Reengineering winter road maintenance

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Advances have been made in the application of the de-icing and anti-icing technology with the planning of salt treatment action on road networks. The logistics of winter road maintenance are directly linked to the weather changes. With the Reengineering Winter Road Maintenance (RWRM) I profit from the development for road weather forecasting models, sensors, prewetted spreaders, snowploughs, communications-, action-, training-, and network systems. My goal is to ensure the continuous improvement of the winter road maintenance by constantly managing all operations with an on-line action information system. After six years I ascertain the quality and the cost effectiveness of the RWRM, applying it I created a safer cantonal road network.

1. CASE FOR ACTION

The 1986 swiss federal environment law must be fulfilled, in order to do this the canton Lucerne changed his own road law in 1995. To fulfill that new law I created in 1993 this reengineering process. This process is also necessary in order to be able to develop better working conditions.

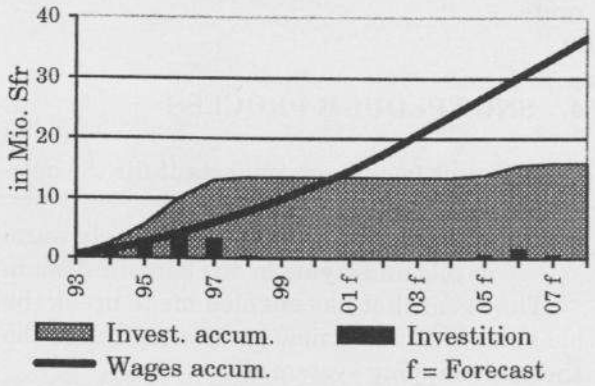

Figure 1. Invests plan

Some jobs are being canceled as the correspondent employees are going in pension. New jobs are being formed more humanely. This policy considers the psychical and physical burden of the workers. It has cost the canton since 1993 until now SFr. 13,4m but it has also brought the canton already SFr. 12,2m out of the saved accumulated wages (Figure 1).

2. VISION

Michael Hammer (1) said, there are two key components of the larger message that senior management has to communicate to the organization to get reengineering underway. The first is the „let's change" part - the case for action; the second is „to what" - the vision.
My vision is: *Planning the treatment action.*

3. REENGINEERING PROCESS

The major step was to find the significant processes for the RWRM, because processes, not organizations are object of reengineering (1). The result of the *spreader process* is a spreader with a range from solid salting, prewetted salting, liquid salting to abrasive. The *snowplough process* is the key of the salting routes optimization. Standard processes for all treatment actions are the result of the *decision making process*. The following systems have been installed since 1993 (Table 1).

Table 1
Installed systems with the Reengineering Winter Road Maintenance (RWRM)

Systems for 600 km roads	Cantonal road 508 km; communal road 90 km [3,9m m^2]
750 km thermal mapping	9 climatic domains
40 Road Weather Information System (RWIS)	20 km per RWIS
28 prewetted spreader + snowplough + ice terminal; 15 Salt silos; 2 solid salt pump stations (25 t/h); 8 liquid tanks with magnet card reader and liquid salt pump stations (< 250 l/min)	Maximum 33 km of salting route with snowplough
action information system, raincast and satellite pictures	One active system
12 video cameras for snowfall	50 km per video camera

4. SPREADER PROCESS

Numbers of publications demonstrate clearly, salt spreading has a very high utility for the economy. On the other hand there is not high utility for abrasive (sand, ground slag, chips, stones, bottom ash or cinders) (2).

For the environment salt and abrasive are „considerable" burdens. *Measures have to be taken to reduce both substances.* To fulfill the vision some spreader actions must be taken on dry roads. On 19'000 actions since 1995, the RWIS provided the canton with optimal results by three different winter ices: *hoar frost, icy roads (black ice), and low prior intensity freezing rain (sleet)* thanks to the *prewetted salt spreader*. In the *prewetted salt* operation, the liquid is mixed with the solid in the spreader just before the combined ingredients are dispersed onto the pavement. The *prewetted salting* is much more effective to prevent the bonding of the snow or ice to the pavement than to destroy the bond once formed. The use of salting before snow falls and when it starts snowing has given good results. The reason is that the salt is not plowed away with subsequent snow and ice because it already adheres to the pavement. The *prewetted salt* distribution (FS 30) on compact snow and high intensity freezing rain (sleet) is not efficient (3). It is unsuitable on packed snow and on iced pavements. Abrasive are sometimes more efficient. One workman is required for the treatment and the salt filling.

The spreader range must cover solid salting, prewetted salting, liquid salting and abrasive. Investments on solid salt depots with silos and tanks for loading the liquid salt are compulsory.

The diameter of the maximum grain is important to allow minimal salting with 5 gr/m^2. The average salt consume for all actions was 12,7 g/m^2 in the first quartile 1999. *The salt humidity is relevant for the silo storage.* The diameter of the solid NaCl grains the Rheinsalinen AG, CH, provides is *maximum 1 mm* and is dried out to *>1% humidity*. For the *prewetted salting* and the liquid salting I preconize a ~27% NaCl solution with added water to get a NaCl solution of ~21%. This is important to treat with liquid salting. Four types of winter ice are defined in the winter maintenance (Table 2). Pre-adjustments of the treatment actions sets are done for each salting route.

4. SNOWPLOUGH PROCESS

Different factors are important for the optimal design of the salting routes:

1) Definition of the road as relatively warm or cold and laying in one climatic domain

The agent that has enabled me to break the old rules and create new process models is the thermal mapping system (4).

2) Risks with snowplough

Because of the constant pressure to the road pavement the snowplough risks rise extremely at a speed higher than 30 km/h and with the

Table 2
De-icing and *anti-icing* methods with standard pre-adjustment

Winter ice	**hoar frost** >> 0 °C <0 °C	icy roads >0 °C → <0 °C	<0 °C **freezing rain** <0 °C	**compact snow**
De-icing & *anti-icing* methods and Treatments	solid salting with 5 g/m²	*prewetted salting with 6 - 8 g/m² or liquid* salting or solid salting	*prewetted salting* or solid salting with 15 – 25 g/m²	*prewetted salting with 6- 8 g/m²* or solid salting with 8-15 g/m² or abrasive with 35 g/m²

amount of snow which has to be removed. The length of the treatment route should not exceed 33 km. It must be reduced if the snow layer exceeds constantly 10 cm.

3) Size of the road network

With the new road law additional 101 km communal roads were integrated to a total of 594 km from 1.1.96 to 31.12.98 in the cantonal road network. The government reduced 1998 the cantonal road networks back to 508 km. Since then I am optimizing the winter road maintenance integrating some communal roads with the help of local communities into the cantonal road network. For economical reasons I chose for some parts of the road network the opposite strategy: today local communities and other cantons do now the winter road maintenance on part of the Lucerne cantonal road network and the canton Lucerne does the opposite on their road network. On the end the average length of the salting routes is only 21,4 km. To optimized this, I divised the ice terminal. This system, connected with the spreader, is automatically linked to the action information system. The *most important information of the treatment* action like the *start*, *end* and *quality* is shared on-line with the action information system. All this reduces the treatment costs as the private contractors can be sent to two or three salting routes as long as the snowplough is not afforded.

4) Logistic for the salt storage (solid and liquid)

The cantonal road network has only *one maintenance center* and two „solid" NaCl depots. To optimize the salt storage 15 silos between 50 m³ and 200 m³ and 8 tanks for liquid salt between 10 m³ and 160 m³ with liquid pump stations were built. With a solid pumping station on one of the „solid" salt depots the salt is filled in silos and transported from there to the other silos. The solid pumping station is important for the logistic by heavy snowfalls. The silos enable faster filling of spreaders because they allow several trucks to be filled simultaneously and the drivers can load without additional help or equipment.

5) Third party liability cases

For every salting route the standard order for the action is stored on a magnetic card. For the treatment the driver of the truck needs this magnetic card and during the action all the information of the treatment is stored on it. On each depot with liquid tanks there is a magnet card reader at the pump for liquid salt. When the driver put this magnet card in the reader the liquid salt tank opens, the pump starts working, fills the tanks of the salt spreader and the magnet card reader registers all the treatment information from the magnetic card. After the information is stored generated reports of this treatment action are available. This reports may be used as evidence in third party liability cases. This report standard comes from Germany.

6. DECISION MAKING PROCESS

The decision making process enables to accurately predict the start of ice formation and the moment to start the treatment action. The decision maker plans the treatment actions with the help of different systems (Table 3).

Table 3
Responsibilities

Resp.	Action	*System*, Manufacture
SMI[1]	Forecast for nine climatic domains	*Thermal map data, forecast model and RWIS:* Kelag AG, CH (Vaisala TMI Ldt., UK)
Telephone	Transfer of data	*Telephone, ISDN, SMS, Paging:* Swisscom AG, CH
Cantonal Decision makers	Reach data from RWIS, raincast, satellite and video picture when they need it; plan the treatment actions; agrees the plan, orders, controls and close the treatment action	*Raincast:* MeteoRadar Schmid, CH *Satellite picture:* SMI, CH *Video camera:* CBS Video CH *RWIS and Action information system:* Kelag AG, CH (Vaisala TMI Ldt., UK)
Private contractors	Cary out the action with the spreader and snowplough and fill the spreader with solid salt and/or liquid salt	*Spreader and Snowplough:* Boschung AG, CH (Küpper-Weisser GmbH, D); *Ice terminal:* Kelag AG, CH (Vaisala TMI Ldt.,UK) *Silos:* Haudenschild AG, CH (Holten, D); *Tanks*: Ruckstuhl AG, CH

The thermal map gives the location of the sites for the RWIS. As the France highway authority I preconized two sensors on each RWIS station.

The task of the SMI is to give a road weather forecast for the canton Lucerne over the winter period with a accuracy of at least 85% (5). Decisions as to close or reopen a road by snow storms and freezing rain are taken with the help of the video cameras system and of the Raincast system (an automated procedure for forecasting rainfall up to two hours ahead) (7). Every decision is stored on-line on the action information system.

The action information system for treatments with the salt spreader action appears simultaneously on the screens of the traffic police, the road inspectorate authorities, the decision makers and the maintenance center. They get automatic on-line supervision with standard process for all treatments of the salt spreader action. This system is automatically linked to the spreader with the ice terminal in the trucks.

All tasks are being tested for logic and duration by this action information system (6).

The organization of the snow blowers and of removing the snow from the side of the roads and the bicycle roads is not managed through the decision making process (6).

7. EXPERIENCE

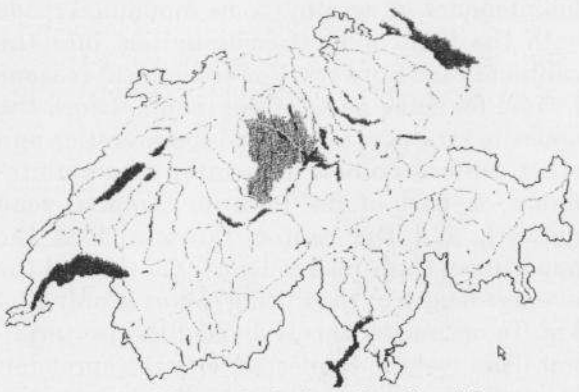

Figure 2. Map of Switzerland with canton Lucerne

The road network of the canton Lucerne ranges from 430 m to 1140 m height. In the following figures I show the new snowfall of Marbach 850m (a village in the south west of the canton of Lucerne).

The result of the winter maintenance activities is the quality control of the costs effectiveness, of the salt dosage, of the salt consume and of traffic accidents (Figure 4 to 7).

[1] Swiss Meteorological Institute

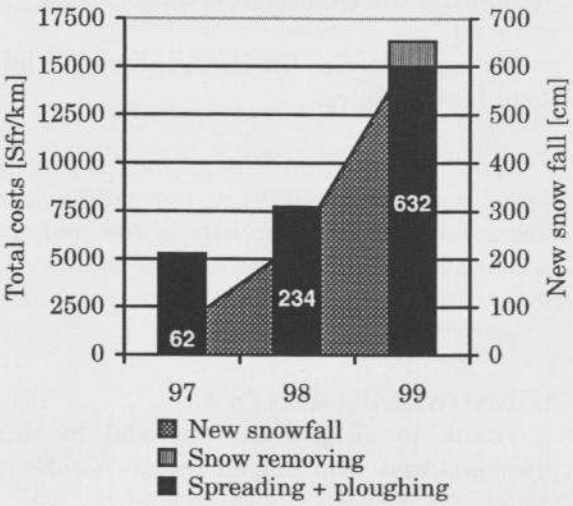

Figure 3. Cantonal road Winter maintenance total costs per km

The 1999 proved the cost effectiveness of the RWRM. In 1999 632 cm of new snow fell twice as fast as it need in 1998 for 252 cm of new snow.

To prove how efficient the winter maintenance is, I am registering since 1998 the treated pavement in m^2 for every action.

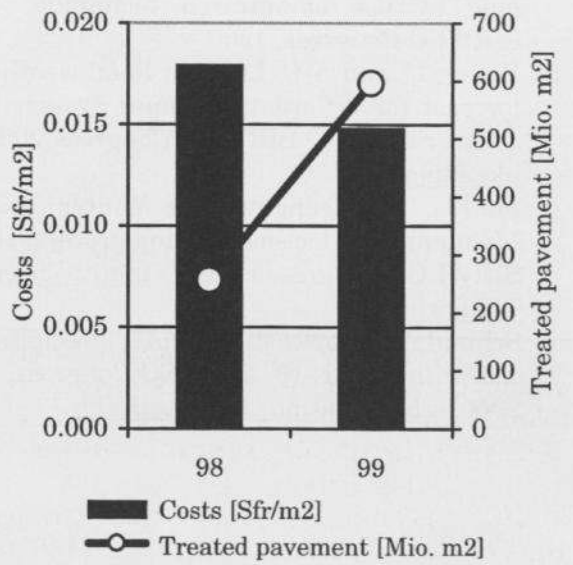

Figure 4. Winter maintenance costs per treated m^2

Planning the right action in the right time to avoid ice on the road reduces the winter maintenance costs.

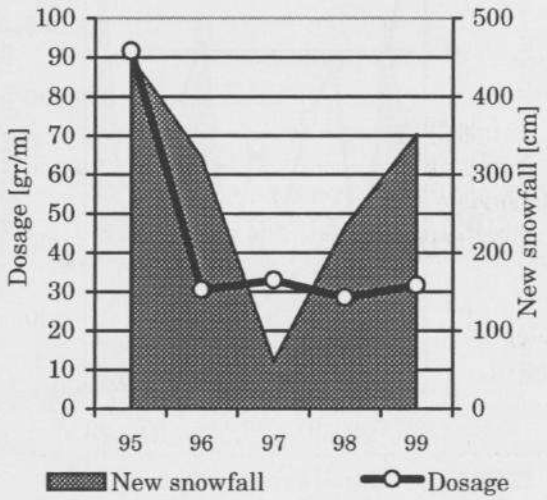

Figure 5. Salt dosage

It clearly shows the different strategy: more treatment actions and only half as much salt per action than before.

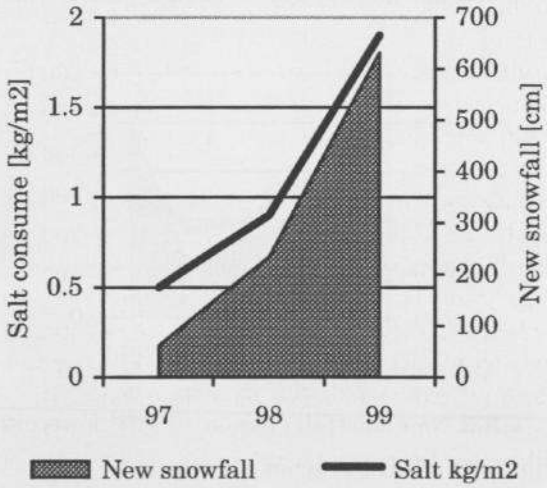

Figure 6. Salt consume

In 1999 with five heavy and long snowfall periods the salt consume reached 1,9 kg/m^2. The average salt consume for all actions in 1998 was 13,7 g/m^2 and 11,1 g/m^2 in 1999.

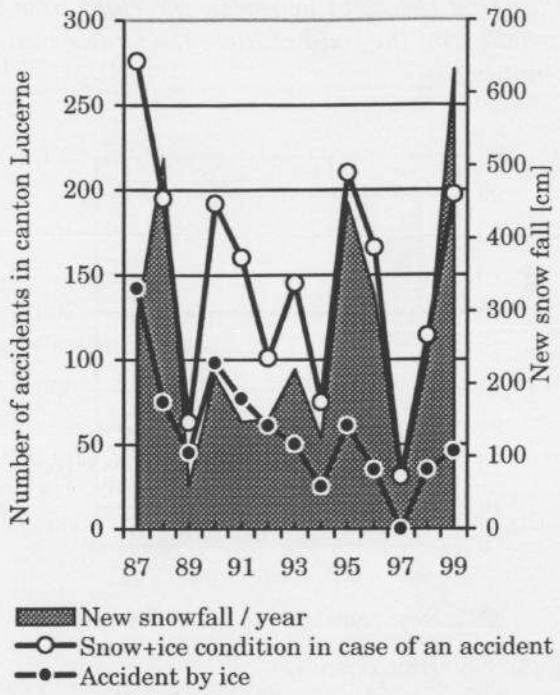

Figure 7. Traffic accidents (Source: cantonal police)

The traffic security has been increased up to ~50% by ice conditions since 1993. Snow is a great danger, but it can be seen by the drivers.

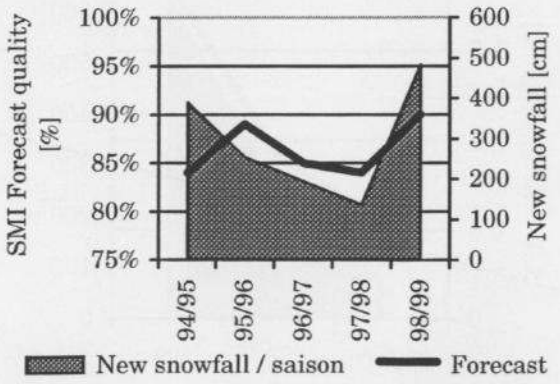

Figure 6. SMI Forecast quality

The better the forecast quality the better the planning of the treatment action.

My experience in the Reengineering Winter Road Maintenance:

Solid salt silos and tanks for loading the liquid salt are compulsory but maintenance centers are not. The capacity of the computer network designs the possible size of the road network.

ACKNOWLEDGMENTS

Thank to all persons involved in these processes and who helped me to realize my vision.

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