winter maintenance managers are not (in general) meteorologists. Their understanding of the details of weather systems is incomplete and they do not need all the information gathered by a typical RWIS station. Thus any weather information presented to them must be carefully packaged so that only the most critical information is presented initially. However, it is important that less critical information be available too, upon request. For example, wind speed is not often a critical factor in winter storm management, unless the wind is blowing strongly. Once wind speeds exceed 15 to 20 mph (6.7 to 8.9 m/s) snow drifting becomes a real concern, and a maintenance manager may need to check occasionally to see if wind speeds are approaching these levels. If not, no further information (on wind direction and so forth) is required.

Accordingly, all information should be evaluated as to relevance. One way in which this can be done is by a simple three-tier system, with a score of 3 for truly critical information (relevant in all circumstances), 2 for occasionally critical information, and 1 for rarely critical information. Scoring information sources in this way allows the collection and display of information to be prioritized, and thus further helps to create a plan for an agency that is beginning the process of information collection and analysis in winter maintenance.

**6. Preliminary Methodology For Evaluating Information Sources**

Optimizing winter service activities requires that the information sources used in winter service decision making be carefully evaluated. This evaluation has two distinct phases. In the first phase, the information system is being established, and evaluation must focus on the extent to which the information under consideration can guide the required decisions. The second phase is an ongoing evaluation of the information source, to examine whether the required level of information is being supplied. The second phase should be somewhat easier than the first, because the first requires a comprehensive evaluation of the decisions required in winter service activities by a given organization. Such an evaluation can require a great deal of effort (see Mitretek, 2000).

Each information source should first be classified according to the decisions that it impacts. No information source should be considered for inclusion in a management system if it does not impact decisions. Given sources of information may impact multiple decisions.

The next step is to determine if the information is static or dynamic. Then the information can be further classified as defined, algorithmic, or measured. At this point, the type of information being considered has been fairly well categorized. Table 2 shows examples of information (taken from Table 1) and how they can be categorized according to this methodology.

| **Information** | **Decision Impacted** | **Static or Dynamic** | **Defined Algorithmic or Measured** |
|---|---|---|---|
| Areas of Road Prone to Snowdrifts | Location of Snow Fences | Static | Defined |
| Current Visibility on Road System | Illumination of Warning Signs | Dynamic | Measured |
| Current Road Surface Condition | Application of Chemicals or Abrasives | Dynamic | Algorithmic (depends on temperature and other factors) |

**Table 2: Winter Service Information Categorized**

The information sources have now been categorized. The next step is to evaluate them according to their timeliness, accuracy, and relevance. In the initial phase there will be some estimation involved (guided by current practice) but over time and with experience the estimates should be improved substantially. Table 3 shows how the information sources identified in Table 2 might be evaluated using this methodology. It should be noted that the evaluation here is strictly for example only.

It should be noted that the timeliness and the accuracy indicated in Table 3 may not be achievable with currently deployed resources. This allows needs for future investments to be clearly identified, with a strong expectation of how those investments will impact future performance of winter service activities.

| Information | Timeliness | Accuracy | Relevance |
|---|---|---|---|
| Areas of Road Prone to Snowdrifts (Road System Manager) | Static, so will not change during a storm. Must be known before winter season. | Road segments should be identified to within 50 m. | Criticality Level 2 |
| Current Visibility on Road System (Road User) | Should be updated every 15 minutes | Vision distance should be accurate to 5 m when below 300 m. | Criticality Level 2 |
| Current Road Surface Condition (Maintenance Truck Operator) | Should be updated every 15 minutes | Should accurately warn of hazardous conditions 95% of the time. | Criticality Level 3 |

**Table 3: Evaluation of Information Sources**

Clearly this methodology is only preliminary and requires a great deal of adaptation for the particular needs of any given agency. Nonetheless, it provides a starting point for developing a system to manage information in winter service activities. Such an information management system has the potential to improve and optimize winter service performance.

## 7. Conclusions

The information used in winter maintenance can be categorized according to the following system:

- Static vs. dynamic
- Defined vs. algorithmic vs. measured

Once categorized, the information can be further evaluated according to its:

- Timeliness
- Accuracy, and
- Relevance

Four different end users of winter service information were identified:

- Maintenance Truck Operators
- Road System Managers
- Road Users, and
- Automated Systems

Using these definitions, a preliminary methodology for evaluating information used in winter service activities has been presented. Such a methodology, while requiring adaptation for any given agencies needs, has the potential to improve and optimize winter service performance.

## 8. References


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