Hanna Kumpula (ed.)

B

Pilot: Using 2D Laser Scanner in Automated Road Monitoring

ALASCA project report

PUBLICATIONS OF LAPLAND UAS
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Foreword

Digitalisation and robotisation are some megatrends that are partly enabled by the development of Internet of Things (IoT), Big Data analytics, and Cloud Computing. Today, these megatrends shape more traditional fields of which transport is a good example. The Finnish government desires Finland to be in the forefront of this development (Ministry of Transport and Communications 2015). Digitalisation, intelligent transport as well as the development of new transport infrastructure export concepts is visible in the regional strategy of Lapland (Lapin Liitto 2017, 34). Currently, the transport sector is on the brink of witnessing its greatest changes. Mobility will become a service; the transport becomes greener and more automated. Information and data collection are and in the future increasingly will be automated.

These megatrends were also the drivers behind the Automated Road Monitoring Pilot Using 2D Laser Scanning (ALASCA) project. As the project title reveals, the project is about piloting the automation of road monitoring by utilising a laser scanning technique. In this case, the automation implies crowdsourcing road information from the existing traffic.

The new technique enables to determine maintenance and investment measures taking into account the life cycle of the road structure. Furthermore, this will help to determine exactly the length of the road where measures are needed. The use of new laser scanning techniques lead to more efficient resource management as well. Naturally, as the gathering of information is carried out automatically, it is more economic than traditional measurements.

The aim of ALASCA project was to develop a road monitoring prototype, which can be mounted on a large goods vehicle (LGV) and which can process and communicate data in real-time. The actual automation is in data processing and, in addition, in reducing, or supporting, the need of inspection in roads in cases where the road can be monitored continuously by the existing LGVs that are able to collect relevant data. Currently, these road monitoring LGVs are likely to be from logistics companies with larger fleets. However, the megatrends are driving the electronics industry to produce smaller and more inexpensive sensors which might be installed in every car in the future. Therefore, the traffic will produce great amounts of data for the support of infrastructure management.

In the ALASCA project the road monitoring is targeting at improved infrastructure maintenance by producing laser scanning information. The benefits of laser scanning emerge from measuring a wider area of the road when compared to some other optical sensors that measure, e.g., slipperiness, or if compared to accelerometer sensors that can measure roughness or vibration. The data needs to be processed in order to produce parameters that are of interest in road maintenance. The greatest changes in road conditions take place during the winter period due to the snow on the road. Laser scanning can effectively produce information concerning e.g. snow ruts and snowbank heights, which are currently under the quality criteria and therefore under inspection in maintenance contracts.

Even today, we gather the data to determine where infrastructure maintenance measures are required by visual inspections by large complemented with site inspections and samples. With new technique, we obtain more accurate and sophisticated data without breaking the structure. Laser scanning gives us information on the structure that cannot be visually observed. We also get the information of the conditions that are about to start causing problems and will become visible after one or two years. This will help us to determine and plan proactive maintenance measures which normally are significantly cheaper than if measurements are carried out when problems are clearly visible.

Table 1 summarises the ALASCA project. In general, the ALASCA project officially begun in January 2017 whereas the project started running at full speed in March 2017. Furthermore, the project completed in April 2018. The project budget was approximately 85 000€ of which most of the financing was granted by the Regional Council of Lapland through the AIKO financing instrument. This financing instrument targeted at enabling short regional innovation experiments that can support the region.

Table 1 Summary of ALASCA project

Name	ALASCA - Automated Road Monitoring Pilot Using 2D Laser Scanning
Duration	1/2017 - 4/2018
Outcomes	Physical vehicle-mounted prototype for crowd-sourced data collection Functional digital user interface prototype for visualising laser scanning information Prototype test reports of three test cases: dry paved road, snow-covered winter road, freezing rain tests in laboratory Report on business context factors of a smart, connected product
Budget	83 780€
Financing instrument	AIKO - Regional Innovation Experiments
Amount of financing	AIKO 70%, 58 646€ Lapland UAS own contribution 30%, 25 134€
Beneficiary	Lapland UAS
Stakeholders	Regional and national companies and authorities

This compilation of articles presents the outcomes of ALASCA project. It starts with a technical overview that consists of principles of 2D laser scanning and current quality monitoring in winter road maintenance. One of the outcomes is the physical prototype, called RoadFly and therefore one of the articles gives an idea of the whole prototyping process. The prototype was put into tests in a dry paved road, and on a snow-covered winter road. In addition, it was also tested in a climatic laboratory. Separate articles are written of all three test cases. Furthermore, one of the research problems was about visualising the processed data of a laser scanner in quality monitoring. An article is presented with user needs and ideas for a digital user interface. Finally, some business context factors related commercialisation of a smart, connected product, are presented. All the results are concluded in the final article.

The project team wants thank the Regional Council of Lapland for granting financing to this pilot project. Very special thanks need to be given to Roadscanners Ltd. for fruitful cooperation, consultancy and reference measurements with. In addition, the Lapland CEDTE gave very valuable input to the project together with other regional and national stakeholder companies, who all deserve our gratitude. The study programme of logistics from The Federation of Education in Rovaniemi (REDU) supported us with heavy trucks for mounting the laser scanning prototype

Jaakko Ylinampa and Heikki Konttaniemi

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Janne Poikajärvi and Jori-Jaakko Niskanen

Technical Background

WINTER ROAD MAINTENANCE QUALITY MONITORING

As ALASCA project is about monitoring mostly winter road parameters, some key issues related to winter road maintenance need to be presented. The aim of the winter road maintenance in Finland is to secure safety and fluency of the traffic. This is carried out by removing snow accumulated to the roadway, by levelling the surface of the road and by preventing the slipperiness of the road. Roads have been divided into five categories: Is, I, IB, II, and III. In conurbation it is possible to use category TIb in exchange for category Ib. The level of service in the class Is is the highest and lowest in the class III. (Liikennevirasto 2015)

The snow removal needs to take place on the ploughing route when the amount of snow exceeds the threshold value at any point on the road. When snowing has ended the ploughing work needs to be completed by the reaction time. Table 1 presents the threshold values for the snow removal. In addition, slipperiness prevention work has own reaction time which means that the road needs to be salted, sanded, or roughened by the given time after the slipperiness falls below the threshold value. (Liikennevirasto 2015) In practice, the aim of the slipperiness rejection is to complete the actions anticipatorily.

Table 1 Threshold values for the snow removal. (Liikennevirasto 2015)

Winter maintenance category	Maximum snow amount during snowing [cm]		Measure time [h]	
	snow	slush	snow	slush
Is	4	2	2,5	2
I	4	2	3	2,5
Ib	4	2	3	3
TIb	8	4	4	4
II	10	5	6	6
III	2			

The maximum snow depth is the largest average depth of snow and slush, which occurs on the road either in the wheel path, between wheel paths, on the middle of the road, or on edge of the lane. This is estimated as an average from the 50 cm width as shown in figure 1. (Liikennevirasto 2015)

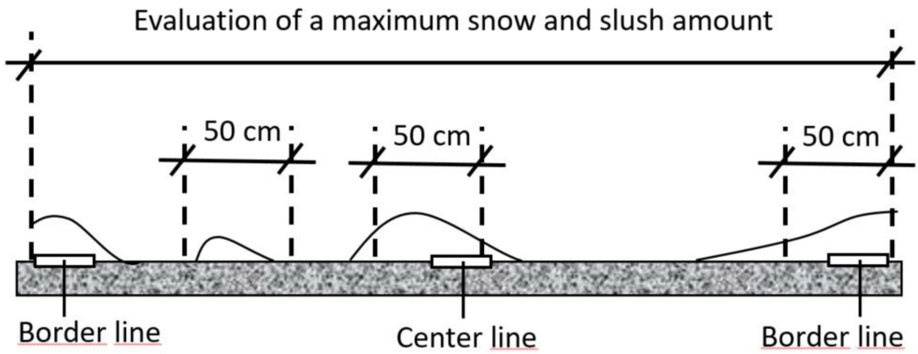

Figure 1 Evaluation of a maximum snow and slush amount (Liikennevirasto 2015)

Traffic causes unevenness in to the hard compressed snow layer on the surface of the road. With maintenance work, the surface of the road must be kept in level continuously. Table 2 presents the requirements of road levelness. (Liikennevirasto 2015)

Table 2 Requirements of road levelness. (Liikennevirasto 2015)

winter maintenance category	maximum unevenness [cm]
Is	-
I	1
Ib	1,5
TIb	2
II	2
III	2

Evenness of hard compressed snow layer is surveyed visually, evaluated by driving response, or measured by 1 m wide screed. Pavement ruts and edge settlements are ignored in the process of evenness of hard compressed snow layer. (Liikennevirasto 2015) Figure 2 shows the performing of the measuring by screed.

Figure 2 Measuring evenness of hard compressed snow layer (Romakkaniemi, 2018)

Visual and driving response based analysis of unevenness does not produce numerical information. The data generated by different evaluators can not be accurately compared to each other, and the produced data can not be stored as historical data. Measuring by 1 m wide screed, on the other hand, produces accurate measurement data, but the problem with the method is the slowness and limited area of the measurement. Measuring also requires a separate visit to the site.

The non-destructive testing methods have been used already for years in Finland in the condition analyses of roads. The unevenness (IRI) and rutting of the paved roads have been measured with ultrasound and laser equipment. Nowadays the modelling of the road surface and adjacent area is based on the laser technologies of different levels. The low-priced devices do not necessarily produce an especially exact measurement data but on the other hand, the affordability of the devices makes the placing of several measuring devices in the vehicles operating in streets and roads possible. The maintenance contractor of the road is interested especially in information about the changes in the conditions and in estimate of the amount of the change.

PRINCIPLES OF 2D LASER SCANNING

In addition, as ALASCA project is about using especially 2D laser scanning technique, it is essential to present some main aspects of laser scanning. In general, light direction and ranging (LiDAR), unit uses infrared, ultraviolet or visible light to measure distances between LiDAR unit and target. Lasers of wavelengths from under 600 nm visible light to 1000 nm near infrared light and 1550 nm infrared light are commonly used. (Nayegandhi n.d.)

Figure 3 shows the basic principle and components of a LiDAR instrument. A very simplified LiDAR consists of laser diode, a photodiode, a mirror with a motor and a bearing sensor, and a high-speed processor. Laser diode emits rapid pulsed beams and the processor takes the time until the pulse reflects back to the photodiode.

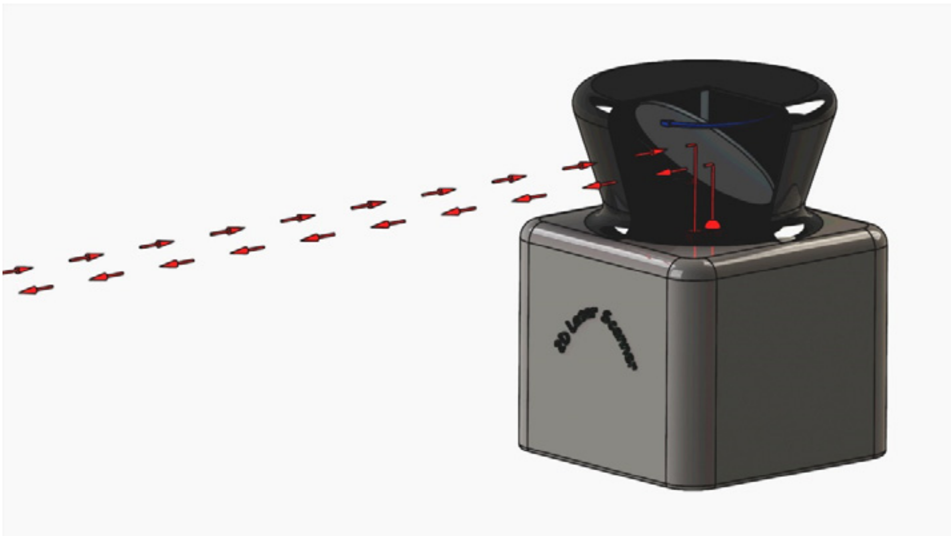

Figure 3 Basic principle of 2D LiDAR

The time it takes the beam to travel back and forth is equal to the time it takes the light to travel twice the distance to the target. Thus, the distance to the target is calculated with (1), where c = constant for speed of light, and = time-of-flight of the pulse measured.

$$d = \frac{c \cdot \Delta t}{2} \qquad (1)$$

The distance to the target with the bearing of the mirror during the measurement can be used to build a 2D map around the LiDAR. A stationary 2D LiDAR can usually only map surfaces in its line of sight.

However, some materials let some of the beam's energy to pass through to next surfaces causing secondary, tertiary and even further reflections, same way as human can see a translucent materials and through them. This way a single beam may be used to produce multiple data points. As different wavelengths penetrate materials differently, most of the data acquired can be utilised by choosing the wavelength based on an application.

Furthermore, if attenuation of the pulse reflection is measured, additional data about the surface material and type can be achieved. Combining all the reflections with corresponding strengths a 2D map can be produced, as seen in figure 4.

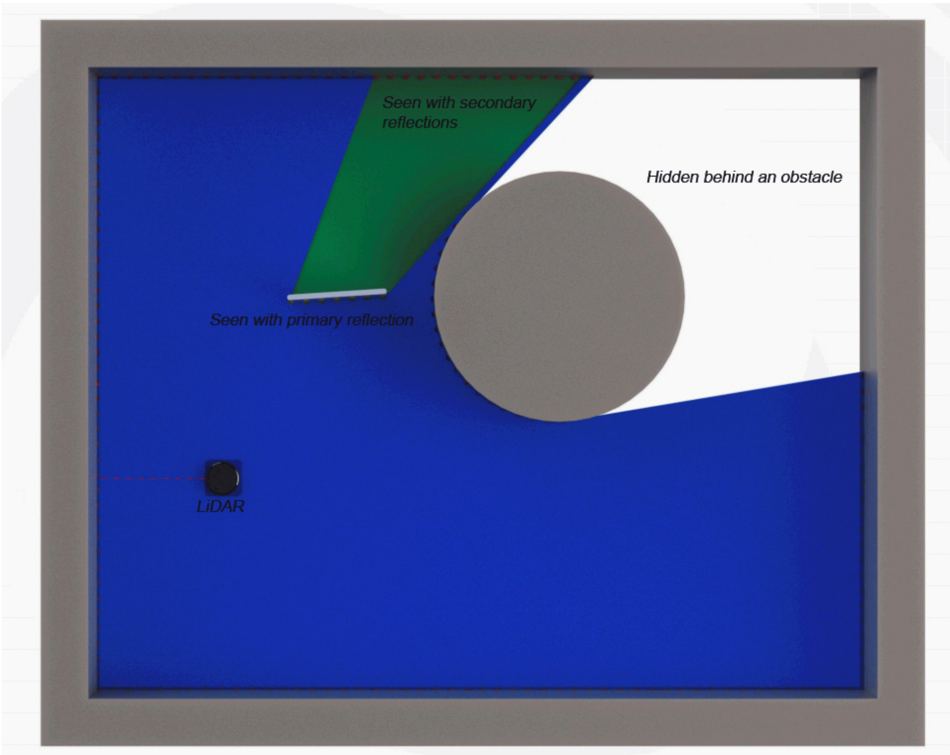

Figure 4 Vision of stationary 2D LiDAR

If 2D LiDAR is moved in space and its data is compiled with positioning data acquired by the global navigation satellite system (GNSS) sensor along with sensor's roll, yaw and pitch acquired by an inertial measurement unit (IMU) a 3D point cloud can be made. Figure 5 shows an example of multiple measurement sweeps of moving 2D LiDAR combined with positioning data.

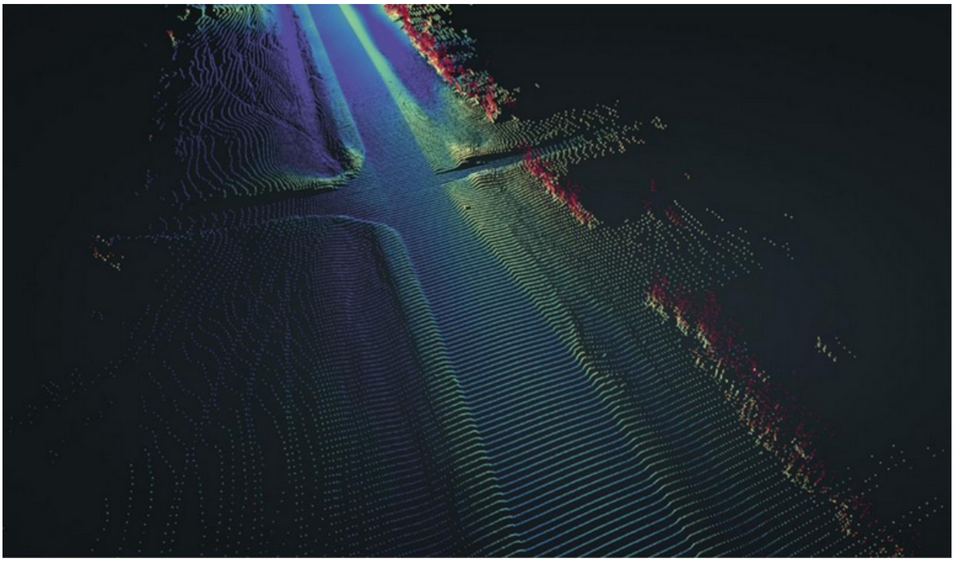

Figure 5 Multiple measurement sweeps of moving 2D LiDAR combined with positioning data (Saarenpää 2018)

Total accuracy of the produced 3D point cloud data is determined by accuracies of all the required components. Thus, depending on a use case a point cloud data can be studied accordingly.

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Juha Autioniemi

Data Acquisition System

INTRODUCTION

This article describes the pre-study for ALASCA project to find suitable combination of hardware components for remote data acquisition system to use with laser scanner unit. Laser scanner unit is located outside a vehicle, preferably on the roof, meaning, that remote data acquisition (DAQ) system must have sufficient level of weather and dust protection and robustness in those components located outside of vehicle. Ingress protection class for this kind of installation should be at least IP65. This means full dust protection and protection against low jets of water from all directions. (FIBOX n.d.)

Process of measuring electronic or physical phenomenon is data acquisition. Typically, data acquisition system consist of three parts: sensor(s), a processing unit, and a computer with software. Remote data acquisition system usually means that computer has cellular connectivity. (NATIONAL INSTRUMENTS n.d.). In this pre-study, the sensor is known beforehand. SICK LMS151 laser scanner unit is used, which actually includes the sensor part and most of the processing part of typical DAQ chain. Post-processing of laser scanner data to meaningful values is done with software provided by Roadscanners.

Pre-study was carried out in three parts: first, general requirements were listed; second, four possible combinations of how to build the system were illustrated; and finally, most suitable combination and hardware components for the selected combination were selected.

General requirements for the data acquisition system:

1. Sensor unit is SICK LMS151
2. Ethernet connectivity for SICK LMS151
3. Roadscanners software is used for DAQ, which requires Windows operating system
4. Global navigation satellite system (GNSS) receiver
5. Cellular connectivity for connection to remote server
6. Suitable 24 VDC power converter

POSSIBLE HARDWARE OPTIONS

OPTION 1

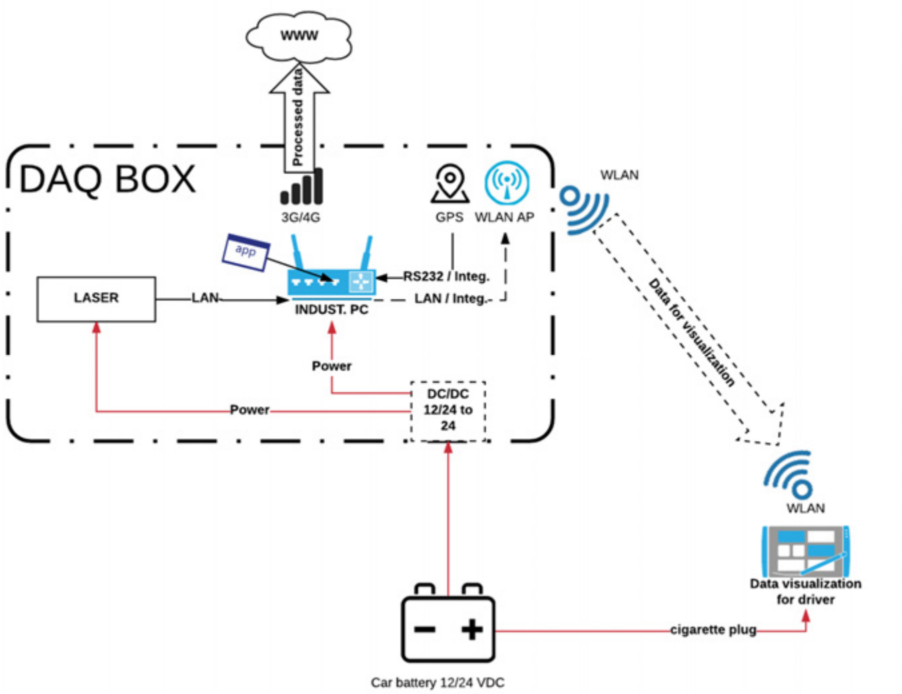

Figure 1 Option 1: all hardware components are packed together in one box on the roof of the vehicle

Figure 1 shows option 1, where all hardware components are packed together in one box on the roof of the vehicle. Data acquisition software is installed to industrial computer that communicates directly with laser scanner via local network. Software processes laser scanner data locally, inserts data to local database and sends to a remote database server.

GNSS receiver, cellular connection, and WLAN access point can be integrated to industrial computer or added as external peripherals via USB or RS232 buses. System is powered from vehicle main power line through DC/DC converter. WLAN access point is optional and can be added, if there is a need to provide local data stream for real time visualisation on mobile device.

OPTION 2

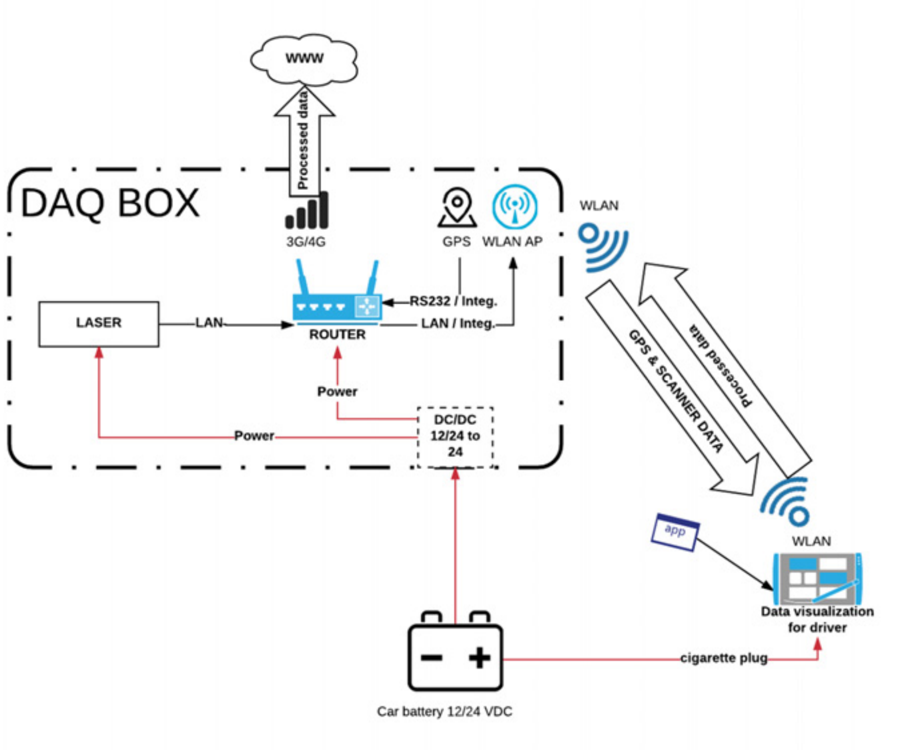

Figure 2 Option 2: where most hardware components are packed together in one box on the roof of vehicle

Figure 2 shows option 2, where most hardware components are packed together in one box on the roof of vehicle. Outdoor unit contains a router, the laser scanner unit, and power equipment. Router has integrated or external GNSS receiver, WLAN access point, ethernet ports, and cellular connectivity.

Data acquisition software is installed to tablet computer located in vehicle dashboard. The tablet communicates with outdoor unit sensors via wireless network connection. Software in tablet processes laser scanner data locally, saves to local database, and sends data to remote database. Laser scanner data is visualised locally on tablet. Outdoor unit is powered from vehicle main power line through DC/DC converter and tablet is powered from typical cigarette plug included in most vehicles.

OPTION 3

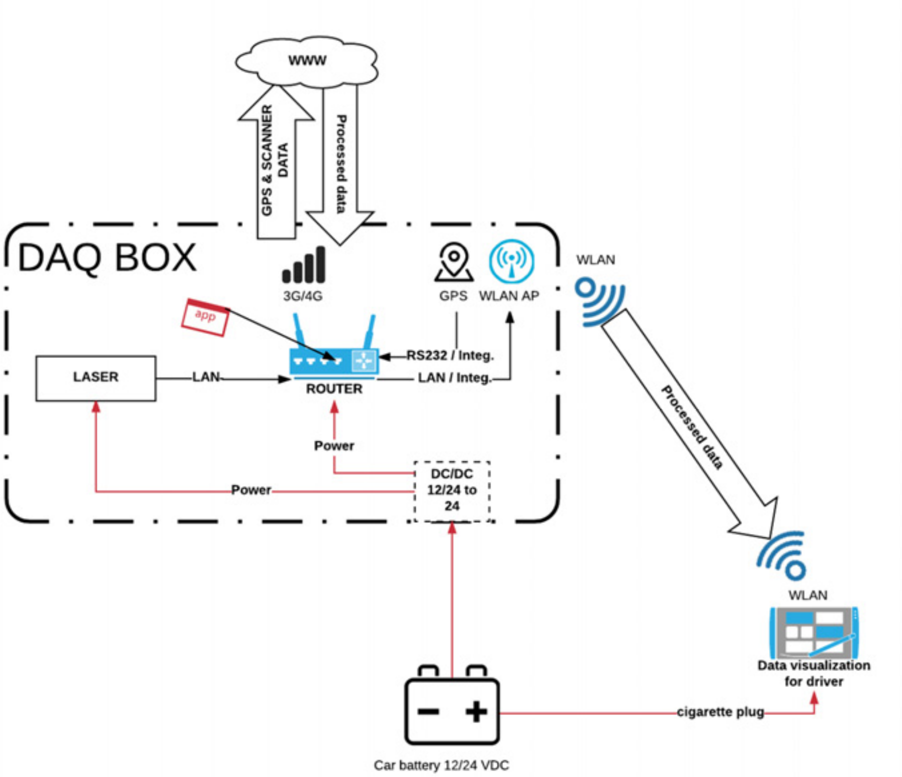

Figure 3 Option 3: all hardware components are packed together in one box on the roof of vehicle

Figure 3 shows option 3, where all hardware components are packed together in one box on the roof of vehicle. Outdoor unit contains a programmable router, the laser scanner unit, and power equipment. Programmable router has integrated or external GNSS receiver, WLAN access point, ethernet ports, and cellular connectivity.

In this case, the raw data from laser scanner unit is combined with GNSS data and forwarded to remote server. Software at remote server processes data and saves to database. Processed data can be visualised for driver on tablet directly from remote server. Outdoor unit is powered using vehicle main power line through DC/DC converter and tablet is powered from typical cigarette plug included in most vehicles.

OPTION 4

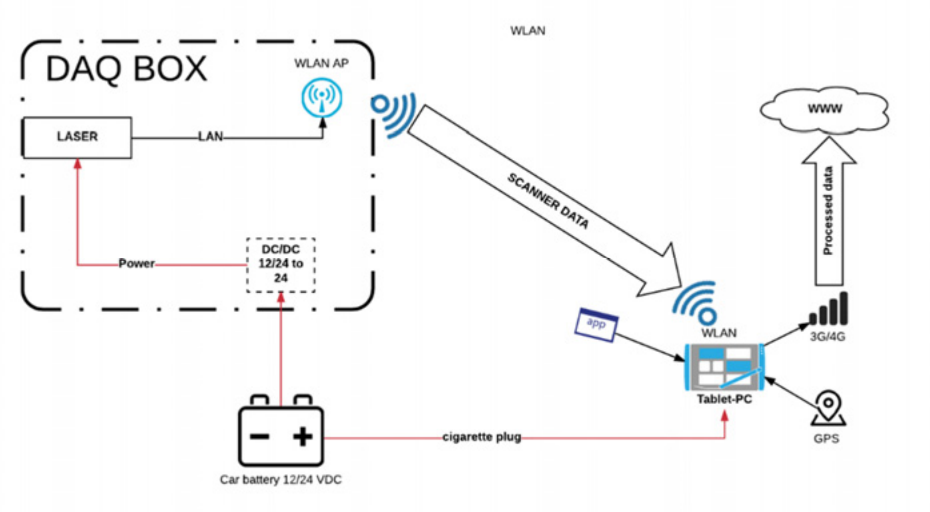

Figure 4 Option 4: where only laser scanner unit, WLAN device and needed power equipment are packed in a box on the roof of vehicle

Figure 4 shows option 4, where only laser scanner unit, WLAN device and needed power equipment are packed in a box on the roof of vehicle. Outdoor unit is powered from vehicle main power line through DC/DC converter.

Data acquisition software is installed on tablet computer located in vehicle dashboard. Tablet communicates with outdoor unit sensors via wireless network connection. Software in tablet processes laser scanner data locally, saves to local database, and sends data to remote database. GNSS receiver, cellular connectivity and WLAN access point are integrated in tablet computer.

CONCLUSION

Selection of best option

Based on pre-study hardware combinations presented in options 2 and 4 were rejected because all mandatory components and software decided to be better to put in one box for easier maintenance and more universal and simpler installation for future use later. Tablet/mobile device and WLAN access point decided also better to be optional. There might be installations where real time visualization is not needed, so also for future use cases and simpler installation these options are not suitable.

Combinations presented in options 1 and 3 were examined more closely. Finally, option 1 was selected over option 3 because it takes much less work to implement system described in option 1 than in option 3. Implementing option 3 would have needed programming new software for programmable modem and partly new software on server-side too. Option 1 was the best approach to start with in this certain project and schedule.

Selecting the hardware for selected option

INDUSTRIAL COMPUTER

Based on knowledge gathered in previous research projects in Lapland UAS and knowledge from Roadscanners about well-known and reliable industrial computer manufacturers six were selected as possibility. They were Axiomtek, AAEON, IEI, Advantech, CEF, and Neousys.

Minimum requirements for industrial computer were wide operating temperature, support for Windows 7/10 operating system, ethernet connection, GNSS/cellular connectivity/WLAN via expansion slot or external bus and most important all of these packed in small size.

Suitable models from each manufacturer were arranged in table and their specifications were compared. Most important parameters that were compared were number of expansion slots, which expansions are available (cellular connectivity, GNSS, WLAN), operating system, operating voltage, operating temperature, and physical size.

DC/DC CONVERTER

Manufacturers for suitable DC/DC converter were Traco Power, CUI Inc, Gaia, Phoenix Contact, and Alfatronix. In addition, these manufacturers were selected based on previous knowledge from other research projects carried out in Lapland UAS.
Minimum requirements for DC/DC converter were 24 VDC output voltage, output power (at least about 70 W), wide operating temperature, wide input range (preferably 9-36 VDC), and small physical size.

One suitable model from each manufacturer were arranged in table and their specifications were compared. Parameters that were compared were input voltage, output voltage, output power, price, availability, operating temperature, and physical size.

Final component list for the data acquisition system

Table 1 Final component list of data acquisition system

Device	Manufacturer	Model
Laser scanner unit	SICK	LMS151
Industrial computer	Axiomtek	ICO310
Expansion card	Bointec	902 WiFi
Expansion card	Quectel	UC20 3G/GNSS
Power management circuit	Lapland UAS	-
DC/DC converter	Traco Power	TEP 75-2415WI-CM

Table 1 lists the components that, as a result of this pre-study, form the data acquisition system used in ALASCA project.

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Riku Närhi

DESIGN PROCESS: PROTOTYPE FOR ALASCA PROJECT

BACKGROUND

The aim of the design in the ALASCA project was to create the visual appearance of the prototype for automated road monitoring device using 2D laser scanner. There were three main demands for the prototype. First, the prototype should be easy to install on various vehicles, on large goods vehicles (LGV), vans, and busses. Second, the visual appearance should be pleasing to the users and co-operators, to ensure their willingness to have the prototype mounted on their vehicles. Third, since the prototype will be used in the arctic area, it should be capable of operating in different weather conditions, especially in cold weather with rain and snow.

In this project, there was an intention to improve the collaboration between mechanical, ICT, and industrial design as well.

DESIGN PROCESS

Design process is most commonly divided in five phases. The first phase consists of a design brief and a project plan with time and cost estimates. In the second Concept Generation phase, the designer creates wide range of concepts, i.e. potential solutions, to the design problem. This includes concept sketches, simple 3D models and visual representation of design ideas. In the third phase, the concepts are evaluated and reduced to one or two candidate solutions, which will go for further development in the fourth phase. The detailed design of the preferred concept includes detailed component drawings or 3D models with dimensional specifications, selection of materials, technical information report and preliminary manufacturing plan. In the last phase the drawings and refined 3D models can be presented and use for communication with the team or the client. Technology influenced design process can be shorter and more simple, since the concept or prototype is determined to enable the particular function of the application of technology (Coelho D.A & Corda F.A.A 2011).

In the ALASCA project there was no actual design brief in the beginning, so the design process was started using different mood boards to evolve possible visual worlds and feelings of the prototype. One of the mood boards was selected to be the base for the concept phase. Four design concepts consisted of quick sketch drawings, simple 3D models, visualisations, and renderings. The last concept was developed further, and the detailed 3D model was created. The final prototype included also mechanical and electronic components. The prototype was tested and introduced to the users and the co-operators.

Moodboards

Mood boards are a popular brainstorming tool in creative industries. In the design process mood boards are used to introduce the certain feeling, theme or consumer world. They are very useful in briefings to communicate the ideas and the visual appearance of a new product. The mood board helps the designers to restrict the range of creative possibilities and align the visual appearance of the end product. On the other hand, the mood board can serve as a source of inspiration, and open the space for creative autonomy, flexibility, and self-expression (Endrissat et al. 2015).

Figure 1 Mood board 1. Very masculine and robust with strong outlines.

Figure 2 Mood board 2. Light and natural, balanced, forward-oriented. This mood board was selected by the team.

Figure 3 Mood board 3. Playful, technical, fast

In the ALASCA project mood boards were a great way to communicate the design ideas, helping other team members to understand designers thoughts and feelings about creative ideas, and styles and rough visions of the possible appearances. Figures 1, 2, and 3 show three mood boards of different styles were created, from which the one presented in figure 2 was selected by the team to be the base of the concept phase.

Design Concepts

Conceptualization is an important part of the process of creating something new. In the design process conceptualisation includes gathering together all the ideas and thoughts, combining and modifying them to create the actual design solution. A concept is a design proposal, where all the functional, practical, and visual aspects are presented detailed enough but still partly incomplete and rough. The structure of the design concept has to meet the needs of function and be able to manufacture. A design concept should consist of concrete drawings or 3D models to convey the designers vision to others (Andreasen et al. 2015).

At the concept phase, the precise shape, colour, and materials are not defined yet, and the features of the final prototype might still change. Usually a couple of alternative concepts with different highlighted features are created. These concepts are compared with each other, in order to select the one that best meets the requirements of function and aesthetics to go for further development (Keinonen & Jääskö 2004).

In this project the selected mood board (figure 2) was used as a basis for several quick hand-drawn sketches. Based on the sketches, four different 3D design concepts were modelled, visualised, and rendered. The aim of the concept phase was to determine the final shape and appearance of the prototype, and the details were refined during the concept phase.

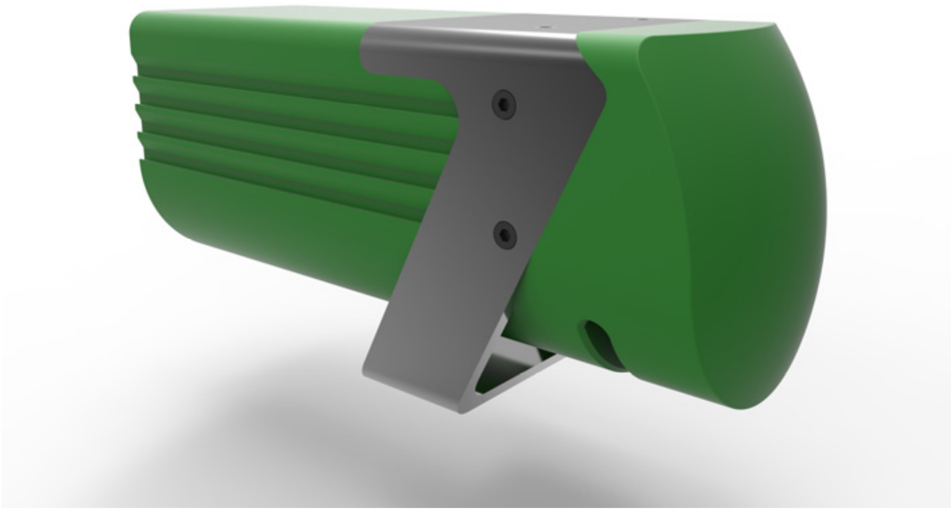

Figure 4 First concept, where the seam of the two plastic pieces is hidden under the aluminium part.

Figure 4 shows the first concept had the largest dimensions. The case consisted of two plastic pieces and a bent aluminium part, which fastens the plastic pieces together. In addition, the aluminium part acts as a mounting piece for the vehicle, and concurrently unifies the parts together giving the prototype a seamless and uniform look. Inside the case, the assembly utilises the attachment points of the 2D laser scanner presented in figure 5.

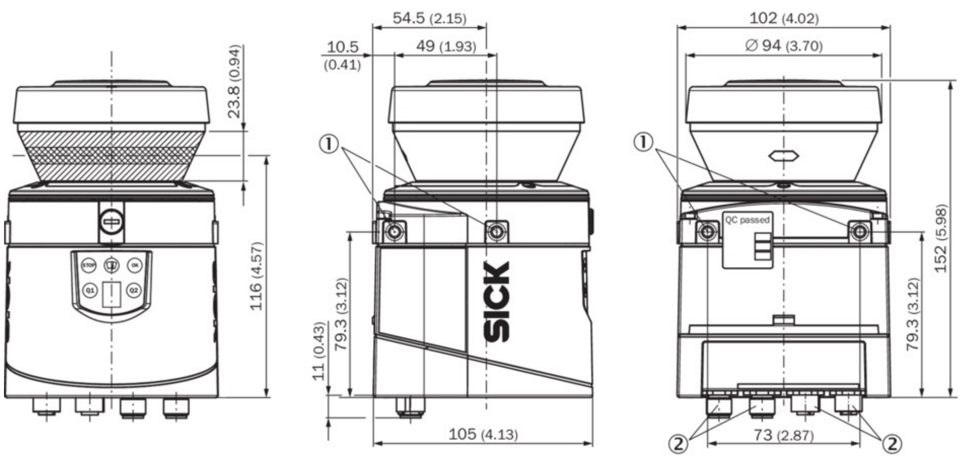

Figure 5 Illustration of the SICK 2D laser scanner, number 1 shows the attachment points.

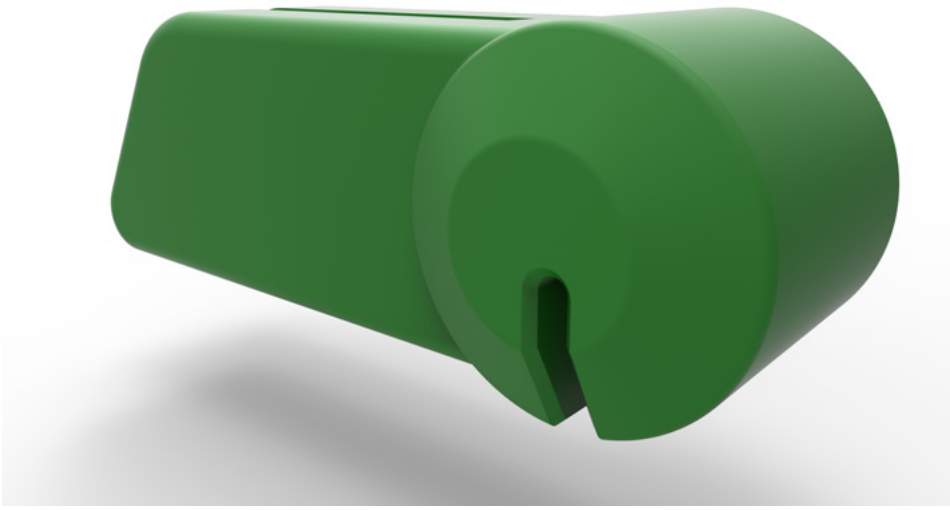

Figure 6 Second concept with the seam of the two plastic pieces hidden in the edge of two different shapes, mounting grooves on the top and the bottom surfaces of the case.

Figure 6 shows the second concept. The visual appearance is already more streamlined and closer to the feeling of the selected mood board (figure 2). The aluminum frame structure was invisible inside the case, and the seam of the two plastic pieces was placed on the edge of different shapes. The frame structure attached to the same attachment points of 2D laser scanner (figure 5) as in the first concept. Similar mounting grooves were designed on the top and the bottom surfaces of the case. This would allow the device to be fastened to the vehicle both above and below. For example, when attached to a side-view mirror of a bus, a top anchorage with a sliding adjustment would work better. However, the device must not interfere the visibility of the mirror. The mirror positioning has been further discussed with the bus manufacturer Carrus Delta Oy.

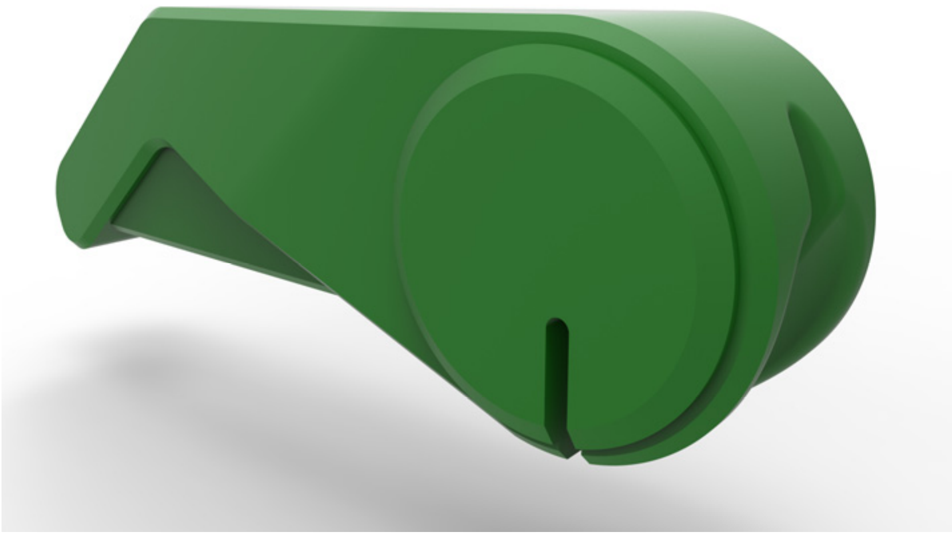

Figure 7 Third concept, with a minimum size solution

Figure 7 shows the third concept designed to be as compact as possible, with all the same electronics inside. The compact look was created by modifying the details and the proportions of the case. In this concept the rear was narrower and longer than the front, making smaller and more refined impression.

Figure 8 Inner aluminium sheet metal case with separate mounting arm, used in the third and the fourth concepts.

In the third and the fourth concept, the frame structure was an inner aluminium sheet metal case presented in figure 8. This makes the case stiff enough for the separate mounting arm for attaching the device to the vehicle.

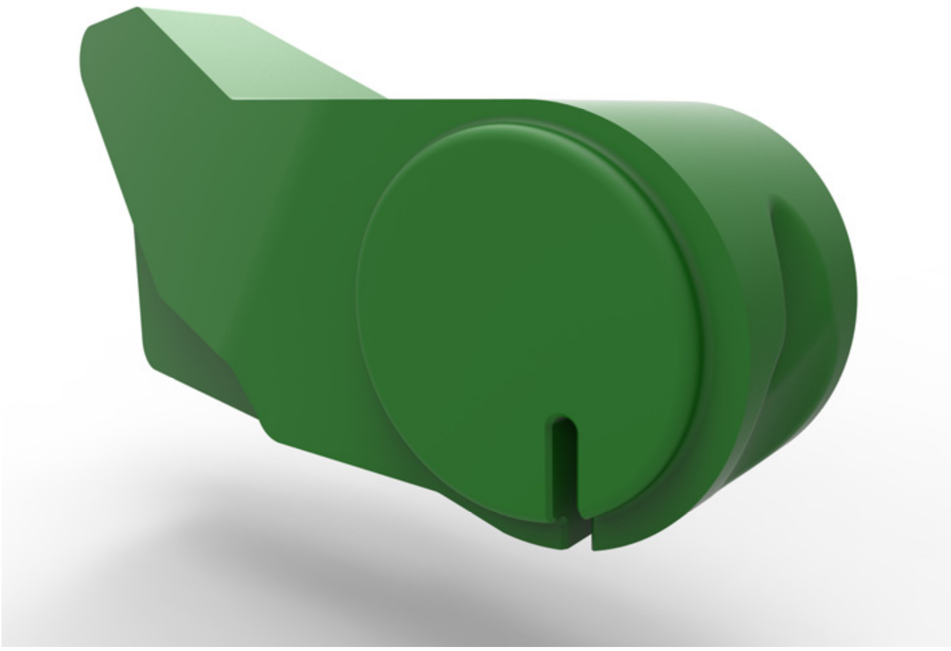

Figure 9 The fourth and the most detailed concept.

Figure 9 shows the fourth and last designed concept, which is the most refined. At this point, the designer had precise knowledge of all the electronic, optical, and mechanical components, which should fit inside the case, and all the possibilities and limitations of the ALASCA prototype were clear. The design changed mostly in the posterior part of the case, and the main reason for the changes was to create more space for the antennas. By changing the small details, the last concept became more expressive and balanced.

DESIGN PROTO

In the prototyping phase, the design idea gets its final appearance. The digital 3D models but especially the concrete 3D models are called prototypes. Compared to the concepts, the prototypes are more advanced, with technical and mechanical solutions, functional details, materials, colours, and graphics. Prototype demonstrates the form and the function, and it can help designer to identify the design issues and to take into account the user requirements and the engineering specifications. In addition, it can be used for testing purposes, which may lead to additional requirements. Usually prototype is wanted to be manufactured quickly and inexpensively. If multiple quick prototypes are made, they enable designer to select the best solution to a design challenge without large amount of money and time invested. In other words, prototype provides an opportunity to minimize design errors that may otherwise occur later in the product development process (Deininger et al. 2017; Kettunen 2001).

After the fourth concept, the ALASCA prototype design process continued with more detailed 3D modelling, choosing the colour, and the material and the method of manufacturing the prototype. The separate mounting foot was designed to be fitted to the selected type of vehicle. The prototype was manufactured to test the function of the device and to evaluate the visual appearance.

3D model

Figure 10 Final 3D model, with all the components and a mounting arm.

The final 3D model of the prototype was designed with IronCAD and SolidWorks softwares. The industrial designer used IronCAD for both concept and prototyping phase, and mechanical design, flow simulations and 2D drawings were carried out by the mechanical designer using SolidWorks software. All the components were assembled together in SolidWorks 3D modelling program, to ensure their compatibility (figure 10).

Manufacturing (3D printing)

Manufacturing the prototype is the last part of prototyping phase. The material and the method of manufacture were selected on the basis of the easiest available, affordable, and fast to produce. The prototype was manufactured in the cooperation with LAO 3D project by using the miniFactory innovator 3D printer (miniFactory n.d.-a).

There were two possible materials to use: Acrylonitrile butadiene styrene (ABS) and polylactide (PLA), both plastic filaments are used in 3D printing.

ABS-plastic is very popular material in industry and it is durable and light. The challenge of ABS plastic is its intense shrinking, which can cause layers detachment and cracks especially in larger objects. PLA is a biodegradable plastic material, manufactured from corn starch. It is a hard and resilient material, and although it is not as durable as ABS, with a well-designed structure it can withstand a lot. With PLA even larger objects are easy to print, because the shrinkage is minimal and cracks very rare. PLA also grips very well on the platform. The problem with PLA is that its glass melting point is very low, 60°C, which means that an object made of PLA may become deformed in direct sunlight. For both materials the optimal printing temperature depends on the layer height used, print speed, the dimensions of the object, and the colour of the filament (miniFactory n.d.-b; n.d.-c).

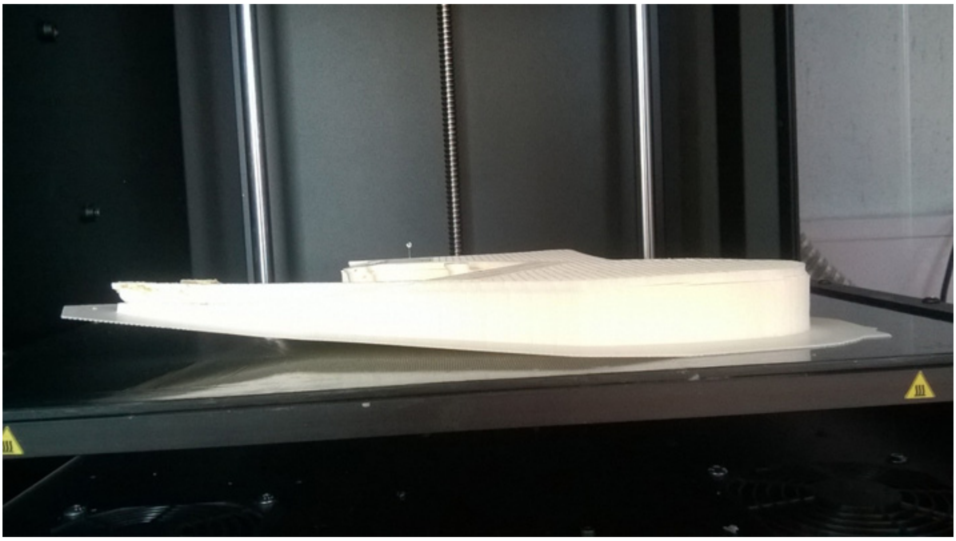

Figure 11 The first printing of ABS plastic material.

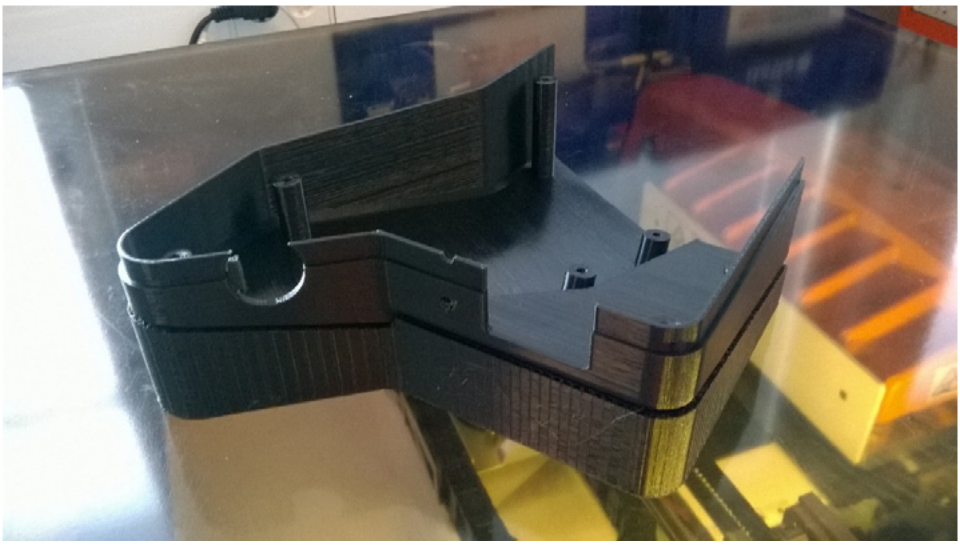

Figure 12 The 3D printed part of the prototype made of PLA material.

The printer size restricted the size of the printed objects, and the 3D model had to be divided into four parts for printing. The initial plan was to use ABS-plastic as 3D printing material. The first prints were made of ABS, but the shrinkage caused material detachment from the platform and bending of the part, presented in figure 11. Figure 12 shows the final printing using PLA due to material features more suitable for printing a larger object.

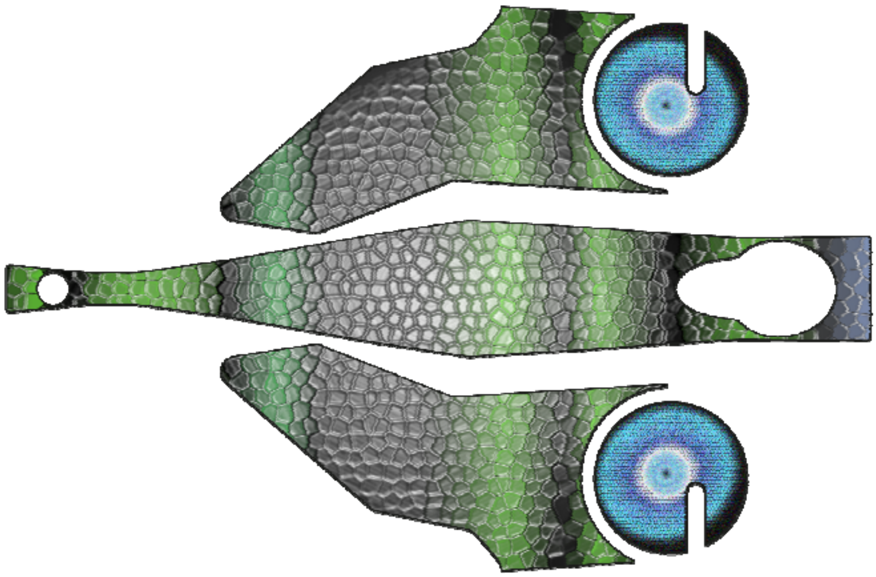

Figure 13 The stickers designed to cover the surfaces of the prototype.

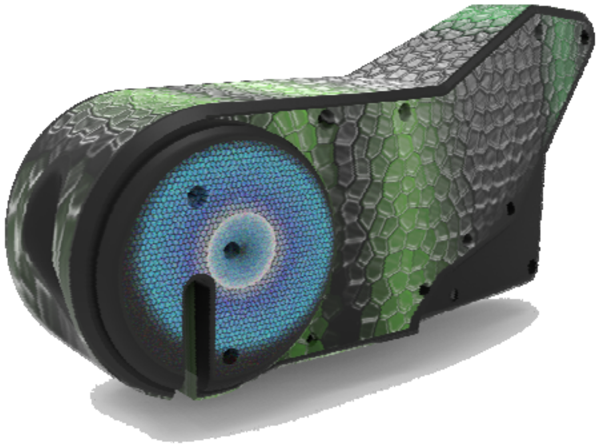

Figure 14 Rendered image of the final prototype, RoadFly.

The low melting temperature of the PLA caused problems with finishing, and the surfaces could not be refined perfectly. Therefore, it was decided to cover the surfaces with stickers (figure 13), which also significantly improved the visual appearance of the final prototype. Figure 14 shows a rendering of the prototype with the stickers applied.

Figure 15 Different scale models of the design

After the prototype was ready and manufactured, it was tested in the laboratory in simulated difficult weather conditions. During testing, snow and ice collected on the prototype disturbing the laser. Therefore, small changes were made to the design in order to avoid this problem. Figure 15 shows the smaller models designed for further tests in simulated environment.

Figure 16 Mounting the RoadFly on an LGV

Figure 16 shows the prototype being mounted on an LGV and tested in real conditions. The mounting was easy and the design fitted well on the roof of the LGV. The difficult winter weather conditions caused some challenges for the function. In general, the team was satisfied with the appearance of the final prototype.

DISCUSSION

The mood boards proved to be a good tool for opening the discussion about the design goals in the team. The name of the prototype RoadFly was inspired from the picture of a dragonfly in the selected mood board. It also inspired for the details of the design. In the future, such a long project should also have a proper design brief and the mood boards could be used as a part of the concept phase. The weakness of the concept phase in this project was that the concepts were not really alternative design solutions, but rather following models, each one more further developed, detailed and refined than the previous ones. The last design concept was pretty close to the final prototype, and the line between the concept and prototyping phase is not clear. The IronCAD software worked properly in the 3D modelling, but while converting the file formats to a file format (STL) understood by the 3D printer, minor difficulties occurred. The size of the prototype was also a challenge for the printing, and it took almost a week to print all the four parts successfully. There was no polysupport material available, and removing the PLA support material was difficult and slow. It could have been faster to manufacture the aluminium frame part with the shape of the design, and add the printed plastic panels with all the details on both sides of the frame.

The ALASCA project offered a good platform to test the co-operation between mechanical and electronic engineers and the designer. It gave a new perspective especially for the prototyping phase. Discussion was open and problems were solved together. It would have been even more simple and flexible, if the same software was used and all the parts were visible for all the designers.

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Jori-Jaakko Niskanen

SNOW AND ICE ACCUMULATION TESTS IN LABORATORY

BACKGROUND AND GOALS

The purpose of the laboratory testing is to validate the usability of the protective casing of the RoadFly measurement unit, which consists of 2D laser scanner and its auxiliary devices. RoadFly could in the future be installed to large goods vehicles, where they contribute to automatic road monitoring.

The focus is to determine whether the casing causes whirling snow or icing rain to build up resulting in measurement error. With the data acquired, the casing is further designed to achieve stable accuracy in extreme winter conditions.

Laboratory testing enables controlled environment for specific inspections whilst field-testing sums all the factors. Therefore, the goal of the laboratory testing is to measure the consistency of the data, not the accuracy, as many of the real-life factors are missing.

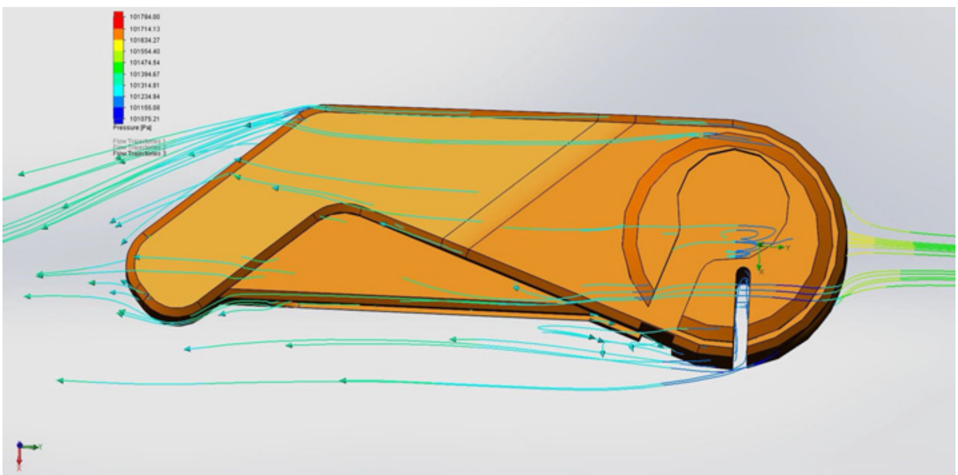

Figure 1 Flow simulation of the casing

Figure 1 shows predicted airflow pattern achieved in the laboratory testing. Simulation result is promising, as air does not flow through the opening for the laser.

METHODS

The method used for laboratory test is the icing rain test. In the icing rain test, the object is placed inside an environmental room at stable sub-zero temperature, controlled airflow and constant water mist. Figure 2 shows RoadFly in regular icing rain test setup. The accumulation of ice is observed visually and the airflow is further studied with Optronis CR450x2 high-speed camera with 800px*600px@1000fp.

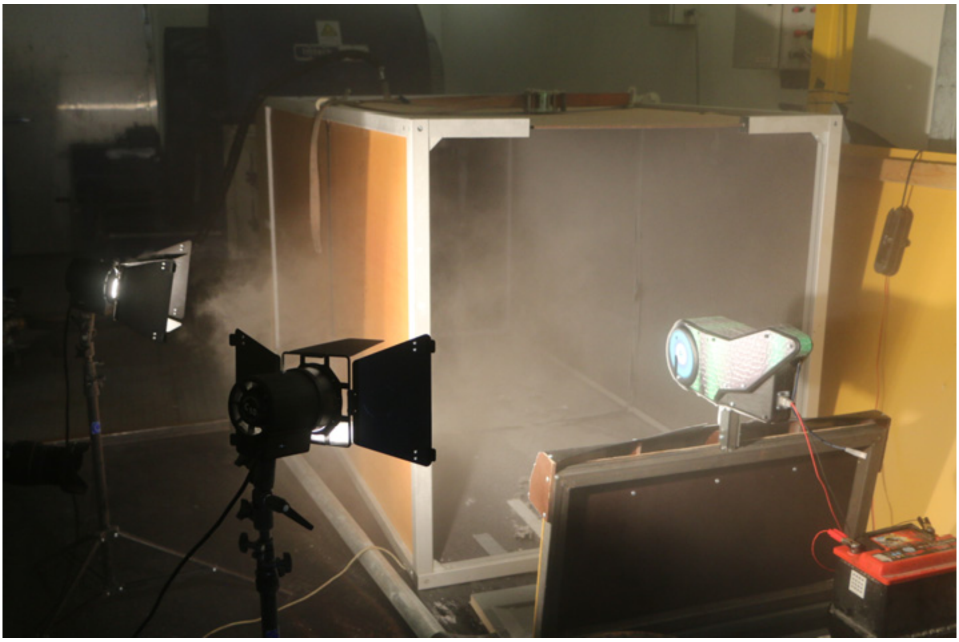

Figure 2 Test setup installation

Temperature during the icing rain test is -20°C. The output flow rate of the airflow blower is 33 m/s, which produces laminar airflow of rate 17 m/s at the end of the wind tunnel, where the RoadFly is located. Water is jet through the nozzles with constant rate, achieved by using the water container pressurised with nitrogen. The pressure of the nitrogen is set to 10 bars. Water spray nozzles were opened only once during the test, as closing the nozzles with water inside may cause them to freeze.

RESULTS AND ANALYSIS

First test

During the first test day, a full size unit with complete instrumentation was tested. In this test, the effect of accumulation of snow and ice was observed. Figure 3 shows accumulated snow in the gap. It was noticed that any snow and ice narrowing the laser's line of sight caused an unwanted drift in the measurements. Based on this result, new miniature models were designed.

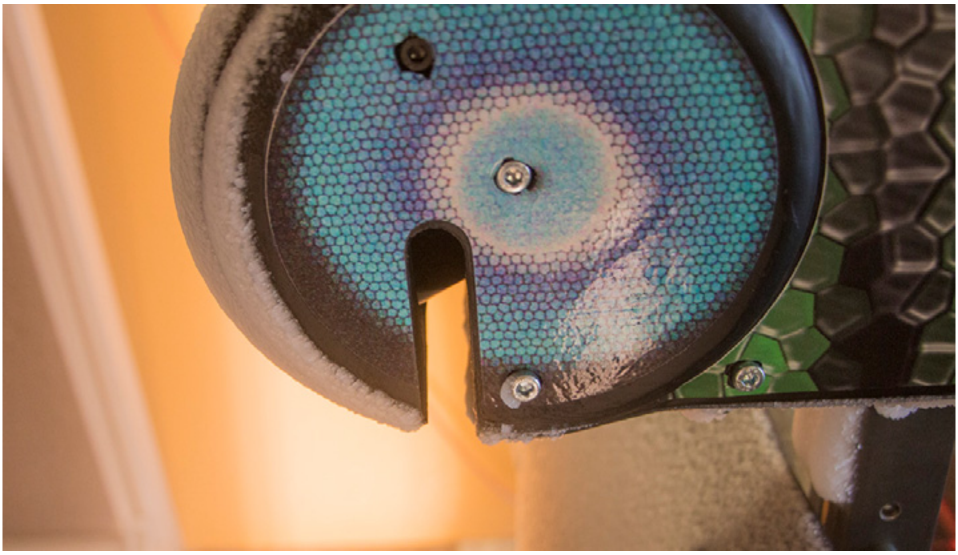

Figure 3 Accumulation of the snow and ice

Another goal for the testing was to validate the simulated airflow pattern with the high-speed camera footage. This goal could not be met with the icing rain test due to the large cross section area of the wind tunnel. Figure 4 illustrates that single particles cannot be traced. The airflow pattern analysis should be made as a separate test with focused and coloured trail of smoke generated by the smoke generator. This was not done because the icing rain test already proved the inconsistency of the results between the simulation and laboratory testing.

Figure 4 Flow of the mist cannot be seen in detail

Second test

Second test was made with five different miniature models. None of the models had any instrumentation inside except one which had a fan in it. The analysis was made based on the result of the first test day, as it seemed that any snow near the laser's line of sight may cause a drift in measurement data. Therefore, only visual inspection was made.

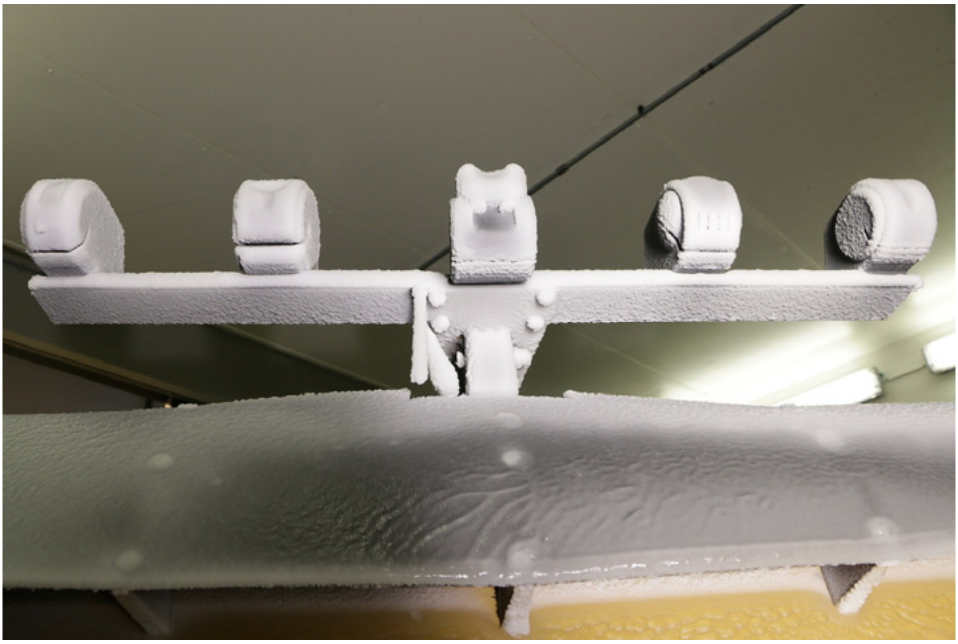

Figure 5 Accumulation of snow and ice in the second test, as seen from the below.

Figure 5 shows that none of the new models could prevent the accumulation of snow and ice in the gap for the laser's line of sight. Therefore, none of the models were deemed viable for a full size instrumented test. Although it might be debatable if such small-scale units with small gap for the laser function as the full size unit would.

CONCLUSIONS

The purpose of the laboratory testing was to verify the result of the flow simulation and LiDAR's tolerance for the accumulation of snow. Study found that combining icing rain test with airflow analysis is not possible if the mist is not targeted to the unit only. Although the airflow analysis was not possible, it was observed that snow and ice accumulated on surfaces where airflow simulation indicated it could not flow to.

Based on these two tests the casing for the instrumentation should be as minimal as possible, protecting only those elements that do not have adequate ingress protection by default. Any additional casing surfaces are likely to cause some accumulation of snow and ice that could cause measurement errors. Based on these tests it is not possible to say if laser's internal lens heating element, which is intended to keep the lens dry, is powerful enough to prevent the accumulation of snow and ice.

Tuomas Sinisalo

FIELD-TESTING OF THE PROTOTYPE UNIT ON A DRY PAVED ROAD

INTRODUCTION

Figure 1 shows RoadFly, a prototype specified, designed, integrated, and tested in the ALASCA project. The project was established for automating the measurements linked to road asset management. The measurements focus on road parameters related to changing winter conditions, e.g. snowbank height and snow -/ice ruts. The aim was to create an affordable solution, which can be easily installed for example on large goods vehicles (LGV).

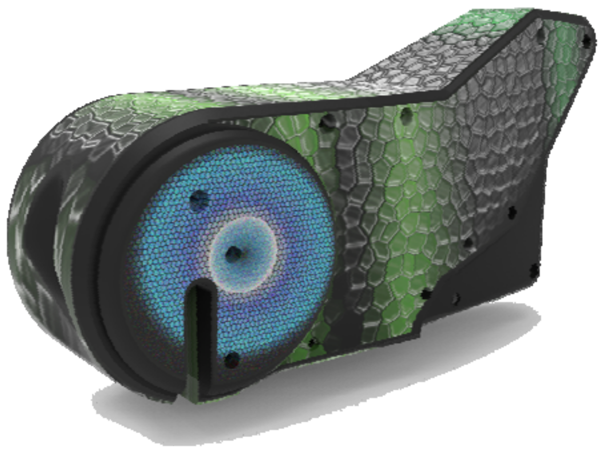

Figure 1 Rendered image of the RoadFly prototype

RoadFly is based on 2D laser scanning by a Light Detection And Ranging (LiDAR) sensor, which is typically applied for creating a point-cloud of the measured surroundings. In the ALASCA project, this point cloud data, or the scanner sweeps, are processed in real time running Road Doctor Maintenance Controller (RDMC) software, a product of Roadscanners Oy, inside RoadFly. The software produces geo-linked measurement values, such as rutting, height of snowbank, and roughness

(Roadscanners n.d.-b). This processed data is sent to a cloud database over a cellular network.

OBJECTIVES AND RESEARCH QUESTIONS

The first aim of the field tests was to gain insight on the reliability of the RoadFly rut measurements in real operational environment on a dry paved road. In addition, the aim was also to acquire some practical usage data of the unit. The rutting data was selected to be of interest due to the fact that the embedded RDMC software was still in a development phase and could not offer other parameters at the time of testing. Testing the reliability stands for knowing whether the measurements of the RoadFly can be reproduced with the same results.

The second aim was to gain insight on the validity of the RoadFly rutting measurements. The research questions for the measurements were:

- How reliable are the rutting measurements of the RoadFly in real operational environment?
- How valid are the rutting measurements of the RoadFly in real operational environment? Does speed have an effect on the validity of the unit's measurements?

TEST METHODS

Test location

The area for the testing was selected to be a 2 km long straight road stretch located in Jokela, which is approximately 30 km to the east from the centre of Rovaniemi (figure 2). The straight part of the road was selected for safety purposes due to the high speed used in the field test. It also had a very low traffic volume and therefore it provided an ideal test surrounding.

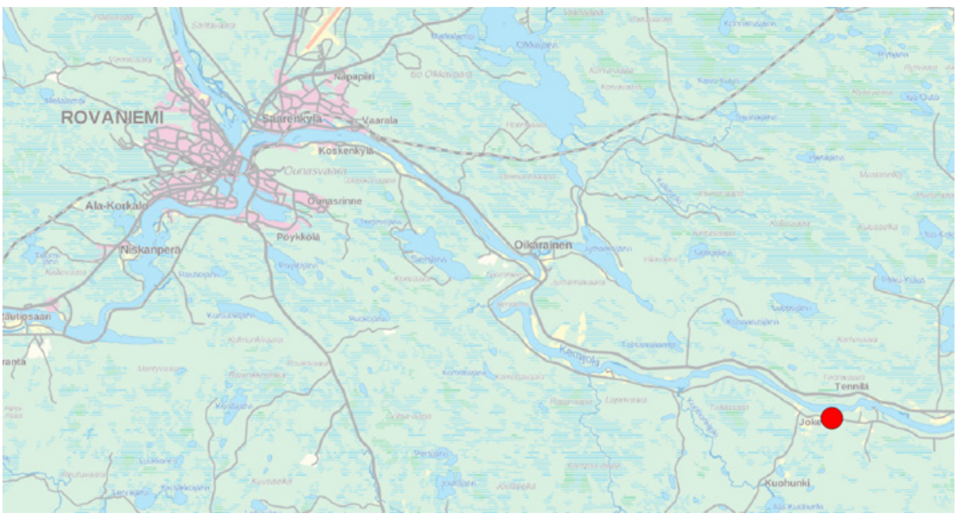

Figure 2 The testing area on a map marked with a red circle

The road at the area was moderately narrow, approximately 4,5 m in width. Due to the narrowness of the road, it did not have lanes for both driving directions. Instead, the test area had meeting points on both sides of the road as seen in figure 3.

Figure 3 A photo from the test location

Visual inspection showed that the road stretch consisted mostly of good surface conditions. However, the test location had a rough part closer to end of its eastern part

Test runs

The test runs and measurements were to be performed using a LGV prime mover, which had the RoadFly mounted on it. Figure 4 shows RoadFly mounted on the front, above the windshield, partly attached to bar holding the lights. From this position, RoadFly was able to scan the road without any visual barriers.

Figure 4 The LGV prime mover used for the tests with the RoadFly mounted to the front.

Table 1 depicts the plotted speeds and number of test runs with each speed. During the test runs, the necessary data was gathered for further analysis. The additional test runs for the highest speed of 80 km/h were carried out because of the global navigation satellite system (GNSS) positioning fixes being further away from each other when compared to lower speeds.

Table 1 The speeds and number of test runs.

Test number	Speed [km/h]	Number of test runs
1	30	3
2	50	3
3	80	5

The plan was to drive through the 2 km road with velocities of 30, 50, and 80 km/h. Through these repeats, the consistency of the measurements would be calculated. The measurement data was transferred in real time to a cloud database.

Reference measurements for validity

Regarding the RoadFly's measurement validity, it was necessary to collect the reference measurements from the test road as accurately as possible. Two independent parties, Roadscanners Oy and Lapland UAS land surveying students, produced the reference measurement data. The coordinate system and the road to be measured was agreed on mutually.

Roadscanners performed their task by using their Road Doctor Survey Van (RDSV) measuring vehicle. The measuring vehicle utilizes a Sick LMS511-HR LiDAR sensor for cross-sectional measurements and a GNSS + RTK + IMU -combination for positioning (Virtala, Alanaatu & Huuskonen-Snicker 2018. 16). The measuring vehicle produces a point cloud of the road pavement, which was later processed in a software developed by them.

The RDSV rutting measurements have been validated in a study performed by the Finnish Transport Agency (FTA). In the research multiple road monitoring assemblies by different companies were tested for their measurements' dependence on velocity, correlation with the reference assemblies, and repeatability. The reference measurements were performed by Ramboll's and Destia's measuring systems. The study revealed that the RDSV's maximum rutting measurements' average of multiple test runs has a deviation of about 2 mm compared to the reference and a coefficient of variation of about 1,8%, when the reference assemblies had an average of 1,9%. Also the measurements' dependency on velocity was insignificant. These results indicate that the RDSV measurements are suitable for the use as a reference material for the RoadFly rutting measurement comparison. (Virtala, Alanaatu & Huuskonen-Snicker 2018. 35, 40.)

The Land surveying students carried out their reference rut calculations based on a point cloud produced by the Nordic Geo Center's mobile measurement vehicle. The Nordic Geo Center vehicle utilizes a Riegl VUX-1HA laser-beam and an inertia-GNSS-unit for their measurements (Nordic Geo Center n.d.). This assembly was also tested in the previously mentioned study and it had slightly more error and variance, yet the students would not use the same method for the rut calculations (Virtala, Alanaatu & Huuskonen-Snicker 2018, 35, 40).

RESULTS AND ANALYSIS

The rut values created by the RoadFly come from the RDMC software. An additional software was created to parse and transfer the RDMC's measurement data to a cloud database in GeoJSON format as seen in figure 5. Then the GeoJSON documents were indexed by the coordinates linked with the measurements. From there it was easily accessed for further analysis and visualisation.


```
{
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    "geometry": {
      "type": "Point",
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        66.44349815
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    },
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      },
```


Figure 5 An example of a one WGS84 geo-linked measurement data document

The data processing and visualisation was performed by using a software named QGIS and JavaScript based Leaflet library with a background map provided by the National Land Survey of Finland. All the test runs were separately drawn on map where the maximum rut value is presented as a colour-coded gradient line where green stands for 0 mm and red for 30 mm rut as seen in figure 6.

Figure 6 A single test run drawn on the map with the rut colour coding (background map NSL Topographic Database 04/2018)

Figure 7 shows comparison of five test runs with a velocity of 80 km/h to the same direction. When the test run rut visualisations are compared there can be seen prominent resembles at the roughest areas.

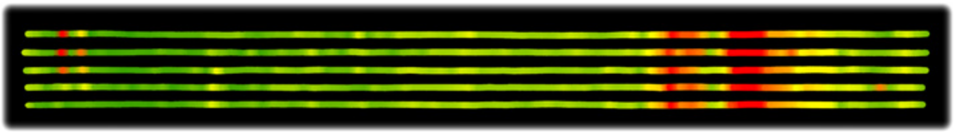

Figure 7 80 km/h test run visualisations side by side

Even though the RDMC software prints out rut values with the precision of millimeters, the real accuracy of the processed output is closer to a centimeter. (Roadscanners n.d.-a, 21). Therefore, if the values were to be rounded up to the nearest centimeter the colour variance would be much smaller, since there would be only three colours (green, yellow, and red) instead of 30.

For each test run, the measured maximum rutting values were averaged to perform a numerical comparison for the results. Figure 8 shows that the repeatability for 2 km averaged measurements are desirable, since the maximum difference for the averages is below 2 mm.

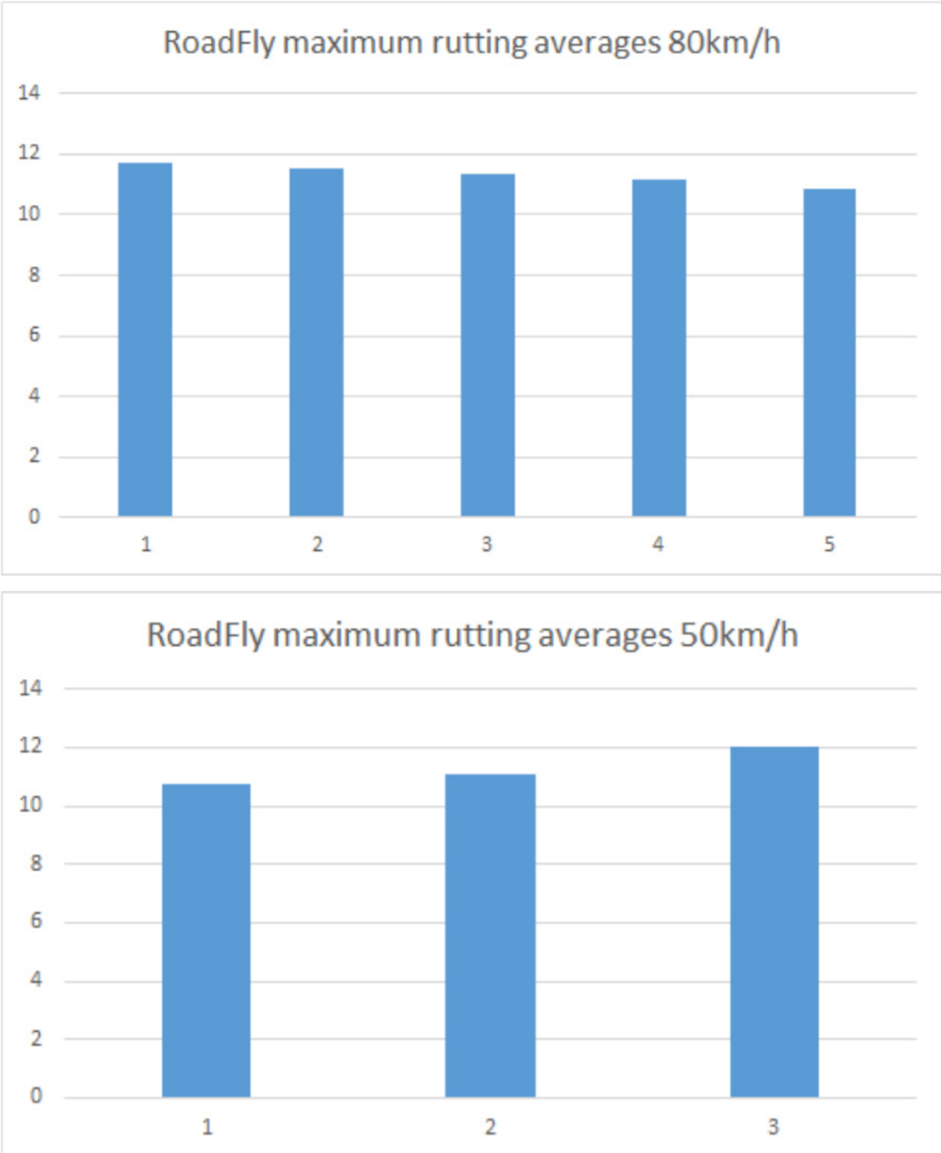

Figure 8 Maximum rutting averages for test runs with different velocities

For the 80 km/h speed measurements, a coefficient of variation was calculated using (1):

$$CV = \frac{s}{\bar{x}} \times 100\% \tag{1}$$

Where CV is the coefficient of variation, s is the standard deviation of the samples, and x is the mean value of the samples.

Which gave a value of 2,6%. Alongside this, all the measured averages between different speeds corresponded to each other within an area of 2 mm.

Reference data

Students calculated the rutting values from a point cloud provided by Nordic Geo Center Oy. Figure 9 shows a part of the visualisation created by the students where is level difference from a manually created reference plane, which gives positive and negative values. According to T. Saarenpää (2018), the method for the rut calculation used by the students differs from the way RDMC does it, which means they are not comparable with each other.

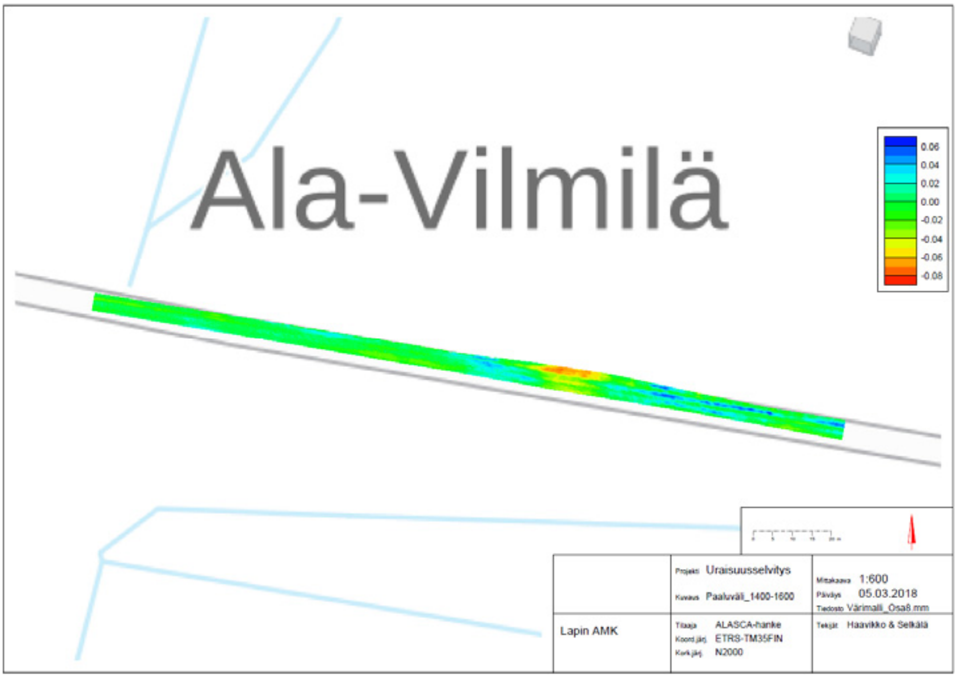

Figure 9 Part of the students' rut measurements (background map NSL Topographic Database 04/2018)

Another set of reference material was acquired from Roadscanners. Maximum rutting calculations were calculated by Roadscanners from the point cloud measured with the RDSV. Table 2 shows the RDSV's minimum, maximum, average and median values for the maximum rutting. It is noticeable that the rut measurements of the RDSV introduce approximately a 1 mm smaller average than the RoadFly's equivalent.

Table 2 Maximum rutting data for 80 km/h RoadFly runs and RDSV reference

MEASUREMENT	MIN [mm]	MAX [mm]	AVERAGE [mm]	MEDIAN [mm]
RDSV REF	1,60	62,80	10,26	6,00
RoadFly RUN 1	3,06	45,26	11,73	9,31
RoadFly RUN 2	3,82	49,03	11,50	9,05
RoadFly RUN 3	3,44	44,52	11,33	9,41
RoadFly RUN 4	3,46	42,08	11,18	9,14
RoadFly RUN 5	3,59	49,89	10,85	8,74

A visualisation (figure 10) was generated to portray the spread of the rutting on the road stretch.

This was also created by Roadscanners using their Road Doctor software and it shares the same colour coding for the rutting with the RoadFly measurement visualisations.

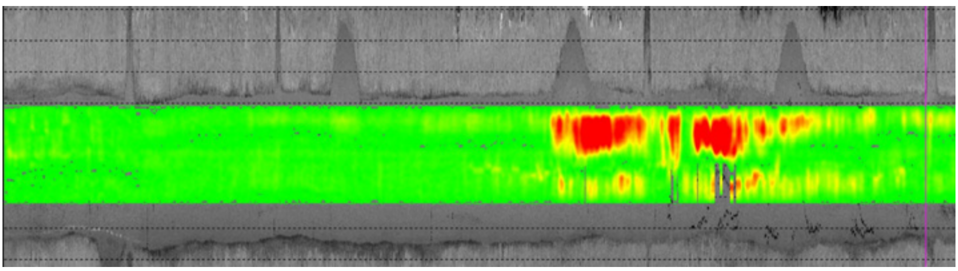

Figure 10 Reference data measured with the RDSV

Comparing the reference and the RoadFly visualisation, areas with low to none rutting and the areas with the highest amount of rutting locate approximately at the same parts of the road. Thus, the RoadFly visualisation is valid for estimating the locations for rutting.

DISCUSSION

Measuring rutting is highly dependent on the knowledge on the location of road lane edges. With the RDMC, this was a configuration where the pavement width and the RoadFly offset from the middle of the vehicle are entered manually. If the rut calculation process were to be fully automated, there is still development to be done to achieve this. Utilizing machine learning or open data could be ways to ease out the work.

More accurate results for the comparison of the rut measurements could have been achieved if the tests would have been performed in a controlled environment on a testing site built specifically for the tests with a well-known rutting. However, it would have been too expensive and time consuming to create.

The comparison between the rutting measurements of RoadFly and the references were made on a large scale due to the way the RDMC works. It calculates the rutting from the crosscuts of the road between the GNSS positioning fixes and outputs the average rutting value in this space between. For example, with a speed of 80 km/h and a positioning frequency of 1 Hz the distance from one fix to another is 22 m. It is therefore not possible to tell the average of the rutting of a distance of 1 or 10 m unless the speed was decreased remarkably but then in the other hand, the lower the speed is, the greater the GNSS positioning error is relatively to a single rut measurement length.

The final results for the validity of the accuracy comparison could be said to be insufficient since both the RoadFly's and RDSV reference data are produced using the same core for the calculations. However, because of the fact that the RDSV's accuracy can be traced to FTA comparison study of road pavement measurement systems, it can be listed as a valid reference. When it comes to the RoadFly's measurements' repeatability, the results were promising to say the least with a 80 km/h speed coefficient of variation of only 2,6%. In addition, when the roughness of the surface is compared with the visual inspection on the field with the visualised rut calculations, both the Roadscanners' RDSV and RDMC measurement visualisations correlate location wise with the condition of the road surface.

It is also important to notice that the road where the tests were performed was not typical since instead of two lanes the road only had one. Therefore, the compounded rutting was also somewhat atypical. Since the coefficient variation resulted from these tests is only from a single 2 km long road stretch, in possible future tests it would be beneficial to perform the test runs on multiple roads, with more repeats, and shorter parts in order to find more trustworthy results.

Another further research topic could be to determine the effect of RoadFly's vertical positioning on the accuracy of the calculation of rutting. The higher from the road surface the LiDAR sensor is located, the fewer of the sensor laser pulses connect with the road surface, making it more challenging to filter out the noise from the actual road surface in the point cloud. On the other hand, the projection of laser pulses on the surface of the road would be more perpendicular, which could strengthen the reflections of the pulses. A study could therefore determine the optimum altitude for the sensor.

CONCLUSIONS

The field test for the dry road surface studied the validity, reliability and validity of the RoadFly prototype of the ALASCA project. The tests were carried out in Jokela, about 30 km east of the centre of Rovaniemi on a 2 km stretch of road. This section was measured with three different configurations, one of which was RoadFly, and the other two reference measuring instruments; Roadscanners Oy's RDSV and the Nordic Geo Center's mobile measurement vehicle.

On the RoadFly, the measurements were performed several times at different speeds and once with both of the reference devices. Based on these test runs, the reliability and repeatability of the measurements were examined.

When it comes to the validity of the measurements, compared to the reference measured by RDSV, RoadFly showed approximately 1 mm higher maximum rutting values, when averaged from a 2 km long road stretch. Since RDSV showed about 2 mm higher results for the measurements in an inclusive comparison test organised by FTA, it can be concluded that RoadFly measures about 3 mm higher rutting values for this 2 km long road. However, the road where the tests were performed was not a typical one with two lanes, but with only one. Which means that the compounded rutting was also atypical.

On the basis of the 80 km/h rutting measurements average values, the coefficient of variation was calculated to 2,6% and the visualisations of the rutting were quite identical with each other. The average values between the different speeds of the rutting measurement correlated within 2 mm.

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Tuomas Sinisalo and Mikael Heikkilä

TESTING THE ROADFLY PROTOTYPE UNIT IN REAL WINTER ROAD CONDITIONS

GENERAL OVERVIEW OF THE WINTER ROAD MEASUREMENTS

The purpose of winter measurements was to investigate the operation of the RoadFly prototype in real winter road conditions. The measurements were aimed at finding limitations of the operation of the device in real intended operational field conditions. The prototype had previously undergone field tests in dry paved road conditions, but the operation of the equipment in winter conditions had not been tested before.

The winter measurements aimed to determine the robustness and validity of the system in field conditions. For robustness testing, it was of interest whether the different ice and snow surfaces affect the measurement results produced by the instrument. It was also examined whether the ‘snow smoke’, or blowing snow, from traffic would affect the operation of the prototype. In a blowing snow, the part of the laser beams is reflected from the snow dust back on the scanner, which can affect the measurement results (Lammi 2013, 37-39). The aim of the validity testing was also to examine the measurement accuracy and global navigation satellite system (GNSS) positioning accuracy of the system against reference data.

The measurements were carried out at two different times to enable the tests to vary in weather conditions and in the composition of snow and ice on the road surface. The purpose was to compare the data generated by the RoadFly prototype to reference data produced by Roadscanners Oy, and to find variation in data. In addition, Trimble SX10 scanning total station was used for producing reference data. For GNSS sensor testing, the values from the RoadFly were compared both mobile and stationary to reference positioning data.

THE DEVICES AND SYSTEMS IN THE TESTS

RoadFly prototype unit

RoadFly is a prototype unit that has been specified, designed, and implemented in the ALASCA project. The purpose of the unit is to automate road monitoring measurements from traffic. RoadFly is placed on the front of the vehicle in order to scan the road conditions. Figure 1 shows a rendered image of the RoadFly.

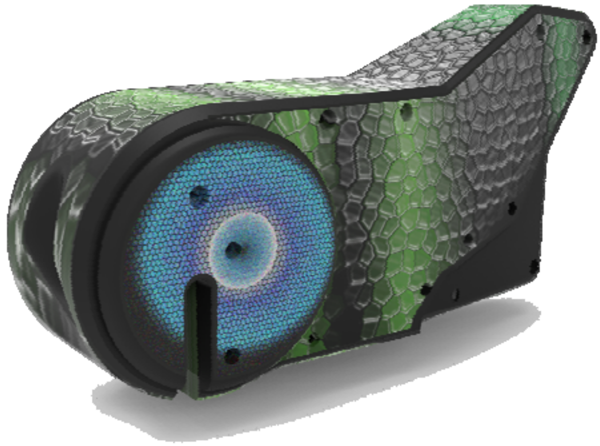

Figure 1 RoadFly prototype unit

RoadFly is based on 2D laser scanning by a Light Detection And Ranging (LiDAR) sensor, which creates a point cloud. This point cloud is processed in real time in the Roadscanners Road Doctor Maintenance Controller (RDMC) software, which is embedded to the RoadFly. The RDMC produces geo-indexed rutting and snowbank height information. The unit has connectivity for real-time transmission of the processed data.

The prototype consists of three main components, which are the LMS-151 LiDAR sensor, the industrial PC and power management circuit. It also includes GNSS positioning and cellular network connectivity. The LiDAR sensor handles all the road surface sensing, transmitting laser pulses at 905 nm wavelength while measuring the distance through laser pulse delays.

The industrial PC handles the measuring data from the sensor and the RDMC program processes the measurement values. In addition, the PC formats and validates values and transmits them over the mobile network to Internet of Things (IoT) cloud platform managed by Arctic Power Research Group in Lapland UAS.

The power management circuit in the system ensures that other components start up automatically when the vehicle starts and shuts down. This will prevent the vehicle's battery system from being discharged.

Road Doctor Survey Van

Road Doctor Survey Van (RDSV) by Roadscanners was adopted for producing reference road data for RoadFly operational field tests. RDSV is intended for extensive road network surveying. The RDSV measurements can be processed and visualised in the Road Doctor software, which is developed by Roadscanners. RDSV uses laser scanning for road surface measurements and features a precise VRS-GNSS system for positioning. The positioning data accuracy is within a few centimeters in xy-parameters. The survey van includes a fiber optical inertial unit, which is adopted for measuring the position of the laser scanner. The inertial unit improves the positioning accuracy especially in cases where satellite availability is lower. Roadscanners offers its RDSV solution for clients worldwide. (Roadscanners Oy 2018, 5-6.) Figure 2 features RDSV and demonstrates the placement of the laser scanner unit on top of the car.

Figure 2 RDSV with the laser scanning unit (Saarenpää 2018)

The RDSV took part in a comparison test organised by the Finnish Transport Agency (FTA). The tests focused on the validity and reliability of various commercial laser scanning services currently in use in Finland. In addition, the effect of speed on measurements was of interest. The maximum rutting values of RDSV compared to reference data were 2 mm higher and the test repeatability variation coefficient was 1,8%, whereas the mean value of the reference data was approximately 1,9%. The effect of speed on measurement mean values were close to non-existent. (Virkola, Ala-Naatu & Huusonen-snicker 2018, 16) In the light of these tests organised by FTA, it can be concluded that RDSV is a solid reference for winter measurements of RoadFly, although it can be criticised that the FTA tests do not provide a complete understanding of RDSV performance in winter conditions.

Both RDSV and RoadFly use 2D laser scanning technique in provision of measurement data. The most significant differences of these two systems emerge from their intended application. RoadFly is not intended for producing high accuracy data in terms of measurements and positioning, whereas these are some basic functions of RDSV. The compact size and reasonable price have been some starting points for selecting the SICK LMS-151 for ALASCA project, and consequently for the RoadFly prototype unit.

Trimble SX10 scanning total station

Figure 3 Trimble SX10 scanning total station on position during measurements on 15.3.2018

The reference measurements featured a Trimble SX10 scanning total station (figure 3), which presents a very efficient combination of total station and 3D laser scanner. SX10 produces high accuracy point cloud data quickly and accurately. The station measures 26 000 points in a second with a maximum measurement distance of 600 m. The point cloud density is high within the whole range. The laser point size is 14 mm in 100 m. (Geotrim 2018.)

SX10 suited well to be used as a reference material in winter road conditions as it provided point cloud data efficiently. In addition, a previous set of measurements was available in ETRS-GK26 coordinate system at the road stretch. As a result, the measurements with SX10 were easily placed in the correct coordinates and were more easily compared to RoadFly data.

IMPLEMENTATION OF FIELD TESTS

The location of the winter measurements was a 2 km stretch of road in Jokela area, Rovaniemi. The road section was very well suited to the tests as there was previously conducted laser scanning station measurements in ETRS-GK26 coordinate system.

All the winter measurements were carried out on two different days, including the simultaneous reference measurements. A large goods vehicle (LGV) provided by the Lapland Vocational School was used in the tests, with the RoadFly mounted on it. In addition, two Trimble R8 GNSS receivers were mounted on the LGV. The receiver offers very high precision location with 8 mm accuracy capabilities (Trimble n.d.). The data from the Trimble R8 was also applied for reference measurements for testing the RoadFly GNSS receiver accuracy.

RoadFly processes 2D scanner data within the unit and transmits real-time data regarding both wheel path ruts on a driving lane. In addition, RoadFly provides values regarding the maximum rutting and snowbank height, which are accessible through configurations within the unit. The processing system of RoadFly calculates the mean values of measurements during 1 s and sends the processed mean values to a cloud platform. In order to able to compare the measurement data in a point cloud, also raw data from the RoadFly was collected and saved with Roadscanners CamLink software.

First Test

The first winter measurement was carried out on 1.3.2018. The weather was cloudy and the temperature was -8°C. The road surface was snowy and covered with dry ice. Figure 4 demonstrates the rutting on the winter road at the test section. The first test aimed at finding out how well the RoadFly performs in clear winter conditions without a snowfall, drifting snow or blowing snow from the traffic.

Figure 4 Road surface conditions on the first day of testing

Overall, three test runs were carried out during the first day of testing with the driving speeds of 30, 50, and 80 km/h. Simultaneous reference measurements were carried out with RDSV.

Second Test

Second winter road measurements were carried out on 15.3.2018. The sky was clear and sunny while the temperature was -9°C. There was dry and shiny ice on top of the road surface. The aim of the measurements was to find out if blowing loose snow from the traffic interferes with the RoadFly measurements. The conditions were created by driving with a passenger car on front of the LGV with the RoadFly mounted on it. Figure 5 depicts how the tests were carried out in practice.

Figure 5 Measurements in blowing snow conditions

The first test was done with a speed of 60 km/h when the amount of blowing snow was too small. For the second test, the speed was raised to 80 km/h which created much more blowing snow. However, it was necessary to keep a short distance to the LGV and drive close to the side of the road.

GNSS receiver tests

Two test cases were implemented for RoadFly GNSS receiver. The first test case included the wandering of the GNSS in a stationary vehicle while only paying attention to the GNSS receiver at the RoadFly. In the second case, the vehicle was mobile and the GNSS receiver values were compared with Trimble R8 reference measurements.

In the stationary test, the RoadFly was placed in an open spot which had minimal restraints with satellite availability such as high concrete or metal constructions. First, the RoadFly was stationary for a period of 10 minutes after which GNSS receiver measurements were carried out for a period of 10 minutes. Overall, the test gave 600 measurements with 1 Hz positioning frequency.

In the mobile tests, the GNSS receiver was compared with Trimble R8 positioning data in a 2 km test drive. Both RoadFly and Trimble R8 were placed next to each other outside the LGV, above the windshield. For both devices in the tests, the updating frequency was set to be 1 Hz.

RESULTS

The measurement data was processed using Road Doctor -software, a diverse software developed by Roadscanners for processing road measurement data. It enables follow-up processing, analysing, and visualising the road measurement data. In addition to road measurements, Road Doctor is used in bridge and railroad measurements worldwide. (Roadscanners n.d.)

Terrain models were made from testing equipment generated point clouds with 3D-Win land surveying software. The points clouds were imported in ETRS-GK26 coordinate system. The terrain models were used in creating cross section images, where all testing equipment could be seen.

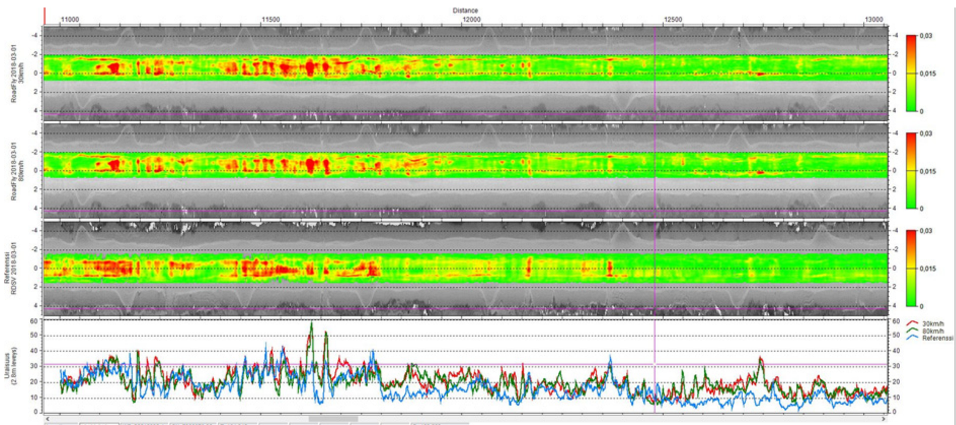

Figure 6 Measurements from the first testing day visualised using Road Doctor

Figure 6 shows results from the rutting measurements of the first testing day visualised using Road Doctor. Colour bands show the measurement results for three different sets: RoadFly at 30 km/h (top), RoadFly at 80 km/h (middle), and RDSV reference material (bottom). Colour coding from green to red corresponds to rutting from 0 to 30mm, respectively. The graph at the bottom of figure 6 shows the same measurements as line graph: RoadFly at 30 km/h (red), RoadFly at 80 km/h (green), and RDSV reference material (blue).

RoadFly measurements were nearly identical at 30 and 80 km/h. Therefore, RoadFly was assumed able to produce reliable results at least at speeds up to 80 km/h. However, there were some differences between the RoadFly and RDSV rut depth measurements, although, the deepest ruts were measured at the same locations on the test road.

Table 1 shows measurements of both test days in numerical form. The table lists the minimum value, maximum value, average, standard deviation, and median of the test road measurements at different speeds of RoadFly and RDSV rutting measurements. The average value of rutting depths measured with RoadFly was 3,5 mm on the first testing day and 4,3 mm on the second testing day larger than the corresponding values measured by RDSV. Differences in the results are most probably due to the measurement uncertainty, as the statistical error of the 2D laser scanner, i.e. in RoadFly, is 12 mm according to the manufacturer. The observed differences in the measurements can be viewed as surprisingly small. (Sick n.d.)

Table 1 Summary of rutting measurements

date	measuring device	speed [km/h]	min [mm]	max [mm]	average [mm]	variation [mm]	median [mm]
1.3.2018	RoadFly	30	6,9	57,8	20,3	7,1	19,3
1.3.2018	RoadFly	80	5,7	57,9	19,3	6,6	18,5
1.3.2018	RDSV	50	2,7	42,5	15,5	7,6	14,0
15.3.2018	RoadFly	60	5,0	43,9	16,2	6,0	15,5
15.3.2018	RoadFly	80	5,5	46,7	17,7	6,3	17,0
15.3.2018	RDSV	50	3,5	39,6	13,5	6,1	11,9

Figure 7 shows the results of the second testing day. The figure shows that when driving at 60 km/h, the ‘snow smoke’ did not affect the measurement results of RoadFly, as there were little to no differences to the reference measurements. Additionally, at 80 km/h, the measured data does not have any major deviations from the reference measurements, except for the singe peak at the end of the measurement, where the RoadFly shows much larger values for the rutting depth. Figure 8 shows a screenshot of the video recorded by RDSV, from which it could be concluded that at that point the LGV had passed too close to the edge of the road. This interfered with the Road Doctor calculations because the software included the height of the snow bank on the right side of the road into the calculation.

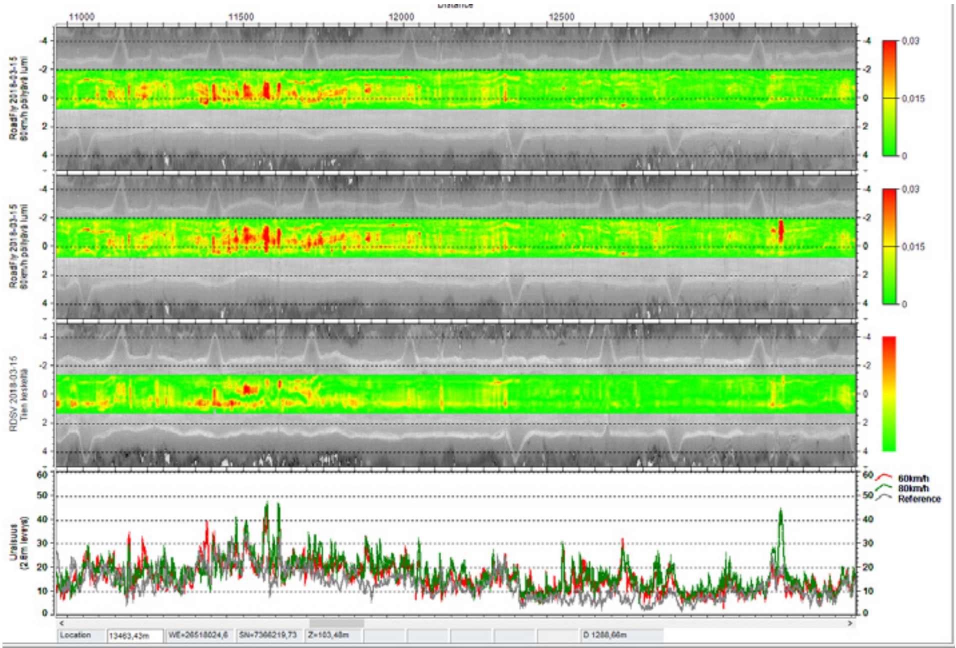

Figure 7 Measurements from the second testing day visualised using Road Doctor

Figure 8 Screenshot of the video recorded by RDSV

Figure 9 shows the cross-sectional view from the 3D-Win software, which combined the road cross-sections produced by the test equipment, from the same road section, coloured according to the measuring device: RoadFly (red), SX10 (black), and RDSV (blue). The cross-section from the RoadFly is horizontally skewed as well as approximately 1 m to the right in relation to the reference material due to the lack of an inertia device and the fact, that in the test measurements the R8-GNSS receiver was attached to the LGV approximately 1 m away from the RoadFly. However, this does not impair the relative measurement accuracy of the device and thus does not affect the rutting measurements it produces. The cross-section of the total station is formed from a thinned point cloud because the 3D-Win software could not handle the original too dense a point cloud. For this reason, the cross-section from the SX10 is not detailed enough for calculating the rut depths from it. Road Doctor turned out to be a more suitable and versatile tool for this purpose.

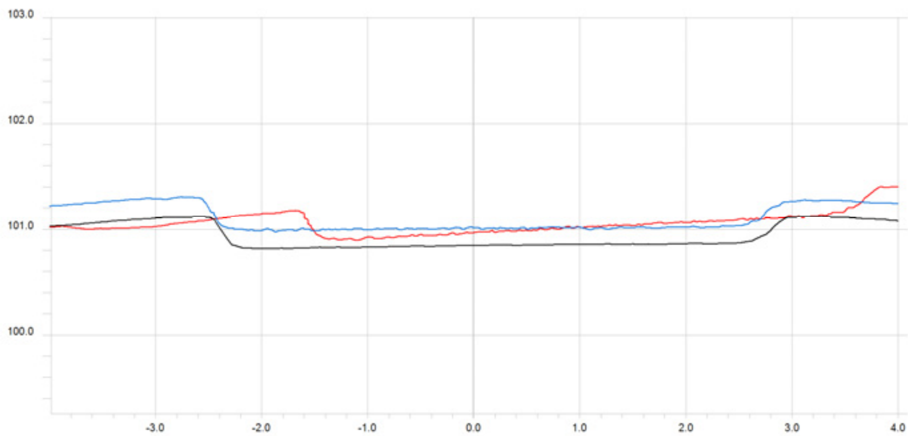

Figure 9 Cross-sectional view from the 3D-Win software

Based on these tests, 'snow smoke' from the car driving in front of the LGV will not interfere with the operation of the RoadFly, as measurement results do not differ significantly from the reference measurements. However, on the day of the test, the road surface was icy and contained too little snow resulting in less snow than there would have been had it been snowing. The effect of snowfall on scanners was not tested in these tests due to the weather conditions and time limit.

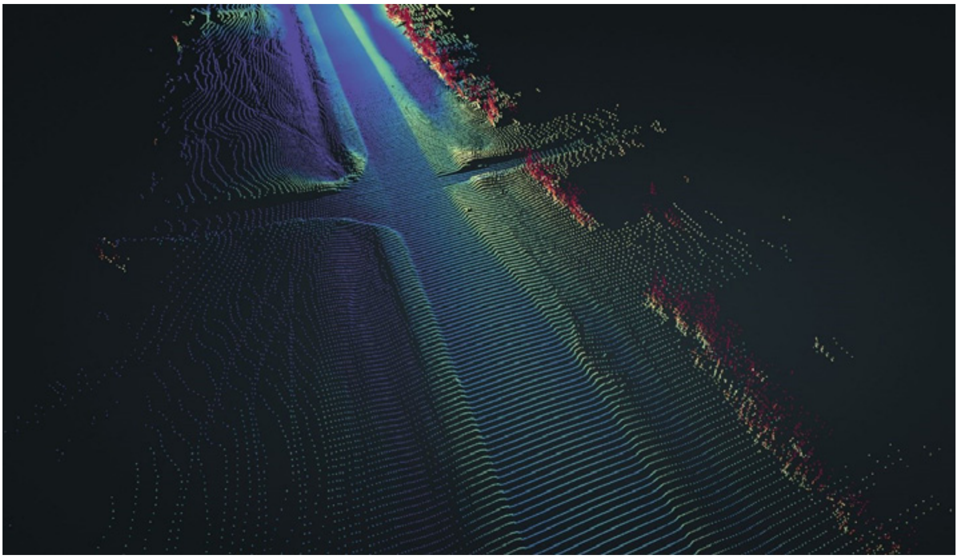

Figure 10 Point cloud data from RoadFly (Saarenpää 2018)

Figure 10 shows the point cloud data measured on the second test day using RoadFly at speeds up to 80 km/h, colour-coded by height. No ‘snow smoke’ is visible in the figure, meaning, that the amount of snow generated in the test did not affect the laser scanner. Figure 11 shows a previous RDMC point cloud measurement colour-coded by height, where thick enough snow is visible in the laser scanner image as error points. RDMC is more inexpensive than RDSV, and can easily be transported from one vehicle to another. Surrounding terrain and the snow banks are visible at the edges of the image. In the middle of the image, the lane is visualised mostly with shades of blue. The ‘snow smoke’ caused by the tires is clearly visible in the middle of the lane as yellow spots. In the RDSV, the laser scanner was attached on the back of the measuring car, where the snow from the measuring car tires reflects part of the laser beams and they appear higher than the road surface. However, RoadFly was attached to the front of the LGV, where the ‘snow smoke’ caused by the LGV did not affect the measurements. (Roadscanners, 2018, 3)

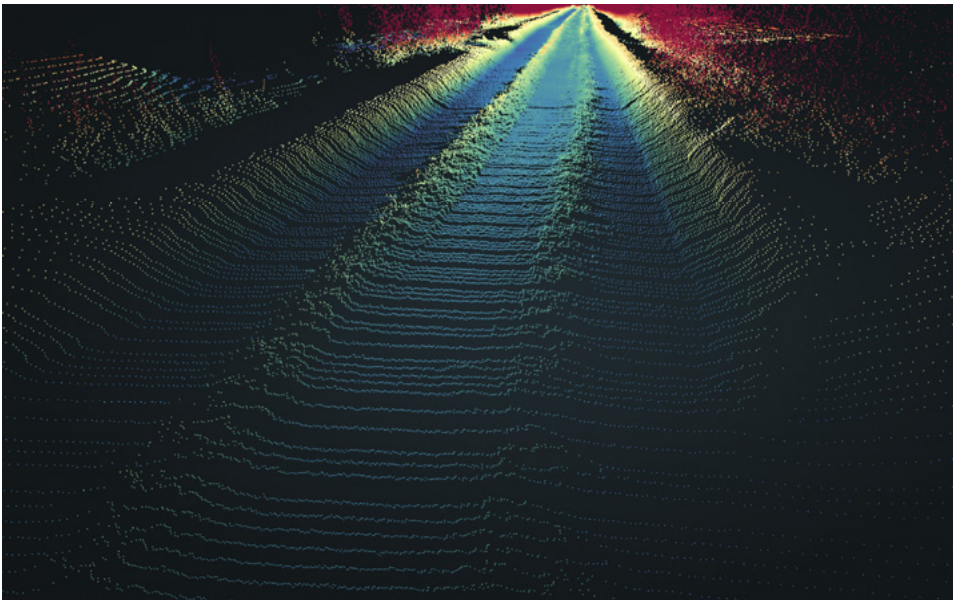

Figure 11 Previous measurements from RDMC. (Saarenpää 2018)

A moist road surface can affect the reflection of the laser beams. Figure 12 shows a very damp road surface visualised. The point cloud is coloured based on the intensity of the laser beam. The figure shows that the laser scanner has received only random measurements from the opposite lane. (Saarenpää 2018.)

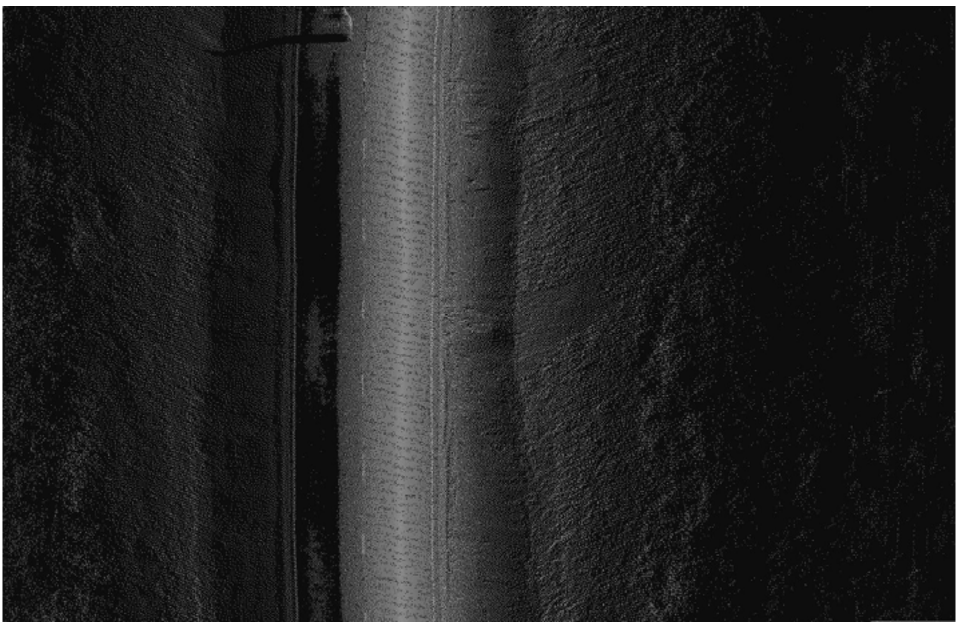

Figure 12 Laser scanning data from a moist road. (Saarenpää 2018)

Operation of the device was planned to test on a damp surface during the winter tests as well. However, the damp road measurements should have been scheduled for spring, when the sun would have melted the ice on the road. However, the schedule of these tests came alive, and no wet ice measurements had been made.

Results for the GNSS location tests

Figure 13 shows the results of the stationary positioning test. The variation in positioning locations was very small.

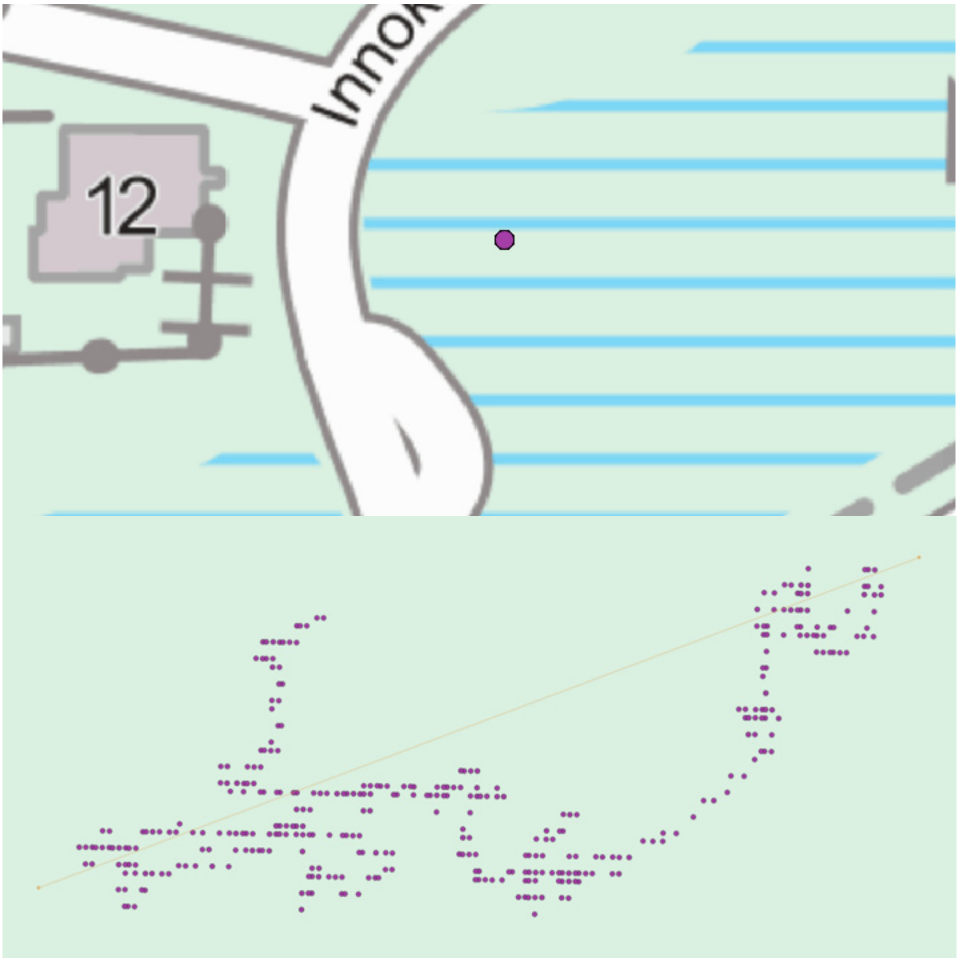

Figure 13 Locations of the stationary positioning test from afar and at close range

A comparison of stationary test positions showed that all positioning for 10 minutes could be limited inside a circle with a diameter of only 125 mm. However, this test does not depict well on the positioning of RoadFly's mode of operation, as it is always in motion while measuring.

RoadFly was subjected to another positioning test while moving, where its positioning ability was compared to centigrade reference positioning. Figure 14 shows the paths for tracking generated by RoadFly (red) and Trimble R8 (blue).

Figure 14 Reference (blue) and RoadFly (red) GNSS positioning paths side by side

Compared to the direction of travel of the vehicle, the positioning of RoadFly deviated from the reference value in the lateral direction approximately -40 - 500 cm. The comparison of the positioning curve perpendicular to the direction of travel of the vehicle was more difficult to implement due to the phase difference of the positioning. However, assuming that the lateral positioning error is of the same class as in the forward direction, it can be stated that at a speed of 80 km/h, the RoadFly positioning error affects the location of the individual measurement by 10 m at a maximum.

SUMMARY AND CONCLUSIONS

The aim of the ALASCA pilot winter test was to measure the RoadFly prototype in different winter conditions and to find limits of the functionality of the device during winter measurements. The tests were carried out on two separate days, obtaining variation in measurements in differing weather conditions and in the ice and snow surface compositions of the road. RoadFly was attached to the front of a LGV in the test measurements and several measurements were carried out at different speeds at the same test portion on both test days. On the first day of testing, the functionality of the device was tested under normal winter conditions and on the second day of test the snow-dust caused by traffic was included. On the basis of the actual test measurements, reference measurements were performed on Roadscanners Oy's RDSV measuring vehicle and on the second test date with the Trimble SX10 total station. RoadFly automatically forwards information concerning the hard compressed snow on the road as well as the height of the snow banks. This article focused on examining the measurement results of hard compressed snow on the road and the accuracy of GNSS positioning.

Based on the test results, it can be concluded that icy and snowy road surfaces will not interfere with the operation of the device, at least if there is no water on the ice.

During the tests, the road surface was dry with ice and snow, and these surfaces did not cause any problems. However, it must be taken into account that the conditions were not the most challenging for the scaling scenario. Prior to testing, frozen surfaces with water on the surface, were thought to be problematic for the reflection of the laser beams. In addition, measurement data produced by Roadscanners Oy before the winter tests during unfrozen soil showed that laser beams are reflected badly on water on the road. Such road surfaces are typical during the end of winter or spring when the sun melts the ice from the road surface. Due to the limited schedule, measurements over wet ice were not possible and should be focused on in any further testing. Furthermore, new winter tests could focus on measuring the snow banks on the edge of the road as well as measurements in, e.g. sleet or snowfall. Dense snowfall would probably prevent laser beams from reaching the road surface. On the other hand, one might wonder whether the device is even intended for use in such challenging conditions.

The snow dust caused by the car driving in front does not interfere with the measurements according to the test results described in this article. During these tests the LGV drove much closer to the passenger car than normally. In addition, the passenger car drove right on the edge of the road in order to cause the largest amount of snow dust possible. Despite these factors, the snow was not found to affect the measurement results as no significant differences in the reference measurements were found. On the other hand, the road surface was frozen, meaning, that the amount of snowfall caused by the passenger car was not as large as it would have been had it been snowing prior to the test. However, even after snowfall, having normal safety distance between the LGV and the passenger car the amount of snow dust caused by traffic would unlikely be greater than it was during the test runs.

The GNSS positioning of RoadFly was tested in two parts. First position test was stationary and the second was in motion, compared to the reference. In the stationary test, only the variation of the received location data was tested for 10 minutes. These positions fit into a circle with a diameter of 125 mm. In the moving test, the positioning of RoadFly was compared to the reference in the transverse direction relative to the direction of travel. RoadFly's positioning ranged from 40 cm to the left of the reference and 500 cm to the right of the reference.

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Hanna Kumpula

Visualising data from 2D laser scanner, Case: Road maintenance quality control

INTRODUCTION

ALASCA project concentrates on exploring the possibility of using a 2D laser scanner in producing measurement data related to road condition. The purpose of the project is to use large goods vehicles (LGV) as data gathering units as they drive through the roads in the north. This data could be used to convey information of the road maintenance quality.

Currently, the road maintenance quality is ensured by quality controllers, each of whom have been assigned one or more contract areas. Quality controllers work with cameras, for proving the findings; calibrated friction measurement system, for verifying the friction values; and hand measuring tools, for measuring some values, e.g. snow on the road. Consequently, the quality control is extremely dependent on humans. (Konttaniemi & Poikajärvi 2017; Kumpula 2017) Finnish Transport Agency (FTA) has published the quality requirements to follow as a separate document (Liikennevirasto, 2015).

The quality control professionals do not have any deliberate indicators showing where they should focus their inspections. In addition, the area under surveillance per professional can be quite large, which sets a natural limit on how many roads they are able to cover. Therefore, they usually drive through the roads on weekly basis. Road weather stations (RWS), knowledge of road maintenance actions, and different sources for feedback are some examples of decision making support tools. (Konttaniemi & Poikajärvi 2017; Kumpula 2017)

The 2D laser scanner rutting measurement capability was verified during ALASCA project, but as the objective was to design an actual tool for the quality control professionals, the user interface (UI) design was able to include other kinds of data as well, without including the source for these or even the feasibility. Additionally, the UI would only be provided as a functional prototype, with no actual data or functionality.

METHODS FOR GATHERING INPUT FOR THE DESIGN

Three main categories for gathering input for UI design were: an online survey, an existing UI designed for road maintenance contractors in WiRMa project, and several documents. Observation was planned but could not be executed due to schedule issues.

Online survey for quality controllers

DESIGN

The online survey was designed to gather information on what the quality controllers view as important and how they would like to see the measurements visualised. The survey contained 23 questions in total, 8 of which were open follow-up questions for the previous (see Appendix A). None of the questions were mandatory. Background information included only the contract areas under surveillance and location of the office. As there are two distinct seasons in road maintenance, information regarding winter- and springtime was kept separate from summer information.

The online survey was the only available option as there was not enough time to deliver and gather paper versions. Surveying over the phone was not possible due to difficulties in scheduling.

Survey was designed using Webropol service. Link from the service was sent to 14 persons, who have knowledge of the road maintenance quality. There were 15 days to complete the survey.

RESULTS

6 responses were received, resulting in 43% response rate. None of the responses were incomplete, which means that every person beginning the survey did complete it. The reason for not answering the survey is unknown and was not inquired.

Results were downloaded from the Webropol service and analysed manually using Excel. The basic reports Webropol provides were not detailed enough.

Figure 1 Responses from contract areas. The darker the colour, the more responses. White signifies none.

Due to privacy issues some background information, answers to open questions, or any answer where a person can be identified will not be displayed. Figure 1 shows the contract areas responses covered as a heat map, where the darker the colour, the more there were responses concerning that area. At least one response per area was received.

GENERAL MEASUREMENTS

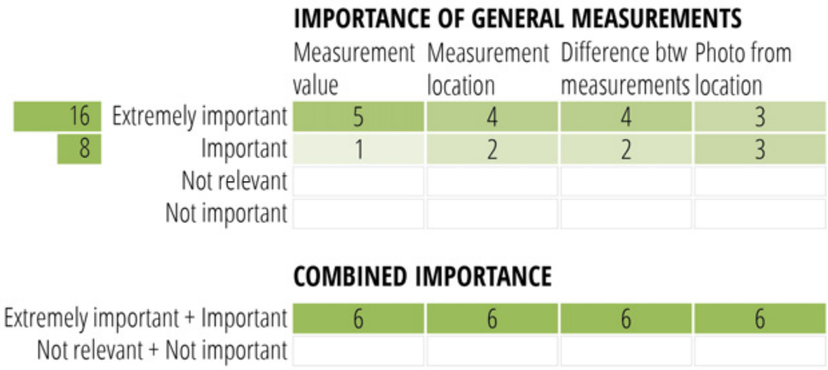


Figure 2 Importance for the General measurements

Figure 2 shows the results for the importance of different general measurements. General measurements are not season specific. The bar graph shows that all general measurements were evaluated as extremely important or important. The actual measurement value was evaluated as extremely important by nearly all respondents. This shows in the heat map. The comparison heat map shows the heat map as combined scales of the important (extremely important or important) and unimportant (not relevant or not important) values and supports the finding that all general values were evaluated important.

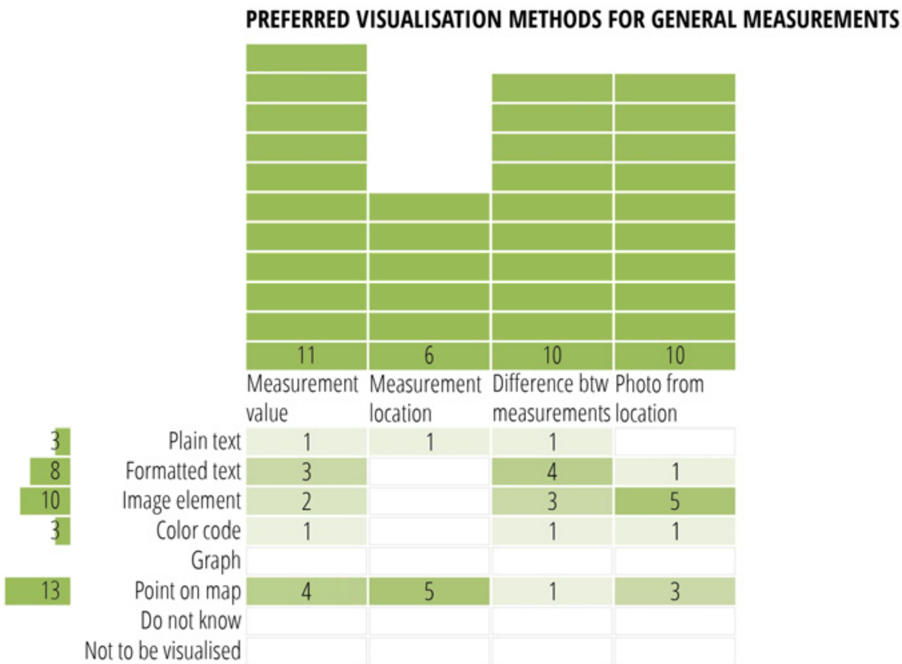


Figure 3 Preferred visualisation methods for general measurements

Figure 3 shows how the general measurements should be visualised according to the survey results. Point on map was the most preferred method for conveying information followed by image elements and formatted text. A few selected colour codes or plain text as convenient. The heat map illustrates, that most of the general values can be visualised using a single element, although both formatted text and image element were seen good method for conveying information regarding difference between measurements.

WINTER- AND SPRINGTIME MEASUREMENTS

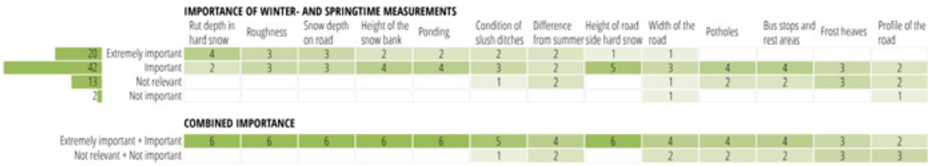


Figure 4 Importance for winter- and springtime measurements

Figure 4 shows the results for the importance of different winter- and springtime measurements. The bar graph shows that different measurements were mostly evaluated as extremely important or important. The heat map shows, that every value was evaluated as important. However, there was a clear difference between the extremely important and not relevant values. Measurements regarding the snow on the road were evaluated more important than the values regarding, e.g. potholes. The comparison heat map of the combined scale of important values (extremely important or important) to the combined scale of the unimportant values (not relevant or not important) supports this finding as well.

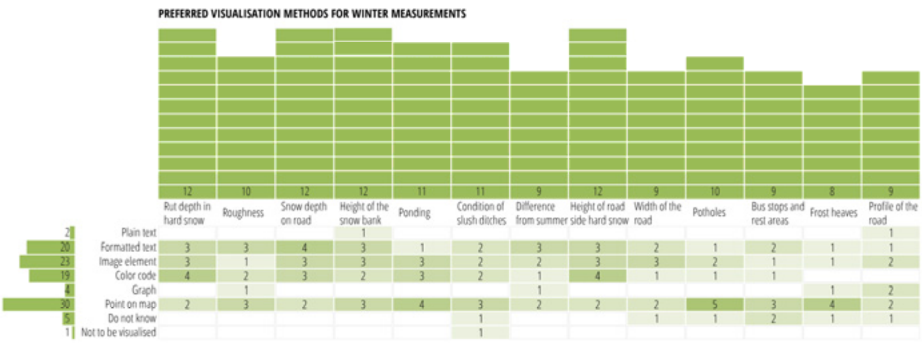


Figure 5 Preferred visualisation methods for winter- and springtime measurements

Figure 5 shows how the measurements for winter- and springtime should be visualised according to the survey results. Respondents were allowed to select multiple values to answer this question. Point on map was the most preferred method followed by image elements, colour coding, and formatted text. Graphs, however, were not evaluated as a useful method for conveying information. The heat map shows that nearly every measurement should be visualised as a combination of different methods. Although, majority of the potholes, frost heaves, and the condition of slush ditches could be visualised using solely points on map.

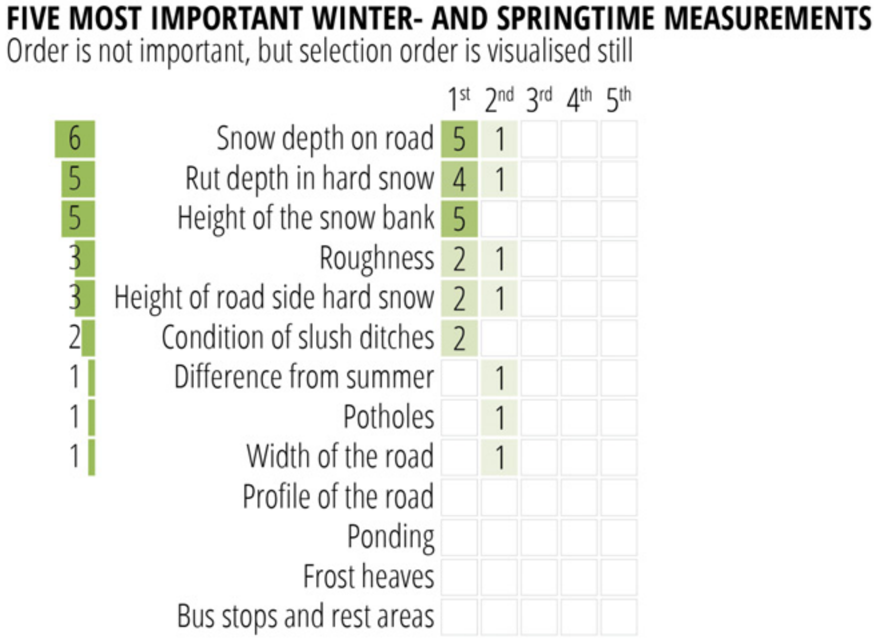


Figure 6 Five most important measurements for winter- and springtime

Respondents were asked to select five most important measurements for winter- and springtime. Order of the responses was not of importance. Figure 6 shows that all responses were quite similar. In descending order, the five most selected values were snow depth on the road, depth of the rut in hard compressed snow layer, height of the snow bank, roughness, and height of the road side hard compressed snow.

SUMMERTIME MEASUREMENTS

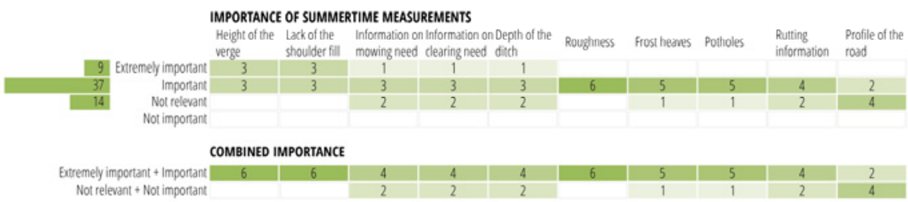


Figure 7 Importance for summertime measurements

Figure 7 shows the results for the importance of different summertime measurements. The graph shows the distribution of importance scale, which illustrates that mostly the measurements were seen as important. The heat map shows, that roughness is clearly most important. Comparison heat map of the combined scale of important values (extremely important or important) to the combined scale of unimportant values (not relevant or not important), shows, that height of the verge, lack of shoulder fill, and roughness were most important for all and frost heaves with potholes secondly important. The graphs show that nearly every value is seen important as only the road profile received more responses on the unimportant part. The fact that none of the values was marked unimportant supports this finding as well.

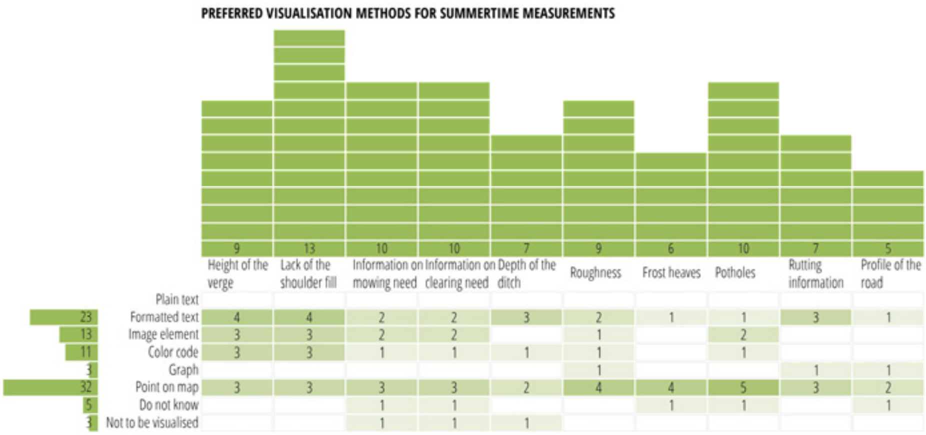


Figure 8 Preferred visualisation methods for summertime measurements

Figure 8 shows the measurements for summertime should be visualised according to the survey results. The results show that visualising the information as a point on map was preferred the most, whereas plain text or graphs should not be used at all. Formatted text was the second preferred method for conveying information followed by image elements and colour coding. The heat map shows that potholes can be visualised only using points on map, while height of the verge and lack of shoulder fill may need a combination of several visualisation methods.

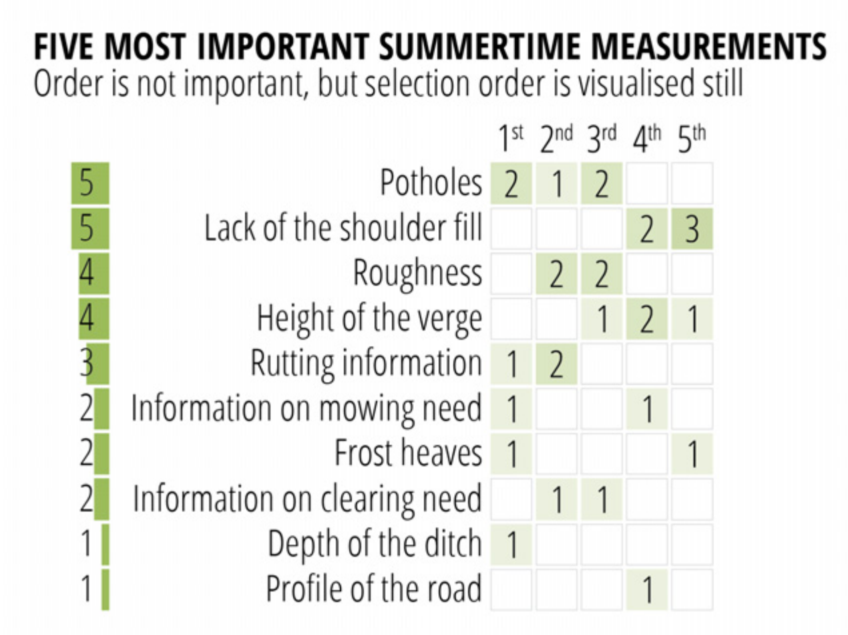


Figure 9 Five most important measurements for summertime

Figure 9 shows responses show values that were selected the most important for the summertime measurements. Responses were distributed between different measurements in almost uniformly. In descending order, the five most important values for summertime measurements were potholes, lack of shoulder fill, roughness, height of the verge, and rutting information. Many responses noted in the open response, that clearing and mowing are scheduled tasks and therefore do need to be measured.

MEASUREMENT ALERTS

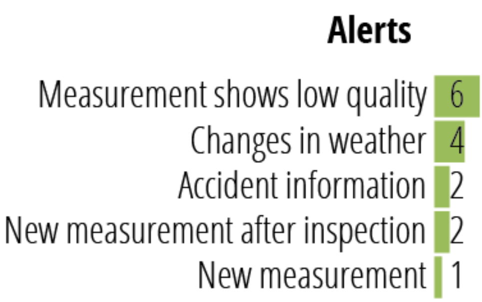


Figure 10 Necessary alerts for ALASCA

Figure 10 shows the necessary alerts according to the responses. Every respondent required an alert if the measurement shows low quality. Most wanted to see alerts when weather changes. Accidents and new measurements were seen useful by some, whereas none required season specific or unclear measurement values.

MEASUREMENT DEVELOPMENT AND HISTORY INFORMATION

Figure 11 Usefulness of marking a measurement as a reference

Figure 11 shows that most of the respondents did not see selecting a value as a reference a useful, despite the difference between measurements being regarded as important (figure 2). This difference between the responses together with the requirement for seeing an alert when the measurement shows low quality (figure 10) suggests, that it is important to see the difference between the measurement and the quality limit, whereas seeing difference between any two values is not important. Respondents were asked through an open question how long a history they would need to see. The responses varied from 2 months to 3 years. Many linked the required history with contract lengths.

USAGE ENVIRONMENT

DEVICE APPEAL

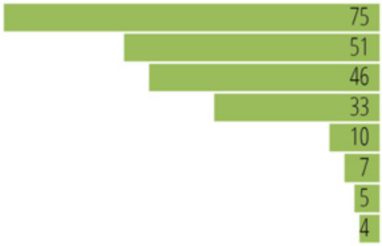
	Most favourite	2nd favourite	Most displeasing
Computer	5	1	
Tablet	1	4	1
Mobile phone		1	5

Figure 12 Appeal of different devices

All respondents would need to see the ALASCA measurements in the field as well as in the office environment. Figure 12 illustrates the appeal of different devices for using the ALASCA UI, with the desktop solution as the most preferred.

SUMMARY OF VISUALISATION METHODS

SUMMARY OF VISUALISATION METHODS



Total	Method	General	Winter- and springtime	Summertime
75	Point on map	13	30	32
51	Formatted text	8	20	23
46	Image element	10	23	13
33	Color code	3	19	11
10	Do not know		5	5
7	Graph		4	3
5	Plain text	3	2	
4	Not to be visualised		1	3

Figure 13 Preferred visualisation methods in total

Figure 13 shows the distribution of selected visualisation methods from general values and each season along with totals. Four most preferred visualisation methods were point on map, formatted text, image elements, and colour coding in descending order of preference.

OTHER NOTES ON SURVEY RESULTS

The online survey was similar for all respondents. The questions were always in same order, which could mean, that some respondents became tired while answering the long questions regarding importance and methods for visualisation. Therefore, it is not certain, that tiring did not affect answering the last summertime-related questions.

WiRMa project

Winter Road Maintenance (WiRMa) project, funded by Interreg Nord, concentrates on present difficulties in winter road maintenance. The RWS network is not dense enough in the north making it difficult for the road maintenance weather center personnel to convey information on the road weather to the contractors. WiRMa project researches the possibility to use LGVs as moving RWSs. LGVs are equipped with different sensors measuring different values directly from the road. These values include road condition, friction, water level on road, and temperature data.

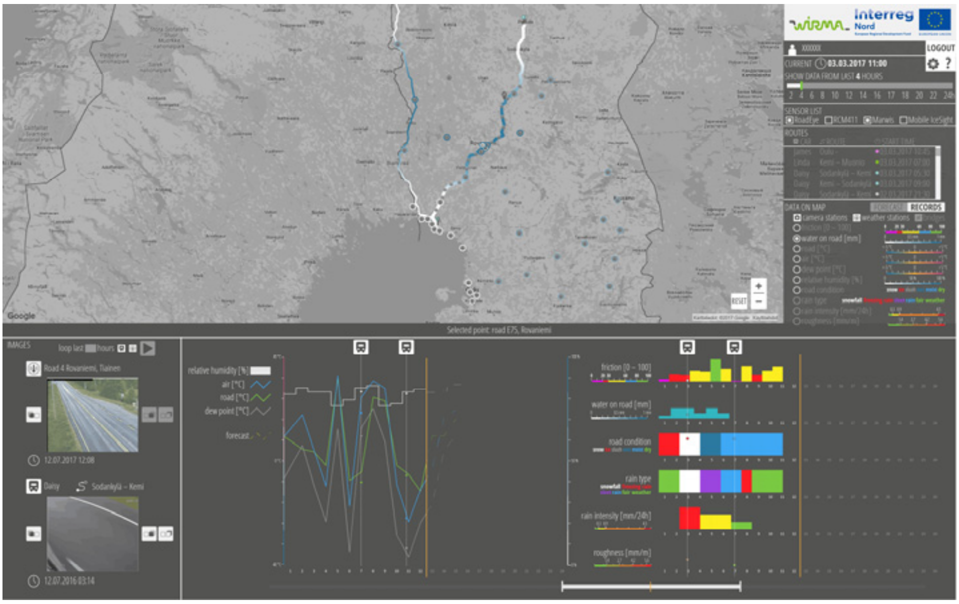


Figure 14 UI in WiRMa project

There are plans for combining all different road maintenance data and visualise it in a common UI. Figure 14 shows the main view of WiRMa UI, which provided a starting point for the UI design in ALASCA project.

Other material

ALASCA STAKEHOLDER INTERVIEWS

During 2017 in ALASCA project several stakeholders were interviewed (Konttaniemi & Poikajärvi 2017). Knowledge of the interview material has had an effect on the UI design, although, it was not systematically used as input.

Material from the interviews, that was indirectly used as input in UI design, includes thoughts on some requirements on visualisation, how the laser could be used, thoughts on possible user groups, some challenges in current methods, and information on requirements. (Konttaniemi & Poikajärvi 2017)

QUALITY GUIDELINES

FTA quality guidelines (Liikennevirasto 2015) were used to show more realistic values in the UI. Additionally, the guidelines were used as input when designing the way to show information.

DESIGNED USER INTERFACE

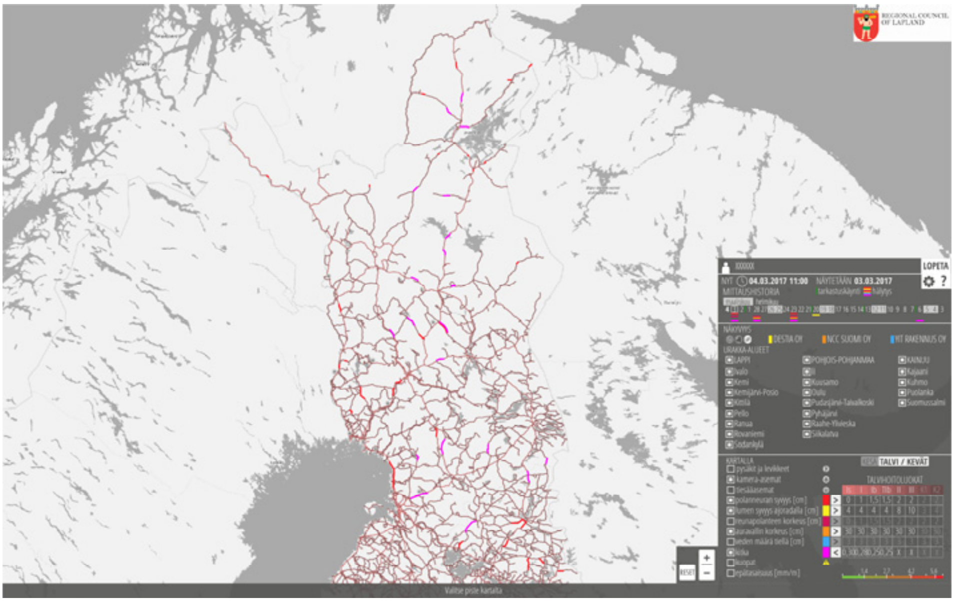


Figure 15 ALASCA UI main view

Figure 15 shows the WiRMa-based ALASCA UI main view. The map takes up most of the space and provides a quick way for the user to the measurement alerts. Map should be based on Google, or similar, map having controls for zooming and panning.

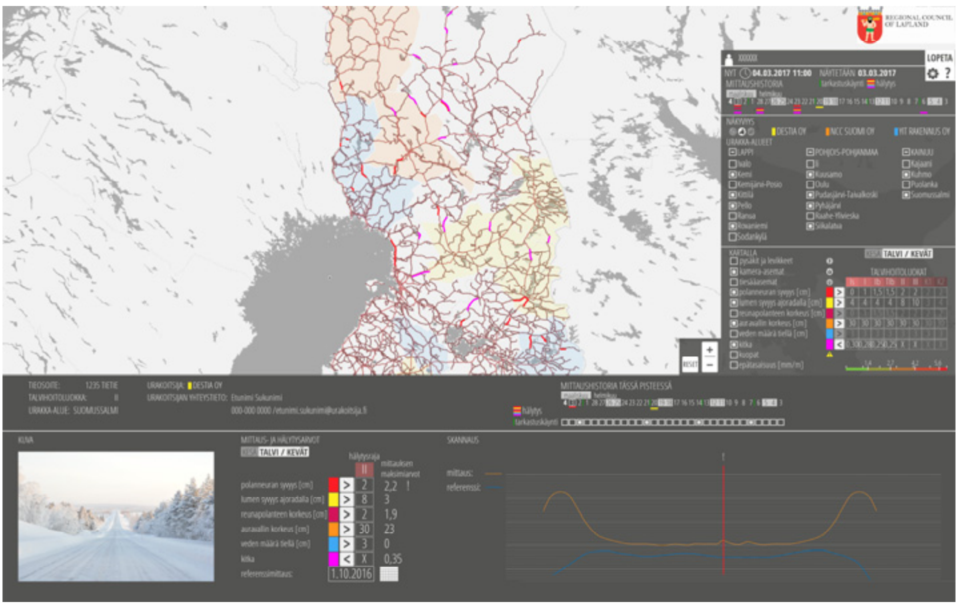


Figure 16 Selected contract areas visualised with filled areas

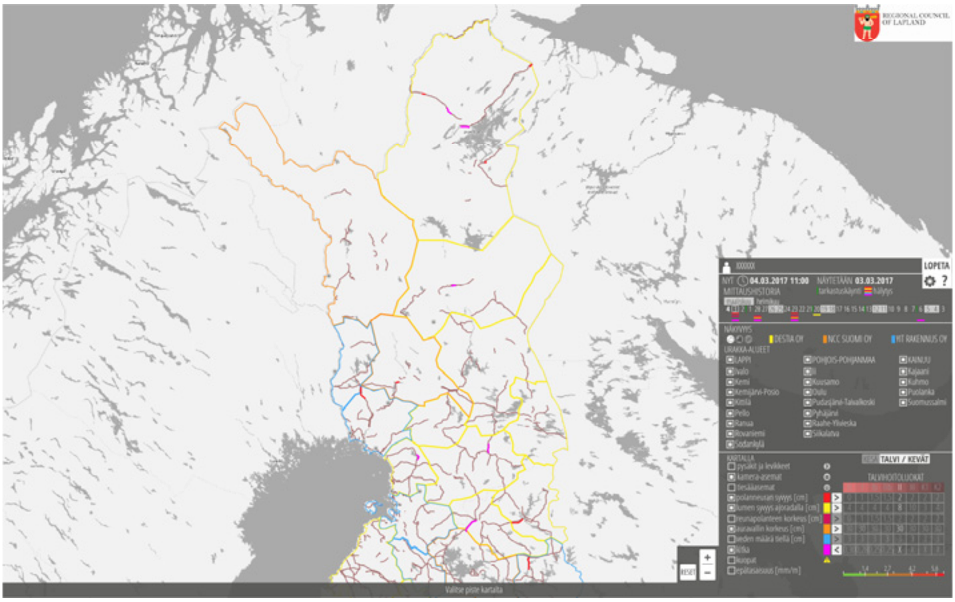


Figure 17 Contract areas visualised using outlines

The survey results indicated, that users view, e.g. the importance of different measurements individually. Therefore, in the ALASCA UI, only data types, contract areas, and roads of interest are visible on the map. Alerts are managed according to both data type and road classification. In addition, users are able to visualise contract areas of interest without tampering with data visualised on the map. In figure 15 the contract areas are hidden, whereas in figure 16 they are visible. Figure 17 on the other hand, shows the contract areas outlined. The colours used in the contract areas correspond with different contractors.

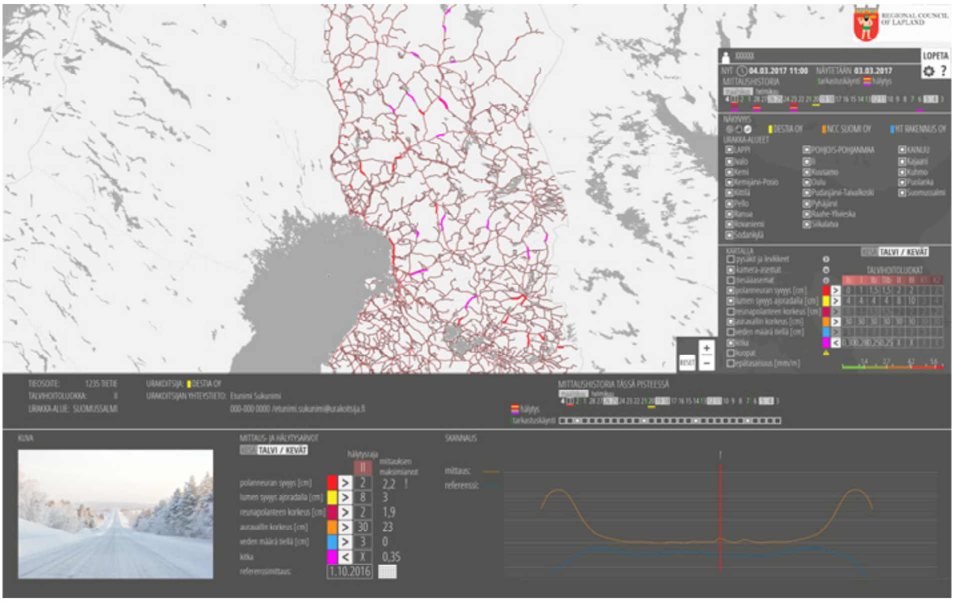


Figure 18 ALASCA UI main view with data view open

Figure 18 shows data view, which provided detailed information of the selected road point. These include possible photo from the road point, information of the contract, and measurements. Measurement history concerns only the selected point. The tools included setting the alert limits, selecting reference values, and marking inspection dates. The laser sweep was visualised as a cross section of the road with measurement alerts on points. Data view doubles many values and controls with the control area. However, data view controls the visible data on map only through alert changes.

The settings, help, or the summertime measurements are not included in this design. In the designer's opinion, both the settings and help should be designed only after the UI design has been finalised. However, summertime measurements were excluded mainly due to the focus of ALASCA project, i.e. winter. Although, a button for switching between seasons was included.

DISCUSSION

This article briefly describes the inputs of UI design process and the UI itself in the ALASCA project. The designed UI is heavily based on UI designed in WiRMa project, due to plans of possibly combining all different road data in the same system.

The main user group for ALASCA UI consists of road maintenance quality controllers, who provided insight for the UI design by answering an online survey. FTA quality guidelines were used in the design process as input for realistic values. Furthermore, stakeholder interviews provided input for the design process as well, although not in a systematic manner.

The aim was to provide a functional prototype that shows not only the laser scanner data but other road management related information as well. UI shows the gathered data on a map and in more detail in a data view.

The ALASCA UI design process is not completed. Next steps require evaluating and discussing the current design with users. Using the WiRMa UI as base was not discussed with the users and the interaction flows have not been verified. Additionally, the different measurements visualised in the ALASCA UI need technical verification from both the measurement and programming aspects. Equally important is to discuss these data combinations with project management, authorities, and companies involved in the projects.

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Heikki Konttaniemi

BUSINESS CONTEXT ISSUES IN THE INDUSTRY OF SMART AND CONNECTED PRODUCTS IN ROAD MAINTENANCE, CASE: ALASCA-PROJECT

INTRODUCTION

When monitoring the road automatically by using regularly driving light goods vehicles (LGV), the use of smart, connected products becomes a viable option. The aim of this article was to establish an understanding of general business context factors and their impact on the forces of competition based on the qualitative data acquired in the ALASCA project. The scope is defined by the ALASCA project which is especially looking at a smart and connected product in the field of automated road monitoring. The ALASCA project is a relatively short regional innovation experiment project, which aimed at testing a laser scanning solution. A first prototype was created during the project with a name of RoadFly. The RoadFly prototype is shown in figure 1. It features a 2D laser scanner, data collection; - processing and – transmission unit; aluminium housing and 3D-printed casing.

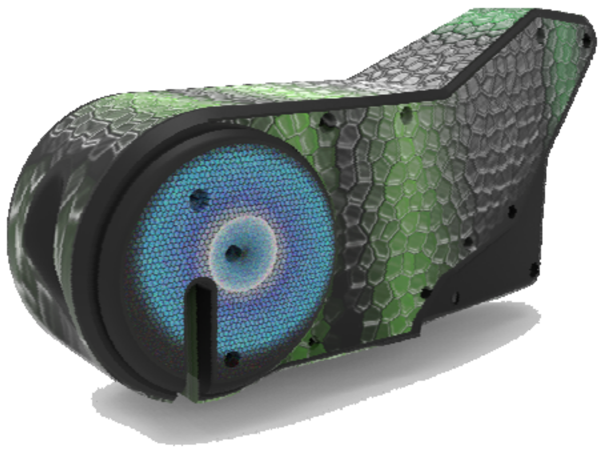

Figure 1 A vehicle-mounted laser scanning unit, RoadFly, enabling automated road monitoring

Some definitions used in this article are Internet of Things (IoT) and smart, connected product. IoT is a megatrend with more devices being connected to the internet. Smart, connected product is a definition by Porter and Heppelman (2014; 2015) and therefore it is adopted also as definition. In this article, however, both IoT objects and smart, connected products are practically the same.

As part of this regional experiment, main stakeholders were interviewed in order to gain expert and user insight on the trend of automating road monitoring by utilizing the existing traffic. This could be also regarded as a 'crowd-sourcing' solution for road monitoring. The IoT, or smart, connected products, play an essential role in the development of the automating road monitoring. The RoadFly prototype is a good example of this. Even though RoadFly can measure road parameters also during summertime, the main focus of the ALASCA-project is in winter parameters.

The actual questions this article seeked to answer, were:

- What are generally the factors affecting on the industry of smart and connected products, or IoT objects, in the field of winter road maintenance?
- What kind of effect do these factors have on the forces of competition in the case of ALASCA project?
- What would be some preliminary implications of these factors in the case of ALASCA project?

It has to be brought out there were some limitations to studying business context issues based on the qualitative data that was acquired in the ALASCA project. Firstly, business issues were not separately addressed in the interviews. Secondly, coming up with a cohesive analysis could not be done based on such data. Consequently, this article provides a starting point, 'initial information', for further studying such issues. This article describes the interview methods and the interview data pre-analysis approach. This data was adopted in business context analyses, which finally give some implications for those developing IoT solutions in the field of winter road maintenance.

METHODOLOGY

The interviews were carried out by using a qualitative interview technique. Qualitative interviews have a conversational mode end two-way communication between the interviewer and the interviewee while enabling open-ended questions (Yin 2016, 146-160). Moreover, the interviews can be partly regarded as interview-data-as-resource as the interviewers and interviewees reflected on the reality outside the interview episode (Seale, Giampietro, Gubrium & Silverman 2013, 15-16). Table 1 demonstrates some general information about the interviews. Overall, the interviewees were selected to provide a comprehensive understanding from different fields of business in the area of road maintenance. For confidentiality reasons, the interviewees' names or companies are not presented in this research.

Table 1 General information regarding the qualitative interviews

Interview number	Interviewer(s)	Business area of interviewees	Duration	Interview Method
1	Janne Poikajärvi, Heikki Konttaniemi	Road Maintenance Contractor 1	76 min	Online Meeting Software Tool
2	Heikki Konttaniemi	Road Operator (Authority)	45 min	Face-to-face
3	Heikki Konttaniemi	Logistics Company	29 min	Face-to-face
4	Janne Poikajärvi, Heikki Konttaniemi	Road Construction Consulting Services and Quality Control	53 min	Face-to-face
5	Heikki Konttaniemi	Road Maintenance Contractor 2	49 min	Online Meeting Software Tool

The interview data was transcribed by a third party for further content analysis. Then, the pre-analysis consisted of assigning codes, or labels, to any meaningful information. Such coding techniques are further explained by Eriksson and

Kovalainen (2008, 128-130) as well as Miles and Huberman (1994, 55-64). In addition, pre-analysis by coding was further encouraged by Seale, Giampietro, Gubrium and Silverman who state that analysing interview data is always a case-by-case dilemma and is determined by the theoretical interests of researchers (2013, 27, 31).

Analysis of qualitative data rests centrally on displays that compress and order the data. In this research, such data displays were close to a conceptually clustered matrix where different responses from interviewees were clustered based on the research questions. Such matrices are especially suitable for non-complex cases with individuals or small groups. It is essential to build displays and/or matrices that help a researcher to answer the research questions, rather than to adopt a display method that does not fit to the purpose. (Miles & Huberman 1994, 127-129, 131, 141). Due to confidentiality issues, the matrices are not published in this research.

The interview questions were segregated into three different categories of automated data collection, ALASCA system requirements and other topics. The interview questions were as follows:

TOPIC 1: Automated Road Monitoring is becoming more common in intelligent maintenance of roads as well as in Intelligent Transport Systems (ITS) services.

- What kind of effect does this trend have on your organisation at the moment?
- What kind of effects do you foresee in near future (3-5 years) on your organisation and how likely do you see this effects take place?

TOPIC 2: Some of the interesting parameters in automated road monitoring are snowbank height, snow and ice ruts, bumps and unevenness. The vision is to measure these parameters through regularly travelling vehicles with a mounted laser scanning system.

- In terms of automated road monitoring and laser scanning data, what are your main interests in terms of this data?
- What kinds of user groups your organisation might have for this data?
- In what user interface this data should be made available? Does this need differ between user groups?
- What are the most important roads to collect such data from?
- How often should these measurements be carried out in order to give added value to your organisation? What kind of requirements are posed by annual seasons and condition changes?
- What should the resolution of the data be?
- How important it would be to obtain historical data from road measurements?
- What kind of other requirements your organisation might have from such a system?

OTHER TOPICS

- Is there anything else you want to bring out related to the topic?
- Would you like to take part into a visualisation process for testing functional prototypes and mockups of user interfaces?

The main theories for identifying and categorising some main industry and business issues are drawn from the frameworks of Michael Porter (2008), Porter and Heppelman (2014; 2015) and those, such as Kaplan and Norton (2008, 47-49) and Cliff Bowman (1998, 89-92), promoting the PESTEL approach in strategic context analysis.

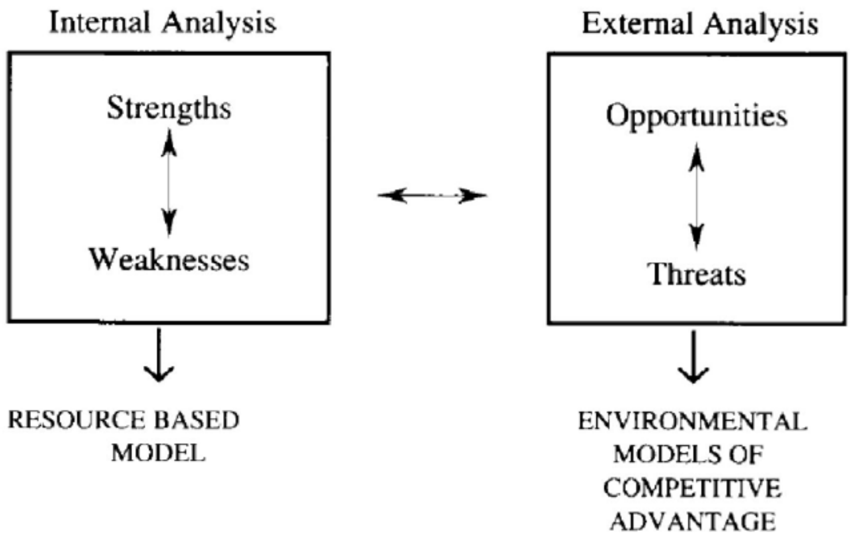

Figure 2 The internal and external factors in strategies in the traditional SWOT analysis (Barney 1991, 100)

In a context of strategic analyses, the PESTEL and Five Forces analysis can be adopted for identifying the external environment of a company. The factors emerging from these analyses can be applied in a strengths-weaknesses-opportunities-threats (SWOT) analysis framework. Figure 2 depicts the difference between the internal and external analyses. The scope of this article is on external issues. The strategic internal analyses are company-specific and not a target of this research.

Finally, it needs to be stressed that the interview information was very heterogeneous, ambiguous and even munificent in terms of drawing analyses based on such theoretical frameworks. Such limitations were considered when drawing conclusions.

GENERAL BUSINESS CONTEXT FACTORS

First, the interview results were categorised in according to the PESTEL analysis, which identifies the most important external factors taking place in a context of an industry. Figure 3 generally summarises the PESTEL-analysis. The factors that arise from the PESTEL-analysis may have an impact on the industry competition. Consequently, the Five Forces approach is linked to this analysis further on and presented further in this article.

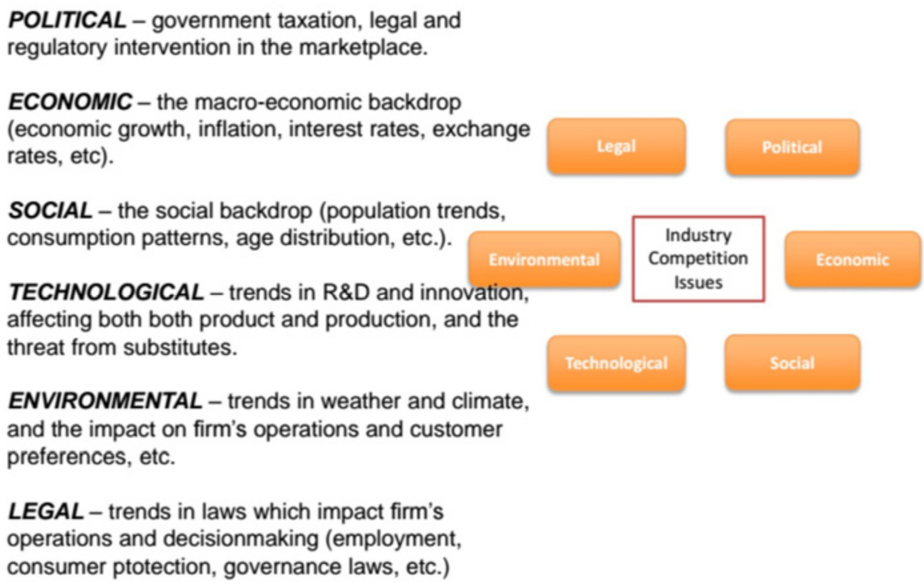

Figure 3 The PESTEL-analysis and its relation to industry competition issues

Table 2 lists the political factors. Generally, the political factors in a PESTEL analysis are anything from elections to business regulations. In the case of ALASCA, clearly the most important political trends are about open data, road asset life cycle approach and changes in the road administration.

Table 2 Political factors

POLITICAL
• Data is opened by authorities and citizens are able to view road maintenance actions • Road asset life cycle is important and is taken into account in public procurements for road maintenance • Road administration is facing a change due to the centralising of agencies and establishing regional governance

The PESTEL analysis also covers the economic viewpoint. However, it was very surprising that the interview results did not have any indications on general economic development, customer purchase power or other economic issues that might be of strategic importance.

Table 3 lists the social factors. There were much of user needs based information since it was one of the main interview topics. PESTEL analysis can also cover consumer behaviour or user needs in a general level. Therefore, the user needs that emerged from the research information are listed here as social factors. Even though the social issues are even quite detailed, there are also major obstacles for digitalisation that arise from having to actually change the current working culture and practices. This will take more time than the actual technological development.

Table 3 Social factors including user needs

SOCIAL
• New road user services need the maintenance information from maintenance contractors • The road users can be sometimes directly in contact with the maintenance contractor • There is daily communication between the maintenance contractor and the road operator • Currently visual evaluations in road maintenance quality control are conducted. This creates a problem as visual evaluation can be different for different evaluators. • Logistics companies have benefitted from open maintenance information because it enables better timing • Quality monitoring consultants see technology even as a threat as it can take business away even though it can also bring new business • The new technologies in automated road monitoring will not change the field very drastically within five years from the viewpoint of quality inspections because the current culture and systems do not change that quick • User need: Current road monitoring pilots have narrow geographical scope even though maintenance is carried out nationally • User need: Maintenance contractors want quick visual information and software products that are very efficient to use • User need: Current software products in road maintenance have very varying customer segments and users. Typically, software products are developed for larger customer segments and individual needs are not taken into account in a sufficient way. • User need: Logistics companies will need to go on the road regardless of the weather but could benefit from accurate road weather and maintenance information through route timing

- User need: Information from automated road monitoring does not have to be very accurate as it could function as a support for making decisions on physical work (inspections), and not as a tool that gives explicit information
- User need: The maintenance contractor wants to prove that they have met the quality in the roads
- User need: The frequency of automated data collection is not homogeneous as different frequencies are needed for example in summer vs. winter maintenance of roads Road monitoring solutions have the potential of saving the human work by eliminating unnecessary physical inspection needs in road maintenance quality monitoring
- User need: In heavy snowfall, all the maintenance equipment need to be on the road plowing but there is missing information what is the status after the operations.

Table 4 lists the technological trends. Clearly, there are numerous systems currently in user in different areas of winter road maintenance operations. However, the various data sources and systems are scattered with very little integration to each other. In addition, the quality of the data does not currently enable it to remove the human inspections from the user perspective, as the accuracies of IoT systems do not meet the winter road maintenance quality standards. Furthermore, there were many technological advances mentioned in the interviews in a general level.

Table 4 Technological factors

TECHNOLOGICAL
• Big data masses are in use currently: Ground Penetrating Radar (GPR) data, camera images, laser scanning • Data from different sources is not very effectively connected and used together at the moment • Data is scattered in different platforms and databases • Internet-connected devices do not always function correctly in border areas due to connection losses • The current crowd-sourced solutions cannot replace the expert work because the data gathering road users, or logistics companies, are not experts of road maintenance • The accuracy of the current crowd-sourced sensor data solutions do not meet the requirements of road maintenance, expert inspection is still necessary. • Based on user experience, the open road maintenance operation information is not always valid • Robotisation of winter road maintenance equipment

• Camera systems for worksite monitoring are getting more common • There are in-vehicle computers and displays in the logistics companies cars and it would be beneficial to link new sensors to those existing systems • Accelerometer data is already existing in some logistics companies fleet systems and the company is able to acquire information if there have been bumps on the road

Table 5 lists the environmental factors, which are very much about the current road conditions. Longer cold periods decrease the need of winter road maintenance monitoring because the road conditions do not change very much. However, larger regions, such as Lapland, have very heterogeneous road environment, as there are city areas and rural areas. Furthermore, the roads have pre-existing rutting which has occurred even after two years from paving. The non-paved gravel roads are typically in a very bad condition despite the current maintenance actions and requirements.

Table 5 Environmental factors

ENVIRONMENTAL
• Long cold periods decrease the need for winter road maintenance monitoring • Heterogeneous environments for winter road maintenance in Lapland when considering the rural areas versus Kemi-Tornio and Rovaniemi city areas • Older roads have conditions that could be detected by a laser scanner • Roads have pre-existing rutting which enhances the snow/ice ruts in winter time • Roads start to have rutting usually after two years of paving • The non-paved gravel roads are usually in very bad conditions despite the maintenance actions and requirements

Table 6 shows the legal factors. The road maintenance sector is very controlled since it deals with societal safety and functionality. Consequently, there are many legal trends and developments taking place or in force.

Table 6 Legal factors

LEGAL
• Privacy issues in data gathering need to be resolved in order to fully tap on the benefits of existing data • Data ownership issues are not clear when data is collected from many sources and systems • Current traditional maintenance contracts are coming to an end • Alliance contracts in road maintenance • Contracts need to be able to change during the five year period of typical winter road maintenance contract in order to provide flexibility • Road operators increasingly consider procuring performance and outcomes in winter road maintenance. Such procurements do not even necessarily increase the need for quality inspections. • Digitalisation will play even greater role in future maintenance contracts • Maintenance contracts can enforce data to be open but it raises a concern of protecting the business secrets related to operational actions in the field • The road operator still requires the traditional maintenance quality control measurements to take place (measuring tape, straight edge) • The road maintenance quality control contracts last from two to four years • Road operator wants to procure the results and wants to increasingly also specify the equipment requirements • Open data is not always published in real-time in order to secure the maintenance contractors work • All the maintenance actions carried out are not required to be open information/data (such as cleaning the traffic signs from snow) • Maintenance contractors are required to drive the roads on their responsibility and make an inspection once a week themselves • In case of legal disputes, the historical information from roads would be beneficial • Because of bad road conditions, currently the road operator has to pay a considerable amount of money because of damage done to road users' vehicles

Much of the legal issues can be linked to any political development as well. However, some main issues emerge through data privacy and ownership issues even though the current practices in winter road maintenance contracts represent a majority of legal issues.

THE EFFECT OF BUSINESS CONTEXT ISSUES ONTO THE FORCES OF COMPETITION

The PESTEL factors can have an impact on the competitive landscape. Porter's (2008) Five Forces tool is a very widely adopted approach to analysing the competition. This part of the article will focus on drawing conclusions on the impact of the PESTEL factors on the Five Forces of competition. In addition, the Five Forces analysis will be complemented slightly by the generally known facts of the business. This is due to some generally identified industry issues such as the low amount of major maintenance contractors in the business. Figure 4 summarises the Five Forces: threat of entry, power of suppliers, power of buyers, existing rivalry and threat of substitutes. In essence, the forces are threat of entry, the power of suppliers, and the power of buyers, existing rivalry and the threat of substitutes.

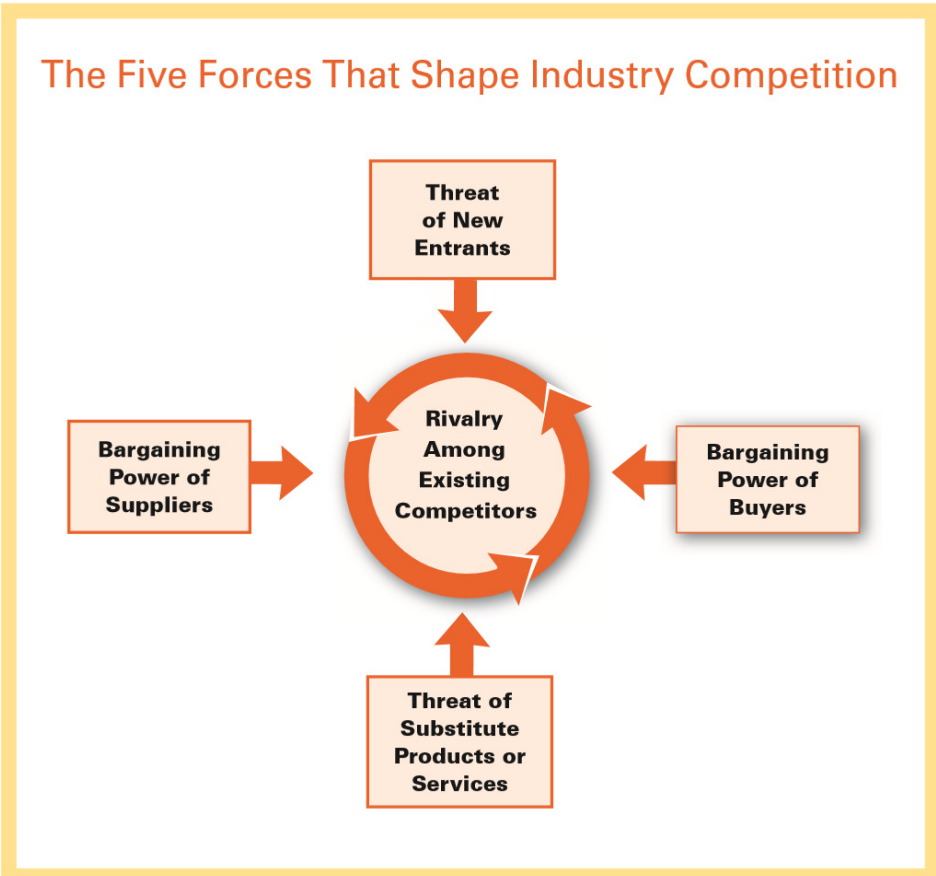

Figure 4 The Five Forces of competition (Porter 2008, 80)

Michael Porter (2008, 87) highlights the importance of setting the right scope for the analysed industry when adopting the Five Forces tool. In this article, the scope is the IoT industry in the area of automated road data collection. Figure 5 depicts the IoT value chain from IoT object components to the end-user, which acts as the case viewpoint.

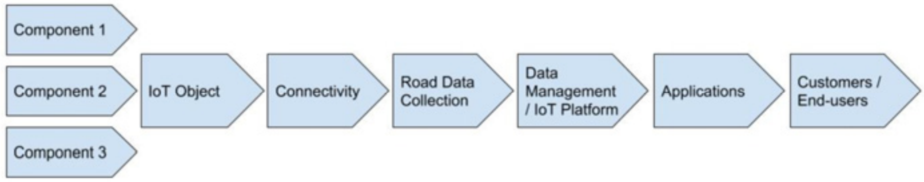

Figure 5 The IoT value chain in the case of ALASCA Project.

Typically IoT solutions have the hardware layer that consists of the sensors, actuators, and other hardware. The IoT objects are offered connectivity through devices and network service providers. In automated road monitoring, the data needs to be collected from the roads which in turn adds data collection as an integral part of the value chain. After the data is collected, typically IoT solutions use enabling software platforms for example for application programming interfaces (APIs), analytics, and integration with third party applications. Consequently, sense is made out of the data through UI development for applications. In case of ALASCA-project, the applications are targeted for road authorities, cities and municipalities, maintenance contractors, road consultants, logistics companies, and other road users. In the long run, the automotive industry could be a customer segment. In the end, also societal benefits could be reached.

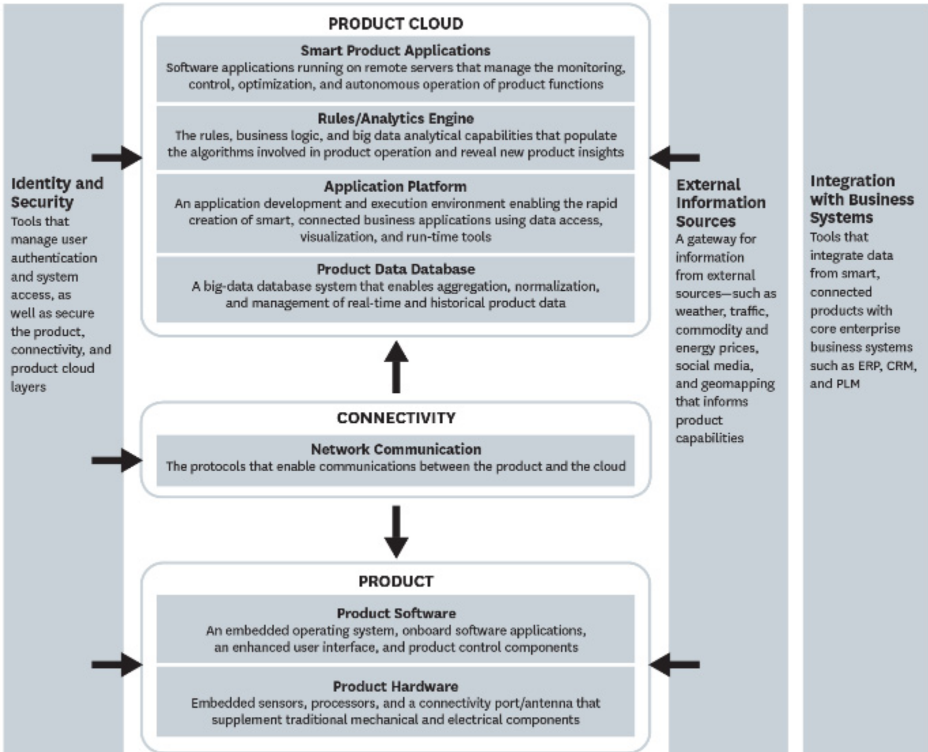

Figure 6 The technology stack of smart, connected products (Porter & Heppelman 2014)

Figure 6 presents a way to describe the technology stack of smart, connected products. The world of IoT consists of many layers. Porter and Heppelman (2014) complement the traditional IoT value chain illustration by adding identity and security, external information sources and integration with business systems into the picture.

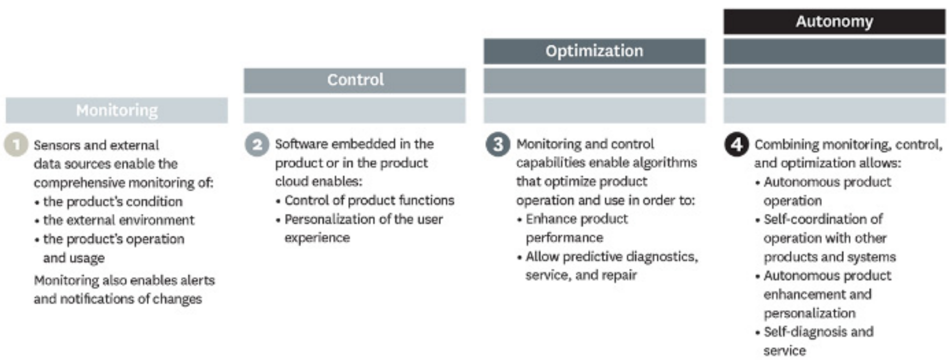

Figure 7 The capabilities of smart and connected product by Porter and Heppelman (2014)

Figure 7 shows Porter's and Heppelman's (2014) segregation between capabilities of smart, connected products. In the case of ALASCA, the new solution is mainly targeting the capability of monitoring the environment even though there might be some control features built-in to the installed package. Generally, new IoT solutions in the market of winter road maintenance seem to be targeting the monitoring capabilities even though larger companies might also offer some control and optimization features as well.

Threat of entry

The Finnish government is opening the data sources for new business, which makes the ITS industry more attractive for new entrants. New entrants bring new capacity to the market and desire to gain market share. Consequently, this puts pressure on prices, costs, and investments. On the other hand, open data might not always be real-time and accurate since it cannot contain certain information, e.g. business secrets.

Furthermore, the threat of entry might be deterred by the unequal distribution of data. Maintenance contractors possess essential data in terms of road maintenance operations, materials, and exact material, e.g. salt, amounts. Such data is very valuable in new digital services targeted for professional and road users.

In addition, the threat of new entrants is hindered due to unclear policies on data ownership issues or government policies on data privacy. This threat can realise itself especially in automated data collection where data is collected from the traffic via dedicated sensors or by adopting (extended) floating car data.

The government is shifting towards performance-based contracts in winter road maintenance. In some cases, the road operator has also specified the equipment the winter road maintenance contractors must use for the operations. Moreover, the new contracts for winter road maintenance highlight digitalisation, which drives the maintenance contractors to look for new solutions that can aid them in winning the public bid. This creates industry attractiveness to new entrants who can come up with effective digital solutions.

The power of suppliers

If the buyers invest heavily in IoT systems, they might face significant switching costs that increase the power of suppliers. However, the supplier power seems to be reduced by offering products that do not meet the needs of heterogeneous users. In addition, the substitutes for new IoT solutions are strong because they can merely assist in human work but not replace it. The traditional work is still the substitute for automated monitoring IoT solutions.

The power of buyers

There are many customers for IoT solutions, from road consultant and road authorities to winter road maintenance contractors as well as cities and municipalities. However, the main customers, namely the road authorities and road maintenance contractors are powerful buyers. They can force down the prices and capture more value for themselves, which can lead to a situation where the suppliers of IoT solutions are played off against one another while the industry profitability suffers. However, the power of buyers can be diminished due to the differentiated products at the IoT solution markets. Consequently, it can be a struggle to find an equivalent product for non-standardised niche offering.

The winter road contractors and road quality inspection consultants compete heavily with price on public procurements. As buyers, these groups become very price sensitive as they are in a constant pressure to trim costs. As the current IoT solutions work on a small scale pilot level, they presumably have only little effect on buyer’s other costs which can further on increase the power of buyers. In the end, in the business-to-business sector of automated data collection IoT solutions, the buyer needs can be more easily quantified and recognised in oppose to business-to-customer markets.

The threat of substitutes

The substitute for new IoT solutions is the current human inspection work as well as the current working culture, which is seen to change very slowly in the traditional field of infrastructure management. Such strong substitutes negatively affect the industry profitability and place a ceiling to the prices. The suppliers of IoT solutions will therefore suffer with growth and profitability issues if they do not distance themselves from the substitutes with superior performance, marketing or other means.

Rivalry among existing competitors

The existing competition takes many forms consisting of discounts on price, new products, campaigns, and improvements in service. If such rivalry is very high, the profitability of the industry is limited. Moreover, rivalry is the greatest when there are numerous equal competitors, growth is slow, exit barriers are high, and rivals are committed to the business. In addition, aggressive price competition is most likely to occur when the products are identical, fixed costs are high, capacity needs to be extended for efficiency, and the products are perishable and became obsolete. (Porter 2008, 85-86)

It is difficult to draw conclusions on the existing rivalry based on the interview data. However, it became evident that there are numerous new IoT solution providers in the market and they are mostly differentiated with features. Niche products do not necessarily face aggressive competition, but there might be fiercer competition in the more general level of the IoT value chain, e.g. in data management. The niche market seems to be in device level analytics especially when it comes to the new innovative entrants.

Five Forces of competition in the ALASCA project

Figure 8 Summary of the forces that shape competition in the case of ALASCA project

Figure 8 summarises the findings of the interviews and some author views on the Five Forces of competition. The plus symbol (+) indicates the factors that increase the threat or rivalry. Consequently, the minus symbol (-) marks the factors that diminish the threat or current rivalry. Quantitatively, most issues were in the force of power of buyers. Additionally, there were also some issues about the power of suppliers and threat of entry.

DISCUSSION

It is dangerous to say that the IoT changes everything. Even though it brings a myriad of technological possibilities, the rules of competition and competitive advantage remain unchanged. The smart, connected products actually force the companies to understand the rules of competition even better than before. (Porter & Heppelman 2014)

In essence, the main job a strategist is to understand and cope with competition (Porter 2008, 79) and to construct the best strategy to be competitive in that environment. The companies that do not have a simple and clear strategy are likely to fall into the category of those who did not execute their strategy right, or worse, those that never even had a strategy (Collis & Rukstad 2008, 1). As Porter and Heppelman describe (2014), the smart and connected products shape the industry and make it ambiguous for companies to even identify the business they are in. Designing a well-defined strategy in that environment might be challenging. New technology, customer needs, and other factors shape the industry forces (Porter & Heppelman 2014). Some main business implications can be drawn based on the interview data and from theory.

Even though a very cohesive PESTEL or Five Forces analysis could not be implemented in the ALASCA project, some initial factors were identified nevertheless. Furthermore, some pre-conclusions can be drawn based on these issues.

The analysis suggested that new data could draw new entrants to the market even though the raw material, i.e. the data, of new services could be distributed unevenly. Additionally, it is described that new entrants to market face significant obstacles of complex technology and multiple layers of new Information Technology (IT) infrastructure even though entry barriers can go down when smart, connected products leapfrog the strengths of incumbents (Porter & Heppelman 2014). New solutions enter the market continuously, which creates a situation where innovative, smart, connected products are not yet standardised. The bargaining power of buyers can be mitigated by expanding the possibilities for product differentiation and by shifting the focus away from the product price. One way to do specialise would be to better know the customer needs, and to develop the customer relationships by collecting usage data from the connected products, and to use it in further product development, respectively. (Porter & Heppelman 2014)

On the other hand, the rich data produced by connected products enables the buyers to obtain better understanding of product performance and may even lead to lower reliance on supplier's product when their advice and support is no longer needed (Porter & Heppelman 2014). In the market of winter road maintenance, when new innovative IoT solutions come to the market, the buyers can also play different suppliers off another. Today, new solutions are typically offered as a service, which further enhances the power of the buyers by low switching costs (Porter & Heppelman 2014).

Most of all, the IoT solutions will shape the current competition due to the high amount of possibilities to differentiate through valued-added services. As it became clear during the interviews, the new IoT solutions do not necessarily fit for the heterogeneous user requirements. The new IoT products enable companies to tailor more specific solutions to the market and to even customise the products for individual customers. Furthermore, the suppliers are able to broaden the value proposition from the product by, e.g., offering new data of product usage.

As stated before, through development of smart and connected products, the actual market can become ambiguous when businesses do not know in which market they are actually operating. Connected products can become a part of larger system of systems (SoS) that are described for example by Institute of Electronics and Electrical Engineering (IEEE) Reliability Society (2014). This is already happening in the market of smart home applications where climate control, entertainment and lighting compete with each other in the connected home even though previously these have operated in separate markets (Porter & Heppelman 2014). Figure 9 shows an example of SoS in the farming industry.

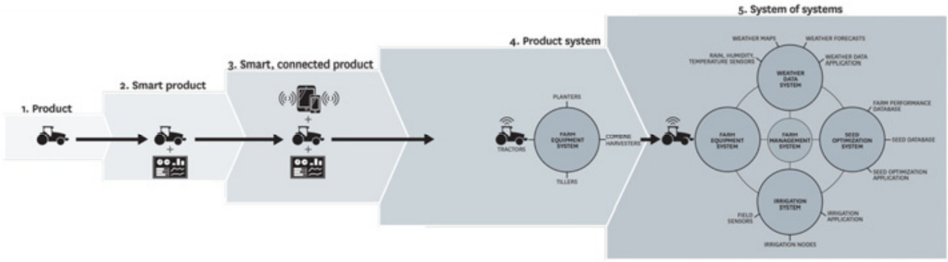

Figure 9 Redefining the industry boundaries by SoS (Porter & Heppelman 2014)

In the context of ALASCA project, the smart and connected laser scanning unit ought to become a part of SoS, a part of 'road management system' when following the logic from the farm industry. Figure 10 illustrates this logic in the case of ALASCA project.

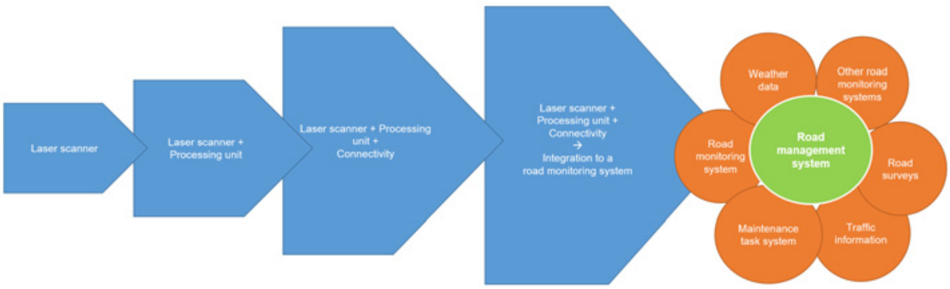

Figure 10 Product's path towards the SoS in the case of ALASCA project

In the field of IoT in winter road maintenance, the rivals are differentiating by offering niche analytics based on smart and connected products. The more there are niche offerings, the less aggressive the rivalry is. However, if the niche offerings focus on the product alone, the threat of substitutes to conventional products is increased with IoT as explained further.

There are not only product innovations as the world of IoT opens up new possibilities for innovative business models. Modern literature displays platform-based ecosystems (Thierry & Lescop 2013; Cusumano 2010), network-based strategies (Zott & Amit 2009), and other ways to innovate a company's business model (Giesen E., Berman S., Bell R. & Blitz A. 2007; Amit R. & Zott C. 2012) to give an example. Furthermore, Porter and Heppelman (2014) explain how smart and connected products are able to create a substitute for product ownership through product-as-a-service business models. In the context of ALASCA project, the substitute for owning a smart system would be to have a system, which does not require heavy investments for the buyer who can even pay only for product use amount.

Some pre-recommendations can be drawn from the perspective of ALASCA project. Those who wish commercialise new IoT solutions to the market of road monitoring have many things to consider. Such issues are further explained by Porter and Heppelman (2015) in their article on smart, connected products transforming businesses. However, based on ALASCA project findings, it can be concluded that the following business issues could be considered:

- Maintain supplier power by offering a niche product
- Exploit the rich data from smart, connected products in order to expand the product value proposition and customer value
- Avoid the race with product features and focus on the features that really add customer value
- Tailor the product system for individual users
- Consider the SoS perspective with the product and expect new competition

However, for companies wanting to more concretely identify how the business should be transformed, they need to answer 10 essential questions.

1. *Which set of smart, connected product capabilities and features should the company pursue?*
2. *How much functionality should be embedded in the product and how much in the cloud?*
3. *Should the company pursue an open or closed system?*
4. *Should the company develop the full set of smart, connected product capabilities and infrastructure internally or outsource to vendors and partners?*
5. *What data must the company capture, secure, and analyze to maximize the value of its offering?*
6. *How does the company manage ownership and access rights to its product data?*
7. *Should the company fully or partially disintermediate distribution channels or service networks?*
8. *Should the company change its business model?*
9. *Should the company enter new businesses by monetizing its product data through selling it to outside parties?*
10. *Should the company expand its scope?*

(Porter & Heppelman 2015)

CONCLUSIONS

This article presented some elements that need to be taken into accounting when utilising the results of ALASCA project for business purposes. The analysis was drawn based on interview data and complemented with some general views of the business. The interview data was not very business-specific so it was impossible to draw a cohesive business context analysis. However, this article gave a preliminary insight on some business context factors that affect the commercialisation of ALASCA project results, i.e. the smart, connected product called RoadFly.

The Porter’s Five Forces tool seemed to be a very useful tool in analysing the industry issues. This usefulness was further enhanced by the modern articles of Porter and Heppelman who have analysed the effect of smart, connected products on competition and companies.

ALASCA is a technologically-oriented project, but ultimately, many of the challenges the companies, that wish to commercialise IoT products, face arise from business-related factors. Companies need to adapt their strategies, shape their business models and excel in operational efficiency in order to be competitive. Smart, connected world brings competition from new areas but simultaneously it offers new ways to expand the value proposition and offer more customer value.

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Hanna Kumpula and Heikki Konttaniemi

OVERVIEW OF ALASCA PROJECT

ALASCA (Automated Road Monitoring Pilot Using 2D Laser Scanning) project concentrated on researching the possible usage of the 2D laser scanner in automated road monitoring. A 2D laser scanner would be mounted on large good vehicles (LGV) having established routes, e.g. delivery vehicles, turning them into data collectors.

The road quality requirements inform the road operators of the road quality measurements and how they must be met on different road maintenance categories. Especially during winter, the road condition quality is more difficult to maintain due to the snow and ice on the roads. The quality requirements even include the time frames during which the road conditions must be brought to the required level of quality.

The data acquisition system was selected from four different options, containing placements and combinations of components. One of these was selected, followed by actual selection of the components. ALASCA project tried to achieve a more affordable system that could be attached and used in LGVs with no effect on their usual performance. With a large number of data collectors, the amount of data would in the future be more reliable. In addition, ALASCA targeted on providing data for the road quality controllers, helping them to, e.g. plan their inspection routes.

The product designer and electrical and mechanical engineers in the ALASCA project specified, designed, 3D printed, and assembled the prototype. The design process for the prototype began with mood boards and discussions within the team, and stakeholders. Prototype was designed in a 3D modelling software and the final version was 3D printed using polylactide (PLA) plastic. The casing was reinforced with an aluminium housing inside the plastic covers. Through the used mood boards, discussions, and the visual appearance, the prototype received its name: RoadFly.

RoadFly was first tested in the laboratory, where its performance in freezing conditions was verified. The laboratory tests showed slight problems with the snow and ice accumulating in front of the laser beam in the icing rain. Despite the further improvements on the design, this problem could not be entirely removed. Therefore, the casing design should be as minimal as possible to prevent the snow and ice from accumulating and causing measurement errors.

The first field tests were performed in the fall of 2017. The selected testing site was a 2 km road stretch located 30 km from Rovaniemi centre. The low traffic volume provided a safe and reliable testing environment. RoadFly measurements were compared to reference measurements of Road Doctor Survey Van (RDSV), a measurement vehicle of Roadscanners Oy, and measurements performed by Lapland UAS land surveying students. Results of all three measurements showed similar results. Therefore, ALASCA project shows that the inexpensive data collection is a true possibility for crowd-sourced road quality data.

Second field tests were performed in the spring of 2018 to test RoadFly performance in real winter road conditions. The tests took place on the same road stretch as the first field tests in fall. RDSV provided the reference measurements for the winter field tests as well. Under normal winter conditions, the RoadFly proved to function without difficulty. In addition, the induced ‘snow dust’ in the tests did not affect the laser scanner. However, the testing period did not include actual snowfall or water on icy surface.

By itself, the RoadFly data is not useful. The data was decided to be visualised in a user interface (UI) and the main user group was selected to be the road quality controllers, whose work is to ensure the road maintenance quality. The UI design was largely based on an existing UI from Winter Road Maintenance (WiRMA) project, funded by Interreg Nord, due to future plans for linking these two projects. Additionally, input for the UI design included an online survey sent for the main user group, interviews conducted during ALASCA, and road maintenance quality requirements. Only a functional prototype of the UI was implemented with no real data.

PESTEL and Five Forces analysis were performed on the interview data. Interviews were conducted during 2017 in the ALASCA project. However, their focus was not to provide a business-specific view. The analysis were still able to give insight on the challenges companies will face when trying to commercialise IoT products for road monitoring, of which RoadFly is a good example. In order to be competitive in a smart, connected world, where new IoT solutions enter the market they need to change their strategies and find new ways to offer more customer value.

ALASCA project was simply a quick technological study simply to verify whether the 2D laser scanner could be used as a crowdsourcing data collector when mounted on LGVs on routes driving through the roads.

However, RoadFly was not attached to an LGV having a scheduled route and driving through varied weather conditions for a long period. In addition, the collected data was not sent to an actual UI or assessed by actual users.

The next steps toward a commercialised 2D laser scanning unit come from two separate directions. The first is to expose RoadFly to varied weather conditions for long periods. This includes refining the casing design in order to remove the effect of the accumulated snow on the laser. The second direction is to improve the design UI by testing and design process. The main user group must be integrated in the process as well. This path must also take into account the data that is available from RoadFly. When these two parts, the laser scanning unit and the UI, are combined a commercial version is ready for the large scale usage tests. Business factors will also need to have an effect on the product features. In the future, RoadFly should offer a niche solution and consider a System of Systems (SoS) perspective in order to be part of a larger road or transport management system.

Appendix A

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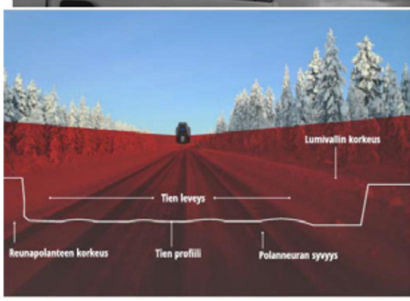
ALASCA-pilotti: käyttöliittymän suunnittelua edistävä kysely

ALASCA-pilotti

ALASCA –pilotin tavoitteena on selvittää ja pilotoida joukkoistamalla tuotettua laserskannausdataa. Pilotissa selvitetään ajantasaisen mittaustiedon tuottamista **ennakoivan kunnossapidon tueksi** sekä **osaksi laadunvalvontaa** hyödyntämällä ammattiliikennettä tiedonkeruussa. Ensi vaiheen pilotissa järjestelmää testataan osana yhtä raskasajoneuvoa ja **keskitytään** järjestelmän **mahdollisuuksiin ja haasteisiin**.

Kehitämme hankkeessa ajoneuvon katon etureunaan kiinnitettävää 2D-laserskannerin **prototyyppiä**, josta lähtevä säde pyyhkii tien yli "metsänreunasta metsänreunaan". Mittausdatasta voidaan reaalajassa laskea esimerkiksi polanneuran syvyys ja reunapalteen korkeus. Alla oleva kuva havainnollistaa säteen pyyhkäisyä sekä siitä tulkittavia asioita.

Ensimmäisessä kuvassa skanneri näkyy asennettuna auton katolle. Mittaussäde pyyhkii tien yli auton etupuolelta. Toiseen kuvaan on havainnollistettu mittaussäde, sekä muutamia siitä tulkittavia arvoja. Toisessa kuvassa näkyy vain skanneri kuvattuna ajosuuntaan. Toisesta kuvasta on poistettu auto havainnollisuuden vuoksi. Kuvien värimaailma ei ole todellinen.



Kysely

Tämän kyselyn tarkoituksena on selvittää käyttäjien vaatimuksia erityisesti mittaustiedon visualisoinnin osalta. Kysely on ensi vaiheessa suunnattu erityisesti ELY-keskuksen talvitienhoidon laadunvalvonnan henkilöstölle.

Kysely on viisisivuinen, joten vastaamiseen voi kulua aikaa. **Pyydämme vastaajaa pohtimaan millainen olisi tulevaisuuden työkalu** ennakoivan kunnossapidon ja laadunhallinnan tehtävissä.

Vastaamiseen kuluvaa aikaa on pyritty lyhentämään käyttämällä **vain vapaaehtoisia kysymyksiä**. Kysymysten yhteydessä on tekstikenttiä joihin voi halutessaan tarkentaa vastaustaan tai esittää muita huomioitaan. Ennen lähetystä kyselylomakkeen sivuilla voi liikkua vapaasti eteen- ja taaksepäin.

Vastausten ja tulosten käsittely

Kyselyn vastaukset analysoidaan ALASCA-hankkeessa toimivien Lapin ammattikorkeakoulun työntekijöiden toimesta. Tuloksia hyödynnetään käyttöliittymäluonnosten suunnittelussa.

Tulokset julkaistaan osana ALASCA-hankkeen loppuraporttia vuonna 2018. Kyselyn tuloksista julkaistavasta materiaalista **yksittäistä henkilöä ei voi jäljittää**. Hankkeen **loppuraportti** on julkinen ja **vapaasti hyödynnettävissä eri tahojen osalta**. Hanke on osa Alueelliset Innovaatiokokeilut (AIKO) –rahoitusta, jonka puitteissa Lapin Liitto on myöntänyt tukea Lapin ammattikorkeakoululle.

Tähän kyselyyn liittyvät kysymykset, kommentit ja lisätietopyynnöt voi osoittaa sähköpostitse Hanna Kumpulalle osoitteeseen hanna.kumpula@lapinamk.fi.

LAPIN LIITTO

Taustatietoja

Mitä urakka-alueita seuraat työsi puolesta?

Lappi

- ☐ Ivalo
- ☐ Kittilä
- ☐ Sodankylä
- ☐ Pello
- ☐ Rovaniemi
- ☐ Kemijärvi-Posio
- ☐ Kemi
- ☐ Ranua

Pohjois-Pohjanmaa

- ☐ Ii
- ☐ Pudasjärvi-Taivalkoski
- ☐ Kuusamo
- ☐ Oulu
- ☐ Raahe-Ylivieska
- ☐ Siikalatva
- ☐ Pyhäjärvi

Kainuu

- ☐ Puolanka
- ☐ Suomussalmi
- ☐ Kajaani
- ☐ Kuhmo

Missä on toimipaikkasi?

Kerro lyhyesti toimenkuvastasi teiden laadunvalvonnan näkökulmasta.

Seuraava -->

LAPIN AMK
Lapland University of Applied Sciences

ALASCA-pilotti: käyttöliittymän suunnittelua edistävä kysely

Käyttöliittymä

Näytettävien mittaustietojen tärkeys

Kuinka tärkeiksi koet seuraavat asiat sovelluksessa? Jos haluat tarkentaa vastaustasi, niin vaihtoehdon perässä olevana tekstikenttään voi kirjoittaa lyhyen tarkennuksen. Kenttä aktivoituu kun vaihtoehto on valittu. Seuraavassa kysymyksessä on vielä tilaa tarkentaa.

	Ei tule näyttää lainkaan	En osaa sanoa	Ei lainkaan tärkeä	Ei tärkeä	Ei merkitystä	Tärkeä	Erittäin tärkeä
YLEISET							
Valokuva mittauspaikalta	O	O	O	O	O	O	O
Mittauspaikka	O	O	O	O	O	O	O
Mittaustieto	O	O	O	O	O	O	O
Mittaustiedon ero haluttuun pohja-arvoon (esim. laatuvaatimus)	O	O	O	O	O	O	O
TALVI-/KEVÄTAIKA							
Lumivällin korkeus	O	O	O	O	O	O	O
Tien profiili	O	O	O	O	O	O	O
Lammikoituminen	O	O	O	O	O	O	O
Heitot	O	O	O	O	O	O	O
Kuopat	O	O	O	O	O	O	O
Epätasaisuus	O	O	O	O	O	O	O
Reunapolanteen korkeus	O	O	O	O	O	O	O
Polanneuran syvyys	O	O	O	O	O	O	O
Sohjo-ojien tila	O	O	O	O	O	O	O
Tien leveys	O	O	O	O	O	O	O
Mittaustiedon ero kesäajan mittaukseen	O	O	O	O	O	O	O
Ajoradan lumisyvyys	O	O	O	O	O	O	O
Linja-autopysäkit ja/tai levähdysalueet	O	O	O	O	O	O	O
KESÄAIKA							
Niiton tarvetieto	O	O	O	O	O	O	O
Raivauksen tarvetieto	O	O	O	O	O	O	O
Tien profiili	O	O	O	O	O	O	O
Uratieto	O	O	O	O	O	O	O
Heitot	O	O	O	O	O	O	O

Kuopat	[ ]	○	○	○	○	○	○	○
Epätasaisuus	[ ]	○	○	○	○	○	○	○
Reunapalteen korkeus	[ ]	○	○	○	○	○	○	○
Reunantäytön/-murskeen vajaus	[ ]	○	○	○	○	○	○	○
Ojan syvyys	[ ]	○	○	○	○	○	○	○

Haluatko täydentää edellisen kysymyksen vastauksia?

[ ]

Mittaustietojen esittämistavat

Millä tavoin tietoja tulisi esittää käyttöliittymässä? Voit valita useamman vaihtoehdon, esimerkiksi sekä kuvan että tekstiä. Seuraavassa kysymyksessä on vielä tilaa tarkentaa vastauksia.

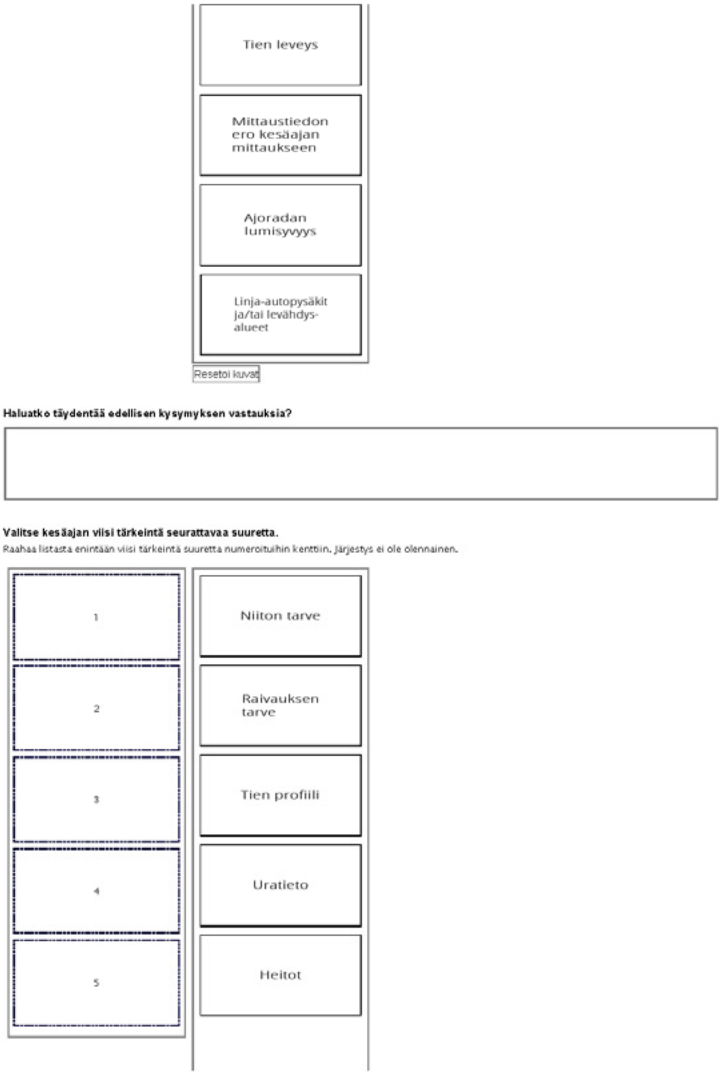
	Ei tule esittää lainkaan	En osaa sanoa	Kuvaaja	Karttapiste	Värikoodi	Kuvaelementti / piirros	Muotoiltu teksti (esim. väri vaihtuu arvon mukaan)	Teksti (ilman muotoilua)
YLEISET								
Valokuva mittauspaikalta	☐	☐	☐	☐	☐	☐	☐	☐
Mittauspaikka	☐	☐	☐	☐	☐	☐	☐	☐
Mittaustieto	☐	☐	☐	☐	☐	☐	☐	☐
Mittaustiedon ero haluttuun pohja-arvoon (esim. laatuvaatimus)	☐	☐	☐	☐	☐	☐	☐	☐
TALVI-/KEVÄTAIKA								
Lumivallin korkeus	☐	☐	☐	☐	☐	☐	☐	☐
Tien profiili	☐	☐	☐	☐	☐	☐	☐	☐
Lammikoituminen	☐	☐	☐	☐	☐	☐	☐	☐
Heitot	☐	☐	☐	☐	☐	☐	☐	☐
Kuopat	☐	☐	☐	☐	☐	☐	☐	☐
Epätasaisuus	☐	☐	☐	☐	☐	☐	☐	☐
Reunapolanteen korkeus	☐	☐	☐	☐	☐	☐	☐	☐
Polanneuran syvyys	☐	☐	☐	☐	☐	☐	☐	☐
Sohjo-ojien tila	☐	☐	☐	☐	☐	☐	☐	☐
Tien leveys	☐	☐	☐	☐	☐	☐	☐	☐
Mittaustiedon ero kesäajan mittaukseen	☐	☐	☐	☐	☐	☐	☐	☐
Ajoradan lumisyvyys	☐	☐	☐	☐	☐	☐	☐	☐
Linja-autopysäkit ja/tai levähdysalueet	☐	☐	☐	☐	☐	☐	☐	☐
KESÄAIKA								
Niiton tarvetieto	☐	☐	☐	☐	☐	☐	☐	☐
Raivauksen tarvetieto	☐	☐	☐	☐	☐	☐	☐	☐
Tien profiili	☐	☐	☐	☐	☐	☐	☐	☐
Uratieto	☐	☐	☐	☐	☐	☐	☐	☐
Heitot	☐	☐	☐	☐	☐	☐	☐	☐
Kuopat	☐	☐	☐	☐	☐	☐	☐	☐
Epätasaisuus	☐	☐	☐	☐	☐	☐	☐	☐
Reunapalteen korkeus	☐	☐	☐	☐	☐	☐	☐	☐
Reunantäytön/-murskeen vajaus	☐	☐	☐	☐	☐	☐	☐	☐
Ojan syvyys	☐	☐	☐	☐	☐	☐	☐	☐

Haluatko täydentää edellisen kysymyksen vastauksia?

Valitse talvi-/kevätajan viisi tärkeintä seurattavaa suuretta.

Raahaa listasta enintään viisi tärkeintä suuretta numeroituihin kenttiin. Järjestys ei ole olennainen.

1	Lumivallin korkeus
2	Tien profiili
3	Lammikoi-tuminen
4	Heitot
5	Kuopat
	Epätasaisuus
	Reuna-polanteen korkeus
	Polanneuran syvyys
	Sohjo-ojien tila



Tien leveys

Mittaustiedon ero kesäajan mittaukseen

Ajoradan lumisyvyys

Linja-autopysäkit ja/tai levähdys-alueet

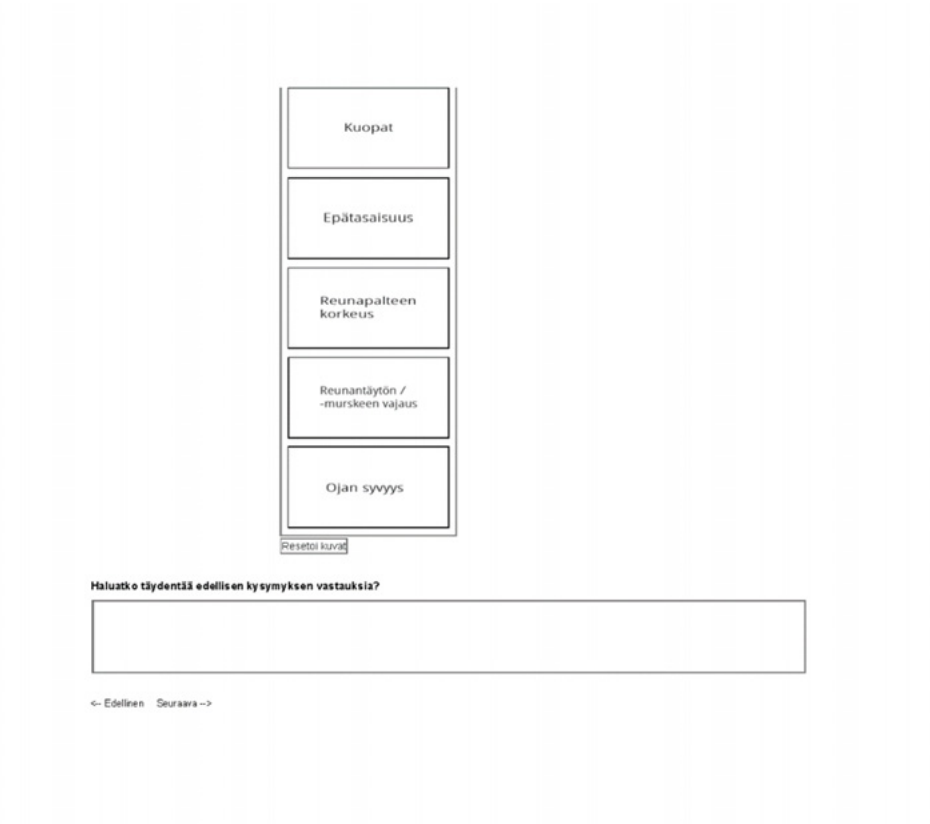
Resetoi kuvat

Haluatko täydentää edellisen kysymyksen vastauksia?

Valitse kesäajan viisi tärkeintä seurattavaa suuretta.

Raahaa listasta enintään viisi tärkeintä suuretta numeroituihin kenttiin. Järjestys ei ole olennainen.

1	Niiton tarve
2	Raivauksen tarve
3	Tien profiili
4	Uratieto
5	Heitot



Kuopat

Epätasaisuus

Reunapalteen korkeus

Reunantäytön / -murskeen vajaus

Ojan syvyys

Resetoi kuvat

Haluatko täydentää edellisen kysymyksen vastauksia?

<-- Edellinen Seuraava -->

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Hälytystoiminnot

Hälytystoiminnot

Minkälaisiin asioihin tarvittaisiin hälytystoiminto? Ajatuksena on, että hälytyksen voi laittaa päälle tai pois. Jos haluat tarkentaa vastaustasi, niin vaihtoehdon perässä olevana tekstikenttään voi kirjoittaa lyhyen tarkennuksen. Seuraavassa kysymyksessä on vielä tilaa tarkentaa.

- ☐ Uusi mittaus tarkastuksen jälkeen (jos tarkastusajankohta on tiedossa)
- ☐ Uusi mittaus
- ☐ Mittaustulos osoittaa laadunalitusta
- ☐ Mittaustulos on epäselvä
- ☐ Ajankohta vaatii erityistä huomiota (esim. lomakauden liikenne)
- ☐ Säätilan muutos
- ☐ Onnettomuustiedot

Haluatko täydentää edellisen kysymyksen vastauksia?

Historiatiedot

Olisiko hyödyllistä nähdä mittaustiedon kehittyminen valinnaiselta ajanjaksolta?

Esimerkiksi: Polanneurien kehittyminen tietyllä ajanjaksolla.

- ○ Kyllä
- ○ Ei
- ○ En osaa sanoa

Haluatko täydentää edellisen kysymyksen vastauksia?

Olisiko hyödyllistä merkitä jokin mittaustieto vertailukohdaksi?

Esimerkiksi: Jokin syksyn mittaus talviajan pohja-arvoksi.

- ○ Kyllä
- ○ Ei
- ○ En osaa sanoa

Haluatko täydentää edellisen kysymyksen vastauksia?

Kuinka pitkältä ajanjaksolta tietoja pitäisi mielestäsi olla saatavilla?

<-- Edellinen Seuraava -->

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Fyysinen käyttöympäristö

Millä laitteella käyttäisit ALASCAn käyttöliittymää mieluimmin?

Järjestä päätelaitteet käyttömukavuuden mukaan siirtämällä ne alaosasta riviin. Mikäli et käyttäisi laitetta, niin **jätä se siirtämättä.**

Mieluisimmat päätelaitteet

Mieluisin käyttää	Seuraavaksi mieluisin käyttää	Epämieluisin käyttää

Tietokone

Tabletti

Mobiililaite

Resetoi kuvat

Tarvitsisitko ALASCA:n mittaustietoja toimistossa?

Sisältäen tietojen katselun ja muokkauksen. Voit tarkentaa vastaustasi tarvittaessa.

- ○ Kyllä
- ○ Ei
- ○ En osaa sanoa

Tarvitsisitko ALASCA:n mittaustietoja kentällä?

Sisältäen tietojen katselun ja muokkauksen. Voit tarkentaa vastaustasi tarvittaessa.

- ○ Kyllä
- ○ Ei
- ○ En osaa sanoa

Haluatko täydentää päätelaitteiden käyttöä?


<-- Edellinen
Seuraava -->

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Haluatko täydentää vastauksiasi tai tuoda jotain muuta esiin?

Vapaa sana

<-- Edellinen   Lähetä

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ALASCA (Automated Road Monitoring Pilot Using 2D Laser Scanning) is a regional innovation pilot project. The objective was to develop and test a laser scanning unit that would enable crowd-sourced data collection from roads, especially by using large goods vehicles (LGVs), with a 2D-laser scanning unit attached to them. The idea was to bring new solutions for road monitoring, especially for quickly changing winter conditions. This report summarises all the results from the pilot project that lasted from winter 2017 until spring 2018.

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