INTELLIGENT ACCES PILOT FOR SPECIAL ROAD TRANSPORT



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Abstract
This paper summarizes findings of the Pilot Intelligent Access Special Road Transport study, which aimed to evaluate the impact of a monitoring system that continuously logs the compliance of applicable conditions for accessing specific infrastructure. The study identified key performance indicators to guide data collection, developed a technical monitoring system, and tested it for six months. Results indicate that such a system could offer useful insights for logistics companies and road authorities and improve overall transparency. However, challenges related to data reliability, upscaling, digitalization of road maps, and standardization of product codes and terminal abbreviations need to be addressed. The study recommends an independent intermediary party to deal with data management for upscaling. Overall, the study confirms the feasibility of implementing a monitoring system for special road transport that operates under exemption, provided that appropriate measures are taken to ensure data quality and address other challenges.

Keywords: Digital Technology and data, Special Road Transport, Intelligent Vehicle System, Real Time Monitoring, Infrastructure Access, Dashboard, Urgent Messages

1. Introduction

For many years now, freight traffic and road transport has been growing most strongly as a result of economic movements. In addition to more trucks on the road, the average weight per truck is also increasing. There are more deviating sizes and weights (special transport) and innovations that lead to higher vehicle loads. One of these examples are the European Modular System 1s (EMS1s) (Also known as Long and Heavy Vehicles (LHVs)). EMS1s benefit the efficiency and sustainability of the logistics sector, but also accelerate the depreciation of the road infrastructure and cause additional wear and tear. These risks will increase even more due to overdue road maintenance and possible overloading of EMS1's. Depreciation of the road infrastructure is eventually a risk for the overall road safety.

As of now, overloading of special transport vehicles, EMS1s and freight transport in general, can easily go undetected and can also be difficult to control. Partly due to the dependence on measuring systems in the road (Weigh-In-Motion) and the enforcement capacity and prioritization within road authority parties. A real-time monitoring system could be a solution which results in a more preventive method of monitoring the road access of special transport vehicles instead of the current more repressive methods. The Dutch ministry of infrastructure and water management has much interest in the topic as well and therefore called out for a pilot that studies the effects of a real time monitoring system on special transport vehicles.

This paper presents the development and findings of a real time monitoring system used in the Pilot Intelligent Access Special Road Transport which goal is to provide insights in the effect of a monitoring system that continuously logs whether and to what extent the applicable conditions to access certain infrastructure are met. It also provides a study on the technological feasibility of a monitoring system on EMS1s. Said monitoring system offers opportunities to demonstrate the advantages and disadvantages of larger and heavier transport, in terms of efficiency, throughput, enforcement and sustainability. Many stakeholders were connected to the pilot. Stakeholders like, road authorities, law enforcement, logistics companies, tech companies and universities.

2. Research Method

This chapter describes the research method that was used while executing the pilot.

2.1. Project phases

The pilot project consisted of three phases. The first phase focused on preparation, which involved exploring how to respond to the key performance indicators (KPIs) and questions posed by Rijkswaterstaat (Rijkswaterstaat is the executive organization of the Ministry of Infrastructure and Water Management). Questions as how to develop such a monitoring system, what it will provide in terms of insights and how to upscale? A crucial component of the pilot was the completion of a Data Protection Impact Assessment (DPIA). During the second phase called the operational phase, the monitoring system was developed and installed on the two participating European Modular Systems (EMS1s). This data gathered from these monitoring systems was then transformed into a monthly report presented as an online dashboard that allowed Rijkswaterstaat to visualize the points of interest (POIs) and the extent to which EMS1 transport adheres to the applicable regulations. Only severe violations of regulations resulted in an "acute notification" to the police or Rijkswaterstaat, which is separate from the monthly reports. The third and final phase was the evaluation phase, where the results, in collaboration with the consortium and stakeholders were reviewed, the scalability was determined and the necessary conditions for successful implementation on bigger scale were formed.

The pilot lasted from October 2021 until April 2023. The initially planned three-month period for the commissioning phase was extended due to research into data protection. The operational phase lasted approximately six months. The pilot was concluded with a four-month evaluation phase.

2.2. KPI's

Before the monitoring system could be developed and integrated, a list of KPIs was generated to be able to put a scope on what information is desired and thus be able to search for more specific sensors and technology that can extract this information in the required type and form as a monitoring system. The list of KPIs was generated through various meetings with stakeholders like logistic companies and road authorities. Based on these discussions the following KPIs were defined:

- 1: Reduce the risk of 'reverse modal shift'[1] for EMS1s.
    - A monthly insight in the percentage of container cargo compared to all other cargo could give insights in the reverse modal shift phenomenon so that it can be acted upon more actively.
- 2: Monitoring the compliance of following allowed routes for EMS1s and prevent driving in restricted areas.
    - A monthly insight in the percentage of EMS1s that have driven in restricted areas and so have deviated from the planned route.
- 3: Monitoring of load on bridges and percentages of overloading.
    - Give insight in the total amount of passages on bridges in relation with the total weight of the EMS1.
    - Percentages of EMS1s that:
        - Stayed withing the permitted axle loads.
        - Exceeds the permitted axle load by < 10% on one or more axles.
        - Exceeds the permitted axle loads by 10 – 25% on one or more axles.
        - Exceeds the permitted axle loads by > 25% on one or more axles.
- 4: Generate an overview of number of incidents (either breakdown or accident) where EMS1s are involved.
    - Give insight in the relation of traffic accidents and EMS1s
        - Monthly overview of trucks that were stationary for mor than 15 minutes with low tyre pressures on one or more tyres indicating a flat tyre.
        - Monthly overview of trucks where the ADAS have sent an alert before standing still indicating a possible accident.
    - Give insight in the relation of traffic accidents (with EMS1s) and road design.
- 5: Insights in traffic jam sensitive road sections for freight transport.
    - Monthly top 10 of road sections where the vehicle speed drops below 50 km/h the most.

[1] The shift of using trucks to transport containers over the road instead of by boat and therefore generating capacity problems on the road network.

- 6: Emissions.
    - Give insights in the emissions that are caused by EMS1s
    - The average emissions are determined by examining the average amount of CO_2 produced per litre of diesel burned and the average consumption of LHV's during each trip. By considering these factors, it becomes feasible to approximate the overall CO_2 emissions generated.

2.3. The monitoring system

The full integrated monitoring system needed to be able to measure the KPIs stated in the previous paragraph. With the KPIs known, the monitoring system was developed by combining certain systems, sensors and existing vehicle sensors together. Below a description of the developed monitoring system is given. This includes a list of what sensors and components form the monitoring system together with what kind of information it outputs and in what form. The separate components of the monitoring system are also linked to the corresponding KPIs for which they are responsible.

2.3.1. Hardware and sensors

The monitoring system exists of the following hardware and sensors:

- Driver behaviour monitoring system
    - A camera-based driver assistant/monitoring-system that can provide notification for the following six types of events and logs them:
        - Forward Collision Warning
        - Headway Monitoring Warning
        - Lane Departure Warning
        - Pedestrian and Cyclist Collision Warning
        - Speed Limit Indicator and Traffic Sign Recognition
        - Crash detection based on accelerometer
    - Can help in identifying traffic accidents (KPI 4)
- Fleet management and tracking unit
    - A GPS system that tracks the vehicle and links it to the assigned route.
    - This provides insights into the route followed, deviations from route, speed of vehicle and idle time (KPI 1, 2 and 5).
- Event data recorder
    - Gathers video material in case of extreme events (traffic accidents).
    - The recorder activates when a certain amount of g-force is reached but can also be active manually by the driver[2].
    - It can provide insights in the type of traffic accident (KPI 4).
- Axle load sensors
    - Determine the axle load for each axle
    - Sensors are mounted on all tractor, trailer and dolly axles.
    - Each axle load is measured individually and a sum is provided to be able to conclude if only an axle or complete combination is overloaded.

[2] It was later concluded that the activation by g-force needed to be finetuned. Since the data recorder was mounted on the truck cabin, the recorder sometimes activated when the cab was moving with for example braking. Mounting the g-force sensor somewhere else (chassis) can be a good solution to this problem.

  - Gives insight into axle loads and possible overloading (KPI 3).
- Tyre Pressure Measurement System
  - Gives insight into the tyre pressures to identify possible flat tyres (KPI 3 and 4).
- Average vehicle emissions calculation
  - Gives insights in the emissions of the vehicle (KPI 6).
- Additional Logistics data
  - Data gathered from the logistics company like, planned (un)loading times, vehicle combination information, validity of EMS1 certificate of driver, etc.
  - Gives more insights into forming some of the KPIs (KPI 1, 2 and 5).

2.3.2. Information usage

The hardware and sensors combined collect data that can be used to provide useful insights into the efficiency, throughput and sustainability of the EMS1s. The data collected can also be used to monitor for possible rule infringements like overloading or accessing (for EMS1) forbidden roads. The monitoring system can also access the Logistics Company database to acquire additional information like cargo and vehicle specifications. The data flowchart shown in Figure 1 gives an overview of what type of data is collected and how it is used.

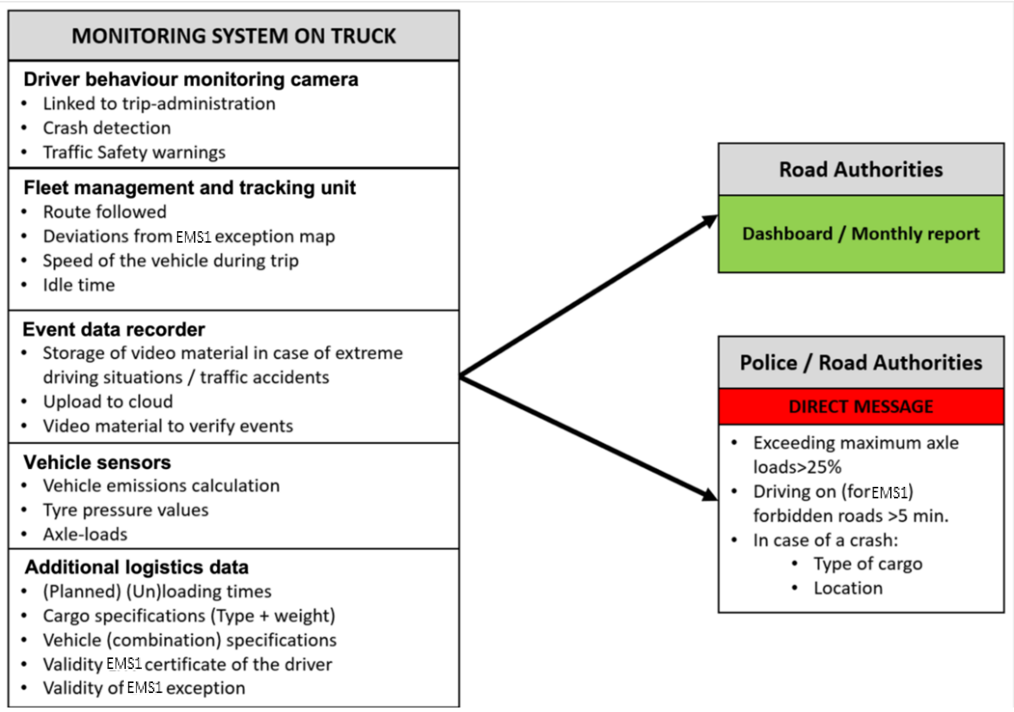

Figure 1 – Data flowchart of the monitoring system

2.3.3. Information Publishing

As can be seen in the flowchart of Figure 1, the collected data is used for two purposes. The first purpose is the dashboard and the monthly reports. The dashboard is accessible for the road authorities and logistics company at all times and give insights into the use of the EMS1 based on the data as shown in Figure 1. The second purpose is the direct message to road authorities and police if rule infringements like overloading or accessing (for EMS1) forbidden roads occur. The road authorities and the police are informed via an e-mail or an automated push notification that contains information on the type of infringement, vehicle details and location of the vehicle.

3. Results

This chapter discusses the results coming out of the operational phase of the project. As said in Chapter two, the data from the monitoring system was gathered in the operational phase over a period of 6 months. During these 6 months, two EMS1s were equipped with the operating system. The data gathered was transformed into monthly reports or urgent messages. The two forms of data publishing are described more extensively in the following paragraph.

3.1. Monthly reports

Forming the monthly reports has been an iterative process during the operational phase of 6 months. Over this time, the reports have been changed to come to a definitive version which gives answer to the formed KPIs. Since the data used for the monthly reports was gathered only from two EMS1s, the data is not statistically relevant. However, it does provide useful insights into possible upscaling for the near future which was the overall goal of the pilot. For the sake of the paper, it goes too far to discuss the full monthly report in detail. Therefore, a list is given with the information that is shown. Some of the items are provided with an example for more context. The information that is given in the monthly reports corresponds to the KPIs listed in Paragraph 2.2. The monthly report contains of:

The monthly report starts with an overview of all the driven routes of the EMS1 in that period. This section consists of:

- A map of driven routes and corresponding vehicle speeds as shown in Figure 2.

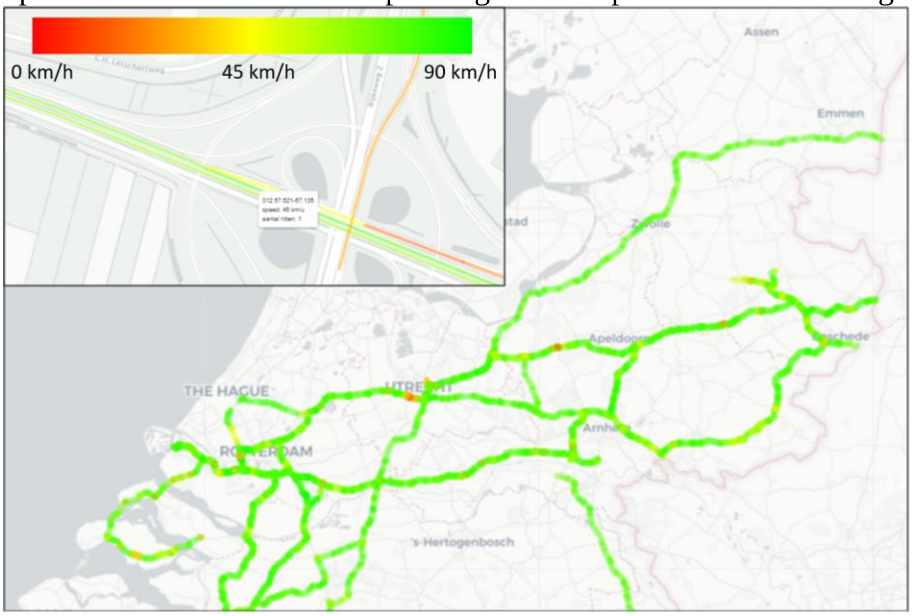

Figure 2: Map of driven routes and corresponding vehicle speeds in the Monthly report.

- A graph which shows on which period of the day the vehicle speed drops below 50 km/h.

The next section of the monthly report are the events. These events are triggered either by the ADAS on the truck or manually by the driver (event data recorder). The section consists of:

- A graph with an average amount of events per route.
- A map which shows where the events are triggered as shown in Figure 3. Figure 3 also shows the five types of events that can occur. They can also be filtered in the monthly report as shown in Figure 3 since only the “harsh braking sensor triggered” is checked.

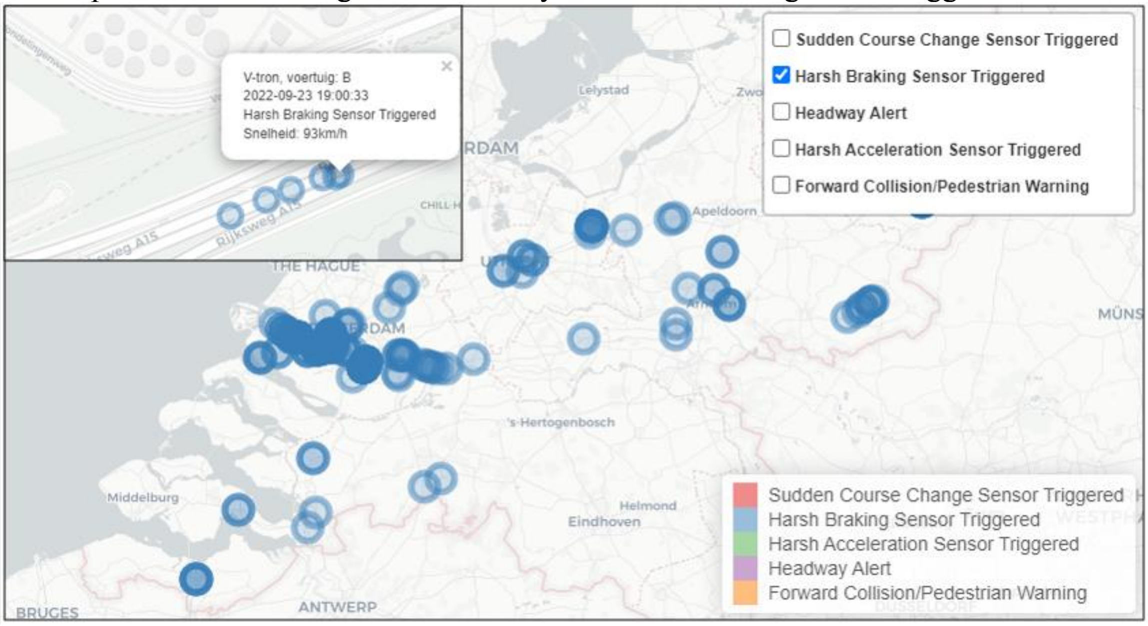

Figure 3: A map of the location of triggered events as shown in the monthly report.

- A top 10 of road sections where the most events occur.

The third section of the monthly report contains the information of transported goods. The information is displayed in a clear graph (Figure 4) which gives a good overview of what goods have been transported monthly and how many times.

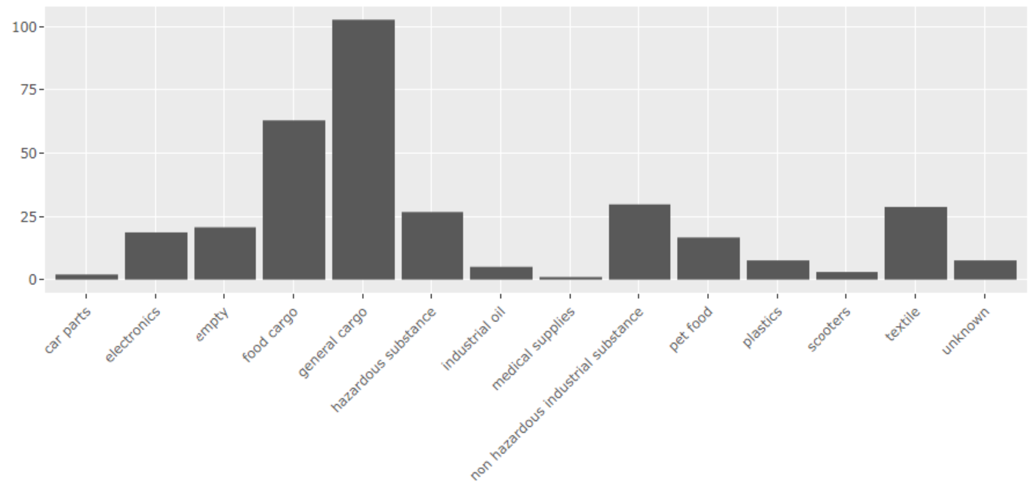

Figure 4: Types of tranpsorted goods and the corresponding amount of trips .

The fourth section is a small overview of the start and end points of each trip. With the help of a map, the start and end points are displayed to give an overview of where monthly trips are delivered.

The fifth section contains information about the fuel usage of the trucks together with the corresponding emissions. The information contains:

- The average fuel usage per trip per EMS1.
- The average CO_2 emissions per trip per EMS1 (Figure 5).
- CO_2 emissions specifically in so called 'Natura-2000' areas[3]. This example was given since it is a hot topic in the Netherlands and Europe and with the information of digital maps combined with the emissions of EMS1s it can give useful insights in if the emission regulations are met in the 'Natura-2000' areas which highlights the potential of the monitoring system.

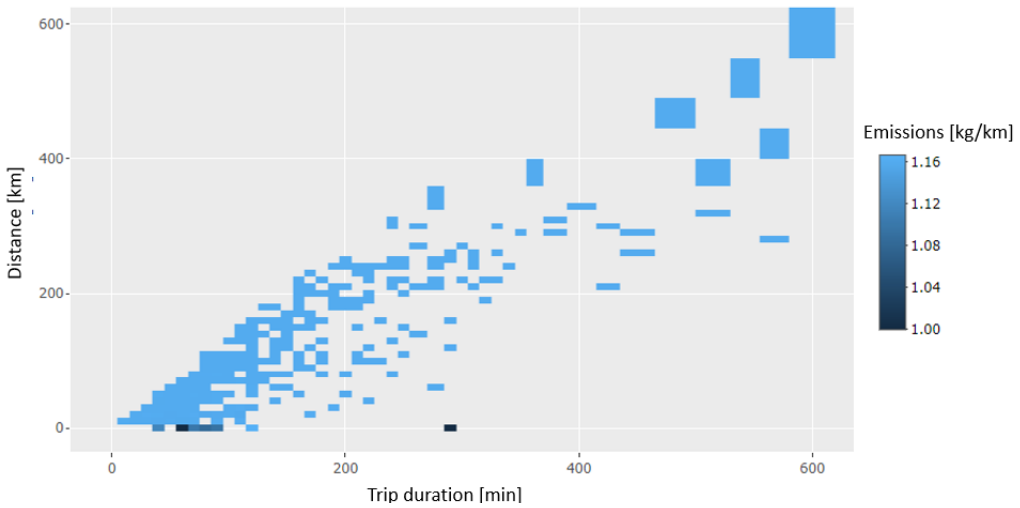

Figure 5: Average CO_2 emissions based on trip duration and length.

The sixth section contains the information regarding driving in restricted areas. This can be visualised by the help of digital maps and restricted areas with so called 'geofencing'. The section gives an overview of:

- Warning when a geofenced area is entered.
- Warning when driving over structures with the corresponding load on that structure for example vulnerable or historical bridges.

The last section contains information about standing still on the road networks. The graph shows how many times an EMS1 stood still on the main road network and for how long.

3.2. Urgent Messages

Next to the monthly reports, the monitoring system is also used to send out urgent messages to road authorities[4] and law enforcement in case of emergencies or rule infringements. It was noted that a monitoring system does not only have potential for the logistics companies but can also prove valuable for road authorities and law enforcement. As stated in the background, monitoring of EMS1s and if they comply with regulations is a difficult and passive process as of now. A monitoring system has potential in making the process of

[3] Natura 2000 is a European network of protected natural areas where endangered and vulnerable animal and plant species are protected and therefore emissions are heavily monitored and regulated in these areas.
[4] Road authorities can in their turn inform corresponding emergency responders if needed.

checking compliance with regulations more active. In order to do so, the monitoring system developed during this pilot has a functionality of sending out urgent messages to corresponding parties. This section describes what the urgent messages look like and how they work.

First, it is important to know what kind of events require urgent messages. During the operational phase the events were determined via an iterative process of meeting with corresponding stakeholders. The events for urgent messages and their receivers are listed in Table 1.

Table 1 – Type of event and the corresponding receiver for urgent messages.

Event	Receiver of urgent message
>25% Overloading of EMS1[5]	Police
Blown or flat tyre(s)	Road authorities
Crash or traffic accident noted by the data event recorder of the monitoring system.	Road authorities
Standstill on road network for longer than 15 minutes	Road authorities
Driving on prohibited roads for EMS1 for longer than 5 minutes	Police

If one of these above listed events occurs, the urgent message is sent out. The urgent message contains the following information:

- Type of event (as specified in Table 1).
- Time of occurrence
- Location and heading of EMS1 (if also known the destination)
- License plate of EMS1 (all vehicle units in that combination)
- Difference between time of occurrence and time of urgent message
- Phone number of corresponding logistics company (optional)

Providing the information above gives the road authorities or the police a complete picture of what has happened or is happening and therefore can respond in a fast and correct way.

4. Lessons learned and Action points

The most important part of this pilot is to evaluate if the developed monitoring system has the expected and desired effect. As stated in Chapter 2, this was done during the evaluation phase after an operational phase of 6 months. This Chapter contains a discussion regarding the lessons learned and provides action points on how to further develop and implement a monitoring system in the logistics sector.

4.1. Lessons learned: General

Firstly, this pilot's main focus was the EMS1s. The EMS1s are a good starting point for a pilot since a lot of data was available, regulations are clear and the amount of EMS1s is controllable. A next step in upscaling would be to expand the monitoring system to a different type of transport that requires exemptions. The desire to monitor all freight transport in the

[5] When driving longer than 5 minutes to give the driver a chance to stop driving or unload. Overloading under 25% is not an urgent message, but will be displayed in the monthly report.

Netherlands seems unrealistic for now. This is mainly due to the fact that there is great diversity in nationalities of carriers on the Dutch roads. Only equipping Dutch freight carriers with a monitoring system might feel like a ‘disadvantage’ for Dutch logistics companies. The feeling of having a ‘disadvantage’ was something that Logistics companies spoke of. The feeling of being monitored all the time might give drivers and carriers an uneasy feeling. Therefore, a closer collaboration between road authorities and logistics companies is needed. If logistics companies want to be encouraged to deploy the monitoring system, it should be made clear for logistics companies what the advantages are for using the monitoring system. Road authorities and governments can for example do this by rewarding logistic companies in certain ways. Think of fastening the process of handing out permits or by reducing the number of physical checks on the road and therefore saving time.

What came up during the evaluation phase, was that most of the workload when implementing a monitoring system can fall on the logistics companies themselves. An example of this is the integration of the route planning system in the transport management system (TMS) and fleet management system (FMS), the installation of necessary sensors for data collection, and enabling the unlocking of data to an external party. In order to be able to make a monitoring system feasible, the workload should be shifted towards a more equal workload for both the logistics company and the road authorities. This can be achieved by for example using an independent intermediary between the logistics companies and road authorities. This results in a lower workload for the logistics companies and also prevents that a logistics company ‘assesses its own work’. The intermediary party can also act as a safekeeper of a so called ‘trust domain’. Since a monitoring system deals with data coming from logistics companies and is processed and used by the road authorities, it should be made high priority that this data is correct and trustworthy since the data is being used by public and private parties.

Further digitization is required in the field of the exemption map. Currently, there is no workable digital map or overlay of the EMS1 exemption map. As a result, the "prohibited" locations for EMS1 vehicles must be manually mapped. For any potential scaling up, an automatically implementable digital map (which is frequently updated when new information is available) is needed to allow all participating parties to perform real-time verification. This could be achieved well with only incremental updates for changes and a push method towards the receiver or access point. Like the previous point, a trust domain is important here. The receiver must be able to rely on the information being correct and updates being traceable. Note that this only has an effect when the transporter also uses this information when planning the routes.

4.2. Lessons learned: The process

Some lessons learned about the process are discussed in this paragraph. First, not every transportation company uses a TMS system with an integrated route navigation system. In the example of the collaborating logistics company during this pilot, the driver determines the route and selects it in accordance with the EMS1 exemption map. This makes it difficult to check the route for compliance before the trip. Therefore, it remains an "urgent notification" during driving when the route is not followed, or this urgent notification will be reported afterwards. Further digitization in this area and the use of a route navigation system that considers the current prohibited areas for EMS1s could certainly work in favour of the carrier.

The second lesson learned was that the weight declaration for EMS1s comes from the mandatory CMR (or in the future e-CMR)[6]. It is however still difficult to verify this weight with the actual axle loads because not all transport allows time for it to be done from a planning perspective. It can be a matter of minutes between choosing where which container goes and by which vehicle and the actual departure. The check is still carried out manually by the driver with the help of analogue gauges.

Thirdly, keeping track of parameters such as CO_2 emissions is being done using general calculation methods. More detailed measurements are very deviant due to many factors. It is for example expensive to standardize and implement on a large scale because specific equipment is required unless OEM measurements/reports based on 2019/1242/EU can be used. In addition, the question is which emissions fall under which transport in case of shared loads and in case of Natura-2000 areas, where emissions are emitted. During the pilot, it was not possible to perform simulations based on CAN bus data. In addition, not all truck manufacturers have standardized CAN messages to unlock vehicle parameters from the CAN bus. This makes it difficult and expensive to simulate these emissions for possible upscaling.

Furthermore, it was found out during the pilot that it is not possible to classify goods for all transport (e.g., containers) and it is difficult to get a clear picture of what exactly is being transported. In the case of the participating logistics company, they must rely on the description of the goods in the container as stated on the consignment note. They have however no idea what the contents are in a large part of the containers and verify it unless the mandatory full description of goods is required by (European) standardized product codes. This standardizing can also be done with the names or abbreviations used to designate the origin and destination terminals. As of now this is not the case, but it could help to get better insights in the origin-destination relationship when upscaling container transport.

5. Conclusions

Pilot Intelligent Access Special Road Transport goal was to provide insights in the effect of a monitoring system that continuously logs whether and to what extent the applicable conditions to access certain infrastructure are met. It was furthermore studied if such a system was technically feasible and what should be done for full implementation. Before the monitoring system was developed, a list of KPIs was generated that gave answer to the question what information needs to be gathered by a monitoring system. The monitoring system was developed by combining technical components that gather the needed information and it was tested during an operational phase of six months. The main conclusions that can be drawn from the evaluation phase is that there is much potential in implementing a monitoring system since it gives useful insights into the transport of goods (now mainly focussed on EM1s) for both the logistics companies and the road authorities. With implementation of a monitoring system, the overall transparency can be improved. However, when looking at upscaling, there are some challenges that need to be overcome. These are written down as recommendations in the next chapter.

[6] A CMR is a mandatory freight letter that all trucks should carry that specify the freight and load. An e-CMR is the digital version which is upcoming in the logistics sector.

6. Recommendations

Since this project was a pilot, some topics were not studied during the pilot itself, but are interesting to mention. Some open discussions and action points are formed into recommendations below.

To ensure the reliability of data in the monitoring system, it is crucial to establish a robust data assurance mechanism. While this pilot study demonstrates the technical feasibility and precision achievable through sensor integration, the ultimate value lies in the accuracy and trustworthiness of the data. Considering this, implementing an independent intermediary party to oversee and manage the data could be the optimal solution for scaling up. Such a party would play a vital role in verifying and validating the data, instilling confidence and ensuring that the collected information is both correct and reliable.

Clearly study and communicate the specific advantages that specifically the logistic companies can expect from participating in the pilot, such as improved logistic process management, enabling smart maintenance schedules, and creating more favourable driving conditions for drivers. Additionally, ensure that the identified key performance indicators (KPIs) align with the company's goals and objectives to measure and track meaningful progress. By providing a clear understanding of the benefits and focusing on relevant KPIs, the logistic company can make informed decisions and actively participate in shaping the implementation of Smart Access.

Ensure future research includes an analysis of how the average fuel use, as reported monthly, is influenced by the total vehicle load. While the paper acknowledges this as an interesting point, it is not yet fully analysed. Incorporate this aspect into the next phase of the pilot study, as logistics companies have expressed their interest in understanding this relationship further. By conducting a thorough analysis, the findings can provide valuable insights for optimizing fuel efficiency based on varying vehicle loads.

Further investigate the challenges mentioned in the paper with axle load monitoring, emission assessment, tyre pressure measurement, and the EMS1 exemption map, as mentioned in section 4.2. These challenges directly impact KPIs 2, 3, 4, and 6, which represents a significant portion (4 out of 6) of the KPIs mentioned. It is important that further studies not only highlight the technical feasibility but also the availability of sufficient equipment, relevant CAN data, and the potential impact on the logistic process for the Dutch EMS1 fleet. While acknowledging that this is a pilot study and conclusive results may still be pending, addressing this information will provide a comprehensive understanding of the factors influencing the study's outcomes.

7. Acknowledgements

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