The Wheel Profile Measurement System at Sunderbyn, Sweden: Final Report

Distribution list
The report is open for distribution within Trafikverket, LKAB and LTU. Each party is responsible for its own in-house distribution.
Acknowledgements

We would hereby like to extend special thanks to the following organisations which made this research project possible, both financially and intellectually:

- LKAB
- Trafikverket (the Swedish Transport Administration)
- Luleå University of Technology (LTU).

Furthermore, we would like to thank the following people who contributed to the preparation of this report:

- Thomas Nordmark, LKAB
- Matthias Asplund, Trafikverket
- Robert Pallari, LKAB Malmtrafik
- Per Gustafsson, LKAB Malmtrafik
- Dan Larsson, Damill AB
- Ramin Karim, LTU.
Summary

The background to the realisation of this project comprises an increasing number of rail replacements and an increasing volume of traffic with a 30-tonne axle load on the Swedish Iron Ore Line (IOL). When comparing the maintenance costs of all the different systems in the Swedish railway network, the maintenance costs for the track and wheels are by far the highest at present. The wheel profile measurement system (WPMS) was considered to provide the possibility of picking out wheels approaching the maintenance limits for wear and thereby of controlling maintenance in a more cost-effective way.

Accordingly, LKAB and Trafikverket (the Swedish Transport Administration) reached an agreement concerning the initiation of a joint project in which a new type of measurement equipment would be tested. To obtain assistance with data storage and processing, etc., Luleå University of Technology (LTU) and its eMaintenance Lab were engaged in the project.

The objective of the project has been to investigate and verify whether equipment for automatic wheel profile measurement is capable of registering wheel data and sending alerts concerning the passage of wheels which deviate from the safety and maintenance limits defined in the project, with regard to the climate and conditions prevailing along the Swedish IOL.

The fundamental idea behind this project has been that, through continuous measurement of wheel profiles, one should be able to take vehicles out of service before any deviating wheel profiles give rise to accelerating wheel and rail wear, and that one should thereby be able to reduce the maintenance costs and increase the operational life of both wheels and rails. An additional result of the project has been increased safety on the track, since it is possible to measure wheels that have exceeded the safety limit for wheel parameters and remove them, which was impossible previously.

The following conclusions can be drawn from this project.

- There are benefits to be derived from development projects conducted jointly between industry, infrastructure managers and academia.
- In order to ensure good results, it is important to perform all the steps in a project, from the concept phase to the handing-over phase. In support of this, the V-model was used, which represents the life cycle of the system according to EN 50126.
- The selection of a technical solution and a supplier was made on the basis of the technology level, reference installations, and operation and support possibilities, and not merely based on the price. A development project of this nature is not primarily a question of putting equipment into operation, but of transferring knowhow concerning the possibilities and limitations associated with the technology in question.
- The resource requirement for testing and evaluation was underestimated, which resulted in the project being delayed by one year compared with the original timetable.
- The information generated by the equipment installed is very useful for all parties working with the development of railway maintenance.
- The challenge with regard to utilising the benefits afforded by the measurement station at Sunderby lies in the ability to process the generated condition data for the maintenance organisations concerned and integrate these data in the operations of these organisations.
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1 Project description

1.1 Background

The background to the realisation of this project comprises an increasing number of rail replacements and an increasing volume of traffic with a 30-tonne axle load on the Swedish Iron Ore Line (IOL). When comparing the maintenance costs of all the different systems in the Swedish railway network, the maintenance costs for the track and wheels are by far the highest at present. The wheel profile measurement system (WPMS) was considered to provide the possibility of picking out wheels approaching the maintenance limits for wear and thereby of controlling maintenance in a more cost-effective way. An additional benefit envisaged was an improvement of the important wheel-rail contact, which influences the wear and fatigue damage of both wheels and rails; such an improvement would increase the operational life of both wheels and rails.

1.2 Objective and purpose

The factor that exerts the greatest influence on the degradation of the rails is the contact between the wheels and the rails, and 42.5% of the maintenance cost for railway infrastructure originates in the wheel-rail interaction (IHHA, 2009). As far as LKAB’s ore wagons are concerned, the wheel maintenance cost represents 50% of the total maintenance cost. With an increased axle load, it becomes more important that the wheels rolling on the track should have a profile that matches the rails. With an automatic WPMS one can control the wheel profiles so that they keep within the range of values (e.g. safety and maintenance values) that do not cause unnecessary wear of or damage to the rails. LKAB’s traffic alone subjects the IOL to a load from approximately 9,200 wheel passages per day.

The objective of the project has been to investigate and verify whether equipment for automatic wheel profile measurement is capable of registering wheel data and sending alerts concerning the passage of wheels which deviate from the safety and maintenance limits defined in the project, with regard to the climate and conditions prevailing along the Swedish IOL.

The fundamental idea behind this project has been that, through continuous measurement of wheel profiles, one should be able to take vehicles out of service before any deviating wheel profiles give rise to accelerating wheel and rail wear, and that one should thereby be able to reduce the maintenance costs and increase the operational life of both wheels and rails.

This document constitutes a report on the extent to which the project objective has been achieved and provides recommendations as to how this technology can be implemented in a normal production environment.

1.3 Project organisation

The project has been a cooperation project involving LKAB, Trafikverket (the Swedish Transport Administration) and JVTC (Luleå Railway Research Center). LKAB has been responsible for the purchase and installation of the WPMS and for the training of the personnel working with the measurement station. Furthermore, the measurement data from the installation at Sunderbyn have been collected, processed further and analysed at the eMaintenance Lab of Luleå
University of Technology (LTU). The eMaintenance Lab is intended to serve as a platform for decision support in maintenance through advanced information and communications technology.

Trafikverket has been responsible for placing the equipment, for the infrastructure and for the maintenance of the equipment. Within the framework of the eMaintenance Project, JVTC has collected and stored the measurement data and made them available to researchers and the participating partners for further analysis. LKAB and Trafikverket signed an agreement regulating the above-mentioned distribution of responsibility. The project has been of the FOU/FUD type and participation has been limited to one resource/project leader from each organisation. These persons have secured support internally within their own organisations for developments within the project, and have spread information about such developments within their respective organisations.

1.4 Limitations

The project has comprised the operational testing of a selected WPMS. Moreover, the project has been limited to one geographical area for the WPMS, i.e. the southern loop of the IOL, with the measurement station being located at Sunderbyn, close to the city of Luleå. In addition, the project has been limited to a temporary installation of the WPMS in the railway network, with a view to using the system to generate decision-support data for a possible permanent installation. The project has also considered the issue of how the data generated should be utilised in the maintenance and/or operation organisations of the parties concerned. However, the project has not been responsible for the actual utilisation of the data in the organisations of the parties concerned.

1.5 Project timetable

The table below presents the original timetable for the project and deviations from that timetable. For larger deviations, the planned date of completion is given in parentheses before the actual date of completion.

The biggest adjustments of the timetable were caused mainly by the fact that the test period was extended by 1½ years to make it possible to evaluate the reliability of the equipment during an additional winter.
Table 1: Project timetable.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date of completion</th>
<th>Org. responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project start</td>
<td>1/2/2010</td>
<td>LKAB, Trafikverket</td>
</tr>
<tr>
<td>Survey of suppliers</td>
<td>10/5/2010</td>
<td>Damill</td>
</tr>
<tr>
<td>Visits from suppliers</td>
<td>1/10/2010 to 19/10/2010</td>
<td>LKAB, Trafikverket</td>
</tr>
<tr>
<td>Purchase of equipment</td>
<td>1/5/2011</td>
<td>LKAB</td>
</tr>
<tr>
<td>Installation of infrastructure, incl. equipment cabin</td>
<td>30/9/2011</td>
<td>Trafikverket</td>
</tr>
<tr>
<td>Installation of the WPMS</td>
<td>15/10/2011</td>
<td>LKAB</td>
</tr>
<tr>
<td>Start of operational test</td>
<td>15/10/2011</td>
<td>Joint responsibility</td>
</tr>
<tr>
<td>End of operational test</td>
<td>(1/3/2012) 1/9/2013</td>
<td>Joint responsibility</td>
</tr>
<tr>
<td>Presentation of final report</td>
<td>(1/11/2012) 1/3/2014</td>
<td>Joint responsibility</td>
</tr>
<tr>
<td>Decision on possible continuation of operation</td>
<td>(31/12/2012) 1/6/2014</td>
<td>Joint responsibility</td>
</tr>
<tr>
<td>De-installation unless otherwise decided</td>
<td>(1/7/2013) 1/6/2014</td>
<td>Joint responsibility</td>
</tr>
</tbody>
</table>
2 The measurement results of the WPMS

The WPMS measures the profiles of railway wheels, and Fig. 1 shows a basic sketch of a wheel profile measurement (WPM) unit.

![Basic sketch of an automatic WPM unit.](image)

Certain wheel profile parameters are safety-related, e.g. the flange height, flange width and flange angle (see Fig. 2). It is important to have control of these parameters in order to promote sound finances, improved reliability and a high level of safety in the railway system.

At present these parameters are measured manually, which is time-consuming. It is therefore a great advantage to be able to measure the wheel profile parameters automatically during operation with the help of a WPMS. An additional benefit to be derived from a WPMS is that the data generated can be used for finding trends and predicting maintenance needs. Another field of application for the WPMS is taking stock of the whole wheel fleet and filtering out individual wheels which have exceeded or are close to the limit values.

![Wheel profile with the flange height (Sh), flange width (Sd) and flange angle (qR).](image)
2.1 System requirements

The specification of requirements for the system was written by Trafikverket and LKAB, together with Damill AB. The requirements can be summarised as follows:

- the system must be commercially available;
- the system version in question must be in operation in a similar climate;
- the system must measure the wheel profiles at line speed;
- the system must require a minimal level of maintenance and calibration;
- the data generated must be reliable;
- there must be a high level of equipment availability.

No specific numerical values were decided upon for each requirement, but rather the requirements were of both a qualitative and a quantitative nature.

2.2 Project realisation

Trafikverket was responsible for the planning, preparation and adaptation of the infrastructure. LKAB and the supplier (Beena Vision) were responsible for the installation of the system. The performance measurement, acceptance testing and functional evaluation were carried out by LKAB and Trafikverket. Trafikverket’s Investment Department was responsible for the project management for the preparation of the infrastructure, and for this assignment Trafikverket’s Department of Maintenance Development acted as the client. The system life cycle can be represented by the V-model from the EN 50126 standard (see Fig. 3). The system was installed by the autumn of 2011 and was then ready for the start of the operational test.

Figure 3: The V-model representing the life cycle of the system, according to EN 20126. 1=Trafikverket, 2=LKAB, 3=Supplier of the WPMS, 4=Damill AB, and 5=JVTC.
2.3 Operational testing 2011-2013

The operational testing of the system started in October 2011, after the installation, and lasted until the end of December 2013. During the operational testing, information on maintenance and calibration actions was logged from the system. In addition to performance tests, comparisons were performed on several occasions between measurements made with MiniProf equipment and measurements made with the WPMS.

2.4 Maintenance of the WPMS

The maintenance carried out on the equipment is shown in Table 2. Many of the actions may have been due to running-in problems and development of the system. Examples are the actions performed on the residual-current circuit breaker, and the installation of the web camera and the RFID reader. Service performed on the system is also included in the table.

<table>
<thead>
<tr>
<th>Date</th>
<th>Problem</th>
<th>Action</th>
<th>Time (h)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/12/2011</td>
<td>No current</td>
<td>Reset of residual-current circuit breaker</td>
<td>4</td>
<td>Fine-tuning</td>
</tr>
<tr>
<td>9/12/2011</td>
<td>Ditto</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>9/1/2012</td>
<td>Northern axle detector out of order; Rail heater disconnected</td>
<td>Fault localisation</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>10/1/2012</td>
<td>Southern axle detector out of order</td>
<td>Fault localisation</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>19/1/2012</td>
<td>Web camera</td>
<td>Installation</td>
<td>27</td>
<td>Installation</td>
</tr>
<tr>
<td>20/1/2012</td>
<td>Northern &amp; southern axle detector</td>
<td>Repair</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>23/3/2012</td>
<td>Northern axle detector out of order</td>
<td>Fault localisation</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>23/4/2012</td>
<td>Camera grabber card out of order</td>
<td>Fault localisation</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Problem</td>
<td>Action</td>
<td>Time (h)</td>
<td>Comment</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------</td>
<td>-----------------------------</td>
<td>----------</td>
<td>------------------</td>
</tr>
<tr>
<td>4/5/2012</td>
<td>Camera grabber card out of order</td>
<td>Repair/replacement</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>8/5/2012</td>
<td>Axle detectors out of order</td>
<td>Repair/replacement</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>11/5/2012</td>
<td>Axle detectors missing wheels</td>
<td>Adjustment</td>
<td>5</td>
<td>Fine-tuning</td>
</tr>
<tr>
<td>18/6/2012</td>
<td>RFID reader</td>
<td>Installation</td>
<td>20</td>
<td>Installation</td>
</tr>
<tr>
<td>31/8/2012</td>
<td>No Internet connection</td>
<td>Change of IP address in the router</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>13/12/2012</td>
<td>Annual service</td>
<td>Assisting Beena Vision</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>8/3/2013</td>
<td>Laser 1 out of order</td>
<td>Fault localisation</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2/4/2013</td>
<td>Laser 1 out of order</td>
<td>Assisting Beena Vision during repair</td>
<td>10</td>
<td>Bad contact</td>
</tr>
<tr>
<td>26/9/2013</td>
<td>Annual service</td>
<td>Assisting Beena Vision</td>
<td>16</td>
<td>Laser probably replaced</td>
</tr>
</tbody>
</table>

**Total time (h)**

| 154 |

### 2.5 Availability and reliability

The system availability was evaluated by compiling the results for the process rate (PR) parameter. This is a parameter which the system itself generates for every train passage and which informs us of the percentage of passing wheels which have been analysed in each train. The availability limit in the system is 70% and PRs under 70% are alarming rates. A compilation of train passages with alarming PRs is shown in Figure 4. This diagram has been split into two parts for increased readability and shows how many trains per day had fewer than 70% of their wheels analysed. These figures have to be considered in relation to the total number of trains on the stretch of rail, which was approximately 35 trains per day. Out of these 35 trains, around six trains per day were ore trains, of which three were loaded and three were empty.
There are four problematic periods with a low number of measurements and a PR under 70%: April 2012 (1), December 2012 (2), January-February 2013 (3) and March 2013 (4). The problem in April 2012 (1) can be linked to a camera that was not working (23/4/2012) and the problem in March 2013 (4) can be linked to a bad contact in a laser (8/3/2013) (see Table 2). On the other hand, the problem concerning the large number of trains missed during December 2012 (2) and January-February 2013 (3) could not be linked to any faults in the system. However, there was a great deal of precipitation during December 2013 and thus a large amount of snow smoke, which probably contributed to the low PR value. No general explanation for the poorer results obtained during January-February 2013 has been found, but snow smoke might be the reason for them too.

2.6 Measurement precision

The measurement precision of the system was evaluated by comparing measurements performed on four ore wagons using the MiniProf equipment with corresponding measurements using the WPMS. A total of 31 wheels were included in the measurement series. The results show that:

- the flange height, flange width and flange angle have different levels of precision;
- the flange height has the smallest mean value, while the flange angle shows the biggest difference between the MiniProf equipment and the WPMS.
Figure 5 shows a boxplot for the measurement errors for the flange height (1), flange width (2) and flange angle (3). A visual examination of the figure shows that all the mean values for the deviation are positive, that the spread is smallest for the flange height and largest for the flange angle, and that there is one outlier for the flange width and one for the flange angle.

Figure 5: Boxplot for the measurement errors for the flange height (1), flange width (2) and flange angle (3).

A summary of the statistics for the comparison between the MiniProf equipment and the WPMS is provided in Tab. 3. The largest standard deviation concerns the flange angle, which also shows the largest deviation for the mean value. The parameters belong to two different groups, group A and B, with the flange height belonging to group A and the flange angle belonging to group B. All the measurement deviations have a normal distribution.

Table 3: Summary of the statistics for the comparison of the measurements.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Measurement information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flange height</td>
</tr>
<tr>
<td>Mean value (mm)</td>
<td>0.02</td>
</tr>
<tr>
<td>Standard deviation (mm)</td>
<td>0.15</td>
</tr>
<tr>
<td>Circumference error included (mm) (^1^) [info accord. to XXXX]</td>
<td>0.151 [0.09]</td>
</tr>
</tbody>
</table>

\(^1^\) Out-of-roundness included in each parameter according to the literature (Fröhling & Hettasch, 2010)
2.7 The results related to the requirements

The requirements specified are of a qualitative nature, as a result of which there are no exact values indicating whether the results fulfil the requirements. The requirements are presented and commented on in Tab. 4, which also shows a simple quantification of the requirement fulfilment according to a scale of 1-5.

Table 4: Requirement fulfilment for the WPMS.

<table>
<thead>
<tr>
<th>No.</th>
<th>Requirement</th>
<th>Comments</th>
<th>Requirement fulfilment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The system must be commercially available.</td>
<td>This system can be purchased.</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>The system version in question must be in operation in a similar climate.</td>
<td>There are a number in operation in a similar climate.</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>The system must measure the wheel profiles at line speed.</td>
<td>It manages speeds up to 130km/h. It has problems med low speeds (below 40km/h). The supplier has an implementable solution to this.</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>The system must require a minimal level of maintenance and calibration.</td>
<td>The system requires a low degree of calibration and maintenance.</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>The data generated must be reliable.</td>
<td>From what we have seen, the system generates reliable data as far as the actual measurements are concerned, but there is a question mark concerning the missed measurements.</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>There must be a high level of equipment availability.</td>
<td>The system availability was not measured in the project, but is estimated to have been 90% during the testing period.</td>
<td>4</td>
</tr>
</tbody>
</table>

* Requirement fulfilment according to a scale of 1-5: 1=requirement not fulfilled; 5=requirement fulfilled completely
3 The value of the project (achieved compared with expected)

The project has shown that it is perfectly possible to conduct a joint project between a train operator and an infrastructure manager, at the same time as academia (through LTU) is involved. Moreover, it is the opinion of the project participants that the results were better than if there had only been one organisation owning the project. This is based on the fact that all the parties felt more involved and wanted to contribute their competence and their ideas in order to achieve the objectives and perhaps, in certain cases, to achieve more than the objectives. An additional advantage of such a development project is that the risks are shared, as a result of which the parties involved are more inclined to achieve the objectives of the project and urge each other to do so.

Furthermore, the measurement station exhibited a high degree of availability, after the initial trimming-in phase, as well as a low need for maintenance and service considering the complexity of the technology concerned. When maintenance actions were actually needed, the local service partner was fast and competent, which contributed to the high level of availability and the low operating costs.

The equipment met the requirements concerning the quality of the measurement data in the climatic conditions prevailing in the area in question. That we should miss readings owing to ice, the cold, and driving snow was a problem that we had reckoned with, but the results turned out to be better than expected and clearly passed the test.

It took a longer time than was first estimated for LKAB to use the wheel profile data within their operations. A certain amount of time elapsed before LKAB Malmtrafik started to utilise the information from the WPMS.

The use of information from the system in LKAB Malmtrafik’s operations during the project mainly concerned the use of warning reports (concerning maintenance limits exceeded) to bring vehicles in for maintenance. However, no extensive work has been performed to integrate the measurement station into the daily maintenance. This may have been partially due to the fact that LKAB Malmtrafik was waiting until its new maintenance system, Maximo, would be installed and operating, so that they could then integrate condition data directly via the system to create work orders.

4 Project results

When the WPMS detects worn wheels, it produces two types of alerts via email, namely warnings and alarms. Warnings are based on maintenance limits, while alarms are based on traffic safety limits. Two group mailboxes have been created at LKAB, one for warnings and one for alarms. The personnel at Kiruna and Malmberget have followed up these alerts and taken out wagons for wheel replacements. The maintenance engineers at LKAB have also had access to the mailboxes and, among other things, have performed follow-up checks of the alert values against measured values. LKAB have only followed up alarms (based on traffic safety limits), and no follow-up checks have been performed on warnings.
The WPMS has checked and reported on four different parameters: flange height, flange width, rim thickness and tread hollow (see Table 5).

Table 5: Warning levels and alarm levels for locomotives and wagons.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Warning Levels</th>
<th>Alarm Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower level</td>
<td>Higher level</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Flange Height</td>
<td>Fanoo: N/A</td>
<td>Iore: N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flange Width</td>
<td>Fanoo: 22.5</td>
<td>Iore: 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tread Hollow</td>
<td>Fanoo: N/A</td>
<td>Iore: N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rim Thickness</td>
<td>Fanoo: 23.5</td>
<td>Iore: 65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The rim thickness was a problem in the beginning and gave many false alerts. The reason for this was that normally the rim thickness is measured on the outside of the wheel, while the WPMS measures the thickness on the inside of the wheel at the flange. After this problem was remedied, the measurements of the rim thickness became reliable.

The delivery from Beena Vision included an analysis tool called “Wheel Query”, which gives the user access to all the measurement data from the “Wheel View” system. The following are examples of features of the “Wheel Query” software:

- search functions for data for each wheel or wagon, based on the parameters reported for each wheel;
- export of text files in the PDF and Excel format (other formats can be added);
- graphic representation of measured wheel profiles and the data belonging to them;
- overlay of the profiles of the same wheel measured during a certain period of time, for the purpose of wear analysis;
- trends for profile data collected during a certain period of time or over a certain operating distance;
- comparison of wheel data with standard profiles.
LKAB has unfortunately not been able to use this tool, since it must be installed on the database which stores the results from the WPMS. During the project period the data have been stored at both Beena Vision and LTU, as a result of which LKAB have not been able to produce statistics and carry out follow-ups. This is also part of the reason why it has only been possible to follow up the alarms, which are based on traffic safety limits, because follow-up checks of wear and other parameters are very time-consuming without access to “Wheel Query” or some similar program.

LTU has used “Wheel Query”, but considered it too limited for their activities and instead developed their own application for the analysis and presentation of data. Towards the end of 2013 the supplier developed a web-based version which LKAB has been given a quote for. This application is connected to data stored at Beena Vision in the USA.

As far as LKAB is concerned, the benefits gained from the WPMS have been limited, since “Wheel Query” has not been available for following trends and extracting statistics. Nor has it been practically possible to compare results from the WPMS with results from the track force measurement performed at Sävast about 10 km from the WPM unit. However, the reporting of worn wheels has worked well and provided us with a good picture of the current situation. It has been possible to detect wheels that have exceeded the set maintenance limits and bring them in quickly for maintenance. For further justification of continued operation of the WPMS, “Wheel Query” or some other equivalent database management system should be utilised to connect the results directly to Maximo, the maintenance system of LKAB Malmtrafik.

5 Experience gained and lessons learned from the project

5.1 Project management function

The project has been conducted as a joint project involving LKAB and Trafikverket, with LTU acting as a supportive resource. Each party had its own project leader, who was responsible for and led their part of the project. For example, LKAB purchased the equipment and installed it, as well as training personnel, etc. Trafikverket was responsible for preparing the site and providing an equipment cabin, the power supply, data communication, etc., while LTU was responsible for setting up an IT environment where all the data would be stored etc.

The project management and coordination were then carried out through regularly held project meetings and follow-up meetings. Each project leader secured support for the project and disseminated information in their own organisation. There was no formal steering group or reference group. On the other hand, project participants demonstrated the measurement station and the WPMS to both external and internal interested parties on several occasions.

5.2 Finances

Tab. 6 and 7 below present the costs which LKAB and Trafikverket have had for this joint project. In the implementation agreement signed by both parties, the intention was to apportion the costs relatively equally, while still delimiting the responsibility for the different parts of the
project. A compilation of the project costs shows that the total cost was SEK 6.9 million, which was shared 60:40 between LKAB and Trafikverket.

Table 6: Project costs for LKAB during the period 2011-2013.

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Cost amount (SEK)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement equipment</td>
<td>3,724,270</td>
<td>Beena Vision + Customs</td>
</tr>
<tr>
<td>Support + peripheral equipment</td>
<td>400,611</td>
<td>Damill + Transcore</td>
</tr>
<tr>
<td>eMaintenance Lab</td>
<td>100,000</td>
<td>LTU</td>
</tr>
<tr>
<td>Project administration</td>
<td>283,120</td>
<td>Participants’ own time + current operating costs</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,508,001</strong></td>
<td><strong>Budget SEK 5.5 million</strong></td>
</tr>
</tbody>
</table>

Table 7: Project costs for Trafikverket during the period 2011-2013.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost amount (SEK)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>2,318,943</td>
<td>Mainly investment costs</td>
</tr>
<tr>
<td>2012</td>
<td>148,554</td>
<td>50% investment – 50% operation and maintenance</td>
</tr>
<tr>
<td>2013</td>
<td>47,697</td>
<td>Operation and maintenance</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,515,194</strong></td>
<td><strong>Operation and maintenance</strong></td>
</tr>
</tbody>
</table>

5.3 Challenges and unresolved issues

In the implementation agreement signed by LKAB and Trafikverket prior to the project, there is a clause stating that a decision is to be taken as to whether the operation of the measurement station is to be continued or terminated when the project has been completed. This decision has to be taken in the near future. Moreover, the parties should also come to an agreement concerning the issue of ownership and utilisation. At present the actual equipment is owned by LKAB, while the actual infrastructure is owned by Trafikverket. In addition, the right to the condition data is reserved to LKAB, Trafikverket and LTU at present.

5.4 Benefits of the project

The operative maintenance personnel at LKAB Malmtrafik have been very pleased with the results which they have been able to use to render the maintenance of wheels more efficient. Those wagons whose wheels have been worn faster than planned have generated warnings when the maintenance limits for the wheels have been reached and the wagons have then been
brought in for inspection. As a result the wear has not had time to pass the safety limits and expensive wheel axle replacements in the field have thereby been avoided.

The following benefits have been derived from the project.

- Unique and important knowledge has been obtained concerning the reliability, availability and measurement accuracy of the WPMS. The system has been improved, shortcomings have been identified and proposals for further improvement have been recommended for the WPM unit.
- Furthermore, the project has tested the possibility of conducting a joint-project in which the infrastructure manager and a train operator share the financing and the risks and at the same time derive full benefit from the system.
- The project has revealed the complexity of handling the large quantity of data in question.
- The project has elucidated which wheel profile parameters are associated with the lowest and highest tolerances.
- The project has developed a good cooperation with the equipment supplier.
- The project has revealed a potential for developing the maintenance of both vehicles and infrastructure with the help of data from the WPMS.

In addition to the above-mentioned benefits, our competence has been improved concerning measurements in a railway environment in general, and measurements of wheels in operation in particular; this applies to all the parties involved in the project, Trafikverket, LKAB, LTU and the maintenance contractors. The project has advanced the research front in this field through the presentation of many research papers at conferences and the publication of many research articles in scientific journals (see Section 6.2).

6 Research generated by the project

6.1 Connection to research

The project has been conducted in close cooperation with LTU, which has resulted in a sound and stable evaluation of the equipment, showing the reliability, availability and measurement accuracy of the WPMS. Moreover, shortcomings have been identified, and proposals have been recommended for further improvement of the system. To accomplish this, tools and competence from the world of research have been utilised.

6.2 Publications resulting from the project

The following is a list of publications which either completely or partially concern the WPMS.


7 Proposals for improvement

At present there is no analysis tool for performing follow-ups and maintenance planning, as a result of which one has to concentrate only on alerts triggered by values that exceed the maintenance and/or traffic safety limits. Such an analysis tool could, for example, be designed as a web application with a reporting function and export to Excel. In order to develop, optimise and forecast wheel maintenance, it is necessary for the data to be handled and processed in a suitable manner, especially when large quantities of data are concerned, as in the present case.

The system’s protection against objects knocking into the equipment or against damage from some other source can be improved by providing the contractors concerned with better information. The system also needs to be lowered so that it will be placed 50 mm under the running surface of the rail to prevent road-rail vehicles damaging the equipment.

To enhance the benefit from the WPMS and understand better how wheel profiles influence the track, the results from the track force measurement unit at Sävast should be connected to the results from the WPMS.

Install vibration measurement equipment and connect it to the WPMS, so that the vibrations can be followed up to provide indications as to when the track under the system must be tamped.

Implement an adaptive algorithm to make it possible to measure vehicles at low speeds.
8 Conclusions

The conclusions that can be drawn from this project are as follows.

- There are benefits to be derived from development projects conducted jointly between industry, infrastructure managers and academia.
- In order to ensure good results, it is important to perform all the steps in a project, from the concept phase to the handing-over phase. In support of this, the V-model was used, which represents the life cycle of the system according to EN 50126.
- The selection of a technical solution and a supplier was made on the basis of the technology level, reference installations, and operation and support possibilities, and not merely based on the price. A development project of this nature is not primarily a question of putting equipment into operation, but of transferring knowhow concerning the possibilities and limitations associated with the technology in question.
- The resource requirement for testing and evaluation was underestimated, which resulted in the project being delayed by one year compared with the original timetable.
- The information generated by the equipment installed is very useful for all parties working with the development of railway maintenance.
- The challenge with regard to utilising the benefits afforded by the measurement station at Sunderby lies in the ability to process the generated condition data for the maintenance organisations concerned and integrate these data in the operations of these organisations.

9 The future

The installation of a WPM station in the northern loop of the IOL would result in a more comprehensive system and mean that vehicles with poor profiles could be taken out of service more quickly and safely. Most of the trains run in the northern loop and in many cases the vehicles run in the same loop for longer periods of time. The statistics show that LKAB’s vehicles run in the northern loop during 70% of their operational time.

A WPMS in the northern loop would also offer the possibility of seeing differences in wear between the different loops. At present both the loops are treated in the same way with regard to rail and wheel profiles, but perhaps different profiles should be used owing to differences in geometry and traffic between the loops. This mainly concerns the rail profiles.

The further development of the maintenance plan and the provision of spare parts for the measurement equipment can be improved, for example by inspecting the equipment more frequently, adapting necessary maintenance actions and keeping more critical spare parts in store based on the experience gained from the operational test.

The placement of the database and access to data are issues that one needs to look into. How and where should the data be stored? Should one be able to fetch data or should they be sent, and, in that case, who should send them? The project participants have not been able to make a
recommendation as to who should do what, but rather choose to leave this matter for the maintenance organisations of Trafikverket and LKAB to deal with.

A connection to Maximo, the maintenance system of LKAB Malmtrafik, and/or the ATI system is a measure that may be considered in the future and may result, for example, in automatically generated work orders and the import of current key values, etc.

At present the system does not have a special socket for an RFID reader of the GS1 type. This can be solved either by providing the system with its own additional aerial and software, or by importing reader information from other reader sites. We apply the latter solution today, in that the Sunderby station receives RFID data from the measurement station at Sävast, which utilises both types of readers. The data are at present joined together in LTU’s database, not in the WPMS.

The axle detectors used at present are relatively sensitive to mechanical influence. It would be preferable in the long run to replace them with Trafikverket’s standard axle counters (made by Siemens).

In future systems the hollow steel sleeper housing the camera should, if possible, be placed lower to avoid the risk of objects knocking into it. The sleeper should also be provided with a corrugated (or course-grained) surface to decrease the settlement over time.

10 References

