NCHRP 20-68A
US Domestic Scan Program

Scan 07-03
BEST PRACTICES IN WINTER MAINTENANCE

Summary Report

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Submitted to:

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Overview

As recent as 50 years ago, some highway maintenance superintendants in snow –country USA still dispatched-out their most sophisticated operators with un-cabbed motor graders with a simple V-plow on the front. The operators often had only his own intuition to provide confidence that he was still on the roadway and not heading for the ditch. If they did get stuck, they often to depend on faith alone that someone would eventually come out and find them. Back in the higher traffic urban areas, their fellow tradesmen were standing up in the box of a truck, hand-shoveling sand off onto the slippery street below.

Contrasting these images, in April of 2009, our six-member scanning team completed a 14-day tour to five different states and had the chance to sit in cabs of snow control trucks amongst so much electronic gear (gadgets, screens, cameras and buttons) that there was not any room left for anyone other than a single operator. We saw dispatching centers with high walls covered with multiple screens showing roadway conditions received in real time from cameras relaying the same image that the snow-fighter is seeing from his/her cab. We talked to dispatchers who, at any given time, could know exactly where every truck was distributed on the road network (as does every individual driver themselves). We met on-site meteorologists who were updating weather forecasts for the snowfighters based on real time information received from stationary devices out on the network, coupled by real time information conveyed directly from the cab of the trucks. Chemical application rates are being adjusted accordingly on the spot. We observed plowing trucks, operated by a single driver that could clear two traveling lanes at a time using a follow-behind tow plow. A wide range of anti-icing and deicing chemicals could be distributed in both liquid and solid form, separately or together. Solids were being distributed at zero-ground speed to almost eliminate bounce (thus less waste). At the end of the day, the amount of chemical placed on the roadway, what roads are covered and even whether the plow is up or down is automatically being recorded instead of the driver having to do it by hand, or worse yet, not at all.

The purpose of the Winter Maintenance Scanning Tour was to seek out and observe the progress that State and local highway agencies are making in advancing today's technology in the area of winter roadway maintenance. While this was the first *domestic* tour in the USA, it was tailored after three previous scanning tours that had been conducted in European and Asian countries in 1994, 1998 and 2002. Much of what had been learned from these earlier international scans had become a new benchmark to several USA counterparts, inspiring them to pursue similar advances. Knowing this, *NCHRP 20-68A, US Domestic Scan Program* was developed under the auspices of AASHTO, FHWA and NCHRP to assess the state-of-the-practice of several transportation subject areas in the USA and to evaluate the extent to which the international scanning tours had an impact on domestic operations. One of the nine tours included in this program is *Scan 07-03 Best Practices in Winter Maintenance*.

The Winter Maintenance Scan was conducted from March 25-April 7, 2009 by a six-member team that consisted of:

- Ben McKeever, Co-Chair, USDOT

- William Hoffman, Co-Chair, Nevada DOT
- Terry Nye, Pennsylvania DOT
- David Ray, Ohio DOT
- Steven Lund, Minnesota DOT
- Mike Schwartz, Virginia DOT

Also traveling with the team were Rodney A. Pletan, who served as Subject Matter Expert (SME) and is charged with preparing follow up reports and presentations, and Armando Perez, American Trade Initiatives, who arranged for and coordinated all logistics relative to the tour.

While the initial composition of the team membership changed along the way, early in the process the Scanning Team met together and decided which locations to visit based on a Desk Scan prepared by the SME in October, 2008. Clearly, several good examples of the state-of-the-art in winter maintenance exist today in multiple locations. These sites were scattered among several states and local agencies throughout the snow-belt states. It was necessary to narrow down the list to a workable number. In some cases, sites were chosen because they had several examples to observe at one time. In other cases, sites in close proximity to other good candidates made the cut. Emphasis was made to include examples of state, county, city and toll road operations. After a full meetings discussion, the following locations were selected, listed in the order that they were visited:

- Minnesota DOT/TOC
- Colorado DOT/TOC, Cities of Denver, Ft. Collins & Grand Junction & E-470 Toll Road, including tours at the Eisenhower Tunnel and Holland Tunnel Centers
- Utah DOT/TOC
- Indiana DOT
- Virginia DOT

To assist the host locations to prepare for the Scanning Team visits, they were provided in advance a list of topical areas the team wanted to focus on together with a listing of amplifying questions. The focus areas were:

- Maintenance Decision Support Systems (MDSS)
- Automatic Vehicle Location System (AVL), Geographic Positioning System (GPS) and Vehicle Infrastructure Integration (VII)
- Equipment Technologies
- Training and Development
- Management Issues
- Integration of Weather, Traffic and Maintenance Operations

Summary of Initial Findings

The host agencies were all very well prepared to receive the Scanning Team, all focusing on the topical areas and amplifying questions that had been sent out in advance. The meetings took on a variety of forms including presentations, classroom discussion, field demonstrations, tours and discussions. Most special was the opportunity to meet face-to-face with the movers and shakers themselves, i.e. the champions of change who were actually developing, implementing and/or using the new technologies being presented.

Note that the title of this section is *Findings.* The name of the tour uses the terms *best practices.* The terms *state-of-the-art* and *state-of –the-practice* were also used in preliminary and background articles referring to this scanning tour. So do all these terms mean the same thing? Are *findings* all *best practices*? If something is referred to as the *state-of-the-practice* or *state-of the-art*, does that mean the same as *best practice*? Doesn't *best practice* mean the best there is *any place* and *every place*? What if something is deemed *best* in one situation, does it have to be *best* in other situation in order to be called a *best practice*?

While the objective of the scanning tour was to seek out and observe *best practices*, once the tour limited itself to a specific number of sites to visit, it is probably not completely correct to jump from the *best-of-what-was-seen* to be level of the *best-there-is*. The fact remains that the Desk Scan did not identify every *best practice* that exists because it was only conducted from the *desk* and was limited to the phone calls and information gathered from the *desk.*

None-the-less, this scanning tour did see a lot of the *best* and it can report on the *best-of-what-was-seen.* So for purposes of this report, while it may be a play on words, the word *findings* and *best practices* are often used synonymously, meaning that they are findings that were found to be the *best-that-was-seen* **compared to** what was seen at the other places visited. That may mean that the findings are the findings are the *best-there-is* but the scope of study made during the scanning tour did not look at everything-everywhere.

Initial findings of the Winter Maintenance Scanning Tour are listed by topical areas:

1. **Maintenance Decision Support Systems (MDSS)**
    - Data is being communicated back and forth between:
        i. the truck
        ii. the dispatch center
        iii. the MDSS provider (who generates treatment recommendations and the site specific weather/pavement forecasts, and
        iv. potentially others
    - During winter events, data elements include:
        i. Before event
            1. Pavement forecast
            2. Treatment recommendations
            3. Start time
            4. Route assignment
        ii. During event
            1. Truck location (GPS, AVL)
            2. Video views of pavement condition from cab
            3. Radar
            4. Current pavement and atmospheric temperature
            5. Material usage, application rates
            6. Plow up/plow down

7. Travel speeds
8. Revised forecast
9. Revised treatment recommendations

iii. After event
1. Routes covered
2. Material usages

- In summer, some new MDSS applications are being pursued (chip seals, paving, grass mowing, weed spraying, lane striping, roadside assistance, etc)
- Some agencies are beginning to identify cost benefits, with savings potential from saving chemicals and number/length of shift deployments, forced accountability,
- Various marketing and implementations strategies are being used
  i. Grass roots involvement and research
  ii. Statewide vs. by regions vs. by crew vs. scattered unit implementation
  iii. Focus on benefit to operator
  iv. Top down direction
  v. Combinations of above
- MDSS is being used to establish, supplement or replace winter severity index
- MDSS is having positive impact on management and employee culture

2. Automatic Vehicle Location (AVL)

- A variety of vendors are involved with AVL and systems related to AVL like MDSS
- AVL is being used for multiple purposes, ranging from route reporting, to resource consumption to incident response
- Benefits to both management and operators becoming more universally understood
- Low resolution (like >5 min intervals) meets some decision making needs but high resolution (like <30 second intervals) is required for replacing manual data collection systems

3. Equipment Related Technologies & Facilities

- Plows & Wings
  i. Underbody plows are common in several agencies
  ii. Wider front plows and dual wings are being experimented with
  iii. Tow plows allowing full two lanes per pass are being successful
  1. Tow plows can also distribute solid or liquid chemicals
  2. There have not been any safety issues or unfavorable accident history with the tow plow to date.
  iv. "Hydraulic Assist" engineering is being used to reduce plow weight on the blade when conditions warrant, thus reducing cutting edge wear and extending life up to two winter seasons.
- Plow cutting edges (plow blades)

    i. Composite carbide and rubber blades (Joma) are getting good reviews
    ii. Triple blade (carbide, seriated and rubber slush blade) units are being tried
    iii. Lighter poly blades have potential to replace some heavier steel blades
- Saddle tanks are being designed and integrated with dump boxes and beds on both tandems and single axle spreader trucks, leading to better weight distribution and higher carrying capacity, allowing for longer route coverage during pre-wetting operations at optimized application rate of 20-30 gal/ton.
- Spreaders
    i. The zero-velocity concept is continuing to be pursued
    ii. Slurry augers are being used so chemicals in slurry form can be distributed
    iii. Agencies using slide-in spreaders justify them for overhead clearance and tailgate sander users justify theirs because of reduced dead load, initial investment and maintenance costs
    iv. 5000 gallon tankers are used to during anti-icing as well as resupply station between storms
    v. Off season rental water tank trucks are rented as anti-icing units
- New equipment accessories being tried include:
    i. Video cameras on plow trucks to provide
        1. front view images of driver's front windshield perspective back to the dispatcher
        2. side and rear of truck views for the operator
    ii. Wiper blade vibrators to reduce ice buildup
    iii. Air blowers to keep side mirrors clear of snow
    iv. HID headlights
    v. Fog Busters to lift fog above drivers line of sight
    vi. Laser beam guides to tell operator how far out the wing or tow plow is
    vii. Collision avoidance systems have potential in white-out conditions
- Fixed Automatic Spray Technology (FAST) systems have developed and proven to the point that they are no longer experimental
- Equipment replacement purchases are funded by a variety of mechanisms, including:
    i. Annual appropriation from legislature or council
    ii. Revolving accounts (where user units pay rent to owning units)
    iii. Escrow accounts (where agency puts money every year for every unit so it is fully funded when replacement is due)
- Road Weather Information System stations advancements include:
    i. Low cost portable units
    ii. Solar or wind powered units
    iii. Stations that include remote controlled cameras providing streaming video

iv. Non-invasive sensors to replace pucks embedded in pavement

- Friction measurement systems continue to be developed both domestically and internationally for purposes of measuring winter performance
- Progressive and environmentally sensitive agencies store all solid chemical under roof year-around with space available to load trucks inside the same building
- Brine making and brine storage systems have become automated and controlled
    i. Some are housed inside in same building as solid salt
    ii. Some are dispensed using fuel management systems to permit easy sales to other local agencies and to internally keep track of amounts loaded onto individual trucks
- Sophisticated truck washing facilities employ sediment traps, reuse wash water
- Contaminated truck washing water and runoff from stockpile sites and loading areas are being collected and used to make brine so as to avoid entrance into the environment at equipment and chemical storage sites

4. Training & Development

- Downsizing government is leading to more and more agencies setting up flexible workforces where generic "transportation worker" classifications are replacing separate "construction" and "maintenance" classifications at time of hire
- Where this is not happening, non-maintenance employees are being cross trained to operate snow and ice equipment during winter storms or otherwise supplement/support the winter maintenance effort
- Such changes are causing both challenges and opportunities for training and retraining workers
- Several agencies are setting training programs using simulators, training academies, symposiums and other systems to incorporate internally and externally developed training programs like the AASHTO Computer Based Training (CBT) program
- At least one training program involves an iPod based program where an operator is directed as to where to turn and what to watch out for, from beginning to end, throughout this entire assigned route

5. Management Issues

- Maintenance Operations Research & Development
    i. Dedicated and reoccurring funding for operational research with maintenance promotes an innovative spirit from grass roots on up
    ii. Creating an environment where ownership of new ideas at the grass roots level leads to greater by-in, but this buy-in may take time to achieve, thus extending implementation time compared to "top down" directed policy.
    iii. There exist vivid examples where employees are convinced that management is open and willing to try their new ideas

iv. The attitude of continuous improvement can co-exist at all levels in an organization

- Culture & Management/Employee Relations
  i. Top down support and direction is essential to more rapid implementation
  ii. Identifying projected savings and committing them to research and implementation of new directions can lead to enhanced upper management support
  iii. Short term mobility assignments (6-12 months) of field maintenance into central office to work on research development and implementation reaps many benefits
  iv. Success in achieving new directions is dependant on the extent to which key players have ownership and feel they are receiving value from it (Example: During the stress of plowing snow, the operator has to be convinced that the value of MDSS exceeds the extra work and distraction it causes while driving)
  v. An ideal example of management caring for operators was the installation of a gas-station-like hot dog maker that is supplied free-of-charge to drivers during winter emergency events in their crew room.
- Outsourcing vs. In-house work
  i. Outsourcing work is being done at various levels or degrees
    1. Equipment rental only, operated by agency
    2. Equipment with operator, supervised by agency
    3. Equipment with operator, supervised by contractor, managed by agency
    4. Full turnkey contracts where all road maintenance is managed completely by a private contractor and the agency only inspects for deficiencies
  ii. Defined expectations are not always the same between in-house and outsourced work
    1. Expectations can be defined
      a. Quantitatively (# of trucks on the road during event, size of trucks, etc)
      b. Methodologically (show up time, speed of travel, defined application rate, hours of coverage, etc)
      c. Outcome based (regain time, achievement of bare lanes or bare pavement, etc)
    2. Some agencies measure *in-house* work at the outcome performance level more extensively than other agencies measure performance of *outsourced* work
    3. Some agencies define higher expectations for *outsourced* work than it appears is expected or deemed acceptable *in-house*
  iii. Pay Items for outsourced work varies from agency to agency
    1. Pay units of input (labor hours, equipment hours, etc)

2. Extra pay for show up or standby time
3. Guaranteed hours
4. Extra pay for equipping private equipment vs. agency mounting accessory equipment on private vehicle
5. Disincentives for failure to meet expectations

iv. Management of outsourced work becomes complex if pay items do not directly relate to defined and measured performance expectations

- Winter Performance Measurement
  i. Outcome based measurements best correlate with how customers achieve satisfaction, thus the development of measures like friction and regain time
  ii. Market research conveys what satisfies the public and such studies indicate that achieving "bare lane" meets needs rather than working toward achievement of full "bare pavement"
  iii. Monitoring traffic speeds has potential, as is recording frequency and duration of highway closures, because efficiency and availability of system has economic impact on society
  iv. Photos of various levels of service can be used
    1. During focus group meetings to better understand what satisfies the public (market research)
    2. Prior to a winter season to define and train operators (whether public or private) what the expectations are
    3. During an event to define current conditions
  v. Reporting methods vary:
    1. Dashboard gages, which show when performance does or does not meet standards as well as showing when standards are exceeded (exceeding standards indicates opportunities for savings)
    2. Mapping of completed routes during event
    3. Graphs and charts showing comparisons between crews, districts or regions; do not necessarily set firm targets but motivate operation units to progress to at least 85th percentile (best practices reporting systems)
  vi. Data Gathering Mechanisms include:
    1. Automatic data collection (plow-up, plow-down, application rates, etc) using MDSS/AVL technology
    2. Streaming video from operators cab to dispatcher or RWIS site to Traffic Operations Center (TOC)
    3. Condition reporting done real time by operator on touch screens in cab
- Consistency (or lack thereof) of level of service between winter plow routes or across internal organizational lines and even jurisdictional boundaries is something customer measure government by.
- Internal and External Communications
  i. Snow and Ice plans are prepared in advance

ii. Equipment mechanics are involved in planning and meetings
iii. Many different levels and frequency of meetings exist
    1. annual pre-season meetings
    2. pre-storm meetings
    3. post-storm meetings
iv. Some involving locals and others involving statewide
v. Some involving other jurisdictions, including adjacent states (to discuss consistency of service across boundaries)
vi. Some involving user groups and media
vii. Agencies are learning how to capitalize on public access to web sites and tweeter boards
viii. One agency has set up automatic email alerts to subscribers, including schools and trucking companies

- One agency provides designated drop zones so that stalled and stranded vehicles can be moved off the highway during winter events

6. Integration of Weather, Traffic & Maintenance Operations

- Traffic Operations Centers (TOC) are being designed and organized to physically integrate representatives of several disciplines together during winter and other emergency/incident management type events. Examples already incorporated into one or more TOC are:
    i. Full-time salaried Meteorologist
    ii. Maintenance Operations Dispatcher
    iii. 511 Coordinator
    iv. Highway Patrol Dispatcher
    v. Courtesy Patrol, Motorist Assistance Dispatcher
    vi. Snow and Ice Operations Coordinator
    vii. Traffic signal control coordinator
    viii. Retired maintenance supervisor on-call as TOC operator during events
    ix. Public funded, on site, FM Radio announcer who, on moments notice, provides continuous traffic reporting during incidents, including winter weather, and reverting back to broadcasting jazz music at other times.
    x. Special space and provisions for housing media representatives during events
- Some of the above integration is full time, year around and others are only during incidents, including winter events
- One agency has a former radio announcer on staff as a TOC operator
- In the case of an agency having a full time meteorologist, that position manages a private meteorology team under contract who does the actual forecasting from space provided in the TOC. The staff meteorologist teams with maintenance operations in the agency to best utilize the forecasts.

- The key benefit to having up-to-date weather forecasting and road conditions in the TOC is that it allows for more timely updates to 511, web sites and other sources of information that the public has access to
- Some agencies have converted to statewide 800 MHz for all emergency services, including maintenance operations (Voice-over "ARMER" system was extremely valuable during 35W collapse)
- Traffic signal timing is adjusted on key corridors in response to winter events.

Recommendations

Based on the above listed findings, the preliminary general recommendations of the Scanning Team are as follows:

Maintenance Decision Support Systems (MDSS)

- Inasmuch as MDSS has proven itself to add effectiveness and efficiency to winter operations, the return on investment will greatly increase as it becomes applied to summer activities as well.
- In order to be successful and be able to implement MDSS expediently, there are some marketing and implementation strategies that have been tried and proven to be more effective than others.

Automatic Vehicle Location Systems (AVL)

- AVL systems have multiple uses, many of which are beneficial to employees and operations, and it use is expected to be universally expanded into maintenance operations. The higher the resolution (frequency of readings recorded), the greater the cost; but the lower the resolution, the lower the potential value received.

Equipment Technologies

- Indications are that the tow plow has great potential in many areas. They are able to be operated with a single driver and accidents have not been a problem. Tow plows do, however, required a truck to pull it that meets certain minimum specifications, probably not available today in existing winter maintenance fleets.
- The concept of "hydraulic assist" should have potential of extending life of some cutting edges (plow blades) up to two years.
- The Joma plow blade (composite of carbide blade inserted in rubber) are well liked, thus showing promise nationwide.
- Poly plow blades should be considered, at least in certain environments.
- The use of video cameras to expand the range of view of a snowplow truck operator should be considered as a safety enhancer.
- Laser beams extended to the front of trucks to indicate extended wing or tow plow are economical and most probably cost effective.
- Though evidence of research was limited, vibrating wiper blades shows promise.
- Visibility enhancers like Fog Buster, HID headlights and other technologies that enhance ability for operators to see and be seen should always be pursued and employed once they have proved successful.

- It is very important that agencies do whatever is necessary to 1) prevent the formation of salt brine at stockpile sites and 2) collect any brine formed from runoff or truck washing at a storage site. Sediment traps permit salt brine runoff to be reused or recycled.

Training and Development

- Flexible work forces need to be considered as demand for services continue to rise and downsizing government is being expected.
- Cross training can be successful in supplementing snow plow operators.
- Several generic and custom made training programs are available as state-of-the-art examples for use at training academies or symposiums. Real life simulators coupled with classroom lecturing and computer based programs (AASHTO CBT) can be used for both initial and retraining purposes.

Management Issues

- Inter-jurisdictional relationships are important to promote consistency of levels of service between otherwise invisible governmental boundaries.
- More work needs to be done to develop improved outcome-based and customer-oriented performance measurements (like regain time, friction measurement, speed monitoring, road closure frequency/duration, etc) and such measurements need to be implemented, applied and reported to better manage both in-house and outsourced winter maintenance services.
- Models of dedicated and reoccurring funding for operational maintenance research funding needs to be copied by more winter maintenance agencies. Successful models lead grass roots ownership, thus a creation of a continuous improvement culture and improved relationships between employees and management.

Integration of Weather, Traffic and Maintenance Operations

- Integrating traffic operations, weather forecasting, maintenance operations, highway patrol, media and incident management into Traffic Operations Centers is proving to be a best practice.
- Better approaches for conveying real-time traveler information to the public using 511, web sites, e-mail alerts, text messaging, etc. are emerging. Information related to traffic conditions, surface conditions and weather forecasting is being disseminated.
- Implementation of special signal timing plans during winter events has the potential of improving traffic flow for the traveling public, as well as the snow plow operators.

Planned Implementation Actions

The winter maintenance community provides many conduits to disseminate the findings and recommendations of this scanning tour. Included, but not limited to, are the following:

- Short Term
  - Presentations at scheduled conferences (mostly scheduled at least annually)
    - PIARC World Road Association Winter Road Congress (scheduled 2010 Quebec City)
    - TRB Annual Meeting
    - TRB Winter Maintenance Committee
    - TRB Committee on Surface Transportation Weather
    - TRB Snow & Ice Symposium (scheduled 2012)
    - AASHTO Subcommittee of Maintenance
    - PNS Pacific Northwest Snowfighters
    - APWA American Public Works (Winter Maintenance Committee)
    - NACE National Association of County Engineers
    - AASHTO Eastern Snow Expo
  - Presentations to Pooled Fund organizations
    - SICOP Winter Maintenance Technical Service Program (WMTSP)
    - Clear Roads
    - Aurora
    - Clarus Initiative
    - PNS
  - Other meetings
    - National Winter Maintenance Peer Exchange
    - MDSS Showcase
  - Webinar -

- Medium Term
  - Identify potential projects with Pooled Fun organizations
  - Coordinate activities with Lee Smithson, SICOP Coordinator
  - Promote more MDSS-type Showcases
- Longer Term
  - Assist in developing Problem Statements for NCHRP