Improving Energy-Efficiency in Operational Logistics using the Internet-of-Things

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ABSTRACT
With the growing use of logistic services for both personal and commercial purposes, logistic service providers at all levels have to cope with higher utilization of transport channels. Rapid, accurate and well-informed decision-making is very critical, but often not possible due to missing information or direct contrast, information overload. Related work shows how interconnected sensors within vehicles (internet-of-things) can provide insight in performance on low-level operations (e.g. vehicles). After analyzing trends on energy-efficiency in logistics, several logistic service providers have been studied that have projects under implementation, which use sensor-data to obtain insight in driving behavior and other vehicle related information to improve fuel efficiency.

The cases show that there exist big differences between the studies modalities when it comes to interoperability of vehicle sensor-data. The declining costs of sensor-bearing mobile computers and high availability internet-connectivity, provide alternative methods for organizations to collect vehicle information to report and improve energy-efficiency.

Keywords
energy-efficiency, sensor-based networks, process optimization, logistics information management, managing information, internet-of-things

1. INTRODUCTION
Logistics is an inter-organizational activity where doing the job right and on time is of high importance. With the ever-growing utilization of all transport channels, operations have to cope with the also-growing amount of information for decision-making at all stages. This requires logistic service providers (LSP) to be efficient in both time and costs [44][22] and maintain quality of service.

To accomplish this efficiency, LSPs need to make decisions based on both internal and external factors; current planning systems however, are perceived to be significantly inaccurate “due to the credibility of the forecast times quoted for individual vehicle trips” [24].

Most of the currently used transport vehicles are equipped with sensors [8][9]. Combining information of the individual sensors on vehicles and let them communicate, can generate an “internet-of-things” [33][56] which enables accurate, real-time information about the utilization of transport channels and thus improve vehicle routing and scheduling [44].

On the operational level, drivers gain situational awareness and allow for persuasive technology which can inform or even take over drivers tasks [46]. When successfully implemented efficiency raises, but could potentially render human professionals redundant and thus have impact on employee satisfaction [33].

2. PROBLEM STATEMENT
Initial literature search confirms that because of e-commerce and globalization, effective global supply chain management is a necessity [55]. This effectiveness can be measured in the efficiency of assets using Key Performance Indicators [34]. In this research efficiency will be defined as the accuracy and speed of decision-making of operational logistics. Energy-efficiency is a subset of this focusing on factors that impact decisions on fuel-usage and environment friendliness.

Research by [16] shows that horizontal collaboration in the logistic sector can improve efficiency. [29] and [17] built upon this idea and explores how Service Oriented Architectures (SOAs) can facilitate developing efficient open communication standards.

Because of insufficient incentives and security concerns, supply chain stakeholders are reluctant to invest in novel technology like SOAs for improvement of efficiency and maximizing supply chain-wide profit [36].

Research by [35] shows that the concept Internet-of-Things (IoT) has been gradually developing in the domain of supply chain management (SCM) in general. This concept is described by [15] as the interconnected network of objects embedded with sensors and the ability to communicate.

[35] also states that the organizations they investigated, executed logistic planning processes which require quick and reliable operational data, but the information layer lagged behind. They emphasize the need for better information handling in logistical planning operations.

Research by [46] shows that information systems can fulfill even more persuasive roles. They do note that every change in the way the system works, the driver also changes their behavior, making the real-world implications very hard to predict.

Human Factors literature [28][30] confirms that a decrease in autonomy can affect employee motivation and thus satisfaction in a negative way [63].

According to [31] the concept of gamification has been successfully been used to generate incentive for truck drivers, which led to good driving behavior and a permanent reduction.
in fuel consumption at Scania [59]. The research by [31] also notes that interviews with the target audience could identify additional factors to take into account, improving efficiency even more and simultaneously maintain employee satisfaction by engaging them in the improvement process.

This paper aims to provide a trend analysis of the internet-of-things in the logistics sector and show how logistic service providers in the Netherlands managed to do so.

3. RESEARCH QUESTIONS
To find a solution to the problem statement, the following research question has been formulated:

What role can the internet-of-things play in improving energy efficiency in operational logistics?

The answer will be given by:

- Providing a trend analysis to explain the current adoption of the internet-of-things itself and related concepts
- Illustrate how companies manage to accomplish this so far using explorative case studies.

We will define operational logistics as the planning and transportation activities of delivering freight.

Improvement will be defined as making decisions faster and more accurate. We expect that using sensor-based data, real-time information will improve operational processes and analysis on historical data will improve forecasting.

Study by [33] found that “high levels of perceived control was associated with high levels of job satisfaction, commitment, involvement, performance and motivation […]”.

Decision-making taken over from employees by automated systems reduces the level of perceived control. The case studies show how employees cope with this when it improves environmental performance of the organization and how organizations use concepts like gamification to generate incentive for adoption of new technology.

4. RESEARCH METHOD
To get an overview of the already known facts about the domains this research will cover, initial literature search has been conducted. The information found is used to formulate the research question.

Initial literature search indicates that real-world implications are hard to predict [46]. To take this in consideration, explorative case studies will be conducted at several LSPs, this will be further explained below.

4.1 Literature review
The literature search will be conducted using the five-step grounded-theory method by [62], summarized in Table 1.

The result is expected to give a complete overview that is relevant and up-to-date.

4.2 Case Study
For cover all important aspects during the explorative case studies, the architectural TOGAF model [53] will be used. This model allows a holistic approach to enterprise architecture. It consists of several phases, which are shown in Figure 1.

The framework aims to be a set of tools, which can be modeled at four levels: Business, Application, Information and Technical Infrastructure.

Table 1 Stages of the Grounded-Theory method for literature search

<table>
<thead>
<tr>
<th>Number</th>
<th>Task</th>
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<tbody>
<tr>
<td>1. DEFINE</td>
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<tr>
<td>1.1 Define the Criteria for Inclusion/Exclusion</td>
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<tr>
<td>1.2 Identify the fields of Research</td>
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<tr>
<td>1.3 Determine the Appropriate Sources</td>
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<td>1.4 Decide on the Specific Search Terms</td>
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<tr>
<td>2. SEARCH</td>
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<td>3. SELECT</td>
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<tr>
<td>3.1 Refine the sample</td>
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<td>4. ANALYSE</td>
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<tr>
<td>4.1 Open Coding</td>
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<td>4.2 Axial Coding</td>
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<td>4.3 Selective Coding</td>
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<td>5. PRESENT</td>
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<td>5.1 Represent and Structure the Content</td>
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<td>5.2 Structure the Article</td>
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[35] built a framework upon TOGAF to “specify architectural development aspects of information systems for logistical planning and investigate how the Internet-of-Things concept has arrived in this domain”.

Their research showed a discrepancy in the design of the information layer when looking at cases. The information layer is defined as the “describing layer of an organization’s logical and physical data assets and the associated data management resources.”

Figure 1 Phases of the TOGAF

By conducting explorative research we try to obtain a representative view of the adoption of the internet-of-things concept and discover related concepts and alternatives which can feed back to theory building [38]. An overview of the research is given in Figure 2. The organizations to be studied are listed in table 2.
Figure 2 Research Overview

Work by [19] introduces the following processes to obtain a better understanding in the decision-making processes:

- Organizing problem parameters
- Structuring the decision problem
- Simulating policies and events
- Finding the best problem solution

These processes will be used to structure the interviews. To illustrate how the separate elements are related a non-exhaustive overview is given in the table below.

Table 2 Planned case studies

<table>
<thead>
<tr>
<th>Cofano Software Solutions</th>
<th>Software developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cofano Software Solutions developed several internet-based logistic applications that provide both LSP’s and their customers insight and control over the logistical chain.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Combi Terminal Twente</th>
<th>Barge shippers</th>
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</thead>
<tbody>
<tr>
<td>Combi Terminal Twente (CTT) is the largest inland terminal in the Netherlands. They provide handling and transport of sea-containers. Together with Bolk Container Transport B.V. they offer the possibility to transport contains by truck.</td>
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</table>

<table>
<thead>
<tr>
<th>NS Reizigers</th>
<th>Train drivers</th>
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<tbody>
<tr>
<td>NS Reizigers is part of Nederlandse Spoorwegen (Dutch Railways, NS). They are responsible for the inland passenger transport within the Netherlands. Their department “Energie &amp; Milieu” (Energy and environment) has several projects that aim to improve energy-efficiency.</td>
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</table>

<table>
<thead>
<tr>
<th>Scania Fleet Consultancy</th>
<th>Truck drivers</th>
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<tbody>
<tr>
<td>With Fleet Consultancy by Scania, Scania offers transporters a service that aims to reduce fuel-usage and carbon-emissions using the concept of gamification. Which includes training of drivers and post-trip feedback of driving behavior.</td>
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</tbody>
</table>

5. LITERATURE REVIEW

Declining prices of mobile devices and technology in general [6, 52, 54] gives new opportunities for organizations to add sensors like GPS for tracking purposes and internet-connectivity via mobile computers for lower prices than earlier possible.

This enabled government, corporate and academic organizations to collect enormous amounts of data provided by sensors. Unfortunately this data is to often locked within organizations and underutilized by the community [42].

5.1 Efficient use of open data

Fortunately more and more government organizations are offering their data on open-data platforms [5, 20, 64], but as stated by [27] there is a distinction between the opportunity for digitally enabled activity and the actual realization of those opportunities in the form of “effective use”.

Gurstein proposed in [27] a seven-layer model which itemizes various elements that are required to be in place to have the opportunity for this effective use of open data. They are summarized in the table below.

Table 3 Example questions and keywords related to TOGAF phases

<table>
<thead>
<tr>
<th>TOGAF Phase</th>
<th>Example question</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Architecture (B)</td>
<td>How does the project fit within the business strategy?</td>
<td>Strategy alignment</td>
</tr>
<tr>
<td>Information Systems Architecture (C)</td>
<td>What are the functional requirements of software to be used?</td>
<td>Requirements engineering, Business Intelligence</td>
</tr>
<tr>
<td>Technology Architecture (D)</td>
<td>What does technology require to meet requirements?</td>
<td>Sensor based-networks, Service oriented architectures</td>
</tr>
<tr>
<td>Opportunities and solutions (E)</td>
<td>What opportunities does the project provide? Is it a solution for problems that the organization faces?</td>
<td>Situational awareness, mobile collaboration</td>
</tr>
<tr>
<td>Migration Planning (F)</td>
<td>How to manage employees perceived usefulness, perceived autonomy and satisfaction?</td>
<td>Technology Acceptance</td>
</tr>
<tr>
<td>Implementation Governance (G)</td>
<td>How to measure project goals? How to ensure effects do not ware off?</td>
<td>Technology Continuance</td>
</tr>
</tbody>
</table>

Table

<table>
<thead>
<tr>
<th>Internet</th>
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<tbody>
<tr>
<td>Computers and software</td>
<td></td>
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<tr>
<td>Computer/software skills</td>
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<tr>
<td>Content and formatting</td>
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<tr>
<td>Interpretation/Sense making</td>
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</table>
## 5.2 Vehicle sensor-data

When looking at the degree of interoperability there exists a lot of differences between the vehicles used at distinct modalities. We will define interoperability as the ability of systems to work together (inter-operate) with other systems.

### 5.2.1 Road

Every modern road-vehicle is equipped with a Controller Area Network, operating over a serial data-bus (CANBUS) [43], in the EU it has been mandatory for all petrol and diesel vehicles sold since 2004 [10]. It can facilitate retrieving among others [13]:

- Actual vehicle speed
- Actual/total fuel consumption
- Brake switch
- Cruise Control Status
- Engine temperature

The CANbus itself specifies a standard for cabling and messaging protocol, only for road-vehicles there a higher-level standards developed which allow for better interoperability.

Advancements in standardization of Onboard Devices Standards for automobile vehicles (OBD-II) allow equipping a truck with fleet management capabilities as easy as plugging in a device [2]. Typical FMS-modules communicate real-time diagnostic data from the vehicle itself, combined with the location collected by the GPS-modules within the module over mobile communication networks like GSM and GPRS [11, 23].

### 5.2.2 Rail

For rail-vehicles the Train Communication Network (TCN) has been developed. It consists of the Multifunction Vehicle Bus (MVB) and the Wire Train Bus (WTB) to connect the MVB parts with the train control system [32].

The TCN facilitates retrieving the same kind of information that CANbus is capable of.

Unfortunately only a few trains are operating via the standard. Most of the trains are still equipped with a proprietary CANbus system and other privately developed systems [49].

TCN has been developed since 1999 but seems to have its shortcomings. Bombardier Transportation which manufactures several train models in use by Nederlandse Spoorwegen and Die Bahn (German railway company) already proposed a new protocol based on the Ethernet-standard [65], which provides higher transmission-speeds and more bandwidth for a lower cost.

### 5.2.3 Maritime

In ship manufacturing, most manufacturers also chose the global CAN network as backbone.

The NMEA 2000 standard built upon this and has been developed as a plug-and-play communications standard for connecting marine-sensors [51]. Unfortunately the National Marine Electronics Association copyrights the NMEA 2000 database and implementation.

Access is restricted to parties that pay for it, and if they do they are not permitted to disclose the information so it is impossible for open-source developers to get access to it, without using techniques like reverse-engineering.

Some developers have reverse engineered the standard to allow projects like CANboat to provide working with the CAN network on ships and vessels [12].

## 5.3 Infrastructure sensor-data

Governments of the countries where the infrastructures reside in do not always fund this for all different modalities. In the Netherlands, the public roads and waterways are managed by government organizations [57, 60], the railways by ProRail.

### 5.3.1 Open Government Data

Several governments, including the Dutch government joined the Open Government partnership (OGP) a world-wide initiative to let governments improve their functioning by openness [58]. The Dutch government offers several services that include the national roads and waterways and their properties (e.g. speed limits and planned maintenance).

The cross-linking of this public-private data from individual organizations allows for non-redundant, enrichment of knowledge while reducing redundant and outdated data [25]. This in turn facilitates more accurate decision-making.

### 5.3.2 Road

NDW, Nationale Databank Wegverkeersgegevens (National Database Road-traffic-data) is collaboration between several government organizations in The Netherlands. This allowed for nation-wide collection, processing and publication of road-traffic information [41].

The database collections information of the current road-situation on highways, main secondary roads and city roads from participating districts. No information about individual vehicles is saved.

NDW only offers basic information to providers of traffic-information and road-infrastructure-managers. They are the ones to inform the road users.

They offer their dataset both under paid license and open data. With the main difference that their open dataset is provided without any warranty on availability.

### 5.3.3 Maritime

River Information Services (RIS) are IT-related services designed to optimize traffic and transport processes in inland navigation [61]. A EU framework directory provided minimum requirements to enable cross border interoperability.

In the Netherlands this has been developed and implemented in the Fairway Information Systems (FIS)-project, which fully complies with a RIS specifications.

Shippers can access this information on the portal vaarweginformatie.nl, which combines all relevant information (e.g. planned maintenance, weather, operating times) on one website. It also offers the possibility to receive this information automatically as an e-mail subscription.

Fairway-information is also partly available in the open-dataset of the government using common open standards.

Location of other ships can be retrieved with the Automatic Identification System (AIS). AIS is based on transponder technology and aims to provide better insight and information through interaction with other ships and traffic control towers.

### Table 4 Seven-layer model for the opportunity of effective use of open data

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advocacy</td>
<td>Initiative to let governments improve their functioning by openness</td>
</tr>
<tr>
<td>Governance</td>
<td>Open data initiative to let governments improve their functioning by openness</td>
</tr>
</tbody>
</table>

The later sections will illustrate how some of the layers pose barriers on the efficient use of open data at several modalities.
One limitation is that it only recognizes other ships if they also use AIS. In the Netherlands all ships are required to be equipped with AIS per December 1st, 2014 [4].

5.3.4 Rail
The Dutch infrastructure manager ProRail operates with several operators. NS Reizigers, the passenger transport division of Nederlandse Spoorwegen, received a concession until 2015 to operate on the main railway network for passengers with regional concessions for smaller operators [1].

For transport of cargo several freight operators are allowed on the Dutch rail-infrastructure [26]

ProRail discloses all needed information about the infrastructure via several applications. One of the key applications for their users is DONNA, which provides insight in the available capacity, planning and eventual conflicts. [45]

5.4 Intelligent Transportation Systems
Research by [40] provides an overview how Intelligent Transportation Systems (ITS) support freight transportation operations. Their research resulted in a classification of Freight ITS, we will describe every category and summarize shortly how their research suggest how they can be used for improving energy-efficiency.

• Traffic controlling and monitoring systems [...] The environmental performance of the transportation operations is increased by decreasing the transportation time and leads to having a more harmonized traffic flow.

• Weight-In-Motion systems WIM systems reduce the risk of accidents of over-weighted vehicles, reduce damages to the infrastructure such as roads or bridges and lead to time savings for both the truck drivers and for the police.

• Delivery space booking systems [...] According to their study the application of such systems reduces the total number of vehicle trips during a specific time period (contribution to the environment) and maximizes the utilization of the parking place (contributing to the efficiency of transportation infrastructure). [...] 

• Vehicle location and condition monitoring systems [...] by having [...] the location of the trucks on the roads the customs service providers can identify the arrival time [...] and prepare the documentation on the borders to decrease the waiting times [...] By using such information the port operators can send expected arrival update signals to the trucks in case of delays of the ships. [...] The supported dimensions of transportation after using such systems are effectiveness/efficiency and security/safety. [...] 

• Route planning systems [...] the dynamic vehicle routing and scheduling will be beneficial for carriers by reducing their costs, for customers by receiving a better level of service and for the environment by reducing the traffic congestion.

• Driving behavior monitoring and controlling systems [...] The speed and acceleration of the driver during the transportation operations is analyzed and feedback for improving the driving is given by using such systems. Such feedback leads to reducing the fuel consumption of the vehicles and therefore makes more eco-friendly transportation. [...] 

• Crash Preventing Systems [...] Such systems increase the safety of the transportation operations by reducing the probability of accidents. [...] 

• Freight location monitoring systems [...] the usage of such systems for waste management contributes to having a better environment. [...] 

• Freight status monitoring systems [...] The usage of them for controlling the shipments of chemicals, explosives and other dangerous goods can lead to a more safe and eco-friendly transportation.

5.5 Employee attitude towards environmental management
Research by [37] shows that behavioral intention of initial adopters is mainly influenced by satisfaction, attitude and perceived usefulness.

When combining this with the conceptual model by [18] for organizational citizenship behavior directed toward the environment (OCBE) it shows that perceived usefulness of technology to improve energy efficiency is dependent on the environmental concern of the individual and its organizational commitment. High environmental concern and organizational commitment provide for employees that help their coworkers in environmental efforts, and promote environmental performance in the aggregate [18].

The concept of gamification [31] facilitates comparing individual environmental performance with coworkers using leaderboards and challenge each other using duels. This will be further explained in the next section.

6. CASE STUDIES
To analyze the current state of how Intelligent Transportation Systems support freight transportation using sensor-data, several Dutch LSP’s have been studied which started projects to improve energy-efficiency of their drivers.

6.1 State of on-board vehicle-technology
According to the performed case studies, all vehicles used at the organizations contain on-board computers.

6.1.1 Road
Because the before-mentioned standardization of the OBD-II connector, Scania was able to set-up their Fleet Consultancy project which allows post-trip feedback about the individual drivers as a simple extension (module) for existing AFMS. They provide a web-based application where drivers and team managers can log in to see their driving behavior.

Scania also participates in better horizontal collaboration, their Fleet Consultancy-services are not limited to Scania manufactured trucks only.

6.1.2 Rail
Nederlandse Spoorwegen (NS) owns a fleet that consists of trains manufactured by various manufacturers. The case study revealed that most on-board systems are able to collect information but is not retrievable in a standardized fashion. To work around this information gap, they reconstruct the energy consumption of their trains by creating speed-profiles based on their infrastructure utilization [47] combined with the
energy consumption of individual trains by using track section entrance- and departure-times.

When linked to the technical specifications, this allows for one series of their trains for information about the driving behavior on a limited set of routes.

Because the limitations of the on-board information systems, statistics are presented on paper booklets together with advice for eco driving per specific train routes.

NS is now preparing an alternative way of providing train-drivers and train-conductors this information via separate handheld devices and on-board displays.

6.1.3 Maritime
For shipping companies more challenges arise, since there are two common constructions. Ships are sailing as independent contractors or employed by a shipping company. Since vessels are used a long time, there exist big differences between ships. As mentioned in the trend analysis, standards are available but our case studies at Combi Terminal Twente and Cofano Software Solutions suggest that there is generally available solution available yet which facilitates communication between the on-board system and the shipping companies.

Our case study and [7] showed that engineers are willing to improve interoperability.

6.2 Linked data
At Combi Terminal Twente (CTT) the declining prices of mobile computers (tablets) triggered the development of a proof-of-concept, which combined the gathering of location-data via the contained GPS-chips with among others, open-data provided by the Dutch government.

Enriched by private data from the organization it provides the captain with an enhanced view of their situation [7].

The aggregation of sensor-data of individual ships can facilitate better horizontal collaboration. GPS-data allows organization to track the movements of their assets, combined with locations of vehicles of other users of the same infrastructure via AIS provides enhanced situational awareness and sensor-driven decision analytics to plan around congestions and other time-sensitive factors, like lock operating times.

![Figure 3 Prototype of barge-application which shows planned maintenance at waterways.](image)

6.3 Technology-fit
Research by [39] emphasizes the need of the right information technology for a value chain to collaborate and be flexible. Research by [50] confirms this could help in improved time management, better planning, cost reduction and an improved flow of information between trading partners.

The framework developed by [35] showed that projects which aimed to improve decision making in the logistical planning function did not realize great advancements on the information layer, they partly explain this by the operational focus of the design utilizing existing data.

One of the questions that might arise is why organizations should give away information for free. This is one of the elements of data governance which became very important the last years [14].

6.3.1 A software developers-view
Cofano Software Solutions develops software that gives LSP’s and their customers better visibility in the logistical chains Founder Marco Huijsman started the company after seeing the inefficiency of the way things were being done at the port of Rotterdam. One of their products is InlandLinks, which allows for planning the most efficient intermodal routes [3].

The case study reveals that the collection of information needed to provide their service required a lot of transformation of non-machine-readable data. Sometimes even from paper-sources. One example mentioned during the interview is the exporting of information to Excel, printing it on their stationary, scan it to a PDF-file and ultimately it by e-mail.

The ease at which tasks can be performed with their application opened the eyes for the parties they work with that information sharing allows for new opportunities, but unfortunately, transition is very slow. A lot of terminals in their area (Port of Rotterdam, NL) still type in their load- and unload-confirmations by hand (M. Huijsman, personal communication, December 13, 2013).

6.4 Adoption and continuance
Related literature shows that adoption by employees of new behavior in general and behavior in IS acceptance and continuance [37][63] poses several challenges. Our case studies revealed however, that when it comes to sustainability and energy-efficient driving, employees already perceive it as very important.

There are many programs which goal is to learn drivers to be more energy-efficient, but in a lot of cases the effect is gone after a few weeks [48][31].

6.4.1 Scania
Scania designed their latest program together with their drivers in mind. The drivers were seen as the heroes and they know best how to drive their truck.

The interviews yielded a way to present them with post-trip feedback, which raises awareness to the individual driver. Furthermore, the concept of gamification has been added. Gamification is defined as adding game-elements in a non-game context. They added experience points, levels and badges for repeated performance. The highest level requires maintaining the highest performance [31].

They have deliberately chosen to not provide feedback during the trip to not distract the driver, which could impact safety. (L. Lapré, personal communication, December 24, 2013).

6.4.2 Nederlandse Spoorwegen
At Nederlandse Spoorwegen, their project to improve energy-efficiency was initiated by one of their drivers. Their project is similar to Scania as described above. Since the on-board
information systems on their trains are very closed, they are limited to presenting energy efficiency per route. Per-month statistics of eco-driving results on team level (group of 20-50 train-drivers) are made available to all drivers; this stimulated comparison and a positive form of competition between teams. The individual employees perceive energy-efficient driving more and more as a distinctive skill. A growing number of drivers are asking for reports of their individual performance with regard to eco-driving (R. Luijt, personal communication, December 18, 2013).

6.4.3 Combi Terminal Twente
Projects to stimulate energy-efficient sailing behavior commissioned by the Dutch Government [21] showed higher savings at shipping companies than independent contractors. They noted that when the shipping pay their own fuel, the savings were 38 to 50% higher.

Combi Terminal Twente (CTT) cooperates with several individual shippers with their own owned ships. This posed another challenge to retrieving their information needed to determine their energy-efficiency.

At CTT the individual shippers were very reluctant at first when it came to sharing their fuel-usage. The application described earlier provides added value for the shipper in first-place, by showing context-sensitive information to raise situational awareness, and thus create incentive to use the application. In return the application collects useful information about the location and energy-efficiency of the ship to CTT [7]. This is also fed back to the shippers to raise awareness of their own efficiency. Furthermore it allows comparison with other shippers and to challenge each other to perform better. (D. Otter, M. Glandrup, personal communication, December 17, 2013).

7. CONCLUSION
The standardization of vehicle on-board computers shows to be the lagging component in facilitating interoperability between the vehicles and IS; the internet-of-things, which are mandatory for analysis and decision-making for improving energy-efficiency.

Our research has shown that every analyzed modality has their own vehicle bus, which among others allow for on-board computers to perform gathering real-time vehicle information. Only for road-vehicles confirming to a documented standard is mandatory, accelerating development of value-adding applications for this information like real-time analysis of driving behavior.

Although information gathering by sensor-bearing devices has become cheap, adding it for this purpose only is redundant and can be easily solved by vehicle-manufacturers by facilitating interoperability using (open) standards.

Because the impact of transportation-sectors’ energy-efficiency on the environment, governments should think of developing these open standards if they do not exist and enforcing them internationally. The benefits have already been well illustrated when looking at the advancements of AFMS using the enforcement of OBD-II in road-vehicles.

8. DISCUSSION
It is possible that some of the vehicle manufacturers do provide better interoperability, but were limited by license restrictions. This possibility was not explored during the case studies.

Individual manufacturers also seem to be interested in improving interoperability, but because of the manufacturer diversity within fleets of LSPs it was impossible to consult individual manufacturers.

It should be noted that the case studies were only performed at Dutch companies.

When looking at energy-efficient performing of organizations there are other factors of influence like weather-conditions. For the sake of illustration the focus in this research was on improvements that can be improved by individual driver behavior and well-informed decision-making. The weather-conditions eventually could be communicated to the driver to improve situational awareness.

Air-transportation has been kept out of scope because of time constraints.

9. FUTURE WORK
This research only studied LSPs in the Netherlands. Future work could compare state of both technology- and vehicle-infrastructures; it is very probable that legislation in some countries can pose more enforcing barriers to collecting, aggregating and presenting individual drivers performance.

The analysis of individual vehicle manufacturers’ interoperability could also provide an interesting starting point, which could include both licensing-models as preparedness to improve interoperability in general.

10. REFERENCES


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Seventh Framework Programme Presentation of Existing Driver Advice Systems.


