Jukka Leinonen

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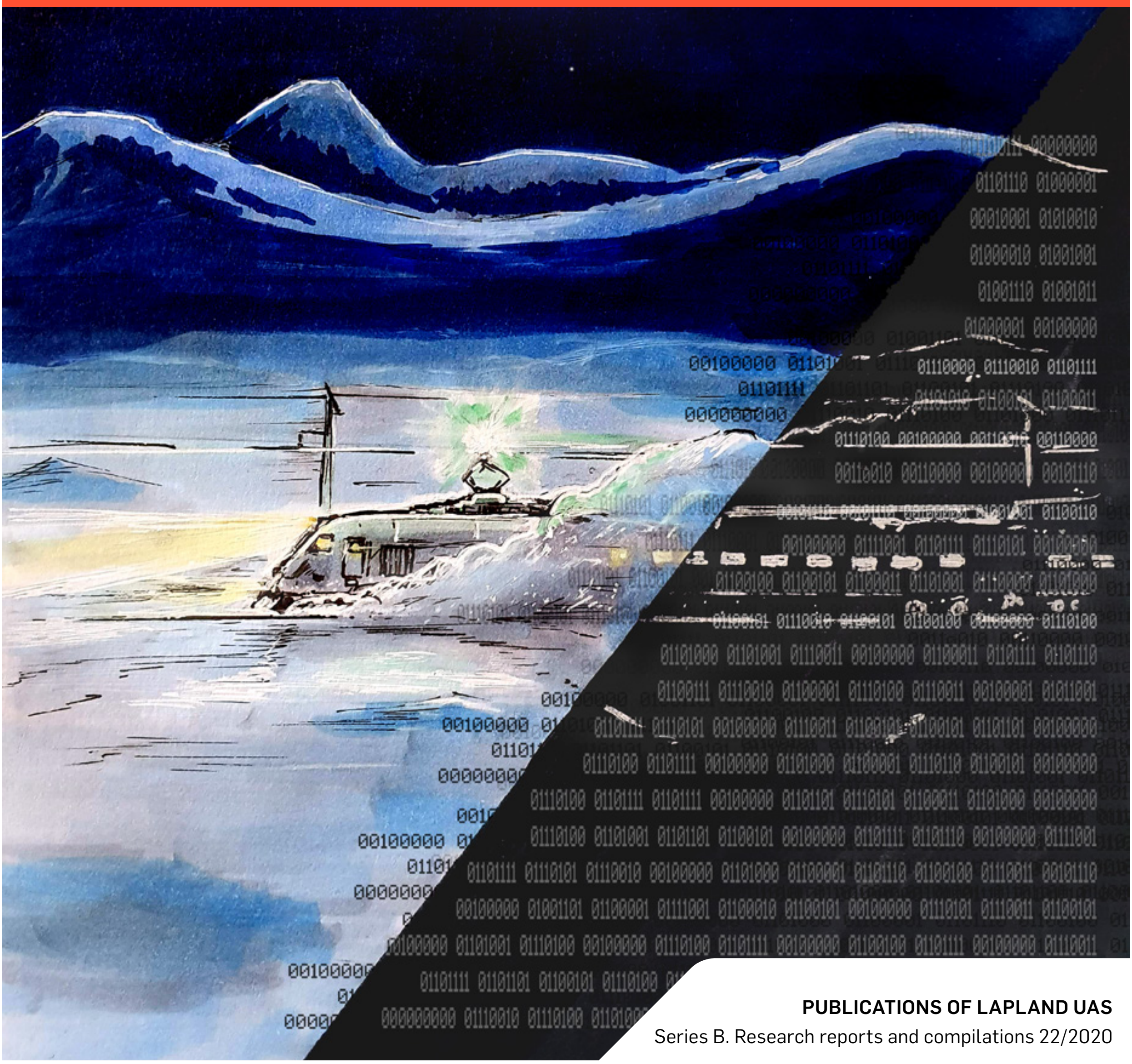
Wayside Rolling Stock Monitoring and Railway Inspection in Finland



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1. Introduction

Nowadays, there is an increasing demand for railways to be better utilized through heavier, longer, faster and more frequent trains. This means that the railway infrastructure must be designed, maintained and monitored in such a way that people and goods are delivered on time, all year round. Railways also play a key role in the Kolarctic region in transporting ore, minerals, timbers, goods and passengers. The Kolarctic region includes northern Norway, Sweden and Finland, as well as northwestern Russia.

Increased traffic and higher axle weights will cause more track wear which means more frequent faults and extensive maintenance requirements. Improved uptime and punctuality will require increased use of more efficient monitoring and measuring systems, so that errors and unwanted accidents can be uncovered earlier, and that maintenance and repairs operations can be carried out at the right time and in a more cost-effective way.

Arctic Railway Infrastructure in Kolarctic II (ARINKA II) project aims to develop a cross-border railway research and development collaboration between countries in the Kolarctic region. Another goal is to exchange railway technical know-how and best-practice solutions with the goal of making the Kolarctic railways more reliable through robust infrastructure solutions, more cost-effective maintenance and repair operations, and effective infrastructure monitoring and advanced sensor technologies. The project is financed by the Kolarctic CBC 2014–2020 Programme with co-financing by the EU, Finland, Norway, Russian Federation and Sweden. The project will be carried out between 2018 and 2021.

The ARINKA II project involves SINTEF Narvik AS, Luleå University of Technology, Lapland University of Applied Science, Emperor Alexander I, St. Petersburg State Transport University and Kola Science Center of the Russian Academy of Sciences. The project also involves the railway companies from each country, i.e. Bane NOR, Trafikverket, Finnish Transport Infrastructure Agency and October Railway.

In order to exchange know-how and best practices, a survey was conducted on the railway infrastructure monitoring and advanced sensor technologies in use in the Kolartic region. This publication is the result of the survey and provides an overview of the railway monitoring and sensor technologies used in Finland in 2020. Chapter 2 describes wayside rolling stock monitoring systems and chapter 3 describes the railway inspection measurements.

2. Wayside Rolling Stock Monitoring Systems

Figure 1 shows the rolling stock monitoring equipment on the Finnish rail network in 2020. The rolling stock is monitored by hot bearing, wheel load and pantograph detectors. To identify the rolling stock, it is equipped with a remote-readable RFID tag that is read at a height of 500 to 1100 mm from the back of the rail. The RFID tag can be used to quickly assign detection information to the correct rolling stock and its maintainer. (Liikennevirasto, 2018b, Liikennevirasto, 2014) The following sections provide more detailed information about the monitoring equipment.

2.1 HOT BEARING DETECTOR

Hot bearing detectors (figure 2) are an essential part of the rolling stock control on the Finnish rail network. Hot bearing detectors use infrared beams to measure the surface temperatures of the bearing inner and outer rings. The bearing inner ring measurement sector is 18 mm and the outer ring is 120 mm. Overheated bearings and sticking brakes can be detected by increasing temperature. An overheated bearing will eventually seize, resulting in axle overheating which can lead to axle failure and derailment. (Junnikkala & Untinen & Haataja, 2016)

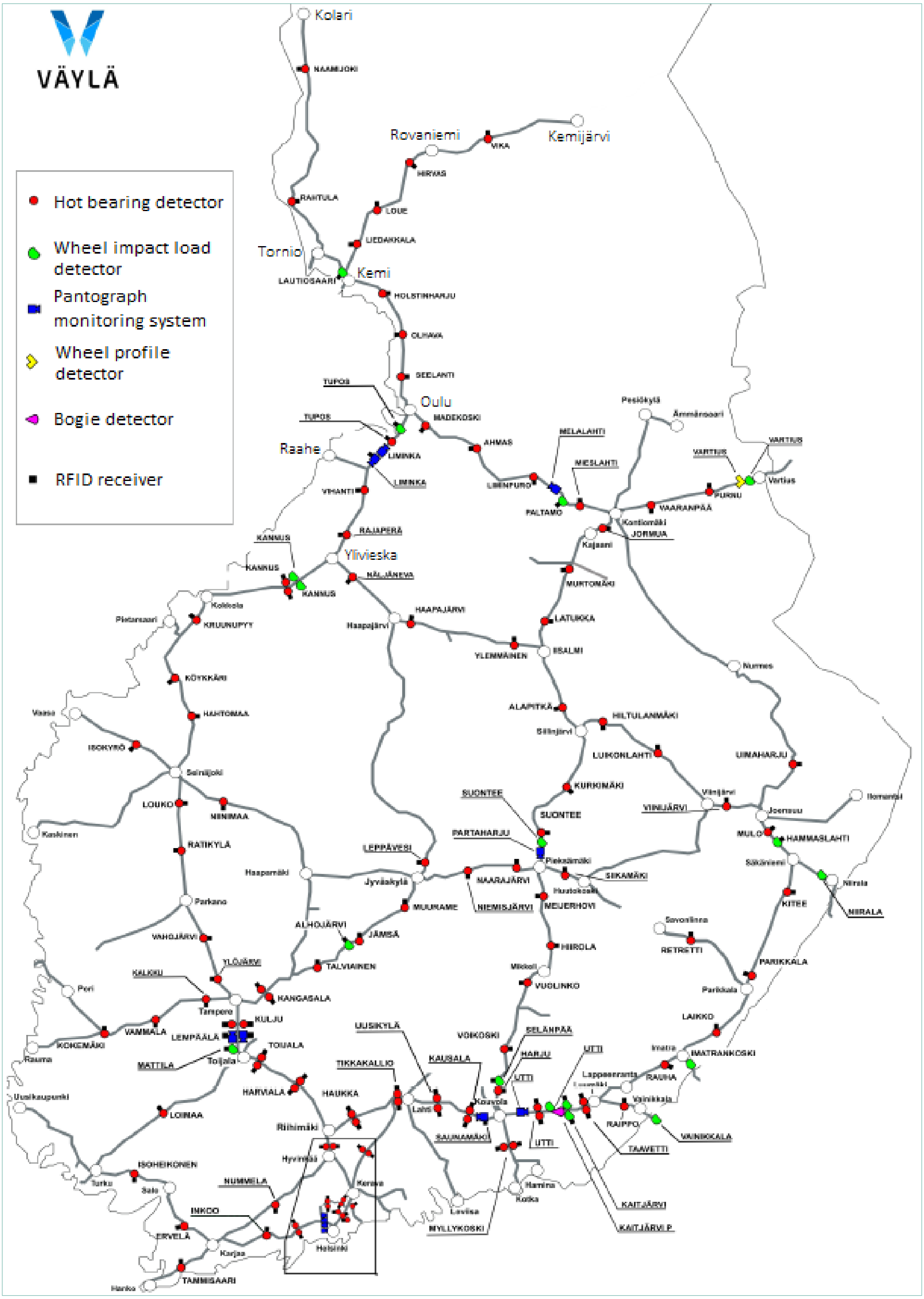

Figure 1. Rolling stock monitoring systems on the Finnish rail network in 2020. (Liikennevirasto, 2018b (modified by Leinonen, J.))

Figure 2. Hot bearing detector. (Liikennevirasto, 2010)

The hot bearing detector measures the bearing surface temperature several times in the direction of rolling stock movement. The measurements are used to form a temperature matrix of the bearing temperatures. Figure 3 shows two examples of the temperature matrix of the bearing causing the alarm. In the upper picture, all measurement results for the right-hand bearing in the shaft have increased significantly, almost to the maximum limit of the detector (150 °C). In the lower picture, the bearing inner ring temperatures have increased. In addition to bearing failure, this may be due to for example sticking brakes. (Junnikkala & Untinen & Haataja, 2016)

Figure 3. A temperature matrix is formed from the measurement results of the hot bearing detector (Liikennevirasto). (Junnikkala & Untinen & Haataja, 2016)

The hot bearing detectors are installed on the rail network at intervals of about 50 km. The installation distance may be greater for sections of track with maximum permitted speed less than 160 km/h. There are 86 measuring stations on the Finnish rail network with 105 hot bearing detectors installed. Track mounted sensors detect the arrival of rolling stock and activate hot bearing detectors. The rolling stock that has passed a measuring station is identified by an RFID tag. The measuring station also measures the speed of the rolling stock before and after the measuring station, so that braking situations that could distort the measurement results can be identified. (Liikennevirasto, 2018b, Junnikkala & Untinen & Haataja, 2016)

The measuring station thus measures the bearing temperatures, analyzes the measurement results and, if necessary, forwards alarms to the Finrail's Technical Control Centre as well as to the traffic control of the railway line section in question. The detectors have their own alarm limits for different types of rolling stock, so that individual limits can be set for the bearings. In this case, monitoring is as effective as possible without unnecessary alarms. There are four different alarm types and two alarm levels, warm and hot bearings. (Liikennevirasto, 2018b, Junnikkala & Untinen & Haataja, 2016)

Figure 4 shows a function diagram of hot bearing detector alarms. In the case of a warm bearing, the traffic control, together with the railroad engineer, shall determine the next possible checkpoint up to a maximum speed of 50 km/h. In the case of a hot bearing, the traffic control orders the train to stop immediately. (Liikennevirasto, 2018c)

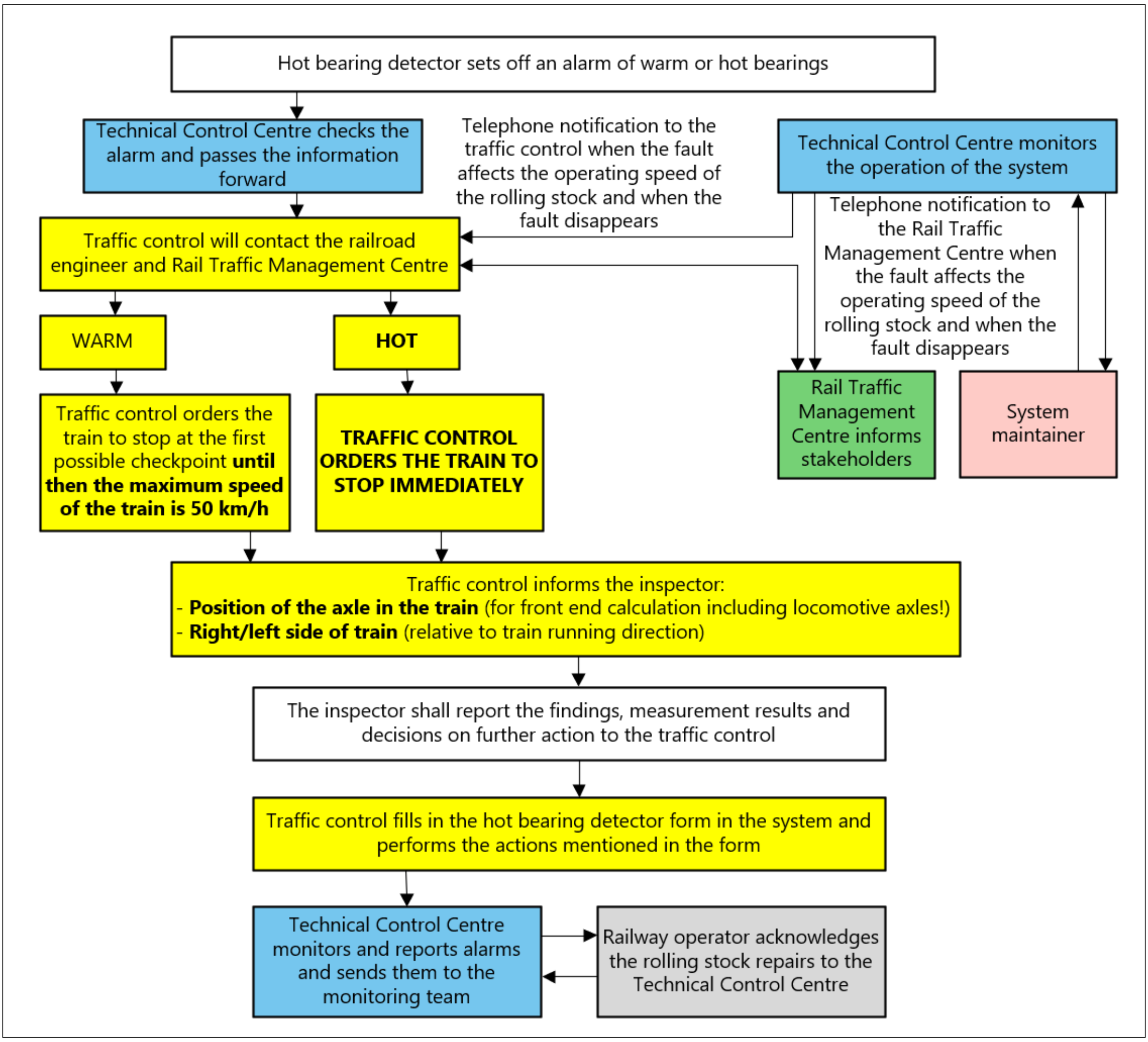

Figure 4. Functional diagram of hot bearing detector alarms. (Liikennevirasto, 2018c (translated by Leinonen, J.))

If the hot bearing detector does not work, the traffic control receives information from the Finrail's Technical Control Centre. The traffic control shall impose a temporary speed limit of 160 km/h from the last active measuring station to the next active measuring station. (Liikennevirasto, 2018c)

2.2 WHEEL IMPACT LOAD DETECTOR

High speeds, heavy loads and challenging weather conditions make rolling stock wheels tough. They may develop flat spots due to locked brakes, which makes the wheel wear out of roundness and causes damage on the rolling stock and the rails. Material defects or steel fatigue may also cause pieces of the wheel to come loose. (Tamtron)

A flat spot or tread cracks on a wheel's running surface hit the rail on each revolution and the wheel bearings are also subjected to an equivalent force. When this continues long enough, the bearings start to break and finally jam. In the end, the axle may break and derail the train. In addition, at extremely low temperatures, the rail develops such high stresses that when a flat spot hits, the rail may even break, which may result in safety equipment failures, traffic disruptions and accidents. (Tamtron)

The wheel impact load detector detects wheel defects by measuring the static and dynamic load from the wheel to the rail. Sixteen wheel impact load detectors have been installed on the Finnish rail network as comprehensively as possible. The detectors are mounted on the track (figure 5) and so that the rolling stock crosses at least one detector on its regular routes at least once. The measuring system will turn on when the train arrives and will measure every rolling stock, i.e. locomotive or wagon, fully automatically. The measuring system identifies the rolling stock with the RFID tag. This information can be used to track the progress of a single wheel defect. Wheel impact load is measured over a distance of about 6 meters, ie two complete rounds, and it is possible at the speeds of 20 to 250 km/h. (Liikennevirasto, 2018b, Liikennevirasto, 2018a, Tamtron)

Figure 5. Wheel impact load detector. (Liikennevirasto, 2014)

Figure 6 shows the results of the wheel impact load detector. The figure graphically shows the force of the impact of the wheel from two turns and the maximum force. The figure also shows wheel-specific masses for wagon and axle-specific overloads and loading errors. (Tamtron)

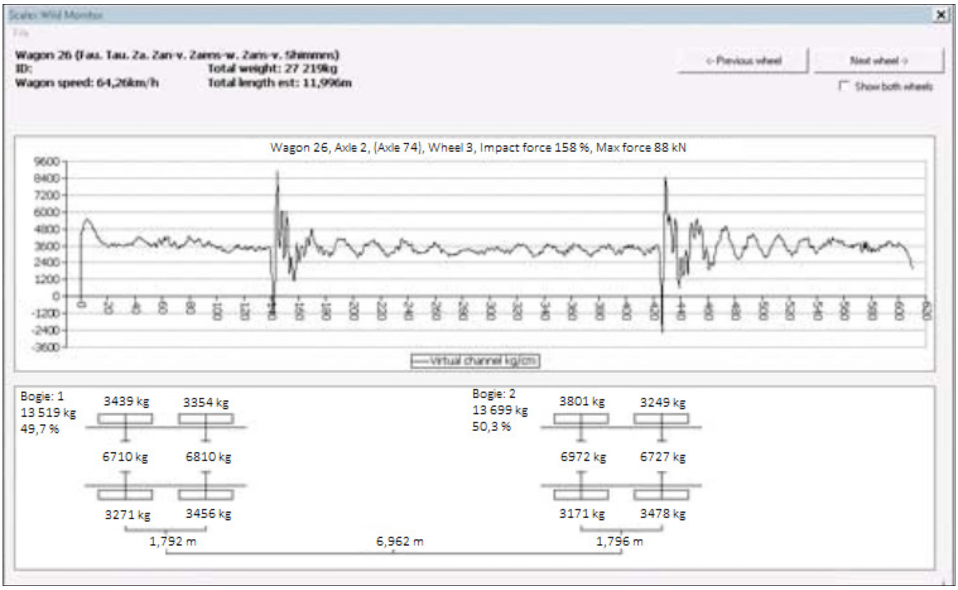

Figure 6. Wheel impact load detector results. (Tamtron)

During the use of the wheel impact load detector, it has been found that it can also detect wagon and axle specific overloads, longitudinal and transverse unevenness loading errors and out of round wheels. (Liikennevirasto, 2018a)

Figure 7 shows a diagram of the operation of the wheel impact load detector alarms. Thus, the wheel impact load detector measures the static and dynamic load from the wheel to the rail, and analyzes the measurement results and, if necessary, causes an alarm at the Finrail's Technical Control Centre. The Technical Control Centre checks the correctness of the alarm and critical alarms are transmitted via SMS and e-mail to the traffic control of the railway line section in question. (Liikennevirasto, 2018b, Liikennevirasto, 2018c)

The traffic control shall contact the train which caused the alarm. If the measured dynamic load exceeds 400 kN, the train may continue to its destination, but with a maximum speed of 50 km/h. Thereafter, the rolling stock which caused the alarm shall not be reloaded before the repair. If the measured dynamic load exceeds 450 kN, the rolling stock shall be removed as soon as possible and the maximum permitted speed shall be 50 km/h. The alarms caused by uneven loading are forwarded to the Finnish Transport Agency's Rail Traffic Management Centre. (Liikennevirasto, 2018c, Väylä)

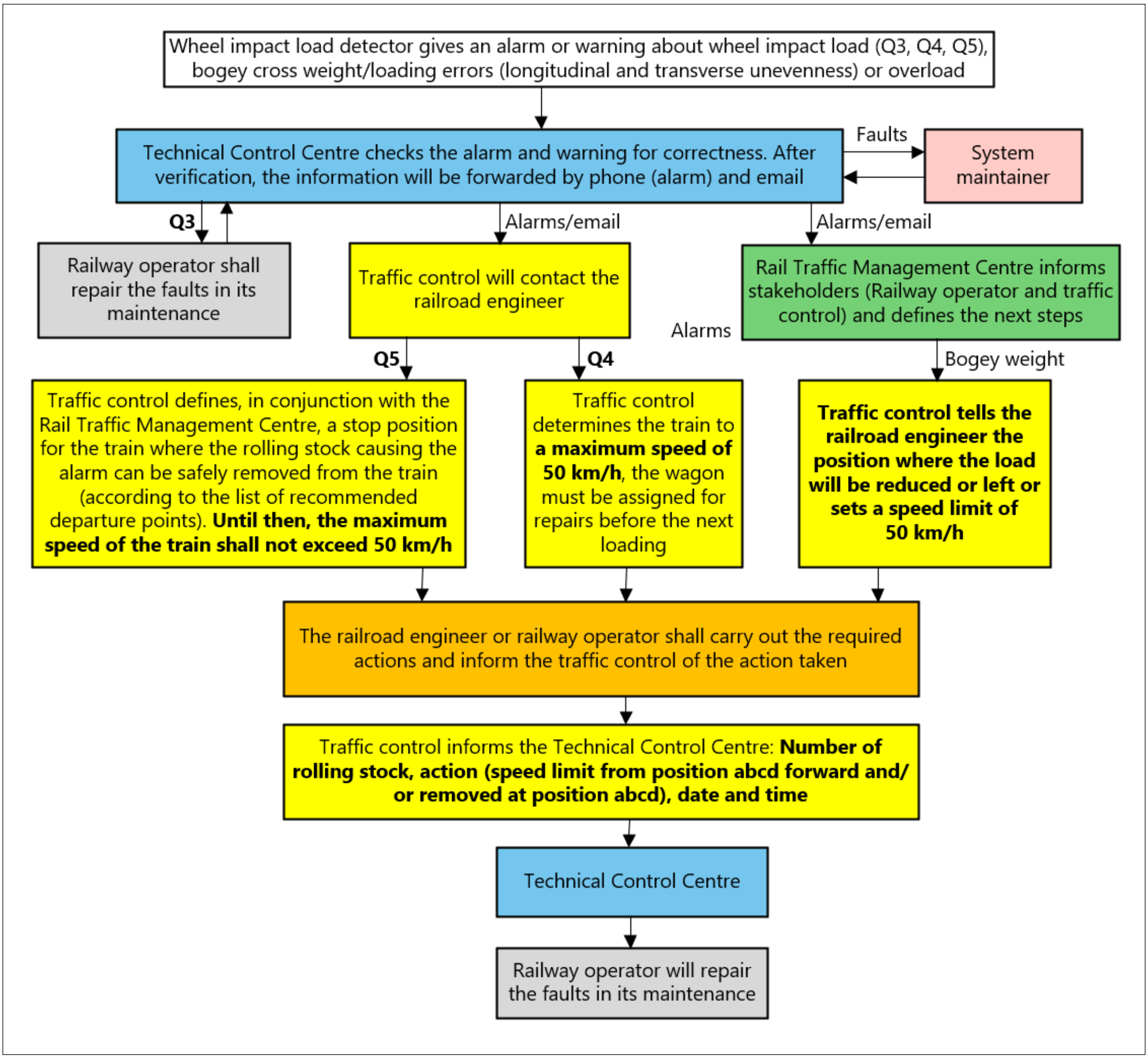

Figure 7. Functional diagram of wheel impact load detector alarms.
(Liikennevirasto, 2018c (translated by Leinonen, J.))

2.4 PANTOGRAPH MONITORING SYSTEM

The electric locomotive draws its power from the contact wire through the pantograph. The pantograph provides an electrical connection to the contact wire via carbon strips on the top of the pantograph. Damaged carbon strips cause additional stress on the contact wire, which can cause the contact wire to break. This is expensive to repair and causes a break in rail traffic. In addition, there is a serious safety risk when the high-voltage contact wire hits the ground. Most of the carbon strips damage on the pantograph is a so called impact damage. This occurs, for example, when the mushroom peg at the end of the contact wire is broken and the contact wire moves over the guide. (Saarinen, 2009, Liikennevirasto, 2014)

The pantograph monitoring system monitors the condition of the carbon strips in pantographs on electric traction units and there are 12 of them in the Finnish rail network. The pantograph monitoring system have mainly been installed on road bridges overpassing the track. The pantograph monitoring system includes a radar, a flash unit and a camera (figure 8). The radar detects an oncoming train and recognizes its speed, distance and direction of travel. The camera can capture all active pantographs on the train. (Liikennevirasto, 2018a, Liikennevirasto, 2014)

Figure 8. Pantograph monitoring system. (Liikennevirasto, 2014)

The photographs taken by the system will be forwarded to the operator's maintenance department and to the Finrail's Technical Control Centre. The photographs are analysed manually. The traffic control informs and instructs the railroad engineer if the condition of the pantograph requires immediate action to avoid damage on the electric track or rolling stock. Figure 9 shows an example photo of the pantograph. (Liikennevirasto, 2014, Saarinen, 2009, Liikennevirasto, 2018b, Väylä)

Figure 9. Photograph of rolling stock taken by pantograph monitoring system. (Saarinen, 2009)

2.4 WHEEL PROFILE DETECTOR

Wheel profile detector (figure 10) is used to inspect wheels for preventative maintenance, maintenance scheduling, derailment prevention and to reduce track and rail damage caused by excessively worn wheels. When the wheels of the rolling stock are checked the rolling stock will stay in service longer. (Trimble Inc, 2018, Trimble Inc, 2019)

Figure 10. Wheel profile detector. (Trimble Inc, 2018)

Wheel profile detector is camera and laser based system and it uses proprietary algorithms. Laser illumination on the wheel is captured by cameras and the measurement system calculates the wheel profile, wagon identification by axle spacing, speed and direction based on input from axle counter. Wheel profile detector is installed on a custom steel sleeper and wheel profile is possible to measure at speeds of 0 to 140 km/h. (Lane, 2019, Trimble Inc, 2018)

There is only one wheel profile detector on the Finnish railway network in Vartius near the Russian border. At this point in time, the wheel profile detector results are used mainly by researchers by doing statistical analysis of wheel profiles. (Liikennevirasto, 2018b, Lane, 2019)

2.5 MONITORING SYSTEMS SUCCESSES AND AREAS FOR DEVELOPMENT

Below are some ideas from the Finnish Transport Agency for 2018, when the monitoring systems were successfully introduced, what were the reasons for it and what needs to be developed and improved in the future.

Successes:

- hot bearing monitoring system has become reliable
- wheel impact load monitoring system was able to obtain previously unavailable information
- contact wire damages decreased during monitoring (Liikennevirasto, 2018a)

Reasons for success:

- modern monitoring systems
- co-operation with railway companies
- rolling stock RFID tags
  - accurate tracking and traceable history
- Finrail's Technical Control Centre
  - operates 24/7
  - immediate action on faults and disregards for false or irrelevant alarms
  - operations are actively being improved (Liikennevirasto, 2018a)

Things to develop and improve:

- more accurate wheel and wagon loads
- hot bearing monitoring system should be developed to reduce interference from dragging brakes
- in addition to pantograph monitoring system, the contact wire monitoring must be expanded
- there are no devices yet for measuring rigid bogie center pivots
- wheel profile monitoring should be expanded
- multifunction measuring stations needed
- RFID tags for all rolling stock
  (Liikennevirasto, 2018a)

3. Railway Inspection Measurements

Railway inspection measurements are part of the maintenance of the railway whose main tasks are to ensure railway safety and to know the condition of the railway. Knowing the condition of the railway is important in order to be able to schedule maintenance work timely. The measures include superstructure and substructure, level crossings, bridges, traffic control and safety equipment, electric railway and high current equipment and land areas. (Ervelä, 2014)

Finland has a railway inspection system in place to ensure that its maintenance objectives are met. The purpose of the inspection system is to provide timely information on deficiencies and defects that, if allowed to develop, would create safety risks or limit railway availability. Inspection wagons, measuring vehicles and hand-held measuring equipment are used for railway inspection. (Ervelä, 2014) These are described more in detail in the following paragraphs.

3.1 EMMA INSPECTION WAGON

The Emma inspection wagon (figure 11) measures track geometry with track gauge, cross level, longitudinal level, twist and alignment. An incorrect track gauge or excessive twist may cause the train to derail. An incorrect cross level causes an increase in harmful transverse acceleration and new problems such as the formation of alignment deviation. The longitudinal level or too high alignment will result in speed restrictions. Geometrical deviations are corrected mechanically by adding aggregate to the ballast layer. (Ervelä, 2014)

Figure 11. Emma inspection wagon. (Kaleva, 2003)

The Emma inspection wagon uses a chord measuring method, using three-point measurement with a measuring wheelset. In it, the two bogies form two measuring points and a separate measuring bogie in the middle makes a third point. The measurement base, as in the distance between bogies, is 12 meters and the distances to the center measuring bogie are 5 and 7 meters. It can also perform the static inspection of the contact wire and measure the contact wire height, zigzag size, and longitudinal inclination. (Liikennevirasto, 2014, Ratahallintokeskus, 2008)

The Emma inspection wagon measures the lines with the highest speeds six times a year, the other lines with passenger trains three times and the other lines carrying freight only twice. Emma can take measurements at speeds of up to 120 km/h. (Lane, 2020)

3.2 ELLI INSPECTION WAGON

The Elli inspection wagon (figure 12) is used to measure contact wire and railway track. Elli's roof has a laser optical measurement device that measures the height of the contact wire and the registration arms. Measuring the position of the registration arms is used to determine the position of the wagon, which is important for the analysis of the results. Measuring the height of the contact wire also gives the zigzag size and the calculated slope, i.e. the difference in height of the contact wire between two registration arms. The deviations on the contact wire can cause significant excess wear on the carbon strips in the pantographs. For example, a too small zigzag size consumes carbon strips over a small area. (Ratahallintokeskus, 2008)

Figure 12. Elli inspection wagon. (Talman, 2013)

The Elli inspection wagon can also measure the contact force between the carbon strips and the contact wire, the vertical and longitudinal acceleration of the pantograph, the contact wire voltage, the outside temperature and the vertical and lateral acceleration of the train body. Too high contact force causes premature wear on both the contact wire and the carbon strips. Too small contact force can cause interruptions in power take-up and sparking, resulting in electrical wear of the contact wire. The maximum permissible static contact force is defined as 100 N, but the aim is to keep it below 70 N. Contact force can only be adjusted by adjusting the pantograph. The Elli inspection wagon is used to inspect electrified railways once a year. (Ratahallintokeskus, 2008, Ervelä, 2014)

3.3 ULTRASONIC INSPECTION OF RAILWAY TRACKS

Ultrasonic measurements detect internal defects in the railway tracks and turnouts. Measurements are made either on foot or on a measuring vehicle. During the measurement, the inspector documents the defects and marks them, for example, with a waterproof chalk. Most defects do not lead to an immediate breakage of the railway tracks. The increase in defects is influenced by the amount of traffic load and the variation in tension of the railway tracks. Measurements should be taken at least every 5 years and, in some cases, even once a year. (Ervelä, 2014)

Track and turnouts failures are divided into four fault categories: 1, 2/1, 2 and 3. Fault category 1 includes cracks and failures that are most likely to cause traffic problems or derailment. Category 1 failures must be rectified immediately by the service technician. If the failure cannot be repaired, the traffic must be stopped or restricted until it is repaired. Fault category 2/1 includes failures that are likely to cause a risk of cracks or traffic problems due to extreme fluctuations or decreases in rail temperature. Category 2/1 failures must be rectified before winter. (Ratahallintokeskus, 2006)

Fault category 2 includes failures that are likely to cause traffic problems and which, empirically, last over the next winter but not following winter. The service technician should remedy the failures during the next maintenance work, at the latest before the next ultrasound examination. Fault category 3 includes damages and defects which, by experience, do not lead to cracks or traffic problems, and which grow very slowly. Surface defects are repaired by maintenance and other defects are placed under close monitoring. (Ratahallintokeskus, 2006)

3.4 INSPECTION OF TURNOUTS

The turnout contains a large number of special components which are of great importance for the operation of the turnout. The main purpose of the inspection and maintenance of the turnouts is to keep the tracks in a safe condition for train traffic. Right time maintenance extends the life of the turnouts and its components. (Kosonen, 2011, Liikennevirasto, 2017, Liikennevirasto, 2016)

The inspection of the turnout includes measurements and visual inspection of the turnout components and the ballast layer. If necessary, drilling and soil surveys of the ballast and subsoil layers are also carried out. The area to be inspected also includes the area on both sides of the switch unit. The size of the area depends on the maximum permitted speed, but is always at least 50 meters. (Kosonen, 2011)

The most important tool for measuring the geometry of the turnout is the Emma inspection wagon. It checks the lines with the highest speeds six times a year, the other lines with passenger trains three times and the other lines carrying freight only twice. Geometrical deviations are corrected by the track maintenance contractor. (Lane, 2020, Kosonen, 2011)

The geometry of the turnout, the ballast layer and the condition of the turnout parts are also visually inspected. The visual inspection shall include the tightness and condition of the turnout fittings (e.g. bolts, bolted joints). The clearance between the blade of the closure rail and the stock rail is done using a feeler gauge. The wear level of the blades and the stock rail is done using a special wear measurement tool. Visually inspected rails can be welded, grinded or replaced. (Liikennevirasto, 2016, Liikennevirasto, 2017)

After the visual inspection, an ultrasound inspection may also be performed if necessary. The ultrasonic inspection detects cracks inside the rail, but only the first crack from the surface can be detected. Ultrasonic inspection effectively enables the measurement and monitoring of the cracks. The measurement and monitoring of the cracks are very important, for example a 5 mm crack in the blade may break the blade in half a year. Track faults are marked on the rail with a waterproof chalk. Grinding and welding maintenance work is planned based on the inspection results. (Liikennevirasto, 2017, Kosonen, 2011)

The main track switches with a maximum permitted speed of more than 120 km/h shall be inspected at least four times a year with a maximum interval of 110 days. Other main track switches shall be inspected at least twice a year and at intervals not exceeding 7 months. Side track switches shall be inspected at least every two years and at intervals not exceeding 26 months. If the turnout has a higher load than normal, its inspection intervals may be increased. Increased inspection intervals are required, for example main track switches where traffic is mainly via the diverging track, turnouts on grades or turnouts in curves. The Finnish Transport Infrastructure Agency decides on the need for changing the maintenance intervals. (Liikennevirasto, 2016)

A comprehensive inspection of the main track switch must be carried out at least once a year, including welding technical inspections in addition to the normal ones. When the comprehensive inspections of the side track switches are carried out, they are done in connection with the normal inspection of the turnout. If the side track switch is planned to be replaced within the next five years, the turnout shall be subject to a comprehensive inspection at least once a year. (Liikennevirasto, 2016)

Ultrasonic inspections are carried out annually for main track switches and for side track switches during periodic inspections or prior to welding. Ultrasound inspections are done for joint welds after welding and, for insulation joints, before repair work. The components of a refurbished switch are inspected with ultrasound before installation and the joint and overlay welds at the work acceptance test. (Ratahallintokeskus, 2006)

Turnout geometry measurements shall be carried out in such a way that it is possible to detect deviations from the acute limits. If any measurement on the turnout deviates from the acute limit, traffic at the turnout must be interrupted until the cause of the measurement error has been corrected. (Liikennevirasto, 2016)

3.5 ACCELERATION MEASUREMENTS

Acceleration measurement shall be carried out when there is reason to suspect a decrease in travel comfort. Vertical and transverse acceleration is measured by accelerometers mounted on the wagon bodies and bogies. Acceleration measurements also reveal a great deal about the quality of track geometry, such as track side and elevation deviations and curve radius unevenness. (Ratahallintokeskus, 2006)

The acceleration measurements are gathered in a measurement report that shows all D and * category defects. The results of the acceleration measurements and the measurement report shall be submitted to the track maintenance contractor, for maintenance work. The * category defect shall be corrected immediately. A category D defect must be included in the maintenance plan and corrected in the near future. (Ratahallintokeskus, 2006)

3.6 TRACK FORCE MEASUREMENTS

Track force measurement shall be carried out when there is a reason to suspect a decrease in travel comfort or permanent deformation of the railway. Track force measurements shall also be made when receiving a new or upgraded railway with a maximum speed exceeding 140 km/h. (Ratahallintokeskus, 2006)

Rolling stock exerts vertical and horizontal forces on the railway tracks. These forces can be measured with a special measuring wheel set and this is called track force measurement. Track forces are measured to ascertain the rolling stock's running characteristics and to ensure the quality of the track geometry, for example in cases where travel comfort is suspected. (Ervelä, 2014)

Track force measurements are gathered in a measurement report that shows all D and * category defects. The results of the track force measurements and the measurement report shall be submitted to the track maintenance contractor, for maintenance work. The * category defect shall be corrected immediately. A category D defect must be included in the maintenance plan and corrected in the near future. (Ratahallintokeskus, 2006)

3.7 INSPECTION OF JOINT EXPANSION GAPS

An incorrectly sized joint expansion gap can contribute to the formation of heat curves, breakage of sleeper joints, and increased fracture of connecting rod bolts and holes. The joint expansion gap must be large enough for thermal expansion on the rails. (Ervelä, 2014)

The inspection of joint expansion gaps is made as needed. The need may be determined, for example, during a walk-through inspection if the size of the joint expansion gaps is found to be uneven. The measurement of the joint expansion gaps will be gathered in a measurement report. The measurement report shall be submitted to the track maintainer and the contractor, for maintenance work. (Ratahallintokeskus, 2006)

3.8 OTHER MEASUREMENTS AND INSPECTION METHODS

Other measurement methods are the measurements of the running surface of the railway tracks and ground-penetrating radar. Other inspection methods are walk-through, on-board and bridge inspections.

The running surface of the railway tracks is measured mechanically and based on that the need for railway tracks profiling is determined. The profiling methods used are milling and grinding. The running surface of the railway tracks is measured mechanically on continuous main tracks every three years. The most common method for repairing short localized rail profile defects is surface repair welding, which can remedy problems caused purely by track wear. Track milling can only be used for the running surface repair when the maximum speed for the track is below 120 km/h. (Liikennevirasto, 2017, Ratahallintokeskus, 2006)

From the results of the ground-penetrating radar it is possible to calculate, for example, the foulness of the ballast layer, to see the thickness of the structural layers and to determine the causes of the track geometry problems. It is used for railway tracks maintenance and renovation planning. Location data, video and laser scanning are also usually collected during ground-penetrating radar survey. (Ervelä, 2014)

Walk-through inspection is a form of visual inspection based on the use of measuring instruments. Walk-through inspection is based on visual observation but measuring instruments can also be used. The inspection shall pay attention to the superstructure (sleepers, rails, ballast layer), geometry, drums, substructure, equipment, signals, environment, structures and turnouts. The inspector shall compile an inspection document of the results and submit it to the track maintenance contractor. (Ervelä, 2014, Ratahallintokeskus, 2006)

On-board inspection means the detection of track errors on a train or other rail track-based vehicles. Detecting errors is based on sensory evaluation but accelerometers can be used as an aid. The track errors found during the inspection shall be reported to the person in charge of maintenance. The track errors affecting train safety shall be reported immediately to the person in charge of maintenance and the inspector may impose a speed limit on the line section. Where appropriate, the errors found on an on-board inspection shall be further studied using another track inspection method. (Ratahallintokeskus, 2006)

Inspections on bridges include walk-through, annual, general and special inspections. Inspections are mainly visual, with the exception of special inspections carried out on measuring equipment. (Ervelä, 2014)

4. Conclusion

Three different wayside rolling stock monitoring systems are in use in Finland. They are a hot bearing detector, a wheel impact load detector and a pantograph monitoring system. In addition, there is one wheel profile detector in Vartius near the Russian border. At this point in time, the results of the detector are used mainly by researchers by doing statistical analysis of wheel profiles.

The hot bearing detectors are an essential part of the Finnish rolling stock monitoring. There are 86 measuring stations with 105 hot bearing detectors installed on the rail network at intervals of about 50 km. Hot bearing detectors use infrared beams to measure the surface temperatures of the bearing inner and outer rings. In the case of a warm bearing, the traffic control, together with the railroad engineer, shall determine the next possible checkpoint up to a maximum speed of 50 km/h. In the case of a hot bearing, the traffic control orders the train to stop immediately.

Locked brakes may develop flat spots which makes the wheel wear out of roundness and causes damage on the rolling stock and the rails. Material defects or steel fatigue may also cause pieces of the wheel to come loose. The wheel impact load detector detects wheel defects by measuring the static and dynamic load from the wheel to the rail. Sixteen wheel impact load detectors have been installed on the Finnish rail network as comprehensively as possible. If the measured dynamic load exceeds limits, the maximum permitted speed shall be 50 km/h and the rolling stock shall be removed as soon as possible or at the destination. It has been found that the wheel impact load detector can also detect wagon and axle specific overloads, longitudinal and transverse unevenness loading errors and out of round wheels.

The pantograph of the lokomotive provides an electrical connection to the contact wire via carbon strips on the top of the pantograph. Damaged carbon strips cause additional stress on the contact wire, which can cause the contact wire to break. The pantograph monitoring system monitors the condition of the carbon strips and the photographs taken by the system are analysed manually. The systems have been installed on 12 Finnish rail network.

Railway inspection measurements are part of the maintenance of the railway whose main tasks are to ensure railway safety and to know the condition of the railway. Knowing the condition of the railway is important in order to be able to schedule maintenance work timely. Two inspection wagons, measuring vehicles and hand-held measuring equipment are used for railway inspection in Finland.

The Emma inspection wagon measures track geometry at speeds of up to 120 km/h. The Emma inspection wagon measures the lines with the highest speeds six times a year, the other lines with passenger trains three times and the other lines carrying freight only twice. The Elli inspection wagon is used on an electrified track to measure contact wire and railway track once a year. The Elli inspection wagon can also measure the contact force between the carbon strips and the contact wire, the vertical and longitudinal acceleration of the pantograph, the contact wire voltage, the outside temperature and the vertical and lateral acceleration of the train body.

The inspection of the turnout includes measurements and visual inspection of the turnout components and the ballast layer. The turnout contains a large number of special components which are of great importance for the operation of the turnout. Ultrasonic measurements are carried out annually for main track switches and for side track switches during periodic inspections or prior to welding. The most important tool for measuring the geometry of the turnout is the Emma inspection wagon.

The railway tracks ultrasonic measurements should be taken at least every five years and, in some cases, even once a year. Ultrasonic measurements detect internal defects and failures are divided into four fault categories. Ultrasonic measurements are made either on foot or on a measuring vehicle. Acceleration measurement shall be carried out when there is reason to suspect a decrease in travel comfort. Vertical and transverse acceleration is measured by accelerometers mounted on the wagon bodies and bogies. Other measurements include e.g. the measurements of the running surface of the railway tracks and the track force measurement. Other inspections include e.g. the inspection of joint expansion gaps and bridge inspection.

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Railways play a key role in the Kolarctic region in transporting ore, minerals, timbers, goods and passengers. Nowadays, there are increasing demands for the use of the railways for heavier, longer, faster and more frequent trains in the Kolarctic area. This means that the railway infrastructure must be designed, maintained and monitored in such a way that people and goods are delivered on time, all year round. Improved uptime and punctuality will require increased use of more efficient monitoring and measuring systems.

This publication is the result of the survey and provides an overview of the rolling stock monitoring systems and railway inspection measurements used in Finland in 2020. The rolling stock is monitored by wayside hot bearing, wheel load and pantograph detectors. Railway inspections measurements are made with inspection wagons, ultrasonic and acceleration measurements, among other things.

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