<table>
<thead>
<tr>
<th><strong>Project</strong></th>
<th>Road Marking Management System (RMMS)</th>
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<tr>
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<td>2020-07</td>
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<td>Statens Vegvesen (NO)</td>
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<td>Michael Ruben Anker Larsen, Vejdirektoratet (DK)</td>
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</tr>
<tr>
<td><strong>Scientific partners</strong></td>
<td></td>
</tr>
</tbody>
</table>

| **Report title** | RMMS Road marking management system Deliverable 4: Software implementation |

| **Summary** | In this report, the learnings from phase 1 to 3 in the project Road Marking Management System (or RMMS) is developed into a software environment and also tested with a reference group. Together with the results from previous work, a general asset management software called RIMS has been developed with added modules, functionalities and database structures for road marking data. The work concluded a software with the possibilities to visualize road marking performance as-is today, establish budgets and strategies, with deterioration models estimate upcoming years maintenance need and do multiple year maintenance planning based on a maximized efficiency. A reporting back function where also implemented by adding possibilities to extract maintenance plans to an in-field mobile device and report back the status on each maintenance section. |

The system where developed together with a reference group from Statens Vegvesen region East, Norway. The team consisted on two road marking operation managers and one regional project manager for pavements and road markings, namely:

| Torgrim Dahl (Project manager, pavements and road markings, Statens Vegvesen Region East) |
| Jon Haglund (Operations manager, road markings, Statens Vegvesen Region East) |
| Daniel Kristiansen (Operations manager, road markings, Statens Vegvesen Region East) |

<p>| <strong>Keywords</strong> | Road marking management system, RMMS, software implementation |</p>
<table>
<thead>
<tr>
<th><strong>Language</strong></th>
<th><strong>Number of pages</strong></th>
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</thead>
<tbody>
<tr>
<td>English</td>
<td>32</td>
</tr>
</tbody>
</table>
Contents

Background ........................................................................................................................................................................... 6
Prerequisites ................................................................................................................................................................................. 7
  Response variables .................................................................................................................................................................. 7
  Explanatory variables .............................................................................................................................................................. 8
  Functional limits ....................................................................................................................................................................... 9
  Deterioration ........................................................................................................................................................................... 9
  Strategies and workplans ...................................................................................................................................................... 10
Road Marking Asset Management Software ............................................................................................................................... 11
  System Components for RMMS ........................................................................................................................................... 11
  System Functionality and Basic Features for RMMS ................................................................................................................ 12
  Base map and network ........................................................................................................................................................... 14
  Input data .................................................................................................................................................................................. 14
  Analysis ................................................................................................................................................................................... 14
  Reporting ................................................................................................................................................................................ 14
Data structure .............................................................................................................................................................................. 15
  Road network ......................................................................................................................................................................... 15
  Input data ................................................................................................................................................................................. 16
  Response variables ................................................................................................................................................................. 16
  Functional data: ................................................................................................................................................................... 17
  Descriptive data .................................................................................................................................................................. 18
  Road marking related data .................................................................................................................................................... 18
  Image capture data .............................................................................................................................................................. 19
Road marking modules ................................................................................................................................................................. 20
  Statistics module .................................................................................................................................................................... 21
  Dynamic module for prediction of road marking functionality ............................................................................................ 21
  Module for unit cost ............................................................................................................................................................... 22
  Module for Calculation of Backlog ....................................................................................................................................... 22
  Module to present Planned Maintenance works .................................................................................................................. 23
Maintenance planning .................................................................................................................................................................. 23
  Analysis and creation of maintenance plans ........................................................................................................................ 23
Executing .................................................................................................................................................................................... 27
  Reporting output ................................................................................................................................................................. 27
  Module - Target sections for maintenance work plan for Y years ........................................................................................... 28
Reference test group feedback .................................................................................................................................................... 29
  General ................................................................................................................................................................................... 29
  How does it work today? .......................................................................................................................................................... 29
  Objects ................................................................................................................................................................................... 29
Background

The overall purpose of the RMMS project is divided into four parts

1. To develop and contribute dynamical road marking measurement methods of today.
2. To investigate suitable deterioration models for road markings
3. With the above, investigate suitable strategies, e.g. requirements for road marking quality in terms of functional performance
4. Integrate point 1-3 into an asset management system

The fourth and last part of the project is related to implementation and testing of outcomes in a software environment. This is to prove that project outcomes in phase 1 to 3 are realistic and to get feedback from a user group for functionalities, outputs and interactions. Below is a general scheme of the process from data processing to an actual worksplan for maintenance to be done. This process is of course repetitive, such as work done gets reported and updated with new data – and so on.

![Figure 1, from data to decisions](image)

The following key points have been pinpointed to understand and deploy:

- Description of the road markings in the area (type, amount, etc…)
- Condition state of road marking based on mainly dynamic measurements
- Understanding of functional development over area of interest
- Requirements, policies and standards applied
- Locations where repairs are needed for road markings
- Possibility to plan how to achieve the standards in a cost-beneficial way.
- User friendly solutions that are easily adopted by personnel who works with road markings daily.

Therefore, a reference group testing is very important.
Prerequisites

Response variables

The response variables are the functional variables describing road marking condition, which will also be the variables set for requirements. These parameters where mentioned in phase 1 of the project.

Table 1, response parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Greatness</th>
<th>Interval rate</th>
<th>Typical range</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL_{dry}</td>
<td>Nighttime visibility in dry conditions</td>
<td>mcd/m²*lux</td>
<td>Each 100 meters</td>
<td>0-2000</td>
</tr>
<tr>
<td>RL_{wet}</td>
<td>Nighttime visibility in wet conditions</td>
<td>mcd/m²*lux</td>
<td>Each 100 meters</td>
<td>0-400</td>
</tr>
<tr>
<td>Q_{D}</td>
<td>Daytime visibility in dry conditions</td>
<td>mcd/m²*lux</td>
<td>Each 100 meters</td>
<td>0-360</td>
</tr>
<tr>
<td>C</td>
<td>Coverage</td>
<td>Percent</td>
<td>Each 100 meters</td>
<td>0 - 100</td>
</tr>
</tbody>
</table>

In order for the above data to be traceable and also correlated with explanatory data, it must be stamped with:

- Location
- GPS coordinates
- Distance (from node) in meters
- Date and time of measurement

For any arbitrary interval.
Explanatory variables

Explanatory variables are needed to maintain one or more deterioration models. Explanatory variables are also needed to be able to implement functionality into strategy, regarding to for example road type etc. These are all the different parameters described from phase 2 of the project.

Table 2, Explanatory variables for deterioration model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Greatness</th>
<th>Averaged interval rate</th>
<th>Typical range / classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marking age</td>
<td>(days) from application</td>
<td>days</td>
<td>Each 100 meters</td>
<td>0-2000</td>
</tr>
<tr>
<td>Thickness</td>
<td>At application</td>
<td>millimeters</td>
<td>Each 100 meters</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Material</td>
<td>Type of material</td>
<td>thermoplastic, sprayplastic or paint</td>
<td>Each 100 meters</td>
<td>1-3</td>
</tr>
<tr>
<td>Road type</td>
<td>Road type</td>
<td>Number of lanes, separated or not separated.</td>
<td>Each 100 meters</td>
<td></td>
</tr>
<tr>
<td>Road class</td>
<td>Policy</td>
<td>Class Number</td>
<td>Each 100 meters</td>
<td>0-X</td>
</tr>
<tr>
<td>Structure</td>
<td>Structured or flat marking</td>
<td>Yes or No</td>
<td>Each 100 meters</td>
<td>0-1</td>
</tr>
<tr>
<td>P-class</td>
<td>From the Nordic certification system¹</td>
<td>Class</td>
<td>Each 100 meters</td>
<td>1-7</td>
</tr>
<tr>
<td>Linetype</td>
<td>Edge line, lane line or center line</td>
<td>Edge line, lane line or center line</td>
<td>Each 100 meters</td>
<td>1-4</td>
</tr>
<tr>
<td>Salting</td>
<td>Yes or No</td>
<td>Yes or No</td>
<td>Each 100 meters</td>
<td>0-1²</td>
</tr>
<tr>
<td>Plowing</td>
<td>Yes or No</td>
<td>Yes or No</td>
<td>Each 100 meters</td>
<td>0-1³</td>
</tr>
<tr>
<td>Curvature</td>
<td>Radius</td>
<td>r/1000</td>
<td>Each 100 meters</td>
<td>N/A</td>
</tr>
<tr>
<td>Contractor</td>
<td>N/A</td>
<td>N/A</td>
<td>Each 100 meters</td>
<td>N/A</td>
</tr>
</tbody>
</table>

¹ Reference European Norm EN 1824
² See comments in Discussion about salting
³ See comments in Discussion about plowing
Functional limits

For each single responsive/condition variable, a single or multiple variable limit(s) will be set to be able to monitor the requirement fulfillment and/or achievement of policy aims. Limits for the respective variables are set according to the policy of the road owner (National Road Agency).

For example, \( RL_{\text{dry}} \) could have the fix limit of 150 mcd/(m\(^2\)*lux) where anything above is thought as acceptable performance and anything below is set as non-acceptable performance. Or, a variety of limits could be set as multiple threshold limits, referencing to a strategy plan. The program should be prepared for both situations.

Also, a weighted combined value of the response variables will be needed, as:

\[
RMI = \sum_{i=0}^{n} \alpha_i \cdot P_i \beta_i \quad (eq. 1)
\]

Where

- \( \alpha_i \) = Weight alpha (i) for response variable \( P_i \)
- \( \beta_i \) = Weight beta (i) for response variable \( P_i \)
- \( n \) = number of response variables

\( RMI \) (Road Marking Index) will be another response variable in the system, which will also have requirements based on policy.

In the example in this report, the variable threshold limits where set to the below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Acceptance limit</th>
<th>Statistics (limit red – orange – light green – green)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL(_{\text{dry}})</td>
<td>150</td>
<td>130 – 150 – 200 - ( \infty )</td>
</tr>
<tr>
<td>RL(_{\text{wet}})</td>
<td>35</td>
<td>25 – 35 – 45 - ( \infty )</td>
</tr>
<tr>
<td>QD</td>
<td>130</td>
<td>120 – 130 – 140 - ( \infty )</td>
</tr>
<tr>
<td>SRT</td>
<td>45</td>
<td>40 – 45 – 55 - ( \infty )</td>
</tr>
<tr>
<td>C</td>
<td>70</td>
<td>40(^4) – 50 – 70 - ( \infty )</td>
</tr>
</tbody>
</table>

Deterioration

Phase 2 of the RMMS project related to road marking deterioration models. Machine models where constructed for each country, although no model for coverage was able to be achieved due to lack of data. The software adopted requires models to be linear and classified according to a scenario (for example right edge line, separated highway, 4000-5000 AADT). This means that a series of “master curves” can be constructed for specific scenarios.

\(^4\) There are no existing requirements for coverage today, leading to that this figure will likely be changed for future implementation. Limits where set for testing purposes only.
**Strategies and workplans**

A strategy for maintenance planning is defined by RMMS as where you combine three different fundamentals. *Performance, Budget and Policy.*

- Performance is the functional attribute, as in what extent the network meets requirements set by the user
- Budget is a single or multi-year cash limitation
- Policy and priority are the user weights some different explanatory variables with respect to maintenance, so that for example different road types get different prioritizing with respect to budget.

![Flow scheme](image)

Figure 2, Flow scheme

In RMMS, the **absolute backlog** of assets (meaning the amount of marking that are below a certain threshold at present time) is the key to understanding in what extent network is performing. The backlog will be for example the amount of road marking length in an area which is under specific requirements.

The network backlog, together with asset performance over time (in respect to the deterioration model) will be key to calculate maintenance need over time, hence also cost over time (with respect to worst sections first or based on lowest life cycle cost).

Analysis shall lead to workplans over where maintenance should be done. Contractors shall then report back what work they have done, contributed by new measurements to update databases with fresh information and hence also new analysis. See chapter 3.5 for more information about the process.
Road Marking Asset Management Software

The system used for test-integrating road marking data, visualizations and analysis modules is the Ram- boll RST developed web-based AM system RIMS (Road Information Management System). As this is a general program for handling a multiple set of infrastructural assets, a module for road marking data is developed separately.

System Components for RMMS

The system is made upon seven fundamental aspects:

1. Road network
2. Road marking functional and explanatory data
3. Condition results based on requirements
4. Strategies and priorities
5. Budgets
6. Analysis results based on point 1-5
7. Sections for maintenance works

Overall, the program scheme is constructed according to the below figure. Observe that RMMS is all of the below functions, but individual functions could very well be other interconnected systems, decided when building the system what is best suitable.

Figure 3 RMMS system components
The users have the possibilities to:

- Visualize network response and explanatory data on regional level and road class, down to individual 100 – meter segments.
- Report network response and explanatory data statistics (if numeric or conditional) on regional level and individual sub-regions.
- Analyze the maintenance need with respect to response variables and RMI? on a regional level and individual sub-regions.
- Set a budget for maintenance over X years, compensated for inflation rate on a regional level and individual sub-regions.
- Calculate maintenance work plans for X years and extract them for further use on a regional level and individual sub-regions.
- Report back work which has been implemented and add to system
- Add measurement data

Figure 1, RMMS server setup

**System Functionality and Basic Features for RMMS**

All data and user interface are provided for the user on normal web browser and RIMS functionality is based on Ramboll databases and GIS servers. This provides for the user a visual interface and easy to use tools to work with RIMS.
Possibility for different analysis is created with set of tools integrated in the user interface.

The user has possibility to browse:
- Network data
- Measurement data
- Deterioration modules
- Observation
- Visual inspection data

Conduct analysis according to:
- Deterioration models
- Budget policy
- Maintenance policies and priorities
- Time perspective

Report results according to:
- Statistics
- Condition prediction
- Backlog
- Target sections for maintenance works
**Base map and network**
The base map is a map layer which all data is projected against.

In this case, OpenStreet-map has been used in order to call for a base map.

It is also possible to **search** for an individual road, down to individual segments of road (e.g. searching for HP and kilometre of road E6). The smallest scale is therefore any arbitrary 100-meter segment, the smallest scale in the database.

Network gives the information system which all data will be referenced to. In this case, it is the Norwegian network system based on HP and km.

**Input data**
Descriptive data is data not directly pointed to road marking functionality but indirectly describes it and is useful when doing planning, and to understand circumstances on maintenance.

Functional data e.g. the response variables is the road marking performance data of road markings used to estimate the need for maintenance and overall performance against targets. This data is referenced to according the network and updated every 100 meters.

**Analysis**
Analysis module is used for doing analysis of maintenance need based on deterioration models and also to calculate the road marking index.

**Reporting**
Reporting functionality is based on the dynamic map with possibility extract data to *.csv (MS excel combability files) according to the user selections.
Data structure

Road network
Network implemented in RIMS is generated from supplied shape-files from NPRA and limited to the Region East. According to the NPRA’s road address system, it is divided into segments of road classes. The database classes consists of:

- Region
- County
- Road number
- HP
- Kilometer-post
- Coordinates

Example:

0100 Fv118 hp2
where
01 = fylke
00 = kommune
F = road class
v = road status
118 = road number
2 = hp

Figure 4. Road network and road address reference, down to 100m sections
Base unit is the road section (hp) and each road section is divided into 100m sections. All data and calculations are based on 100m sections.

Table 3. Structure in RIMS database for the road reference data

<table>
<thead>
<tr>
<th>Table name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>road_section</td>
<td>Contains information for road section: road number, hp number, carriageway, etc.</td>
</tr>
<tr>
<td>road_region</td>
<td>Contains region information</td>
</tr>
<tr>
<td>road_distance</td>
<td>Contains information for 100m section</td>
</tr>
</tbody>
</table>

**Input data**

Input data consists of three data sources:

1. Response variables e.g. Measurement / Inventory data
2. NVDB data (general road information)
3. Road marking related information

All data is connected to 100m sections classified and grouped. All data has also timestamp and this gives us possibility to follow the history and changes in data with RIMS database.

Table 4. Data structure for road markings

<table>
<thead>
<tr>
<th>Table name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rmms_linetype</td>
<td>Possible linetypes. Left edge line, Right edge line, centerline, lane line</td>
</tr>
<tr>
<td>rmms_material</td>
<td>Types of marking materials</td>
</tr>
<tr>
<td>rmms_deterioration_model</td>
<td>Contains calculate values for one row in deterioration models</td>
</tr>
</tbody>
</table>

**Response variables**

Response variables are classified for the analysis. Example of the data structure is presented in Table 5 and Table 6.

Table 5. Data structure for response variables

<table>
<thead>
<tr>
<th>Table name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>measurement</td>
<td>One measurement event for on 100m section. Contains data, time and information about measurement type (normal, control)</td>
</tr>
<tr>
<td>measurement_value</td>
<td>Measurement event’s value for one variable</td>
</tr>
<tr>
<td>variable_group</td>
<td>Variable group (Road marking condition)</td>
</tr>
<tr>
<td>variable</td>
<td>Variable name, type etc.</td>
</tr>
</tbody>
</table>

Table 6. Data structure for road marking condition data

<table>
<thead>
<tr>
<th>Table name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable_group</td>
<td>Variable group (road marking condition)</td>
</tr>
<tr>
<td>variable</td>
<td>Variable name, type etc.</td>
</tr>
<tr>
<td>variable_classification</td>
<td>Classification limits for variables used on statistic graphs.</td>
</tr>
<tr>
<td>variable_limits</td>
<td>Limits for variables which tells if the measured or predicted value is acceptable or not.</td>
</tr>
</tbody>
</table>

The user interface in RIMS for Input data
The following attributes has been deployed:

**Functional data:**

- RL(d) – retroreflection night-time dry condition
- RL(w) – retroreflection night-time in wet conditions
- Qd – luminance coefficient in dry conditions
- Friction – marking friction
- C - coverage

Functional data is accessible via the main panel.

---

Figure 5, Example of data groups, condition variables and NVDB data

Figure 6, main panel in system (right)
Descriptive data

Descriptive data is for example:

- Road width
- Road class
- AADT
- Speed limit
- Type of surfacing
- Street lightning
- Tunnel
- Intersection
- County
- Municipality
- Category
- Contractor
- Salting
- Plowing
- Linetype
- P-class
- Curvature

Descriptive data is accessible via the main panel.

Figure 7, visualisation module

Road marking related data

Additional Data is related to the marking itself:

- Marking age (days from application)
- Thickness at application
- Type of material
- Marking structure

Road marking related data is accessible via the main panel.
**Image capture data**

If measurements are delivered with a front facing image, the image gets connected to the specific interval measured. Thus, imagery can be called for by pressing a section of interest.

Figure 2, front-image module, section chosen is seen in the basemap
Road marking modules

The different modules that data will be processed through is both statistics, deterioration, handling of budgets and how to differentiate which sections to prioritize in order to get a functional work plan.

**Statistics module**
This module is targeted to summarize statistics (number of segments below requirements for the different functionality values and indexes – on both levels of region, county and down to specific road numbers. This will also be the base of the maintenance backlog, e.g. what target maintenance should be done against.

**Dynamic module for prediction of road marking functionality**
This module is made upon a series of master-curves for a series of circumstances. This module is used for estimating scenarios of maintenance plans to predict how the overall backlog will change with time.

**Module for unit costs**
In this module, the user inserts maintenance costs for different marking types and situations, in order to multiply the backlog with costs to get targets for budget propositions.

**Module for calculation of backlog**
This module is to be used for predicting backlog over time, for example how road marking functionality levels will change over time with a fixed budget.

**Target sections for maintenance works plan of Y years**
This module will highlight sections chosen for maintenance based on lowest life cycle costs. These sections can be handed to production and be changed by the user if certain conditions apply.
Statistics module

Statistics are presented with graphs and the user can choose presented areas, variables etc. In Figure 8 is presented how condition variable values fall into the predefined categories. Statistics are made possible for all functional road marking parameters. It is also possible to filter on specific regions/areas or individual road numbers or specific sections. Also, AADT in order to visualize demands according to national survey classing.

Figure 8, Example of statistic output

Dynamic module for prediction of road marking functionality

When predicting road marking functionality, every functional variable can be classed dependent on road class, road type, type of material, type of line, and AADT span. Then the equation is presumed to be linear (classified from deterioration models) according to:

\[ F(x) = i - k \times t \quad (eq. 2) \]

Where \( x \) = functional variable
\( i \) = initial value (either from measurements, or if repainted an initial default value is set)
\( k \) = yearly deterioration

Prediction rules can be set from user interface and are saved into the database. User can create rules based on variable, road class, line type and material and AADT.
In order to specify costs related to functional levels below a certain threshold, the overall approach is to have a base cost and a unit cost (such as base cost covers establishment costs of equipment and personnel) and a unit cost for markings (cost per kilometer).

Costs are segmented in a matrix based on:

- Type of material (thermoplastic, Spray, Paint)
- Road category
- Road class (1 lane road, two lane road or separated highway)
- Line type (Right/left edge line, lane line or center line)

**Module for unit cost**

A backlog shows how much funds is needed to repair all road marking segments that are under functional limits. Later, when a maintenance plan is conducted, the user can analyze how this backlog
changes over time. Here one can then see if the overall backlog increases, decreases or is steady-state over time.

![Backlog Calculation](image)

Figure 11. Results from the backlog calculation in RIMS. To the left is an output without any maintenance plan. To the right is a prognosis of backlog 2019-2024 with current maintenance plan (which for this instance was well beyond budget needed)

**Module to present Planned Maintenance works.**

This module will highlight sections chosen for maintenance based on budget and efficiency. These sections can be handed to production and be changed by the user if certain conditions apply.

The user can choose the planned maintenance works, study and revise it before sending it to production.

**Maintenance planning**

Planning the maintenance plan is the key functionality with RIMS. The planning itself is done year by year according to the chosen policy and deterioration models.

The choice of sections is based on the condition and policy settings and the user can choose the sections for maintenance works according the available budget.

**Analysis and creation of maintenance plans**

The user can create multiple maintenance plan scenarios.

Budget can be set to given year interval and each budget for each year can be set individually. Also, budget can be calculated based on inflation rate. Maintenance plan rule defines how selected budget is divided into different road classes. In this phase user can set how short sections are handled. If a short section is in bad condition but too short, it can be set to be not included in the maintenance plan. The other value defines that if there is an approved section between two disapproved sections, should calculation combine all of these into one section that is included.
Figure 12. User defined set up for maintenance plan. To the left one can see the input for skip/keep distance, so that minor intervals not connected to another maintenance section is skipped from the maintenance plan.

Figure 13. Example of skipped and combined sections.

Figure 14. 2 Steps in Maintenance Plan Analysis.
Creating maintenance plans is conducted in three steps. The first is to select which maintenance plan to use. Step two calculates predicted values for selected year. For the first-year values comes from measurements. For the following year prediction is calculated from last years predicted values using given formula for each variable. If the 100m section is included in maintenance plan for previous year all the variables for that 100m section will get a default value according to the initial value in deterioration models.

Calculation makes suggestion which road sections should be included in the maintenance plan. This suggestion is done based on budget and how the budget should be divided into different road classes.

**Calculation procedure is as follows:**

1. Define which 100m sections have at least one variable under the limit and is handled as in need of maintenance
2. Combine short section using given lengths
3. Merge 100m sections into longer homogeneous sections based on road class that are either in need of maintenance or not
4. Sort homogeneous sections by length
5. Add homogeneous sections into maintenance plan starting from longest. Loop if there are funds left on the budget. This phase handles both fixed price for road section and unit price for kilometer.

User can download prediction results as a .csv-file after calculation.

The third step includes the user. As the output is theoretic based on functionality, there are always situations where maintenance should be skipped or added on sections for other various reasons (such as planned pavement maintenance). When adding sections or skipping sections, there is a possibility to override the set budget.

<table>
<thead>
<tr>
<th>Table name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rmms_summary</td>
<td>Summary for each 100m section based on measured condition values. All the used parameters in one table.</td>
</tr>
<tr>
<td>rmms_summary_prediction</td>
<td>Summary of calculated values and parameters for each 100m section.</td>
</tr>
<tr>
<td>rmms_maintenance plan</td>
<td>Information about maintenance plan: name, years, used budget and rules</td>
</tr>
<tr>
<td>rmms_maintenance plan_section</td>
<td>Information about 100m sections selected into maintenance plan.</td>
</tr>
</tbody>
</table>
Figure 15, maintenance plan editor. User can manually add or skip sections by interacting with the map, or adding new ones in the table editor
Executing

Reporting output

One important aspect, when a maintenance plan is accepted, is of course to make sure that it can be communicated on the right way and reported back on progress to follow daily operations.

A module has been set up that can extract all data in the database including the maintenance plan in an excel-format, in order to use in reporting or other external programs. In the example below, we can see sections chosen, skipped or not included in maintenance. Each interconnected section gets a unique ID, so it can be tracked further in the process (seen as section_number). This could also be connected to any other ID the road owner is using to track maintenance.

![Figure 16, maintenance plan extraction in excel](image)

In the software environment specific sections can also be tracked, where the road identifier, line type, length, AADT and price per section is stated. Each year's maintenance plan gets a specific tab. If changes are done manually in the plan for current year, the rest of the years in the plan needs to be recalculated.

![Figure 17, maintenance plan viewer in software](image)
Module - Target sections for maintenance work plan for Y years

In order to be able to follow up sections in-field, a module for exporting the maintenance plan to a mobile application where made. The specific sections are transferred, together with data over the specific section chosen, such as:

**Status**

- Planned
- Ordered
- Pre-marked
- Washed
- Painted
- Q/A control OK
- Accepted

There is also a possibility to change what material was used for the maintenance action, and the applied thickness together with some comments. This material is then used to update the database.

Figure 18, RamApp mobile view for RMMS
Reference test group feedback

General

During the latter half of 2019, the software developed where piloted and tested against a reference group in Statens Vegvesen, Region East. The group consisted of two project managers for road markings and one general manager for both pavement and markings. The thought here where to both get input from a more strategic point of view, and at the same time input from the daily operations of work from a road owner.

How does it work today?

The reference group explained that inventory of road markings where done on the spring and autumn with ocular method and thereafter ordered for maintenance. This means that functional road marking data is not the basis for maintenance at present time and are only available on parts of the network, in connection with delivery and warranty controls. The general manager pinpointed that new methods for doing optimized maintenance based on objective measurement methods was of high priority – both to reduce operation costs, but also to get a better grip on the budget need.

The most fundamental aspect is that the collection of road marking function is not carried out for the purpose of performing annual maintenance, but only as a measure of work done in the regulation of contracts. At present, ocular inspection of the road network is carried out in the spring, which is then laid as a basis for maintenance to the contractor. The inspection is mostly based on the degree of physical wear of the markings, and less on the functional performance. The output is an estimated amount of maintenance as a percentage of a link.

It was in general clear that implementation of a system like RMMS will need to be conducted in steps, to allow time to change both how data is gathered and what is collected from different stakeholders.

Objects

Two objects where chosen as subjects for implementation in the tests, which has also been the illustrated subjects in this report:

Road Rv3 from Elverum to Tynset (HP 9 km 0 to HP 17 km 9.500)
Road E6 from Lillehammer to border Trøndelag (HP 6 km 0 to HP 21 km 3.400)

Feedback

The initial feedback from the testgroup was that the visualization module worked as expected, although there where a comment regarding better segmentation of the marking type in the visualization so that you could visualize multiple road markings at the same time. In order to do this, a fixed offset could be used from the center line of the road, projecting the left and right edge line with a fixed distance from the center one. When it comes to unit prices, there was a clear comment on that thickness of the marking was lacking. E.g. the unit prices is dependant on the ordered thickness of the road marking. This was thought to be dependant on the other factors such as road type and type of line, but there was a clear need to complement with this. This again states the importance to add this to a database – neither of the participating countries in this projects where aware of what thicknesses where situated where in a consequent manner. It is also vital that measurement vehicles are complemented with a inertial navigation system, as coordinates where lost in tunnels and therefore also the connection to the other data.
in databases. When it comes to statistics, the general thought was that the implemented was enough, although it exists different requirements on road markings in Norway dependant on the colour (white/yellow), which needs to be handled. This also means that a database needs to be complemented with the actual colour of the road marking, if this is applicable.
Conclusions

In this report, the process of how to integrate a road marking module within an existing asset management system has been evaluated, together with deploying respective parts in order to be able to go from data to decisions. One conclusion is that road marking is significantly different in terms of referencing, functional parameters, management options and strategies than pavements. It is therefore likely that any asset management system existing today will need to be altered from the basic structure and upwards in order to be fully functional for road markings. For example, road markings does not follow pavement lanes. A lane line could very well be situated on the far right lane, but the very same lane line could also be situated on the lane next to it. Therefore referencing of road markings must be specifically made for road markings. Another general conclusion regarding applicability is that the different stakeholders in road marking management (road owners, contractors and consultants) need to shift general ways how maintenance is conducted – especially when it comes to systematically gathering data needed in a structured way. For example, objective measurement data for road markings did not exist on all the network of the tested subject, hence input data was lacking for a full overlook of the network. Also, data regarding materials is generally lacking, such as thicknesses laid, type of material etc. The results concluded in this report shows that it is possible to in a structured and systematic way, gather the data needed, reference it to a network and conduct systematic and looping maintenance. The results of this report can be used for stating prerequisites needed for functional data gathering, descriptive data that needs to be accessible in national databases and strategies that can be adopted in road marking maintenance.

Discussion

During the work on developing and deploying an asset management system for road markings, there were some significant factors that created difficulties that could be worth mentioning for upcoming work. One factor is the network itself, where road markings needs a separate referencing in order to work properly. There are also describing factors for road markings that are hard to access through common databases, and some are not available at all. Focusing on the marking itself, the thickness of marking produced is not commonly uploaded to databases. Thickness plays a vital part in both estimation of unit costs, and also deterioration. It is important that this factor gets a standardized status as a measure to deliver in road marking contracts. Also, the road marking structure (type II or I) is not commonly stored. This also plays a part in estimating both unit costs and deterioration and should be reported in road marking contracts. Describing factors such as salt and plow-exposed sections are not common knowledge, but is likely affecting road marking deterioration significantly. These measures should also be delivered to a database in a common fashion. The level of resolution for salting and plowing does also need to get better. It is not sufficient to only know if the sections is plowed or salted during the winter or not, but needs to be segmented in frequency as well.

The table 2 in this document could be used in order to specify what explanatory factors in need for reporting in databases. Hopefully, this will facilitate for easier implementation of RMMS in the future.
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