Performance Measures for Sustainable Winter Road Operations

Tina Greenfield

Road Weather Coordinator

Iowa Department of Transportation

Outline

- Why measure?
- Types of measures and how to choose what might work for your agency
- How to use data to make decisions
- How to present data for easy understanding and optimal use

Topic 1:

Why Measure?

Why Measure?

Simply put, winter maintenance is:

- Complex
- Costly
- Constantly changing

Winter administrators must monitor operational effectiveness to make sure standards are met, look for opportunities to improve, and evaluate new methods.

Questions that can be answered through measurement-guided improvement

- Deicer A has a high up-front cost, but does it lead to quicker cleanup times?
- Did the new process lead to better results?
- Can we have the same outcome using less material/hours/dollars?
- Are we moving in the right direction?
- Can we justify a needed expenditure?

Topic 2:

Types of measures and how to choose what might work for your agency

Types of Measures

- Inputs
- Outputs
- Outcomes
- Normalization factors

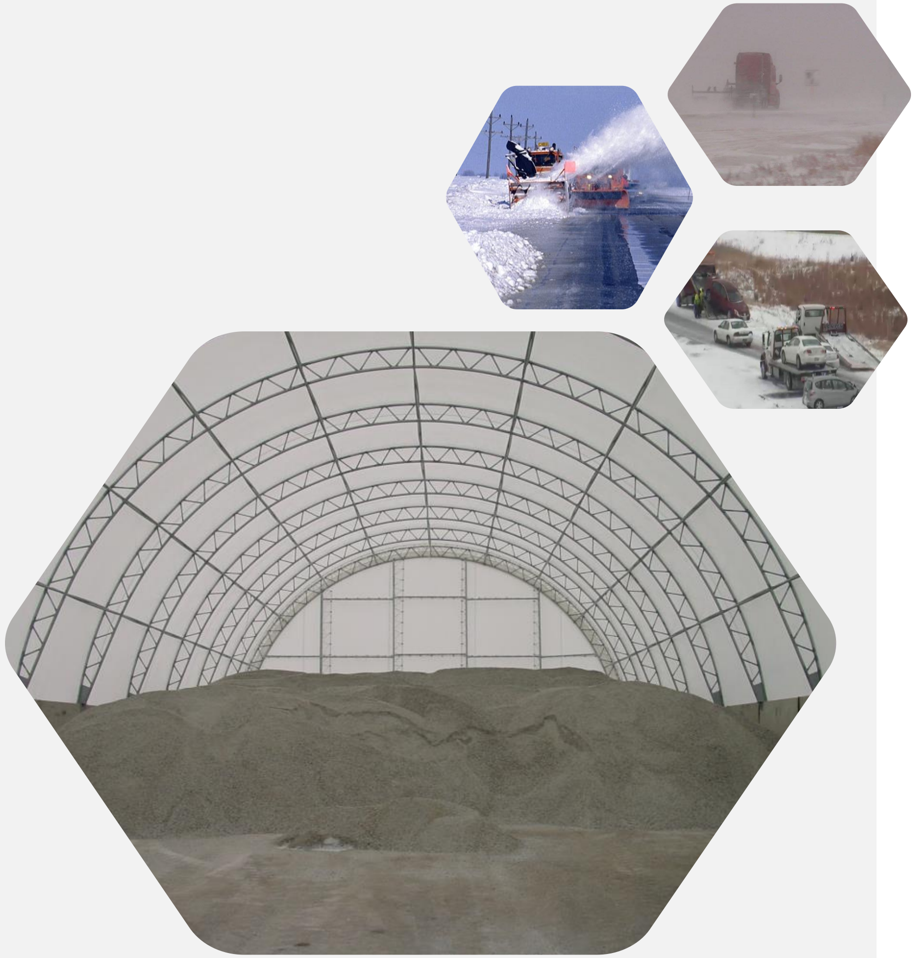
Inputs




- The resources that were expended in order to reach your goals
- Helps describe the expense of the operation
- Tend to be the simplest part of the performance analysis puzzle since they are often collected as part of an agency's budgeting and payroll systems
- Inputs to consider:
  - Tons of deicing chemicals used, and type
  - Tons of sand used
  - Gallons of liquid deicer used, and type
  - Labor hours
  - Equipment hours
  - Plow blades used

Tips for Selecting Inputs

- Start with what you have ★
- If possible, study several inputs because some maintenance activities shift costs from one category to the other
  - Some material might be cheap to use -- but cause high labor cost
  - Nice blades may be expensive – but lead to less material cost
- Study of inputs will help your agency select the most cost effective balance of the available chemical options, equipment, and labor, considering their price, availability, and the outcome they provide.



Outputs

- Tasks that were accomplished in the operation.
- Should describe processes and activities you want to improve or investigate
- Some sample outputs are:
  - Miles plowed by blade type, truck type, plow pressure, plowing width, plowing speed
  - Miles treated by chemical type, rate
  - Timing of plowing treatment — e.g., in anti-ice operations or the frequency of treatment
  - Use of prewet material or various spreader systems for accurate salt placement
  - Adherence to material rate guidelines

Tips for Selecting Outputs

- Again, start with what you have, if you can
- Often these require special data collection
  - Surveys
  - Downloading info from spreaders or GPS/AVL
- Define the output so it is specific to the activity you want to improve
  - “Miles anti-iced” is more descriptive than “miles treated” because it can get down to the specific activity that makes a difference
- Define “control” and “experimental” sides to outputs
  - For example, “miles plowed — by Blade Type A vs. Blade Type B”

Outcomes

- Measure the effectiveness of the operation
- Have a direct impact on the customer.
  - How well were they able to travel safely?
  - How much did they have to slow down in order to keep their perceived risk at an acceptable level?
  - How long did they have to wait for roads to return to a bare or wet condition?
- The outcomes tend to be the hardest to quantify and sometimes require other systems for collecting or recording these measures.

Selecting Outcomes

- Do what you can. Start somewhere
- Visual indication of road condition (e.g., ranked from ‘dry’ to ‘completely covered’)
  - Easy to comprehend
  - Different categories can create a sort of ‘scale’ of impact
  - Can use to study ‘time to normal’ or length of time in a non-normal state
  - Downside is subjectivity, and often self-reported

Selecting Outcomes

- Traffic Speed
  - relies on the assumption that traffic will respond to ‘bad’ conditions by slowing down, and will speed up as conditions improve
  - Can study “speed regain times” or “hours of non-normal speeds”, or magnitude of speed reduction
  - Requires a sensor system or a traffic data subscription
  - Continual measurement throughout a storm, not subjective
  - Can also be influenced by other factors out of agency control




Selecting Outcomes

- Road Friction
  - Highly related to the ultimate goal of winter maintenance
  - Continual measurement throughout a storm, not subjective
  - Must deploy your own friction sensing system




Inputs, Outputs, and Outcomes

- Ideally, agencies should seek outputs (methods) that maximize customer satisfaction outcomes while reducing inputs.
- For example, a certain amount of salt or labor (inputs) can be used in various ways (outputs/methods) either by changing when the material/labor was used, or how frequently, (like anti icing vs. reactive methods).
- These differences in outputs can have different outcomes on the road surface.

Normalization Factors

- Using Inputs, Outputs, and Outcomes seems fairly intuitive
- But please don't stop there!
- You need Normalization Factors




Questions that can be answered through measurement-guided improvement

- Deicer A has a high up-front cost, but does it lead to quicker cleanup times?
- Did the new process lead to better results?
- Can we have the same outcome using less material/hours/dollars?
- Are we moving in the right direction?
- Can we justify a needed expenditure?

I showed this slide earlier…

Questions that can be answered through measurement-guided improvement

- Deicer A has a high up-front cost, but does it lead to qu times?
- Did the new process lead to better results?
- Can we have the same outcome using less materia
- moving i
- Ca

…Sure, cleanup times were down!
…Or did we just get an easy winter?

…Yes, location X does this and their costs are always lower!
…Or do they just have fewer miles to maintain?

Questions that can be answered through measurement-guided

- Deicer A
  times?
- Did th

External inputs are important because they obscure the effectiveness of your agency's inputs if they are not removed with a Normalizing Factor

Normalization Factors

- Complexities that must be considered before drawing conclusions on winter operations performance
- Can be considered “external inputs” that also impact the winter storm situation
- Outside the control of the agency

Normalization Factors

- If the weather is different from time to time, agency inputs, outputs, or outcomes will also be different just because the agency had to react in different ways to the different weather conditions.
  - You need a Weather Index
- If comparing one location to another, you will also need to consider each location’s mileage and Level-of-Service requirements.
  - You’ll need a Mile Index

Normalization Factors

- Simple weather normalizers:
  - Inches of snow
  - Storm hours
  - Number of storms
- Weather indices:
  - Combine multiple weather characteristics into one numerical ‘score’
  - More complete description of the influence of weather than the single-variable normalizers
  - But can also be more difficult to explain
  - Require access to a variety of weather data




Normalization Factors

- Indices can be created on your own or used from a published source
- Which one you choose is often defined by what kind of weather data you have

  - Cohen (1981) uses only two variables:
    - Winter Index = Snow_days + Cold_days

  - McCullouch et al. (2004) uses seven different weather factors:
    - Indiana_Index = 0.71839*Frost_Days + 16.87634*FreezingRain_Days + 12.90112*Drifting_Days - 0.32281*Snow_Days + 25.72981*Snow_Depth + 3.23541*Storm_Hours - 2.80668*Average_Temperature

Normalization Factors

- What should never appear in a weather index are factors for crew activities, material use, or anything else that can be influenced by agency activities
- E.g., salt use is correlated with weather, and it's tempting to include "tons of salt used" in the weather index. But ultimately, salt use is a decision made by the agency, and there are many different ways an agency can decide how or if to use salt
- **Factors that rely on weather *and* agency decisions cannot be used to separate weather *from* agency decisions.**




Topic 3:

How to use data to make decisions

Let’s Use an Example

- Consider an agency with 10 regional maintenance depots
- Each depot tends to use different practices regarding prewetting granular material.
- Is prewetting linked to better outcomes or costs?
- Of course, each depot is responsible for a unique set of roads and has varied weather.

Summary of the Basic Steps

1. **Identify the Inputs and Outputs to study** – Does prewet rate (output) lead to lower Total Material Cost (input)?
2. **Create the Weather Normalization Factor**
3. **Create Lane Mile Normalization Factor**
4. **Preliminary review of Logic Model components** – Collect, compute, and organize the data in a spreadsheet
5. **Application of Normalization Factors** – What's our cost per mile, per unit severity?
6. **Correlation of Normalized Cost to Prewet rate** -- Is the use of prewet linked to a lower cost rate?
7. **Relate output to the outcome** -- Did the lower cost come at the expense of the time to normal measurements?
8. **Continuing evaluation** -- There is always something else to study!

Steps 1-3
Let's Look At What We Have

Input | Output | Outcome | Components for Mile Index | Components for Weather Index

Depot	Total Material Cost	Typical Prewet Rate	Time to Normal After Storm	Miles of Priority 1	Miles Priority 2	Miles Priority 3	Total Snow Hours	Total Freezing Rain /Sleet Hours
A	100,000	5	3	55	40	102	230	14
B	125,000	5	3.5	0	80	200	288	22
C	122,000	0	4	40	100	100	180	26
….								
I	111,000	0	3.75	16	44	108	310	21

Computing a Weather Index

- We only have 2 variables
  - Total Snow Hours
  - Total Freezing Rain/Sleet hours
- They don't fit a published index, but we'll make our own
- Weather Factor = (150 * Snow Hours + 213 * Freezing Rain Hours) / 2,000

Totally made up index, but you're allowed to do that as long as it makes sense ☺

Computing a Traffic Index

- We have miles of A, B, C classification
- Look to your own agency goals/policies for how the different levels relate in terms of expected "presence" or plow cycle times
- LOS Index = Lane miles of A * 1.1 + Lane miles of B * .85 + Lane miles of C * 0.7

This index creates a concept of a "weighted mile". One "weighted mile" would be halfway between an A and B level of effort.

This says an A road will get almost 50% more attention than a C road.

Step 4
Review Data

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index (Mile Index)	Weather Index (Weather Index)
A	100,000	5	3	165.9	18.7
B	125,000	5	3.5	208.0	23.9
C	122,000	0	4	199.0	16.3
D	136,000	10	3.8	217.7	25.8
E	118,000	5	3	209.4	19.5
F	160,000	0	3.5	228.0	25.9
G	152,000	20	3.2	235.5	20.3
H	132,000	0	3.4	154.8	22.2
I	111,000	0	3.75	130.6	25.5

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index	Weather Index
A	100,000	5	3	165.9	18.7
B	125,000	5	3.5	208.0	23.9
C	122,000	0	4	199.0	16.3
D	136,000	10	3.8	217.7	25.[illegible]
E	118,000	5	3	209.4	19.5
F	160,000	0	3.5	228.0	25.9
G	152,000	20	3.2	235.5	20.3
H	132,000	0	3.4	154.8	22.2
I	111,000	0	3.75	130.6	25.5

Let's look at this wrong for a moment...

If you computed a correlation between material cost and prewet rate, the result would be 0.49 — that there is a slight tendency that the more prewet used, the higher the cost!

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index	Weather Index	Normalized Cost (Cost per Mile per Weather)
A	100,000	5	3	165.9	18.7	32.2
B	125,000	5	3.5	208.0	23.9	25.1
C	122,000	0	4	199.0	16.3	37.7
D	136,000	10	3.8	217.7	25.8	24.2
E	118,000	5	3	209.4	19.5	28.9
F	160,000	20	3.5	228.0	25.9	27.1
G	152,000	0	3.2	235.5	20.3	31.7
H	132,000	0	3.4	154.8	22.2	38.4
I	111,000	0	3.75	130.6	25.5	33.3

Step 5: Apply the normalizing indices

Create a "Cost per mile, per weather index"

=Total Material Cost/ Mile Index / Weather Index

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index	Weather Index	Normalized Cost
A	100,000	5	3	165.9	18.7	32.2
B	125,000	5	3.5	208.0	23.9	25.1
C	122,000	0	4	199.0	16.3	37.7
D	136,000	10	3.8	217.7	25.8	24.2
E	118,000	5	3	209.4	19.5	28.9
F	160,000	20	3.5	228.0	25.9	27.1
G	152,000	0	3.2	235.5	20.3	31.7
H	132,000	0	3.4	154.8	22.2	38.4
I	111,000	0	3.75	130.6	25.5	33.3

What Do We See?

Depot D spends the least, considering miles and weather, even though they were just average in raw cost.

Depot H actually has the highest cost, miles and weather considered.

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index	Weather Index	Normalized Cost
A	100,000	5	3	165.9	18.7	32.2
B	125,000	5	3.5	208.0	23.9	25.1
C	122,000	0	4	199.0	16.3	37.7
D	136,000	10	3.8	217.7	25.8	24.2
E	118,000	5	3	209.4	19.5	28.9
F	160,000	20	3.5	228.0	25.9	27.1
G	152,000	0	3.2	235.5	20.3	31.7
H	132,000	0	3.4	154.8	22.2	38.4
I	111,000	0	3.75	130.6	25.5	33.3

Step 6: Correlation of Normalized Cost to Prewet rate

Now if we were to compute a correlation it would be -0.66.

The more prewet, the lower the normalized cost

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index	Weather Index	Normalized Cost
A	100,000	5	3	165.9	18.7	32.2
B	125,000	5	3.5	208.0	23.9	25.1
C	122,000	0	4	199.0	16.3	37.7
D	136,000	10	3.8	217.7	25.8	24.2
E	118,000	5	3	209.4	19.5	28.9
F	160,000	20	3.5	228.0	25.9	27.1
G	152,000	0	3.2	235.5	20.3	31.7
H	132,000	0	3.4	154.8	22.2	38.4
I	111,000	0	3.75	130.6	25.5	33.3

What Else Do We See?

The average Normalized Cost for our zero-prewet depots is 35.3. The average Normalized Cost for the prewetting depots is 27.5.
22% less than the no-prewet depots.

Depot	Total Material Cost (Input)	Typical Prewet Rate (Output)	Time to Normal After Storm (Outcome)	Mile Index	Weather Index	Normalized Cost
A	100,000	5	3	165.9	18.7	32.2
B	125,000	5	3.5	208.0	23.9	25.1
C	122,000	0	4	199.0	16.3	37.7
D	136,000	10	3.8	217.7	25.8	24.2
E	118,000	5	3	209.4	19.5	28.9
F	160,000	20	3.5	228.0	25.9	27.1
G	152,000	0	3.2	235.5	20.3	31.7
H	132,000	0	3.4	154.8	22.2	38.4
I	111,000	0	3.75	130.6	25.5	33.3

Step 7:
Relate output to the outcome

The correlation between Prewet Rate and Time to Normal is 0.1. Close to no relationship. Prewetting (and the accompanying lower cost) neither helped nor hurt Time to Normal

Step 8: Continuing Evaluation

- Keep going!
- Did labor cost compensate for material cost?
- Is there a difference amongst the different prewet rates?

Topic 4:

How to present data for easy understanding and optimal use

Level of Detail

Know Your Audience, Know Your Purpose

Users of Detail

- Local maintenance managers
- Research coordinators
- Winter administrators

- Info is specific enough to pinpoint operational differences
- Specific to their region, their roads – and how it relates to their choices

Users of Summaries

- Public
- Upper management

- Interest in general trends
- Quick-glance understanding
- Short and simple explanations for a non-winter knowledge base

Data Latency

How quickly can results be presented to their audience?

Short Latency

- Can react to the results quicker – faster improvement
- Better able to remember the details of the storm, how/why certain decisions were made, and what maybe would have worked instead.

But

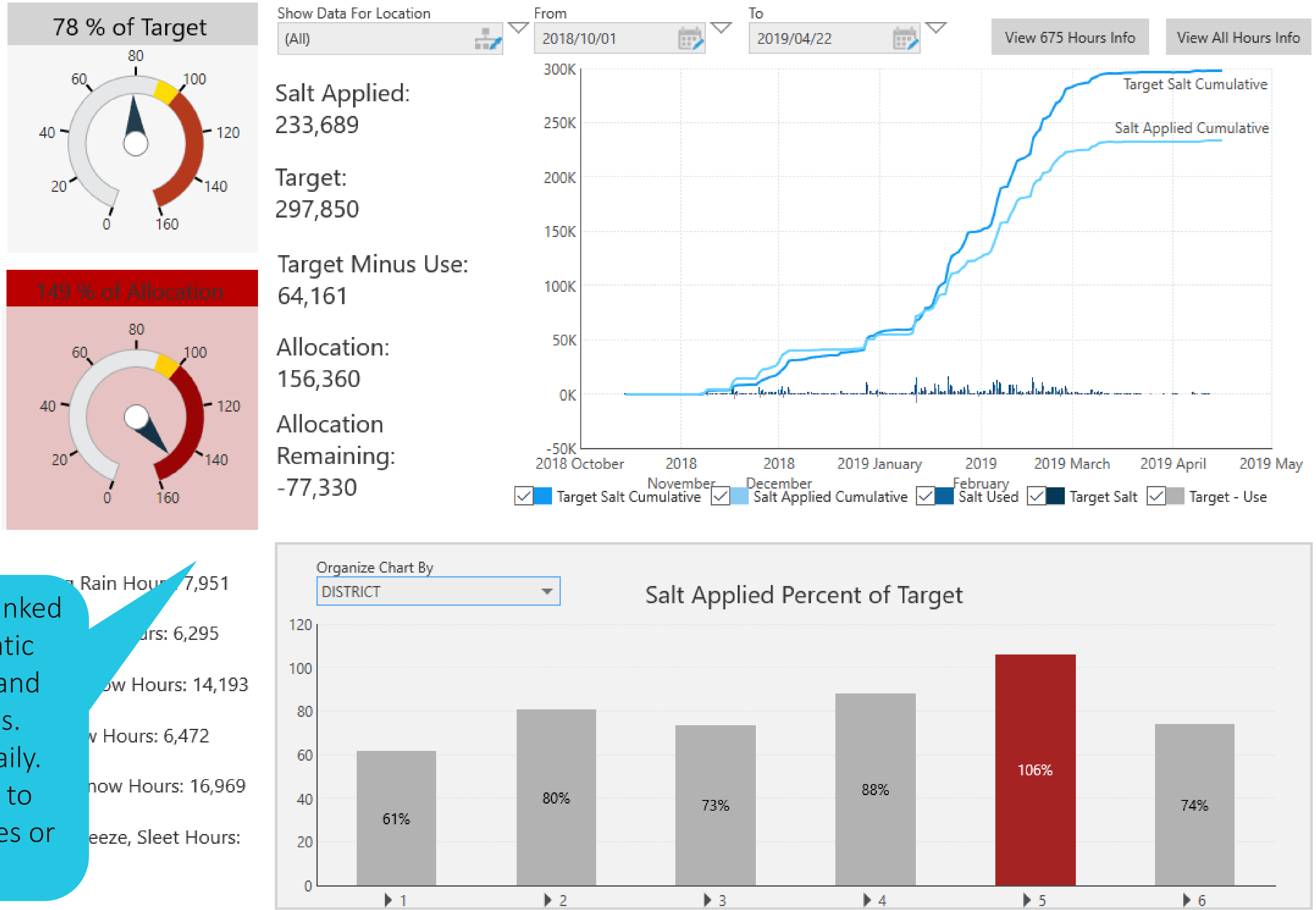
- Requires much more sophisticated reporting and data collection systems

Long Latency

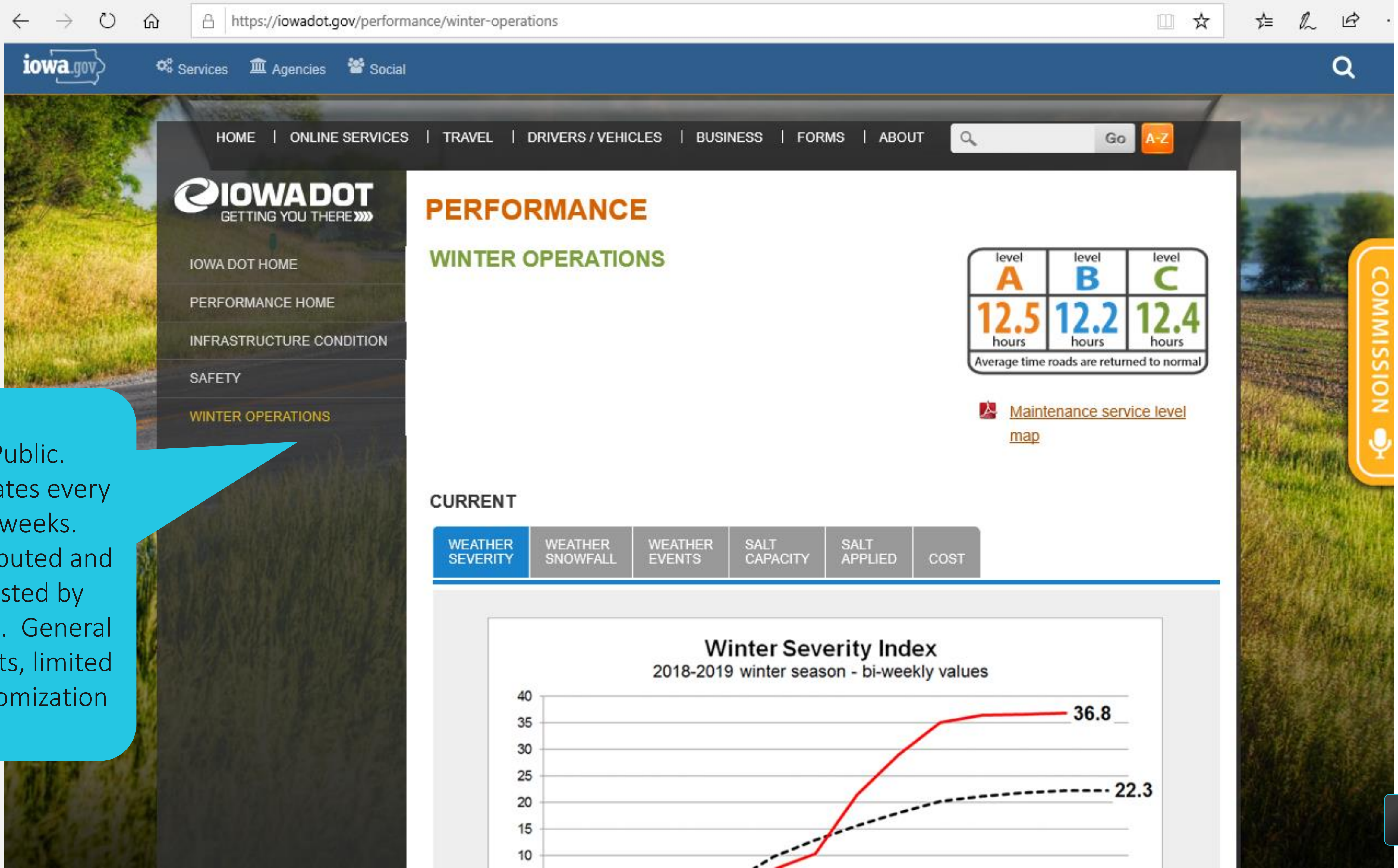
- Mistakes go uncorrected
- Details of what led to the result gets a bit fuzzy and maybe muddled with events from intervening storms

But

- More time to collect and present results
- Can be done ‘by hand’ with normal office tools like spreadsheets and emails



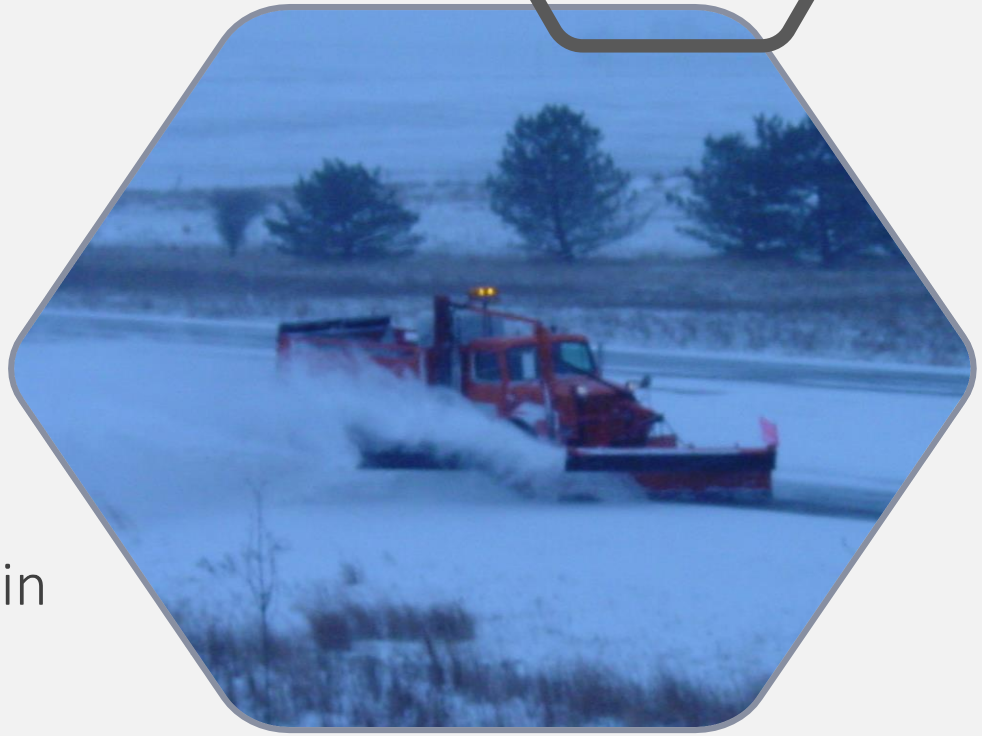
Dashboard linked to automatic programs and databases. Updates daily. Can zoom to specific dates or regions



Public. Updates every 2 weeks. Computed and posted by hand. General results, limited customization

Review

- Measurement is important for improvement
- The components of performance measurement can be thought of in terms of:
  - Input
  - Output
  - Outcome
  - Normalizers (External Inputs)
- Winter maintenance is complex and must be normalized before conclusions can be drawn
- Match the presentation method to the audience, in the best way that you can.



Thank You!

Tina Greenfield

+1 515-233-7746

Tina.greenfield@iowadot.us