DESIGNING ELECTRONIC WAYBILL SOLUTIONS FOR ROAD FREIGHT TRANSPORT

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Designing Electronic Waybill Solutions for Road Freight Transport

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Doctoral Dissertation in Computer Science

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To all those people who suffered for the noble cause of education.
“The important thing is not to stop questioning. Curiosity has its own reason for existing.”

– Albert Einstein
Abstract

In freight transportation, a waybill is an important document that contains essential information about a consignment. The focus of this thesis is on a multi-purpose electronic waybill (e-Waybill) service, which can provide the functions of a paper waybill, and which is capable of storing, at least, the information present in a paper waybill. In addition, the service can be used to support other existing Intelligent Transportation System (ITS) services by utilizing on synergies with the existing services. Additionally, information entities from the e-Waybill service are investigated for the purpose of knowledge-building concerning freight flows.

A systematic review on state-of-the-art of the e-Waybill service reveals several limitations, such as limited focus on supporting ITS services. Five different conceptual e-Waybill solutions (that can be seen as abstract system designs for implementing the e-Waybill service) are proposed. The solutions are investigated for functional and technical requirements (non-functional requirements), which can potentially impose constraints on a potential system for implementing the e-Waybill service. Further, the service is investigated for information and functional synergies with other ITS services. For information synergy analysis, the required input information entities for different ITS services are identified; and if at least one information entity can be provided by an e-Waybill at the right location we regard it to be a synergy. Additionally, a service design method has been proposed for supporting the process of designing new ITS services, which primarily utilizes on functional synergies between the e-Waybill and different existing ITS services. The suggested method is applied for designing a new ITS service, i.e., the Liability Intelligent Transport System (LITS) service. The purpose of the LITS service is to support the process of identifying when and where a consignment has been damaged and who was responsible when the damage occurred. Furthermore, information entities from e-Waybills are utilized for building improved knowledge concerning freight flows. A freight and route estimation method has been proposed for building improved knowledge, e.g., in national road administrations, on the
movement of trucks and freight.

The results from this thesis can be used to support the choice of practical e-Waybill service implementation, which has the possibility to provide high synergy with ITS services. This may lead to a higher utilization of ITS services and more sustainable transport, e.g., in terms of reduced congestion and emissions. Furthermore, the implemented e-Waybill service can be an enabler for collecting consignment and traffic data and converting the data into useful traffic information. In particular, the service can lead to increasing amounts of digitally stored data about consignments, which can lead to improved knowledge on the movement of freight and trucks. The knowledge may be helpful when making decisions concerning road taxes, fees, and infrastructure investments.
Research is a journey, where different people may accompany and guide you. While I haven’t reached my destination yet, I do have come to a milestone with this thesis. This provides me with the opportunity to thank all my traveling companions and guides.

I would like to thank, first and foremost, my supervisors Professor Lars Lundberg and Assistant Professor Lawrence Henesey for their support during this research. I would also like to extend my thanks to Professor Paul Davidsson, Associate Professor Jan A. Persson, and Dr. Johan Holmgren for their valuable support and collaboration during the initial stages of this research. I am grateful for the support and motivation received from all my colleagues at: the Swedish National Post Graduate School on Intelligent Transport Systems (NFITS), Blekinge Institute of Technology (BTH), NetPort Science Park Karlshamn, and the library staff at BTH.

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Finally, I would like to thank the almighty GOD.

Shoaib Bakhtyar
Blekinge Institute of Technology
Karlshamn, May, 2016
Preface

In addition to the Introduction chapter, this thesis includes the following seven papers as chapters. I am the main contributor for all of the included papers. The papers have been reformatted in order to conform to the thesis template. Paper II is an extended and revised version of Paper IX.


The following papers and report are related to but not included in the thesis.


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Introduction
1.1 Overview

In this thesis, we investigate how an electronic waybill (e-Waybill) service can be used to achieve the purpose of a paper waybill and contributes towards improving freight transport. A waybill is a transport document that contains essential information about a consignment, including the origin and destination, and involved actors. An actor in this thesis refers to a person or an organization that plays one or more different roles. We investigate an e-Waybill service by proposing different abstract system designs for implementing the e-Waybill service, which we refer to as e-Waybill solutions. Additionally, in order to fully utilize the potential benefits of the service, we argue that an e-Waybill service can be considered more than a mere replacement of paper waybills. Therefore, in addition to replacing paper waybills, our focus is on the utilization of information entities and functions of the e-Waybill service for different purposes, such as building knowledge about freight movement. The service is investigated for achieving synergies with other existing intelligent transportation systems (ITS) services. Synergies between two or more services can be achieved if they are able to share some common resources, such as information entities and functions. Similarly, synergies can be achieved between the e-Waybill service and other ITS service if information entities and/or functions can be shared between an e-Waybill service and other ITS services. Further, information entities from the e-Waybill service are investigated for building knowledge about freight flows.

Due to several potential benefits, such as, less paper work, time efficiency, and data accuracy associated with electronic documents, there exist several initiatives (Dubovec, 2006) for replacing the traditional paper waybill with an e-Waybill solution. International organizations, such as International Road Transport Union (IRU) and United Nations Economic Commission for Europe (UNECE), that are concerned with road freight transport, support the use of e-Waybill solutions for replacing the paper waybills in order to improve supply chain efficiency through paper-less systems (IRU, 2012). Member states of the UNECE signed an agreement (i.e., the e-CMR agreement) in the year 2008 concerning the use of e-Waybill solutions (UNECE, 2008). The e-CMR agreement is a supplement to the CMR (convention on the contract for the international carriage of goods by road) agreement, which initially suggested the use of paper waybills.
Chapter 1. Introduction

(UNECE, 1956). Additionally, different European Union (EU) projects aim to achieve an e-Waybill solution in addition to improving different transport processes (e.g., e-Freight (2010)). The e-Freight project aims at a single transport document in freight transport (Pedersen et al., 2010). The project proposes a distributed multi-modal e-Waybill solution that can be used to replace paper waybills in multi-modal transport (Cane et al., 2012).

In freight transport industry, the International Air Transport Association (IATA) has already implemented an e-Waybill solution for air freight transport, which is referred to as an e-Air Waybill (IATA, 2012). The e-Air Waybill was designed in order to replace the paper documents that are attached with each air shipment by using systems, such as Electronic Data Interchange (EDI) system and the Enterprise Resource Planning (ERP) system. Another example of an e-Waybill used in road transport is known as the DHL Express Waybill by DHL, which is a Fourth Party Logistics (4PL) service provider. DHL acts as a carrier (transport service provider) that requires the consigner to fill out an electronic version of a waybill before the transport will take place (see, e.g., Cane et al. (2012)).

Achieving synergies between an e-Waybill and other ITS services can potentially increase the effectiveness of the e-Waybill service and ITS services in different ways. The e-Waybill service, if implemented by utilizing synergies with other ITS services, will possibly increase the benefits of an e-Waybill service, as well as, the benefits of the other ITS services. An e-Waybill service, if implemented alone, has the potential to contribute to a paperless flow of information in freight transport, by replacing the traditional paper Waybill with an e-Waybill. The advantages of a paperless flow of information include reduced paper and administrative cost, quick flow of waybill information, and more secured information, as compared to a paper waybill. In addition to a paperless flow of information in freight transport, an e-Waybill service (through utilizing synergies with other ITS services) may provide benefits, such as, supporting the designing of new ITS services or providing input information needed by the services. For ITS service providers, the total implementation cost of the services can be reduced if synergies are achieved between the services due to the possibility of sharing information, functional, or technical resources. For ITS service developers, the benefits of sharing resources can be to reduce development cost and time by reusing the already developed components (i.e., resources).
in multiple services, where those particular components are required. For
the services users, the benefits could possibly include reducing the cost
of having multiple platforms for different services, i.e., achieving benefits
of all the services from a single platform without having to use different
platforms for different services.

In addition, information entities from waybills, if available in electronic
format, can be used together with other types of data, such as Global
Positioning System (GPS) data, in order to build knowledge on the
movement of trucks and freight in a transport network. Hence, an
e-Waybill service can be seen as an enabler for new opportunities to collect
consignment and traffic data and converting the data into useful traffic
information. In particular, the service can lead to increasing amounts of
digitally stored data about consignments and vehicle movements, and
improved methods for analyzing and finding patterns in large collections
of data. The knowledge on the movement of freight and trucks might be of
interest to policy makers, such as the public road administrations, who are
able to observe (and identify) a vehicle at different locations in a network, or
who in other ways are able to collect information about vehicles positions.
The knowledge may be helpful when making decisions concerning road
taxes, fees, and infrastructure investments.

1.1.1 Outline

This chapter provides the background and related work to our research.
The research questions, research methodology used, and a summary of the
research contributions will then follow. Following the introduction chapter,
this thesis comprises of seven research papers. Paper I aims at finding
state-of-the-art of e-Waybill solutions in the literature through a systematic
review. In Paper II, different e-Waybill solutions are proposed and analyzed.
The solutions are analyzed for achieving synergies with existing ITS services.
Paper III expands on the research conducted in Paper II by investigating
the technical requirements of the e-Waybill service. In Paper IV, using
simulation, we study the impacts on processing time of waybills when using
the e-Waybill service in place of paper waybills. A service design method is
proposed and a new service is designed by utilizing synergies between the
e-Waybill and other ITS services in Paper V. In Paper VI, in order to predict
the freight type flowing between different cities, different machine learning algorithms are applied on information entities from waybills. Paper VII continues with the work done in the sixth paper. In this paper, a method for estimating route and freight carried on a specific route is proposed. The method utilizes GPS data and information from waybills.

1.2 Background and related work

A waybill accompanies a consignment and has important information about the consignment under transport. The information content of a waybill is similar to that in a Bill of Lading (BOL), as a result of which a waybill is often used in place of a BOL. Often a waybill is considered to be similar to a BOL as they both contain the same type of information and have almost the same legal properties. Based on the legal functions, there are two types of BOL, i.e., negotiable and non-negotiable. A waybill (for sea, air, rail, and road transport) comes under the category of non-negotiable BOL (Dubovec, 2006). A non-negotiable BOL has less legal functions as compared to a negotiable BOL. Figure 1.1 illustrates the relationship between the different types of BOL.

Figure 1.1: Types of Bill of Lading (Bakhtyar, 2013).
1.2. Background and related work

In case of a negotiable BOL, the owner of the consignment is required to present the BOL to the carrier in order to get possession of the consignment, whereas in case of a non-negotiable BOL, it is not mandatory to present the BOL in order to get possession of the consignment. The final receiver of the consignment is clearly mentioned in a non-negotiable BOL. Hence, the receiver of the goods (i.e., the consignee) has only to confirm his/her identity in order to receive the consignment. A negotiable BOL has the following three legal properties (Dube, 1998; Dubovec, 2006):

- It certifies that the consignment as described on the BOL have been received for carriage.
- It is an evidence that there exists a contract of carriage.
- It is a negotiable document, i.e., the ownership of a consignment can be transferred between actors by exchanging the BOL representing that particular consignment.

A non-negotiable BOL (i.e., a waybill), has only the first two legal properties in the above list (Dubovec, 2006).

1.2.1 Waybill

As mentioned earlier, a waybill follows a consignment (under transport). It is a proof of an agreement of a transport and of its conditions (which has been agreed upon by the carrier company and the consigner). A signed waybill by an actor is a proof that the consignment has been taken over by that particular actor. A waybill contains essential information about the consignment (such as, its origin, destination, goods type, and goods quantity), information about the involved actors (such as, their names and addresses), and other miscellaneous information (such as, remarks section and terms of the transport). It should be emphasized that the focus of our study is on waybills used in road transport, even though we argue that the presented results to a large extent will be applicable also to other modes of transport, since waybills for different modes of transport are similar considering the information content. In cross-border transport, a copy of the waybill should by law follow the consignment, and for freight transport within a country, there often exist similar regulations,
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which typically are based on the CMR (Convention on the Contract for the International Carriage of Goods by Road) convention (Clarke, 2009).

There are a number of roles that are involved with the creation and handling of a paper waybill. We identified the following roles primarily involved with a waybill and the consignment:

- **Consigner:** The sender of a consignment.
- **Consignee:** The final receiver of a consignment.
- **Carrier:** A company that is responsible for the physical transport of a consignment.
- **Driver:** The person maneuvering the vehicle that carries the consignment.
- **Public authorities:** Law enforcement agencies, such as, customs and the police, which are responsible for inspecting the legality of consignments.

We were also able to identify the following functions of a paper waybill:

1. Prior to the establishment of a waybill, a consigner and a carrier agree for the carriage conditions regarding a consignment. A waybill is a proof that there exists such an agreement. This agreement (i.e., prior to the waybill) often does not exist in the form of a document.

2. A waybill serves as a receipt, i.e., confirmation that goods are taken care of by a legitimate actor. Once the carrier takes possession of the goods, the waybill is signed to declare that the goods are now in the possession of this new actor, i.e., the carrier. The receipt can also be a confirmation that the consignment has reached its destination in case the waybill is signed by the consignee.

3. A waybill has information, about the consignment and the stakeholders involved, which is relevant for goods handling.

In a typical freight transport scenario, the roles mentioned above interact with each other to create and handle a waybill. The creation of a waybill is preceded by a contract of sale, which is a contract through which a seller
agrees to sell (the goods) and a buyer agrees to buy (the goods) under certain conditions. After a contract of sale has been established, the steps illustrated in Figure 1.2 are usually followed (in sequence) to create and handle a waybill (Tóth, 2001).

![Figure 1.2: Creation and handling of a traditional waybill (Bakhtyar, 2013).](image)

The steps in Figure 1.2 are explained as follows:¹

¹It should be noted here that steps 9 and 10 are applicable only when the consignment is to be handed over the next actor responsible for the consignment.
Chapter 1. Introduction

1. The consigner and the carrier company negotiate and agree to the conditions for a transport.

2. The consigner or the carrier company creates a waybill based on the conditions that are agreed upon in the previous step.

3. The consignment and the waybill (signed by the consigner) are in the possession of the consigner. At this point of time, the consignment is ready to be loaded to a vehicle for transport.

4. The consignment and the waybill are checked by the driver (for any inconsistency) before accepting the consignment for carriage.

5. The waybill is signed by the driver upon acceptance and the consignment is loaded.

6. The consignment (along with the waybill) is being transported.

7. During the transport, the consignment and the waybill can be inspected by custom authorities.

8. The consignment and the waybill reach their destination. The destination may be the final destination of the consignment and the consignment may be unloaded there if accepted by the consignee. Alternatively, this destination may be a stop where the consignment may be handed over to the next the carrier in case of multi-carrier.

9. At a stop, where the consignment is to be handed over to the next actor responsible for the consignment, the consignment is checked for damages or loss and is accepted by an actor by signing the waybill in case of no damages or loss.

10. In case of any damage or loss to the consignment, remarks are written by the actor accepting the consignment and these remarks are signed by the previous actor responsible for the handling the consignment.

Since a waybill has essential information about a consignment, such as, its origin, destination, and the involved actors. Our interpretation is that the waybill information and functions, if available in electronic form (i.e., the e-Waybill service), can be utilized in different ways, such as for achieving various other ITS services, reducing paper cost, increasing time efficiency, and data accuracy.
1.2.2 e-Waybill service and solution

At present, there exist several initiatives for replacing the traditional paper waybill with an e-Waybill. Replacing a traditional paper waybill with an e-Waybill can contribute to a single transport document for the carriage of goods, which is also an integral objective of the project e-Freight by the European Union (Pedersen et al., 2010). The International Road Transport Union (IRU) supports the introduction of an e-Waybill to improve supply chain efficiency through paper-less systems (IRU, 2012). Replacing a paper waybill with an e-Waybill will also have other benefits, such as, less paper work, greener environment, time efficiency, and information accuracy. In this section, we discuss a number of existing e-Waybill initiatives for different modes of transport, as well as a conceptual initiative for how to achieve an e-Waybill that can be used as a single consignment document in multi-modal transport. Additionally, we present our description of the e-Waybill service, which we have used in our research.

An e-Waybill model for air freight transport is implemented by IATA, which is referred to as an e-Air Waybill (IATA, 2012). The e-Air Waybill was designed in order to replace the paper documents that are attached with each air shipment with electronic messages. The e-Air Waybill uses the Electronic Data Interchange (EDI) system and the Enterprise Resource Planning (ERP) systems of airlines that can provide transport services. Actors can use a web-portal, an ERP system, or an EDI system in order to communicate with the ERP system of the airline. The airline stores the e-Air Waybill. Therefore, the model is based on back-office-to-back-office communication.

In a study by Mei and Dinwoodie (2005), the authors argued for implementing an electronic Bill of Lading (eBOL) in maritime transport, i.e., the eBOL, because of the fraud factor associated with a traditional paper based BOL, and the often late arrival of a paper BOL to the consignee, who are not allowed to take possession of the consignment without showing the original BOL. The authors Mei and Dinwoodie (2005) suggested the concept of an Internet-Based Third-Party Internet Service Provider (IBTPISP), who is responsible for handling the eBOL. The focus of an IBTPISP, as a third party central function, is on organizational-based trust, which ensures to protect the interest of all stakeholders involved in a consignment. SEADOCS is
another electronic solution for a negotiable BOL (for maritime transport). It was a joint project of the Chase Manhattan Bank and the International Association of Independent Tanker Owners (INTERTANKO) and it uses a central registry for storing the eBOL. All actors involved in the consignment are supposed to communicate through this central registry (Dube, 1998).

One example of an e-Waybill used in road transport is known as the DHL Express Waybill and it is used by the company DHL (see, e.g., Cane et al. (2012)). DHL acts as a carrier (transport service provider) that requires the consignor to fill out an electronic version of a waybill before the transport will take place.

For multi-modal transport, the e-Freight project suggested a multimodal e-Waybill that uses an e-Delivery infrastructure (Cane et al., 2012). The e-Delivery infrastructure consists of a network of e-Freight Access Points (EAPs), which are accessible via an Internet connection. The e-Freight e-Waybill information should not be stored and available for access at a single location, instead it should be scalable with the help of EAPs, i.e., the e-Waybill information should be stored and available for access from different locations. In addition, the use of EAPs might help preventing a single point of failure, which could lead to difficulties in accessing the e-Waybill.

In our research, we describe an e-Waybill as a service that is able to store at least the information present in a paper waybill and provide the functions of a paper waybill. It should be noted here that the e-Waybill solutions, proposed in this thesis, specifies different system designs for the e-Waybill service. Therefore, an e-Waybill solution can be defined as a solution that implements the e-Waybill service.

1.2.3 ITS services and synergy

ITS services can be described as systems that use information and communication technologies for collecting, processing, and communicating information in the transportation context in order to achieve benefits, such as safety, efficient use of resources, and economic growth. In the literature, the term ITS services is often referred to as intelligent transport systems, transport telematics systems, transport telematics, intelligent transport
systems tools, ITS user services, and intelligent transportation systems services (Jarašūniene, 2007; Mbiydzenyuy, 2013; PIARC, 2005; Sochor, 2013). In this thesis, we use the term ITS services from the existing terms in the literature. Furthermore, we consider in this thesis that an ITS service comprises of one or multiple functions and information entities, i.e., input and output to/from the service. The ITS services that we consider in this thesis (see, Appendix) are suggested by Jevinger et al. (2010) and Mbiydzenyuy et al. (2012). From the set of collected services, we removed duplicate services, as well as services with different names but identical functions. In the Appendix section of this thesis, we briefly describe the ITS services that we have considered.

ITS services can be implemented either standalone or as a group (i.e., as a package) by utilizing synergies between them. Synergies between services can be achieved by sharing common resources, which are needed by multiple ITS services. The existing literature on synergies by Hickman et al. (1996) suggests the common resources (needed by multiple ITS services) can be information entities, functions, or technical resources. Sharing of information entities is known as information synergy, i.e., common input information entities needed by the services or an output information entity generated by one ITS service is needed as an input information entity by another ITS service. Sharing common functions between multiple services can achieve functional synergy, i.e., to reduce redundant functions by making use of the already existing functions. Technical resource sharing includes sharing common technologies between the services to achieve technical synergy, i.e., the hardware and software technologies used by the services.

We illustrate the concept of synergy between services by describing possible synergies between the ITS services E-call and Estimated time of arrival. Functional synergy between the services can be achieved if a function can be shared between the services instead of implementing it twice for each of the service. For example, a shared function can be to determine the vehicle’s location. Information entities that are needed and can be shared by both the services can lead to information synergies. In the considered services, information about the vehicle (e.g., vehicle size and Id) are needed and can be shared by both of the services. A common technical resource needed by both services can be a GPS receiver. Hence, technical synergies can be
Chapter 1. Introduction

achieved between the considered services if they can share a GPS receiver.

In the existing literature, there are several studies on synergies between ITS services. The study by Balbo and Pinson (2010) propose an agent-based approach to design a transportation regulation support system using functional synergies between an existing information system and a decision support system. The authors in (Crainic et al., 2009) considered ITS as a concept that is based on old and new technologies for transport management. In addition, they argued that the concept of ITS evolves with the realization of synergies between systems using ITS services and other systems. A method is proposed by Mbiydzenyuy et al. (2008) to assess functional synergies between ITS services used in road transport. They suggested that the total cost for service deployment could be reduced by using functional synergy between services. In addition, from the e-Waybill solutions described in the literature, we identified examples of synergies between services implemented by hauliers. For example, DHL provides the service e-Track (Santosa, 2004) for real time tracking of a consignment, which is a part of the e-Waybill system DHL Express Waybill.

1.2.4 Research scope and limitations

We present the scope of our research using Figure 1.3. As mentioned in Section 1.1, the research conducted in this thesis is different from the existing research on e-Waybill service in several perspectives. The existing research on e-Waybill solutions for different modes of transport is limited to such solutions that are based on the storage and access to the e-Waybill information at the back-office only. In contrast, the e-Waybill service investigated in this thesis have different conceptual system design specifications (i.e., e-Waybill solutions) that are focused on storage and access to the e-Waybill information at both the back-office and freight-level. We argue that the storage and access to e-Waybill information at both the back-office and freight level can enable greater utilization of the e-Waybill information and functions, e.g., the e-Waybill information may be used as input to the ITS services that are implemented at the freight-level.

Additionally, in the existing research (according to the best of our knowledge) there is no study concerning synergies between an e-Waybill and other ITS services. We consider this type of investigation to be of
1.2. Background and related work

particular interest to study, because an e-Waybill has essential information about a consignment (under transport) and it follows the consignment. Investigating synergies between an e-Waybill and other ITS services can potentially lead to increased effectiveness of the services. Our argument is that a synergistic approach towards the implementation of the e-Waybill and other ITS services in a package can lead to greater service utilization, i.e., similar functions are implemented only once even though they may be used by more than one service in the package.

Furthermore, in addition to administrative benefits of the e-Waybill service,
Chapter 1. Introduction

our focus is on utilization of the e-Waybill information and functions for different purposes, such as estimating freight flows. We argue that a waybill has essential information about the consignment and if the information is available in electronic format, can be used to estimate freight flows, i.e., freight type and weight, between different cities or on a particular route. We believe that this type of freight estimates might contribute to building improved knowledge, e.g., in national road administrations, on the movement of freight, which may lead to a better infrastructure and transport planning.

A possible limitation of our research is that we do not consider the legal aspects concerning implementation of the e-Waybill service. However, due to less legal functions associated with a waybill (as compared to a bill of lading). Furthermore, the aim was to keep the research independent of brand-specific solutions. Therefore, we have not considered the limitations associated with different technologies, i.e., RFID tags, ZigBee, barcode labels etc., that are available on the market today. Finally, in order to keep the research independent of any specific business model, we have not considered a specific business model or organization when investigating the different e-Waybill solutions.

1.3 Research questions

The purpose of this thesis has been approached from the perspectives given by the following six research questions.

RQ1. What is state-of-the-art of e-Waybill solutions?

In RQ1, we investigate the existing literature for existing e-Waybill solutions and their characteristics. The purpose of this RQ is to identify research gaps in the existing literature on e-Waybill solutions and to contemplate the factors that may be used as a valuable input for future improvement work on e-Waybill solutions.

RQ2. Which e-Waybill solutions are relevant for replacing the traditional paper waybill?

In RQ2, we investigate what e-Waybill solutions should be considered
when replacing a paper waybill with an electronic solution. Additionally, the solutions are analyzed for functional and technical requirements. In addition, in this research question, we investigate how to refine the e-Waybill solutions further based on the requirements for the different solutions and the technologies present today to fulfill these requirements.

**RQ3. How can information synergies be achieved between an e-Waybill and other ITS services?**

In RQ3, the proposed e-Waybill solutions (which could implement the e-Waybill service in different ways) are investigated for information synergies with different ITS services. For this information synergy investigation, we needed to specify the identified ITS services in a uniform way. Addressing this research question will result in identifying different ITS services that can be supported by different e-Waybill solutions.

**RQ4. What are the impacts on processing time of a waybill when using an e-Waybill service?**

In our RQ4, the aim is to investigate the positive impacts, i.e., the processing time, when using the e-Waybill service compared to a paper waybill. Different transport processes may utilize different lengths of time depending on several factors, such as process type, resources availability, and the load level. Since a waybill is central to some key processes, it is highly important to investigate the use of e-Waybill for these processes. The aim of this RQ is to assess the impacts on processing time for waybills when handled electronically or manually with pen and paper.

**RQ5. How can functional and information synergies between ITS services and an e-Waybill service be utilized to design a new service?**

In RQ5, we investigate the information and functional synergies (which are the two types of synergies) between the e-Waybill service and ITS services. In addition to identifying functional and information synergies between and e-Waybill and other ITS services, in this question, we investigate on how to utilize such synergies for designing a new service.

**RQ6. How can information from a waybill be utilized for route and freight estimations?**

In this RQ, we investigate on how to utilize information from a waybill in
order to estimate the freight type and weight that flows between different
cities and on a particular route. The results of this RQ, might contribute to
building improved knowledge, e.g., in national road administrations, on
the movement of trucks and freight.

1.4 Research method

We have followed the information systems research framework suggested
by Hevner et al. in (Hevner and Chatterjee, 2010; Hevner et al., 2004). Figure
1.4 illustrates the information systems research framework. The authors
suggest environment as the problem space, where the problem (which is
of particular interest to solve) resides. In information systems research,
people, business organizations, and their existing or planned technologies
may compose the environment, i.e., the problem space. The goals and/or
problems are defined as business needs by people with different roles
and capabilities within an organization. Once these business needs are
identified, they are assessed with respect to organizational strategies,
structure, culture, and existing business processes. The assessed business
needs are then positioned relative to existing technology infrastructure,
applications, communication architectures, and development capabilities.
The outcome of this process is a research problem for the researchers to
solve.

The study (Hevner and Chatterjee, 2010; Hevner et al., 2004) suggest that
information systems research can be conducted in two phases. Research
may be conducted through the development and justification of theories
that explain or predict phenomena related to the identified business need.
Research may also be conducted through the building and evaluation of
artefacts designed to meet the identified business need. In both cases, the
research is assessed through justify or evaluate activities. The evaluation or
justification may result in identifying weaknesses in the theory or artefact.
In addition, the evaluation or justification may also lead to refining and
reassessing the theory or the artefact. The refinement and reassessment
of the theory or the artefact is most often conducted in the future work.
The knowledge base provides the raw materials, which can help in the
accomplishment of the information systems research. The knowledge base
is composed of foundational theories, frameworks, instruments, constructs,
1.4. Research method

models, methods, and instantiations used in the information research study. Methodologies provide guidelines used in the justification and evaluation phases of the research study.

1.4.1 Application of Research Method

In our research, the environment is considered to be composed of different stakeholders, such as, haulers, ITS service providers, and public authorities. As a starting point, we reviewed the literature, conducted interviews with several people from the transport industry, and studied different real-world business scenarios in order to identify the need/problem for Information Systems (IS) research. We found that the haulers are interested in replacing paper waybills with electronic solutions that enable a paperless flow of information along with the physical flow of goods in order to achieve advantages, such as less paper work and speedy flow of information as compared to paper documents. The ITS service providers are already
providing ITS services to the haulers. For ITS service providers, an important concern is to investigate synergies between the ITS services that they are providing. Investigating synergies between ITS services may lead to benefits, such as, reduced implementation cost through higher utilization of the services platform. Additionally, the haulers and public authorities are interested in utilizing the information from the waybills for building improved knowledge about the freight movement. Together these interests, i.e., replacing paper waybills with e-Waybill solutions, utilizing e-Waybill information for knowledge building, and achieving synergies between ITS services, lead to our research problem. Our research problem is investigating an e-Waybill service that can replace a paper waybill. Additionally, our research concerns investigating e-Waybill information for building knowledge about the freight flows that might be of interest to the haulers and public authorities. In addition, the research problem is also to investigate synergies between e-Waybill and other ITS services.

After problem identification, the next step in our research is to develop a theory or build an artefact that could address our research problem. Based on the literature review, real-world business scenarios, and the interviews, we were able to identify the information and functions of a paper waybill. We were also able to identify the most common roles involved with a consignment and the process of creating and handling a waybill during freight transport. All these activities helped us in identifying and proposing an e-Waybill service with different abstract design specifications, i.e., the e-Waybill solutions. The proposed e-Waybill service is our artefact. The artefact was further refined (to an extent) by following the information systems research framework.

The e-Waybill solutions are analyzed for functional and technical requirements in order to address RQ2. Additionally, we investigate how to refine the e-Waybill solutions further based on the requirements for the different solutions and the technologies present today to fulfill these requirements. The proposed e-Waybill solutions are considered for synergies with other ITS services in order to address RQ3. For investigating synergies between the e-Waybill and different other ITS services, we interviewed researchers and practitioners, who are actively involved with ITS services. We also reviewed different project reports to collect a set of different ITS services. Some of these services exist today while some are only
1.5. Research Contribution

suggested in the literature. The services were specified based on several characteristics, such as, input information entities, output information entities, and the functions performed. This specification was a result of the literature review, interviews, and discussions with other researchers (involved with research on ITS services). The specification led to the identification of different types of synergies that exist between an e-Waybill and other ITS services, as well as, it led us to describing the services in more detail. The e-Waybill service is assessed using a simulation experiment. In particular, the impacts on processing time when using an e-Waybill in place of a paper waybill are assessed in order to address our RQ4.

The methods used for investigating synergies between e-Waybill and different ITS services, correspond to knowledge base in the information systems research framework. The most common methods used for synergy analysis were interviews, discussions, and literature reviews. In the part of our research where synergies are investigated for further utilization, such as, designing a new service, we were unable to find an existing method. Therefore, we developed a service design method to utilize different types of synergies between different ITS services in order to design a new service. The service design method addresses RQ5 as the method utilizes the functional and information synergies that exists between an e-Waybill and other ITS services.

For our RQ6, the e-Waybill information is utilized for the purpose of building improved knowledge concerning freight flow estimations between different cities and on particular routes. A new method is proposed that utilizes on existing data mining algorithms for achieving the purpose of predicting the route a vehicle has traveled and estimating the freight volume of the particular route.

1.5 Research Contribution

In this section, we summarize the research contributions drawn from each of the research papers in relation to our research questions. In Table 1.1, we present the research questions that are addressed by the following research papers. The contributions of each included paper to the research questions are discussed in the subsequent text.
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<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1: What is state-of-the-art of e-Waybill solutions?</td>
<td>PI</td>
</tr>
<tr>
<td>RQ2: Which e-Waybill solutions are relevant for replacing the traditional paper waybill?</td>
<td>PII, PIII</td>
</tr>
<tr>
<td>RQ3: How can information synergies be achieved between an e-Waybill and other ITS services?</td>
<td>PII</td>
</tr>
<tr>
<td>RQ4: What are the impacts on processing time of a waybill when using an e-Waybill service?</td>
<td>PIV</td>
</tr>
<tr>
<td>RQ5: How can functional and information synergies between ITS services and an e-Waybill service be utilized to design a new service?</td>
<td>PV</td>
</tr>
<tr>
<td>RQ6: How can information from a waybill be utilized for route and freight estimations?</td>
<td>PVI, PVII</td>
</tr>
</tbody>
</table>

Table 1.1: Research questions and papers relationship in this thesis.

**RQ1. What is state-of-the-art of e-Waybill solutions?**

The existing literature on e-Waybill solutions indicate that various studies focus on different aspects of an e-Waybill solution. However, there exist no systematic review of the existing literature on e-Waybill solutions. We argue that a systematic review of the existing literature on e-Waybill solutions is important in order to achieve a deeper understanding of the existing solutions. Additionally, according to Kitchenham and Charters (2007), the most common rationale for conducting a systematic review is to identify research gaps in a specific area by synthesizing the existing research literature. Therefore, a systematic review on e-Waybill solutions can be helpful in identifying the research gaps in the existing research on e-Waybill solutions.

We conducted a systematic literature review in Paper I using the snowball method in order to improve the understanding and for validating the research claims on e-Waybill solutions. The systematic review addresses our RQ1.

Our systematic review was aimed at identifying the available e-Waybill solutions and their characteristics in the existing literature. From an industry practitioner standpoint, the results of our review may be used to assess the factors that need to be considered for replacing a paper waybill with an e-Waybill in the industry. From an academic standpoint, the results can be used to map current state-of-the-art of e-Waybill solutions and to contemplate the factors that may be used as a valuable input for future improvement work.
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Following the guidelines outlined in (Kitchenham and Charters, 2007; Wohlin, 2014), a total of over 7470 articles were identified initially for the review. However, after performing three iterations of the snowball method, a total of 11 studies were found to be highly relevant for our review. We found that most of the studies agree on benefits of replacing paper business documents (including Waybills and BOLs) with electronic solutions. In the technologies used for electronic solutions, EDI is the pioneer. In addition, ebXML (Electronic Business Extensible Markup Language) and UBL (Universal Business Language) are developed in order to shift the focus from EDI to other technologies. The use of UBL is important for smaller firms since EDI is considered to be expensive and UBL is flexible to be used with any computer application. Regardless of the document type, there is a need for a uniform standard (in the technology and messaging format) due to the involvement of inter-organizational transactions. Additionally, we identified that there is less emphasis on the services that can be achieved with information and functions from an e-Waybill/eBOL. Majority of the reviewed literature focus on the administrative benefits, such as lesser paper cost and typing errors, of using electronic documents. However, few recently published studies emphasize on using the e-Waybill information for achieving different services, such as estimated time of arrival and real-time tracking and tracing.

Based on the review, we identified some key research gaps concerning e-Waybill solutions that need to be addressed. We found that the trust and security aspects of a proposed solution are of significant importance. A solution with a low security may not be trusted and adopted by an organization since a waybill/BOL contains important information about that particular organization. Hence, information exchange and storage need to be protected, if the solution is to be trusted and adopted. Additionally, a waybill/BOL should not be seen only as a document but as set of information entities and functions that may be utilized to achieve different value added services. There is also a need for research on the cost and benefits analysis of e-Waybills/eBOLs. For practitioners, we suggest to provide low cost technological solutions since one of the limitation of EDI is high implementation cost. There is a need for uniform standards for technologies (for storage and exchange of information). UBL is one such initiative towards a uniform messaging format. Lastly and most importantly, there needs to be a legislation for using electronic documents
in place of paper documents since some of the documents, such as BOLs, have legal functions associated with it.

**RQ2. Which e-Waybill solutions are relevant for replacing the traditional paper waybill?**

In the literature, we found that there exist different e-Waybill solutions. However, these solutions are mainly based on storage of the e-Waybill information at back-office, and on back-office-to-back-office communication. In contrast to the existing literature, we define an e-Waybill as a service that provides the functions of a traditional paper waybill and which is capable of storing, at least, the information present in a paper waybill. We consider an e-Waybill solution as an abstract system design for implementing the e-Waybill service. In Paper II and III, we address our RQ2 by proposing different e-Waybill solutions and investigating on their technical requirements.

In Paper II, in addition to the existing e-Waybill solutions, we proposed other possible e-Waybill solutions based on the read, write, and storage properties of the e-Waybill information. We identified 64 different e-Waybill solutions based on location of storage, and read and write access to the e-Waybill information. From the 64 possibilities, we consider 59 to be unrealistic, e.g., due to cases where no storage location is provided or when storage is provided at one location, while read and write access is provided only at the other location. This leaves us with 5 realistic solutions, each of which have the potential to fulfill the requirements of the e-Waybill service. Table 1.2 presents our proposed e-Waybill solutions. In the column Read access to information, we summarize where the e-Waybill information can be read, since this is the most important property in our information synergy analysis, which we addressed in RQ3.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Back-office</th>
<th>Freight-level</th>
<th>Read access to information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Storage</td>
<td>Read</td>
<td>Write</td>
</tr>
<tr>
<td>1</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

**Table 1.2: e-Waybill solutions.**
In Paper III, we investigated functional and technical requirements of the e-Waybill service. The existing research literature on functional and technical requirements of the e-Waybill service is limited to the existing types of solutions, e.g., in these solutions the focus is on storage of the e-Waybill information at back-office, and on back-office-to-back-office communication. Our research in Paper III is, however, different from the existing literature as we have considered our five different e-Waybill solutions, which differ in where the e-Waybill information is stored (at back-office and/or at the freight-level) and where read and write access, to the information, is provided.

Additionally, in contrast to the existing research, our focus is on identifying functional and technical requirements of the e-Waybill service that can be implemented at different locations in our proposed e-Waybill solutions, while the focus of the existing literature is primarily on technologies for achieving a back-office based e-Waybill solution. This difference is important to consider as technologies are constantly evolving, which means that a technology that may be the best option today, might not be the best choice after some time. An example to consider is of barcode labels and RFID tags. Although barcode labels are still used, RFID tags are slowly replacing them due to the additional features they provide, such as, extra memory, reusability, and readability.

Through the research in Paper III, we contribute to the existing research by identifying important technical requirements of the e-Waybill service, which we present in Table 1.3.

We identified that information storage, synchronization and conflict management, access control, and communication are important categories of technical requirements of the e-Waybill service. These requirements can potentially set constraints on a system, which can potentially implement the e-Waybill service. The contribution, in Paper III, can be seen as a refinement of our conceptual e-Waybill solutions by identifying different relevant functional and technical requirements, and to identify which present technologies are able to address the identified functional and technical requirements.

**RQ3. How can information synergies be achieved between an e-Waybill and other ITS services?**
Chapter 1. Introduction

Table 1.3: Technical requirements of the e-Waybill service.

<table>
<thead>
<tr>
<th>Technical requirements</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encrypted information storage</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Static and dynamic information storage</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Information storage by the freight</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Information storage at back-office</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Read access control by the freight</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Write access control by the freight</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Read access control at back-office</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Write access control at back-office</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Synchronization</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Conflict management</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Long distance communication links</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Short distance communication links</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

The proposed e-Waybill solutions, presented in Table 1.2, were investigated for information synergies with other ITS services in Paper II (in order to address RQ3). We argue that there exists no research that focuses on information synergies between an e-Waybill and other existing ITS services. This type of research, which investigates e-Waybill for information synergies with other ITS services, is significant as it could contribute towards implementing such e-Waybill solutions that enable high synergy with ITS services. This could lead to a higher utilization of ITS services and more sustainable transport, e.g., in terms of reduced congestion and emissions, as well as increased safety.

To analyze the proposed e-Waybill solutions, we reviewed the literature (mostly different EU projects reports) to collect a set of 20 different ITS services for road transport. In the literature, there were more than 20 ITS services but we found out that some of the services were redundant with different names but identical functions. We were unable to find any sort of uniform specification for all of the services, which could be used in our information synergy analysis. Therefore, through interviews and discussions with different researchers (who are actively involved with ITS services) we were able to analyze the services in order to identify what types of input information is required and what types of output is generated. Based on the discussions, we had with other researchers involved with
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research on ITS services, we were able to specify the services based on the location from where they can get the required input information. We identified two locations, where the input information required by a service can be present, i.e., freight-level and back-office level. In Figure 1.5, we present the type of information synergy that was considered in our analysis.

![Figure 1.5: Information synergy between an e-Waybill and an ITS service.](Image)

The freight-level information category contains information types that are accessed (by the services) via a connection to the location of the freight. Since freight is typically on-board vehicles, we included vehicle-related information in that category. In addition, we assume that all types of information that is present in an e-Waybill belong to the freight-level category. The back-office information category contains information types that are normally accessed via a connection to a back-office system. This approach of specifying the services is new, according to the best of our knowledge, and it can support information synergy analysis between other ITS services (apart from the e-Waybill service).

Our main contribution, when addressing RQ3, can be seen as identification of e-Waybill solutions that have higher information synergies with existing ITS services. We found that the e-Waybill solutions, where the e-Waybill information can be accessed, at least, at the freight-level (i.e., solutions 2, 3, 4, and 5), enable better possibilities for information synergy than solutions that store and allow access to the information only at back-office (i.e., solution 1). In addition, our contribution includes the method that we used in the information synergy analysis. The analysis method might be used as a tool to support decisions regarding which type of e-Waybill solution is relevant.
to implement for a particular organization. For example, if a transport operator is interested in a certain set of ITS services, a similar analysis as we conducted, could be made, however, by considering only the services that are relevant for the considered transport operator.

**RQ4. What are the impacts on processing time of a waybill when using an e-Waybill service?**

This research question is addressed in Paper IV, where we contribute with a simulation model and experiment for investigating the processing time, when using an e-Waybill in place of a paper waybill. The simulation model is designed for e-Waybill solutions 2, 3, and 4 (see, Table 1.2), where the e-Waybill can be stored at both the locations, i.e., at back-office and in the vehicle, and a change in the e-Waybill stored at one of the location will be visible at the other location. The e-Waybill solutions 2, 3, and 4 are considered to be of importance when designing a simulation model, since these solutions are able to support a larger number of ITS services (Bakhtyar et al., 2013a). In the literature, there exists research on assessing the impacts of using e-Waybill or e-BOL solutions, however none of these studies focus specifically on e-Waybill solutions for road transport. In contrast to the existing research, our simulation model and experiment are focused on using an e-Waybill instead of the traditional paper waybills in a road transport scenario. We argue that the results from our study provides an evidence of the time saving effects when using an e-Waybill, which is currently missing in the existing studies on e-Waybill solutions for road transportation.

The simulation model was designed for a route served by a medium-sized Swedish transport company. The route consists of 12 freight loading and unloading locations (nodes). The model was developed in the AnyLogic™ tool and the total run-time for the experiment was 90 days in three different scenarios. The focus of the experiment was on the processes that can be performed on paper and electronic documents at the transport company and at the nodes, i.e., at the transport company, the documents are created, batched in a group, and assigned to a truck, whereas, at the nodes, the document is authenticated when loading or unloading the freight.

We identified that a time savings of 65–99% can be achieved when using an e-Waybill instead of paper waybills in three different scenarios. Further, we
found that the difference in invoicing time and the number of processed waybills is not significantly different in case of e-Waybill even though the processing time increases 3-15 times in different scenarios. In scenarios 1, even though the processing time for paper waybills is higher than that of e-Waybill, yet there is no significant difference in the invoicing time and the number of waybills processed. Similar to the number of waybills processed, the savings on electronic waybills is low in scenario 1, when compared to scenario 2 and 3. The overall system’s efficiency is high for e-Waybills and the processing time of the e-Waybills is increased by 5-15 times in the three scenarios when compared to paper waybills.

**RQ5. How can functional and information synergies between ITS services and an e-Waybill service be utilized to design a new service?**

The research question RQ5 has been addressed in Paper V. We have, in Paper V, contributed to the existing research on ITS services by proposing an ITS service design method for supporting the process of designing new ITS services. Our design method explicitly utilizes on, mainly functional, synergies with the ITS services. Although there are numerous possibilities for utilizing on the synergies between different ITS services, there exists, at least according to the best of our knowledge, no study that explicitly considers how functional synergies can be used in order to design a new ITS services. Our proposed service design method can be also used to modify existing ITS service if there exist functional synergies between the service to modify and other existing ITS services. Designing a service based on functional synergies is important because the choice of technologies often depends on the functions to achieve. Similarly, a technology may be designed for achieving some basic functions. However, the same technology may have the potential to achieve more than the intended functions. An example is the On-Board Unit (OBU) in trucks. An OBU may have the capability to achieve more functions than the functions intended for it to achieve.

The proposed service design method is built around the service description framework suggested by Jevinger et al. (2012), which is used to generate uniform descriptions of both existing ITS services and the service to be designed. In Step 1 of our service design method, the functional requirements of the new ITS service are identified. Step 2 is to identify different components of the new service, by applying the service description
Chapter 1. Introduction

framework. The components specified when applying the service description framework represent an initial design of the new service, where all the processing is performed by the service itself without making use of synergies with existing services. Step 3 is to identify all possible synergies between the new service and the existing services, by searching for functions and information entities in the existing services that can replace functions in the new service. In Step 4, the initial description (or design) of the new service is updated by realizing synergies with the existing services. In particular, synergies are achieved when one or more of the functions of the new service are replaced by new components, because of borrowing functions from existing services. For example, a function in the new service can be possibly replaced by an input information entity, which is generated as an output by an existing service, and with a trigger that reacts to the input.

The service design method was used to design a new ITS service, i.e., the Liability Intelligent Transport System (LITS) service, which can be also seen as our contribution. The purpose of the LITS service is to support the process of identifying why, when, and where freight have been damaged, and in case of multi-actor transport, it should also support the identification of which actor should be held responsible for the damage. Since it is sometimes difficult to identify when freight damage has occurred, it might be difficult in multi-actor transport to identify the actor responsible for the damage. Therefore, we believe that the LITS service might have an important role in future freight transport. By using a service to detect possible freight damage, based on the conditions for transport, it would be possible to identify the cause for damages that are not visible to a naked eye.

By applying the service design method in order to create a design of the LITS service, we verified that there exist components in other suggested ITS services, such as, information entities and functions, which can be used by the LITS service. There exist different solutions today to monitor different types of consignments in order to detect damages. However, our approach (to design the LITS service) is new as there exists, at least according to the best of our knowledge, no study that explicitly considers information and functional synergies to design a service similar to the LITS service. The LITS service has a potential to have positive impacts in a transport process by detecting freight damage and the actor responsible for the damage. The LITS
service could lead to better quality control of the freight being transported by monitoring and reporting the freight status in real-time. Additionally, the LITS service could also contribute to the already existing solutions for detecting freight damage. The focus of the existing solutions is on detecting freight damage. Whereas the LITS service, in addition to detecting freight damage, can also identify the actor responsible for the damage.

**RQ6.** How can information from a waybill be utilized for route and freight estimations?

The research question RQ6 has been addressed in Paper VI and VII. In both the papers, we contribute towards answering RQ6 from different perspectives. In Paper VI, we contribute by using and evaluating different machine learning algorithms for estimating freight flows between different origin and destination cities without considering the route traveled by a vehicle. We argue that predicting the freight type transported from a particular origin to a particular destination may help transport companies in improved decision making about the type of transport required for an origin and destination city of a future order. In addition, predicting the freight type may lead to potentially improved decision making such as, investment decisions and policy making concerning the infrastructure (between freight’s origin and destination), e.g., expanding road capacity or route choice in case of dangerous goods.

In Paper VI, we used a dataset that consist of data from a customer ordering database of a Swedish transportation company. The data was matched with the corresponding paper waybills and it was found that the data was similar to the data present in the paper waybills. Therefore, we assumed that similar data can be provided by an e-Waybill. The assumption was made since we were interested in building knowledge from the e-Waybill information but we had no practical implementation of the e-Waybill. We used the open-source tool Waikato Environment for Knowledge Analysis (WEKA), which provides a collection of machine learning algorithms (in a graphical user interface) that can be applied on a dataset.

We found that the waybill data, if available in an electronic format, i.e., an e-Waybill, can help in improving knowledge about the freight movement by predicting the freight type (transported between different origin and destination cities). The algorithms were evaluated based on their weighted
average true-positive (TP) and false-positive (FP) rate, weighted average area under the curve (AUC), and weighted average recall (Recall) values. We found that overall the algorithm IBk performed better than the algorithms SMO and LMT. Based on weighted averages of their TP and FP rate, and Recall value, the algorithm IBk can be considered better than SMO and LMT. Under the same criterion, SMO was at the second place, i.e.; its performance was lower than IBk but better than LMT. However, based on the weighted average AUC value, LMT performed better than IBk and SMO. IBk performed better, based on the weighted average AUC value, than SMO. In Table 1.4, we present the results of the algorithms’ evaluation. Through the results from Paper VI, we contribute with identifying which machine learning algorithm performs better when predicting the freight type (transported between different cities) from the available e-Waybill information.

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<td>Weighted average FP Rate</td>
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<tr>
<td>Weighted average recall</td>
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Table 1.4: Algorithms evaluation.

In Paper VII, we contribute to the purpose of utilizing e-Waybill information for route and freight estimations from a different perspective. We contribute with a route and freight estimation method in Paper VII. There exists research on methods for route estimation, however the main difference between our research in Paper VII and the existing research is that we suggest building estimation (prediction) models for both freight and route. Another key difference between our work and the related research is the intended user; our aim is to support the decision making by public authorities. Our proposed method uses historical GPS data and current vehicle observations in order to estimate the route a vehicle has travelled. Additionally, the method estimates the freight the considered vehicle carried along the estimated route. We used supervised learning for the route estimation, i.e., the Naive Bayes Multinomial Updatable algorithm, which performed rather well for route estimation. For freight estimation, we estimated the freight carried by the vehicle along a particular route as the
1.6. Conclusion and future work

The purpose of this thesis was to investigate on how can an e-Waybill as a service be used for improving freight transport. Different system design
Chapter 1. Introduction

specifications (i.e., solutions) and technical requirements of the e-Waybill service are proposed and analyzed. Additionally, the service is analyzed for information and functional synergies with other ITS services. Finally, information entities from the service are investigated using empirical studies for building improved knowledge about the freight flows between different cities and on a particular route.

We identified, through a systematic review in this thesis, that most of the existing studies on e-Waybill solutions agree on the benefits of using e-Waybills instead of paper waybills. However, the focus of existing studies is more on administrative benefits, such as low paper cost and lesser typing errors. We suggest that an e-Waybill should not be merely seen as an electronic document but as set of information entities and functions that may be utilized further, such as for supporting different ITS services. Additionally, most of the existing research support the use of EDI for implementing e-Waybill solutions. However, limitations (e.g., high cost) make EDI less affordable for small organizations. Therefore, technical aspects of any proposed conceptual e-Waybill solutions need to be investigated. Furthermore, there is also a need for assessing the potential impacts of using the e-Waybill service.

We conclude that there can be more than one e-Waybill solution that can be used to replace the paper waybill. We have suggested five conceptual e-Waybill solutions, which all have the capability of providing the functions of a traditional paper waybill and the capability of storing, at least, the information present in a paper waybill. We were able to identify important technical requirements of the proposed e-Waybill solutions. These requirements may set constraints on a system design, which can potentially implement the e-Waybill solutions. Therefore, the conceptual e-Waybill solutions were refined by identifying relevant functional and technical requirements and, in addition, identifying the technologies that are present today to address these requirements. The e-Waybill service was assessed using a simulation experiment for potential positive impacts concerning the processing time in a typical road-based freight transportation. We conclude, from the simulation study, that a saving of 65-99% in invoicing time can be achieved using e-Waybills instead of paper waybills. The overall systems efficiency is high for e-Waybills as compared to paper waybills even when the processing time of waybills is increased 5-15 times in the three
1.6. Conclusion and future work

different scenarios.

Furthermore, we conclude that the e-Waybill service can have information, as well as, functional synergies with other ITS services. The Investigation of information synergies between the e-Waybill service and other ITS services was conducted in two phases. In the first phase, different ITS services for road transport were identified. A set of 20 ITS services were considered for information synergy analysis. These services are mainly for road transport, however most of them are relevant to be considered for utilization in other modes of transport as well. The first phase contributed towards identifying ITS services that are relevant for achieving synergies with the e-Waybill service. In the next phase, the services were analyzed for information synergies with the e-Waybill service. In this phase, we identified that all of the 20 ITS services require input that might be provided by an e-Waybill. In our information synergy analysis, we focus on the situation where the e-Waybill provides information that may be used as input by other ITS services. We claim that there is a possibility for information synergy between an e-Waybill solution and an ITS service if there is a communication link, between the e-Waybill information storage location and the ITS service, that has been established for transferring information that is not present on the e-Waybill. The synergy is realized when the already existing communication link is used for transferring e-Waybill information from the e-Waybill to the ITS service. It is concluded, that the e-Waybill solutions that store the e-Waybill information, at least, at the freight-level, enable better possibilities for information synergy than solutions that store information only at back-office level.

In addition, synergies between an e-Waybill service and other ITS services can be utilized in order to design new ITS service. We have proposed a service design method, which can be used to design a new service based on functional and information synergies between the e-Waybill and other ITS services. Our service design method supports the process of designing new ITS services by explicitly utilizing on, mainly functional, synergies with the ITS services. We used the service design method in order to design the LITS service, which we believe has potential to contribute to the already existing solutions for detecting freight damage. The focus of the existing solutions is on detecting freight damage. The LITS service, in addition to detecting freight damage, has the capability to identify the actor responsible
Chapter 1. Introduction

for the damage. By applying the service design method in order to create a design of the LITS service, we concluded that there exist components in other suggested ITS services, such as, information entities and functions, which can be used to design a new service.

Further, from the empirical work conducted in this thesis, we conclude that an e-Waybill service can be seen as an enabler for new opportunities to collect and utilize consignment and traffic data into useful traffic and freight information. In particular, the service in collaboration with other technologies, such as GPS, can lead to increasing amounts of digitally stored consignment and vehicle’s movement data, improved technologies for identifying vehicles, and improved methods for analyzing and finding patterns in large collections of data. The knowledge on the movement of freight and trucks can be of interest to policy makers, when making decisions concerning road taxes, fees, and infrastructure investments.

A possible implication of this thesis is that it can possibly lead to the implementation of the e-Waybill service using different e-Waybill solutions that can enable high synergy with ITS services, as well as the service can lead to better utilization of the information entities and functions of a waybill. This could contribute to a higher utilization of ITS services and more sustainable transport, e.g., in terms of reduced congestion and emissions, as well as increased safety. The service design method presented in this thesis can be used to design more new ITS services or further developing the already existing services, by utilizing synergies. Additionally, the route and freight estimation method proposed in this thesis can contribute towards building improved knowledge, e.g., in national road administrations, on the movement of trucks and freight.

The results presented in the thesis form the foundation on which subsequent work will be based. Future work includes extending this research, e.g., by evaluating the e-Waybill solutions further based on different quality attributes, such as, information quality, reliability, power consumption, and usability. The functional and information synergies based service design method can be further developed by proposing a criterion for selecting which ITS services should be used to provide synergies with the service to be designed. It might be very demanding to describe all existing services using the service description framework. Therefore, having a criterion may act as a filtering step to reduce the work. The service design method may
also be applied in future to design a new ITS service or to further develop any suggested ITS service.
Paper I

State-of-the-art of electronic waybill solutions: A systematic review


Under review at Information Technology and Management journal
2.1. Introduction

Abstract

A critical component in freight transportation is the waybill, which is a transport document that has essential information about a consignment. Actors within the supply chain handle not only the freight but also vast amounts of information, which are often unclear due to various errors. An electronic waybill (e-Waybill) solution is an electronic replacement of the paper waybill in a better way, e.g., by ensuring error free storage and flow of information. In this paper, a systematic review using the snowball method is conducted to investigate the state-of-the-art of e-Waybill solutions. After performing three iterations of the snowball process, we identified eleven studies for further evaluation and analysis due to their strong relevancy. The studies are mapped in relation to each other and a classification of the e-Waybill solutions is constructed. Most of the studies identified from our review support the benefits of electronic documents including e-Waybills. Typically, most research papers reviewed support EDI (Electronic Documents Interchange) for implementing e-Waybills. However, limitations exist due to high costs that make it less affordable for small organizations. Recent studies point to alternative technologies that we have listed in this paper. Additionally in this paper, we present from our research that most studies focus on the administrative benefits, but few studies investigate the potential of e-Waybill information for achieving services, such as estimated time of arrival and real-time tracking and tracing.

2.1 Introduction

In freight transportation, a waybill (also known as consignment note) is a transport document that follows a consignment (under transport) and it is a proof of an agreement concerning freight transport and of its conditions (which has been agreed upon by the carrier company and the consigner). A signed waybill by an actor is a proof that the consignment has been taken over by that particular actor. Due to benefits associated with using electronic solutions for replacing paper documents, there exist different solutions for an electronic waybill (e-Waybill) that can achieve the purpose of a paper waybill, for an overview, see, e.g., (Dubovec, 2006). Typical benefits of an e-Waybill solution are: reduced administrative costs, reduced handling (i.e., reading and writing the same information
to multiple waybills), and reduced costs associated with storage of the paper waybills. In addition, e-Waybills enable fast electronic transfer of information between stakeholders, and they may contribute to achieve a paperless flow of information during transport (Bakhtyar et al., 2013a).

For multi-modal transport, the European Union (EU) project e-Freight (Pedersen et al., 2010) suggests a multimodal e-Waybill solution that uses the e-Delivery infrastructure (Cane et al., 2012). The e-Delivery infrastructure consists of a network of e-Freight Access Points (EAPs), which are accessible via the internet. The focus of the e-Freight e-Waybill solution is on a distributed solution using EAPs. A distributed solution can help in avoiding single points of failure, which could otherwise lead to difficulties in accessing the e-Waybill information.

In the industry, International Air Transport Association (IATA) implemented an e-Waybill solution for air freight transport, which is referred to as an e-Air Waybill (IATA, 2012). The IATA e-Air Waybill uses Electronic Data Interchange (EDI) and the Enterprise Resource Planning (ERP) systems of the airlines that provide transport services. Users can use a web-portal, an ERP system, or the EDI system in order to communicate with the ERP system of the airline that stores the e-Waybill information. For road transportation, DHL (Dalsey Hillblom Lynn) uses DHL Express Waybill as an e-Waybill solution (Cane et al., 2012). DHL requires the consigner to fill out an electronic version of a waybill, i.e., DHL Express Waybill, before the process of freight carriage is initiated.

Different studies suggest different e-Waybill solution, which are based on different technologies and characteristics. For instance, the solutions by IATA (IATA, 2012) and the e-Freight project (Cane et al., 2012) both emphasize on a distributed solution using different technologies, i.e., IATA uses EDI and ERP, while e-Freight uses EAPs. In contrast to IATA and the e-Freight project, DHL Express Waybill (Cane et al., 2012) uses a centralized solution based on the internet and centralized storage of the e-Waybill information. In order to identify the choice of which e-Waybill solution to use, and what tools and technologies to consider for implementation, there is a need to investigate the state-of-the-art of e-Waybill solutions. We perform a systematic review using the snowball process to identify the existing e-Waybill solutions and their characteristics using the guidelines outlined in (Kitchenham and Charters, 2007; Wohlin, 2014). From an industry
practitioner standpoint the results can be used to assess the factors that need to be considered for replacing a paper waybill with an e-Waybill. From an academic standpoint, the results can be used to map current state-of-the-art of e-Waybill solutions and to contemplate the factors that may be used as a valuable input for future improvement work. Our main research question is:

• What is state-of-the-art of e-Waybill solutions?

In this study, our focus is on e-Waybill and electronic Bill of Lading (eBOL) solutions. We consider eBOL solution to be equivalent to e-Waybill solution because a waybill is a type of BOL, i.e., a waybill (for sea, air, rail, and road transport) comes under the category of non-negotiable BOL (Dubovec, 2006). We believe, that a solution for replacing a paper BOL has the potential to replace a paper waybill because both the documents have almost the same properties (Dubovec, 2006).

The remainder of this article is organized as follows. In Section 2.2, we describe the planning phase of this systematic review. In Section 2.3, we explain how this research was executed, and the results of the systematic review. The results are analyzed in relation to the research question in Section 2.4. The discussion is presented in Section 2.5, and the paper is concluded in Section 2.6.

### 2.2 Planning

In this section, we describe the planning of our systematic review. We discuss the search strategy, the study selection criteria and procedure, the quality assessment criteria, and the data extraction procedure used to obtain the results. We followed a multistep process based on the guidelines by Kitchenham and Charters (2007) and Wohlin (2014).

#### 2.2.1 Search Strategy

We identified key terms and formulated a search string, presented in Table 2.1, in collaboration with a librarian. For constructing the search string, we
followed the following steps:

- Identification of key terms from the research question.
- Identification of alternate words and synonyms for the key terms.
- Use of Boolean OR to join alternate words and synonyms.
- Use of Boolean AND to join major terms.

<table>
<thead>
<tr>
<th>Key Term 1</th>
<th>Key Term 2</th>
<th>Key Term 3</th>
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<tbody>
<tr>
<td>Electronic</td>
<td>Waybill</td>
<td>Logistics</td>
</tr>
<tr>
<td>Paperless</td>
<td>Contract of carriage</td>
<td>Freight</td>
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<tr>
<td>Carriage contract</td>
<td>Consignment</td>
<td>Transport</td>
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<tr>
<td>Bill of lading</td>
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<tr>
<td>Consignment note</td>
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<td>Supply chain</td>
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</table>

**Search string:** (Paperless OR electronic) AND (waybill OR “bill of lading” OR “consignment note” OR “carriage contract” OR “contract of carriage”) AND (“supply chain” OR freight OR consignment OR logistics OR transport)

*Table 2.1: Key terms and search string.*

We followed the snowballing method by Wohlin (2014) for searching relevant studies (in order to identify our primary studies) instead of database searching, which is the traditionally used for literature searching in systematic reviews. Different studies, such as (Greenhalgh and Peacock, 2005; Jalali and Wohlin, 2012; Skoglund and Runeson, 2009), have shown that the snowballing process performs equally well when compared to the database search technique.

### 2.2.2 Study Selection Criteria and Procedure

After formulating a search string, we established explicit inclusion and exclusion criteria to make sure that we only have relevant studies for further analysis. We included studies that are:

- published in conferences and journals.
- published between the year January 2000 and April 2015.
- available in full text.
- in English language.
2.2. Planning

• focused on the domain of supply chain were included.

In addition to excluding studies that did not meet our inclusion criteria, we excluded studies that:

• are book chapters (due to no full text available to the authors).
• have no discussion on waybill or bill of lading.
• focused on legal issues related to a waybill or bill of lading.

Further, for studies selection, we followed the snowballing method for searching relevant studies. In this method, the first step is to identify a good start set of studies. There can be different criteria for considering a start set to be good. For example, a good start set may include highly cited articles (Wohlin, 2014). Once a start set of papers is decided by including papers that are intended to be used in the review, first iteration of the snowballing process is performed. A single iteration of the snowballing process includes backward and forward snowballing. Backward snowballing is to use the reference list of a paper to identify new potential papers to include, whereas forward snowballing is to identify new papers that are citing the examined paper. The study selection criteria is applied every time a set of papers is identified and before including the identified papers for the snowballing process. For the included papers, the process of backward and forward snowballing is repeated until no new papers are found that can satisfy the study selection criteria.

2.2.3 Quality Assessment

The purpose of quality assessment is to make a decision regarding the overall quality of the selected papers, which can help further in scoping of the literature review. In Table 2.2, we present our quality assessment criteria to evaluate the selected 11 papers.

According to Kitchenham and Charters (2007), the study quality assessment can be used to devise a detailed inclusion/exclusion criteria and/or to assist data analysis and synthesis. We did not rank the studies according to an overall quality score but used a simple Yes, No, and Partially scale. For a
Chapter 2. e-Waybill systematic literature review

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<td>Are the aims and objectives clearly stated?</td>
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<td>Q2</td>
<td>Is the methodology clearly stated?</td>
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<td>Q3</td>
<td>Are the study results clearly stated?</td>
</tr>
<tr>
<td>Q4</td>
<td>Are the study findings conform to the aims and objectives?</td>
</tr>
<tr>
<td>Q5</td>
<td>Do the researchers explain the practical or research implications of their study?</td>
</tr>
<tr>
<td>Q6</td>
<td>If the study includes technology assessment, is the technology clearly defined?</td>
</tr>
</tbody>
</table>

Table 2.2: Quality assessment criteria.

In our study, the quality score *Yes* represents the presence of a quality criteria, *No* represents absence of a criteria, and *Partially* represents our interpretation that the criteria was present although it may not be stated explicitly by the authors. We applied the study quality assessment primarily as a means to guide the interpretation of findings for data analysis and synthesis in order to avoid any misinterpretation of the results due to study quality.

2.2.4 Data Extraction

In order to extract information needed to address our review question, we used the data extraction form presented in Table 2.3. A pilot study was conducted by the authors separately using the data extraction form to ensure consistent results and to eliminate uncertainties. We found some difficulties in interpreting some of the questions. The difficulties were resolved through discussions between the authors before proceeding with a full scale systematic review.

2.3 Execution and Results

An overview of the studies selection process is presented in Figure 2.1. As a starting point, we applied our search string to the Google Scholar database. Google Scholar was selected in order to avoid bias in favor of any specific publisher (Wohlin, 2014). For our start set, we set the publication year to be in the range of 2000-2015 and we found 7470 studies in total. For the identified studies, the titles were scanned and 75 papers in total were found to be highly relevant. Next, abstracts of the 75 papers were read and 36 papers were found relevant. In the next step, the remaining 36 papers were
read in full text and study selection criteria was applied, which resulted in 33 papers for inclusion. Out of the 33 papers, we found 9 papers to be highly cited. We had conflicts over these 9 papers for inclusion and after discussions a consensus was reached among the authors to include 8 papers in our start set.

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<tr>
<td>Methodology</td>
</tr>
<tr>
<td>Case study</td>
</tr>
<tr>
<td>Experiment</td>
</tr>
<tr>
<td>Survey</td>
</tr>
<tr>
<td>Action research</td>
</tr>
<tr>
<td>Solution</td>
</tr>
<tr>
<td>EDI-based</td>
</tr>
<tr>
<td>Non-EDI</td>
</tr>
<tr>
<td>Solution focus</td>
</tr>
<tr>
<td>New conceptual solution</td>
</tr>
<tr>
<td>New technical solution</td>
</tr>
<tr>
<td>Effects/impacts on an organization or process</td>
</tr>
<tr>
<td>Users’ attitude (opinions)</td>
</tr>
<tr>
<td>Suggestions for improvement</td>
</tr>
<tr>
<td>Industrial application</td>
</tr>
<tr>
<td>Success/failure factors</td>
</tr>
<tr>
<td>Technologies focus</td>
</tr>
<tr>
<td>EDI</td>
</tr>
<tr>
<td>XML, UBL, ebXML</td>
</tr>
<tr>
<td>Internet</td>
</tr>
<tr>
<td>RFID</td>
</tr>
<tr>
<td>ERP</td>
</tr>
<tr>
<td>EPC</td>
</tr>
<tr>
<td>PDA</td>
</tr>
<tr>
<td>Solution adopted (in the industry)</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Transportation mode</td>
</tr>
<tr>
<td>Road</td>
</tr>
<tr>
<td>Sea</td>
</tr>
<tr>
<td>Rail</td>
</tr>
<tr>
<td>Air</td>
</tr>
<tr>
<td>Multimodal</td>
</tr>
</tbody>
</table>

Table 2.3: Data extraction form.
Chapter 2. e-Waybill systematic literature review

**Figure 2.1:** Studies selection process.
2.3. Execution and Results

2.3.1 Iteration 1

The 8 papers in our start set had 167 references in total. These references were checked in order to perform backward snowballing. In the first step, titles were scanned and basic inclusion/exclusion criteria was applied. This first step resulted in 58 papers. The second step was to read the abstracts of the 58 papers. After the second step, we found 7 papers to be highly relevant. We then read full text of these 8 papers and applied the detail inclusion/exclusion criteria, which resulted in 1 papers.

After the backward snowballing procedure, we performed forward snowballing on the 8 papers in our start set. We found that the 8 papers were cited by 118 studies in total. After performing the first step of reading the titles and applying basic inclusion/exclusion criteria, we found 29 papers to be relevant for inclusion. After reading the abstracts of these 29 papers, 11 papers were considered to be relevant. We then read full text of these 11 papers and applied the detail inclusion/exclusion criteria, which resulted in 1 paper. The result of the backward and forward snowballing in the first iteration was 2 papers.

2.3.2 Iteration 2

In the second iteration, we performed the backward and forwarding snowballing procedure on the 2 papers that were identified in the first iteration. For the backward snowballing, we found that the 2 papers had 100 references. After scanning the titles in these references and applying basic inclusion/exclusion criteria, we found 39 references to be relevant. After reading the abstracts of these 39 papers, we found 9 papers to be relevant. We then read full text of these 9 papers and applied the detail inclusion/exclusion criteria, which resulted in 1 papers.

In the forward snowballing process, we found that the 3 papers were cited by 26 studies in total. We scanned the titles of these 26 studies and found 10 studies relevant to include. After reading the abstracts of the 10 studies, we found none of the papers to be relevant for inclusion. Hence, the second iteration resulted in only 1 paper to be highly relevant.
2.3.3 Iteration 3

In the third iteration of the snowballing process, we performed the backward and forwarding snowballing procedure on the 1 paper that was identified in the previous iteration. For the backward snowballing, a total of 46 references were found in the paper. However, when scanning the titles in the references, we found that all of the references were from the years earlier than the year 2000. Therefore, the backward snowballing process was not performed further on this paper.

In order to perform the forward snowballing process, we found that the paper is cited by a total of 104 papers. After scanning the titles of the citing papers, we found 19 papers to be relevant. The abstracts of the 19 papers were read and 5 papers were found to be relevant. However, after reading the 5 papers in full and applying the inclusion/exclusion criteria, we found none of the paper to be relevant. Thus, in iteration 3 forward snowballing, similar to backward snowballing, resulted in zero papers to consider further.

The snowballing process was concluded after the third iteration since no new articles were found. In summary, we found 11 articles in total through a systematic snowballing process. The selected articles are presented in Table 2.4.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Paper Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Lee et al., 2000)</td>
<td>2000</td>
<td>A New Efficient EDI System For Container Cargo Logistics.</td>
</tr>
<tr>
<td>(Angeles et al., 2001)</td>
<td>2001</td>
<td>Success Factors For Domestic and International Electronic Data Interchange (EDI) Implementation For US Firms.</td>
</tr>
<tr>
<td>(Chung et al., 2005)</td>
<td>2005</td>
<td>Setting Up a Production Network of E-documents: A Case of a Shipping Company.</td>
</tr>
<tr>
<td>(Holtkamp et al., 2010)</td>
<td>2010</td>
<td>Towards a Logistics Cloud.</td>
</tr>
<tr>
<td>(Cane et al., 2012)</td>
<td>2012</td>
<td>The e-Freight Multimodal e-Waybill.</td>
</tr>
<tr>
<td>(Xie and Allen, 2013)</td>
<td>2013</td>
<td>Information Technologies in Retail Supply Chains: A Comparison of Tesco and Asda.</td>
</tr>
<tr>
<td>(Florin et al., 2007)</td>
<td>2007</td>
<td>UBL an Universal Business Language for XML.</td>
</tr>
</tbody>
</table>

Table 2.4: Selected papers for the systematic review.
2.4 Analysis

In this section, we present our analysis of the included studies. We used the data extraction form, which is presented in Table 2.3, in order to support our findings. Additionally, the quality of each of the study is presented in Table 2.5, where the quality criteria from Table 2.2 are applied. We can see, from Table 2.5, 6 out of the total 11 studies have either missing or unclear methodology. The study (Janssens, 2011) has unclear aims and objectives, study (Holtkamp et al., 2010) has unclear results, and the study (Florin et al., 2007) has unclear connection between the study findings and the aims and objectives.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Lee et al., 2000)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Angeles et al., 2001)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Mei and Dinwoodie, 2005)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Chung et al., 2005)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Tan and Kritchanchai, 2006)</td>
<td>Yes</td>
<td>Partially</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Wamba and Boeck, 2008)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Holtkamp et al., 2010)</td>
<td>Yes</td>
<td>No</td>
<td>Partially</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Janssens, 2011)</td>
<td>Partially</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Cane et al., 2012)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Xie and Allen, 2013)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(Florin et al., 2007)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Partially</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 2.5: Study quality assessment applied.

In our analysis, we found that the studies can be grouped into non-EDI solutions and EDI-based solutions. Each of the group includes different focus areas (from a technological perspective) of the primary studies.

2.4.1 Non-EDI Solutions

Five studies out of the total 11 focus on non-EDI solutions. The studies, which include 3 journal articles and 2 conference papers. The study (Chung et al., 2005), is a case study that focuses on the concept of a centralized documentation center for producing shipping documents. The authors (Chung et al., 2005) focus on the case of NacoPagen Shipping Agencies Limited (NPSL), which is a shipping company located in Hong Kong, China and having 8 branch offices in different cities of China. The company offers shipping services to different organizations worldwide. Each of the
branch office has a documentation department, which is responsible for producing shipping documents for that particular office. NPSL reorganized the documentation centers for all the offices into a single documentation center at the head office in Hong Kong. The authors found that a total of 2540 documents (including Bill of Lading/waybill documents) are required by the head office each month and by merging the distributed documentation centers into an electronic centralized documentation center a cost saving of US$ 43,307 can be achieved.

The studies (Florin et al., 2007; Wamba and Boeck, 2008) investigate technical aspects of non-EDI e-Waybill solutions. The focus of the study (Wamba and Boeck, 2008) is on investigating the potential of Radio-Frequency Identification (RFID) and Electronic Product Code (EPC) for enabling electronic information flow in a supply chain. The authors in (Wamba and Boeck, 2008), test several scenarios integrating RFID and the EPC network in a laboratory setting for a retail firm. The authors identified that most of the activities involving information-flow requires human intervention. Processing of bill of lading is one such activity that involves information processing and requires human intervention. The authors (Wamba and Boeck, 2008) prove that using RFID and EPC, information flow can be enhanced in the supply chain. The benefits of automated information flow include synchronized information, information visibility, reduction in typing errors, and low document handling and processing costs. Further, the authors (Wamba and Boeck, 2008) suggest (through laboratory experiments) that using RFID and EPC instead of an Enterprise Resource Planning (ERP) system for processing bill of ladings, a saving of 98% in handling time can be achieved.

The study (Florin et al., 2007) focuses on the potential of Universal Business Language (UBL) for replacing 31 different documents (including bill of lading and waybill documents) used in freight transportation processes. UBL is based on the Electronic Business using eXtensible Markup Language (ebXML), which is promoted by OASIS (Organization for the Advancement of Structured Information Standards) as a product-independent standard for replacing paper-based transportation documents. UBL 2.0 is the sixth generation of XML standards and include libraries for replacing 31 different documents, such as bill of lading, certificate of origin, forwarding instructions, packing list, transportation status, waybill, receipt advice,
dispatch advice, order, and invoice. The documents are exchanged using XML files, which has a standard structure recognized by any applications (Florin et al., 2007). In addition to a faster exchange of information, UBL is platform independent and can be implemented using free open source tools. Therefore, implementing UBL based solution for electronic documents is a cheap solution.

A cloud-based platform (also known as the logistic mall) for logistic services is proposed by Holtkamp et al. (2010). The logistic mall consists of a Mall Marketplace (MMP) and Customized Access Framework (CAF). MMP offers logistics IT applications and services, which may be developed by different providers. In addition to providers, other users of MMP are buyers and operators. Buyers include managers of companies who are potential buyers and users of the logistic IT services. Providers manage the cloud infrastructure for the offered services and benefit from service fees for sales and operating. CAF implements a Software-as-a-Service (SaaS) layer in order to provide logistics applications and services to a customer company of the Logistics Mall. Users of CAF include managers, administrators, and other actors in an organization that are potential users of the applications and services provided by the Logistics Mall. Some of the applications provided by the Logistic Mall include an ERP system for storing orders, a document management system for storing waybills, and warehouse management system for order processing. All the applications are provided by different providers and integrated in a portal (Holtkamp et al., 2010). Information exchange between the applications is enabled using an EDI converter.

A multimodal e-Waybill solution, i.e., e-Freight multimodal e-Waybill, is proposed by Cane et al. (2012). The e-Freight e-Waybill solution is a part of the e-Freight project Pedersen et al. (2010), which proposes a framework for information exchange between different actors in freight transportation. The framework is based on a harmonized set of message/document specifications. The e-Waybill information can be exchanged using an e-Freight Access Points (EAPs) network. EAP is an open source technology and can be implemented by a stakeholder or an external service provider, in a similar way as an email exchange server. An e-Waybill can be created automatically from the existing data from other processes, e.g., from the order data. The creator of an e-Waybill can set access rights for other actors
in order to control read and write operations on the data. The e-Waybill is then published via an EAP and can be accessed only by those actors who are given access rights. Therefore, the owner of an e-Waybill has full control over the e-Waybill data as it is stored in the owner’s EAP and other actors have access to the e-Waybill via their own EAPs.

2.4.2 EDI-based Solutions

Six journal articles out of the total 11 focus on EDI-based solutions. Lee et al. (2000) investigate the problems and success factors in EDI systems when used for clearing of import/export of containers. Based on their investigation, the authors suggest guidelines for a new EDI system for container cargo (Lee et al., 2000). Different EDI systems, i.e., TRADENET in Singapore, KT-Net and KL-Net in Korea, and SHIPNET in Japan, are considered as case in the study. The Korea Trading Network (KT-Net) was introduced in the year 1990. KT-Net uses an EDI network for exchange of logistics information within the maritime community. In addition to issuing electronic bill of ladings, KT-Net covers the scope of licensing, insurance, customs clearance, request for shipment etc. A major weakness of KT-Net was the absence of support for the ports and the transport operators. In order to remove this weakness, Korea Logistics Network (KL-Net) was introduced in parallel to KT-Net. The evolution of KL-Net is considered to be slow and one major reason is because of the existence of two different systems, i.e., KL-Net and KT-Net.

The potential benefits and implementation cost concerning EDI are discussed by Janssens (2011). The major shortcomings of a paper based bill of lading are cost of producing paper documents and slow transfer of information. Traditionally, EDI is used for exchange of electronic bill of lading; however, EDI is considered to be expensive because of the translator software and value-added network it uses. To overcome the cost, other technologies, such as the internet, can be integrated with EDI. An internet-based EDI can avoid the use of a costly value-added network and may enable small organizations to afford the implementation. However, organizations are reluctant to adopt internet-based EDI due to online security loopholes. Due to online security problems, organizations use private value-added networks, which keeps the EDI cost high.
A case study based on information sharing in the supply chain is presented by Xie and Allen (2013). The use of technologies by two retailers is studied in order to identify the preferences for adopting technologies in practice. EDI is identified as one such technology that is used to exchange information between retailers and suppliers in the retail supply chain. In addition to electronic bills of lading, EDI facilitates electronic invoices, sales and inventory data, purchase orders, and other shipping information. The benefits of EDI includes accurate and timely information, speedy transactions and order processing, and better inventory planning. However, in a retail supply chain EDI has some limitations, such as EDI transactions are business-to-business and not for individual consumers, and the transactions are between computers and not between individuals.

Mei and Dinwoodie (2005) propose an Internet-Based Third-Party Internet Service Provider (IBTPISP) that is capable of producing eBOLs and other documentation services. The authors investigate the users attitude towards the proposed IBTPISP (Mei and Dinwoodie, 2005). In contrast to a traditional EDI, the IBTPISP uses the internet instead of a value-added network. Although majority of the survey participants agreed on the potential benefits of eBOLs; however, the opinion about the technology choice for eBOLs differs. It is found that the users (of BOLs) have more trust and confidence in a traditional EDI as compared to IBTPISP. A low trust and confidence in using IBTPISP for eBOLs is due to the legal status of eBOLs. Therefore, there is a need for a legislation to clarify the legal status of eBOLs.

It is an established fact now, from most of the studies, that the use of EDI is common for exchange of business documents, such as bill of ladings, invoices, and purchase orders. Angeles et al. (2001) investigate the factors that are important to consider for implementing EDI in the US and internationally. Critical factors for ensuring successful EDI implementation are the relation between trading partners, a cross-functional EDI team, and business process engineering. Trading partners, who have deeper business relations, may identify key business processes to achieve greater benefits. At this point, cross-functional EDI teams are formed, whose task is to investigate the use of EDI for the business processes. The business processes may be modified through business process engineering in order to better support EDI. The trading partners need to share important information and
consider themselves as collaborators instead of competitors. Other factors that are critical for EDI implementation include selection of EDI standards, support of top management, availability of value-added networks, and trustworthy security and auditing controls.

A framework for the deployment of supply chain technologies in the logistics industry in proposed by Tan and Kritchanchai (2006). The framework is applied on a company in Singapore as a case study. One important objective of applying the framework is to identify new EDI and internet message standards that could be deployed to existing EDI networks. The goal is to reduce effort, data errors, and cycle time by linking entities electronically in a supply chain. As a pilot implementation, the EDI for Transportation System (EDITRANS) standard was launched with seven EDI messages standards in compliance with UN/EDIFACT in the initial phase. There are efforts by the logistics industry to target shipping lines to use EDITRANS for exchanging bill of ladings between the shipping lines and freight forwarders. However, after a year of launching EDITRANS, it was identified that EDITRANS has a low adoption rate. The reasons for this low penetration rate is because shippers did not participate with the logistics companies in the same proportion of buyers to suppliers, and some shippers have clerks for managing order-processing and export and import documentation. To overcome the shortages of EDITRANS, a system that consist of a single web interface for different IT systems was proposed in order to enable information exchange between shippers, freight forwarders, carriers, and financial institutions. Benefits of the system include lesser data entry steps, less data duplication, less manual efforts, and reduction in human errors.

2.5 Discussion

We find that most of studies are focused on either new or existing technological solutions for exchanging electronic documents. Therefore, when highlighting the benefits of e-Waybills/eBOLs, the studies discuss potential benefits of the technology with a lesser emphasis on the benefit of e-Waybills/eBOLs. This is because the discussed solutions are for electronic documents exchange including, but not limited to, e-Waybills/eBOLs. Irrespective of the technology being used, the benefits of electronic
documents exchange include:

- Reduction in typing errors, e.g., due to less manual information input.
- Low document handling and processing costs, e.g., due to high storage capability and better check control over digital information.
- Funds can be paid or received quickly, e.g., due to tracking and tracing of cargo.
- The capability of monitoring cargo status and generating notifications about the status,
- Improved inventory management, e.g., due to the function of monitoring cargo status.
- Quick response times to customers, e.g., due to real-time information availability.
- Improved demand forecasting, e.g., due to the function of estimated time of arrival.
- Real-time information about transactions’ status.

Some of the above listed benefits, e.g., reduced typing errors, can be true for e-Waybills/eBOLs. Additionally, in one study S3 (Mei and Dinwoodie, 2005), the users of eBOLs perceived a saving of US $125 per bill-set by switching from paper based BOLs to eBOLs.

Although, most of the studies agree on the benefits of electronic documents exchange; however, different studies focus on different technologies. EDI is the most commonly discussed technology for electronic exchange of documents including waybills/BOLs. This is because EDI is the oldest and most commonly used technology for electronic documents exchange. However, there are several limitations of EDI due to which it is not widely adopted by smaller firms. EDI uses value added networks (VANs) and a firm may have to subscribe to several VANs in order to connect with a trading partner. Hence, VANs make EDI an expensive solution for documents exchange. Additionally, EDI may not the best solution in a retail supply chain as it is used mainly for business-to-business transactions between computers and not for individual consumers. In addition, a document transferred using EDI is just a document but in an electronic
format. This limits the possibility to utilize the information contained in the document in any other way, e.g., to achieve any other function other than the document’s function.

To overcome the limitations of EDI, practitioners and researchers are moving towards solutions that are non-EDI based. In addition to overcome the limitations of EDI, the purpose of non-EDI solutions is to utilize the information in a better way by considering an electronic document as a set of abstract electronic information rather than just an electronic version of a document. XML, ebXML, and UBL standard can be used to represent the information in electronic format. UBL can be easily integrated with any computer application as it is based on W3C XSD (World Wide Web Consortium XML Schema Definition) schema. The internet can be used instead of VANs, which reduces the cost. Computers, RFID, EPC, and PDAs are other technologies that can be used in non-EDI based solutions.

2.6 Conclusion

Based on our review, it is clear that most of the researchers and practitioners agree on the benefits of replacing paper business documents (including Waybills and BOLs) with electronic solutions. In the technologies used for electronic solutions, EDI is the pioneer. However, there is a need to use a uniform standard due to which EDIFACT was proposed for EDI. In addition, ebXML and UBL are developed in order to shift the focus from EDI to other technologies. The use of UBL is important for smaller firms since EDI is considered to be expensive and UBL is flexible to be used with any computer application. Regardless of the document type, there is a need for a uniform standard (in the technology and messaging format) due to the involvement of inter-organizational transactions.

Additionally, we identified that there is less emphasis on the services that can be achieved with information from the e-Waybills/eBOLs and any other electronic documents. Most of the included studies focus on the administrative benefits, such as lesser paper cost and typing errors, of using electronic documents. However, few recently published studies emphasize on using the information (from the documents) for achieving different services, such as estimated time of arrival and real-time tracking and tracing.
2.6. Conclusion

Furthermore, we conclude that the snowball method may be improved further (even though it enabled us to identify relevant literature concerning e-Waybills and eBOLs). In particular, a limitation of the method in our case was selecting only highly cited studies. Due to this limitation, we could only select very few studies for analysis in this review study. In order to address this limitation, which may also lead to a potential improvement of the snowball method, a recommendation is to select studies based on their publication venue as an alternative to selecting only highly cited studies. Selecting studies based on their publication venue may help in selecting a higher number of relevant studies as, today, there exist conferences and journals whose focus is on specific topics and/or domains.

Our recommendations can be divided into two parts; recommendations for researchers, and recommendations for practitioners. For researchers, we suggest to consider the trust and security aspects of a proposed solution. A solution with a low security may not be trusted and adopted by an organization since a waybill/BOL contains significant information about that particular organization and the organization cannot take the risk of leaking the information. Therefore, exchange and storage of information need to be protected if the solution is to be trusted and adopted. Additionally, we suggest that a waybill/BOL should not be seen only as a document but as set of information entities and functions that may be utilized to achieve different value added services. There is also a need for research on the cost and benefits analysis of e-Waybills/eBOLs. For practitioners, we suggest to provide low cost technological solutions since one of the limitation of EDI is high implementation cost. There is a need for uniform standards for technologies (for storage and exchange of information). UBL is one such initiative towards a uniform messaging format. Lastly and most importantly, there needs to be a legislation for using electronic documents in place of paper documents since some of the documents, such as BOLs, have legal functions associated with the document.

Future work includes studying the use of e-Waybill/eBOL solutions in industry. This will serve as an additional source of validation for the solutions found in this systematic review, and may also reveal other factors that need to be addressed. A more in-depth analysis of the identified technologies for electronic documents exchange is also part of future work.
Paper II

Analysis of information synergy between e-Waybill solutions and intelligent transport system services

Abstract

We present a study on information synergy between an electronic waybill (e-Waybill) and intelligent transportation system (ITS) services. A waybill is an important transport document, and it contains essential information about a consignment. We consider five e-Waybill solutions, which differ in where the e-Waybill information is stored, read, and written. We analyze 20 ITS services, and for each of them, the required input entities that can be provided by an e-Waybill are identified, and the synergy with each of the e-Waybill solutions is determined based on the location of the e-Waybill information. The analysis shows that e-Waybill solutions with storage at the freight-level enable the highest information synergy with ITS services. Our results may support the implementation of practical e-Waybill systems that provide high synergy with ITS services, which may lead to higher utilization of ITS services and more sustainable transport, e.g., in terms of reduced congestion and emissions.

3.1 Introduction

Freight transport has both positive and negative effects on society. A positive effect is that it enables mobility of goods, which may lead to economic growth. Negative effects are accidents, inefficient use of resources, emissions and traffic congestion. In order to reduce the negative effects, it is possible to use different types of intelligent transportation system (ITS) services. As suggested by various studies, e.g., Hickman et al. (1996); Mbiydzenyuy et al. (2012); Proper et al. (2001), the use of ITS services may lead to more sustainable transport, in terms of reduced congestion, decreased fuel consumption, and reduced amount of emissions, by enabling more efficient use of vehicles and infrastructure. In addition, the use of ITS services might lead to increased safety. For example, the ITS service accident warning information provides information about an accident to nearby vehicles, which may help in reducing the effects of accidents, e.g., queue build up, chain accidents, and rear-end collisions. In case of an accident, Wunderlich et al. (1999) suggests that accident warning information systems may contribute to reducing travel times, fuel consumption, and delays.

ITS services can be implemented either standalone or as a group of services.
Chapter 3. Information synergy between e-Waybill and ITS services

(i.e., as a package), which makes use of synergy between services. It has been shown by, e.g., Mbiydzenyuy et al. (2008, 2011) that implementing ITS services as a package, which uses functional synergy between services, can result in cost reductions. As suggested by Hickman et al. (1996), there are three types of synergies between ITS services:

- Functional synergy, i.e., services share functions.
- Technical synergy, i.e., services share technical resources.
- Information synergy, i.e., services share information entities.

We illustrate the concept of synergy between services by describing possible synergies between the ITS services E-call and Estimated time of arrival. A shared function of these services is the need to determine the vehicle location. Information about the vehicle (e.g., vehicle size and id) may be used by both of the services, and the services may share technical resources, e.g., a GPS receiver.

In this paper, we investigate the possibility for information synergy between different ITS services and the electronic waybill (e-Waybill) service. We consider this type of synergy to be of particular interest to study, because an e-Waybill has essential information about a consignment, including the origin and destination, as well as information about the involved actors. The waybill information, if available in electronic form, can be useful for various ITS services. We define an e-Waybill as a service that provides the functions of a traditional paper waybill and which is capable of storing, at least, the information present in a paper waybill. A waybill is an important document in international transport since it follows a consignment and is a proof of the agreement for transport and its conditions. In addition to providing possible synergies with ITS services, the use of e-Waybills may reduce the administrative costs that are typically associated with paper waybills. For instance, costs associated with that the same information is written on several waybills (for transport involving multiple carriers) and costs associated with storage of the paper waybills can be reduced or removed by using an e-Waybill. In addition, e-Waybills enable fast electronic transfer of information between stakeholders, and they may contribute to achieve a paperless flow of information during transport, as well as achieving the vision of using a single transport document for the carriage of freight, which,
e.g., was an integral objective of the EU level project e-Freight (Pedersen et al., 2010).

For different modes of transport, there exist different e-Waybill systems, but they are based on storage of the e-Waybill information at back-office, and on back-office-to-back-office communication. When studying information synergy between ITS services and e-Waybills, it is important to also consider other types of e-Waybills, since the type of e-Waybill solutions that are traditionally used may not provide the best possibilities for synergy with other ITS services. We therefore identify different e-Waybill solutions that are analyzed in relation to ITS services. The e-Waybill solutions differ with respect to the storage location of the e-Waybill information, and the access rights to the information, in terms of read and write (update). The main purpose of this paper is to study possible information synergies between e-Waybill solutions and other ITS service, and it addresses the following research question:

• What potential information synergies exist between e-Waybill solutions and ITS services?

In the literature (see, e.g., Balbo and Pinson (2010); Crainic et al. (2009); Talib et al. (2010); Van der Perre (2006)), there exists research on synergies between ITS services. However, according to the best of our knowledge, there exists no study that concerns information synergy between ITS services, and in particular no study conducted on synergy involving the e-Waybill service. Due to the possible advantages for information synergies between the e-Waybill service and other ITS services, we consider that it is important to investigate this type of synergy.

It should be emphasized that the focus of our study is on road transport, even though we argue that the presented results to a large extent will be applicable also to other modes of transport, since waybills for different modes of transport are similar considering the information content.

The paper is structured in the following way. In Section 3.2, we describe the methodology that was used to conduct our study on information synergy. In Section 3.3, we present the traditional paper waybill, and in Section 3.4, we review a number of existing e-Waybill initiatives and give an account of research on synergy between ITS services. In Section 3.5, we present
five solutions for implementing the e-Waybill service. In Section 3.6, we analyze our e-Waybill solutions in order to identify possible information synergies with other ITS services, and in Section 3.7, we conclude the paper by discussing our results and providing some pointers to future work.

3.2 Methodology

We here describe the methodology that we used in order to answer our research question. In the research process, we implicitly also studied the following questions:

- Which e-Waybill solutions are relevant to study for information synergies with ITS services?
- What information is required by the existing ITS services and where is this information needed?

As a starting point of our research, we studied paper waybills for road transport in order to identify what information is typically present. We also studied the actual usage and functions of a waybill by interviewing two persons with long experience in road freight transport. One of the interviewees is currently working as a manager at a medium-sized Swedish road transport operator, and the other interviewee has recently been working as a driver, transport manager, and chief executive officer at another road freight transport operator. It should be mentioned, that the second interviewee has interacted with traditional paper waybills in different roles and in different ways. For example, as a driver he used a waybill in a different way than as a transport manager. In order to support the generalization of our results, we also studied waybills for other modes of transport. From the literature review and the conducted interviews we were able to specify functions of a paper waybill, and the types of e-Waybill solutions that exist for different modes of transport. In addition, we reviewed the literature for existing research concerning synergy between ITS services, and in particular synergy involving the e-Waybill service. By analyzing the functions of a paper waybill, we identified important characteristics of a paper waybill, and hence of the e-Waybill service, which were then used to define a number of e-Waybill solutions. From
the literature, and related research projects, we identified a number of ITS services, which we analyzed, mainly in order to identify what types of input information they require. We analyzed the information synergy between each of the e-Waybill solutions and each of the services, by considering at what locations read access is provided to the e-Waybill information, and at what locations the ITS service needs input.

3.3 The Traditional (paper) Waybill

In this section, we describe the traditional paper waybill, which is also known as a consignment note or a CMR document. This is important, since we assume that an electronic replacement of a waybill (i.e., an e-Waybill service) should provide, at least, the same functions as a traditional paper waybill. We specify the actors that are primarily involved in a typical consignment, the functions provided by a traditional paper waybill, and the information entities typically present on a waybill. Our presentation is focused on road transport even though the actors involved, and the waybills used, in other modes of transport are similar.

A waybill follows a consignment during transport and it proves that a transport agreement exists [typically between the consigner and the carrier(s)]. In addition, the waybill specifies the conditions for transport, and it shows which actor is currently responsible for the consignment. By signing the waybill, the responsibility is transferred between different actors. The signatures are used to prove that the consignment has been picked-up, delivered, and transferred between the actors that provide the physical transport service. An important document that regulates the waybills used in international transport, is the CMR (Convention relative au Contrat de transport international de Marchandises par Route) convention by the UN (Clarke, 2009; UNECE, 1956). In cross-border transport, a copy of the waybill should by law follow the consignment, and for freight transport within a country, there often exist similar regulations, which typically are based on the CMR convention.

By studying real-world transport scenarios, and by interviewing practitioners in the transport domain, we identified a number of roles that primarily are involved in a consignment:
Chapter 3. Information synergy between e-Waybill and ITS services

- Consigner: The sender of a consignment.
- Consignee: The final receiver of a consignment.
- Carrier: A company that is responsible for the physical transport of a consignment.
- Driver: The person maneuvering the vehicle that carries the consignment.
- Public authorities: Law enforcement agencies, such as customs and the police, who are responsible for inspecting the legality of consignments.

Many transport solutions today are complex and involve multiple modes and actors, including 3rd party logistics providers and freight-forwarders (Ramstedt and Woxenius, 2006). There are therefore situations that require the involvement of more than the five roles presented above. However, we have chosen to only describe the most basic roles, since we consider these to be sufficient for understanding the role of the traditional paper waybill.

From the information that is required to be present on a waybill, e.g., according to the CMR convention, we specify the types of information that are important in order to achieve synergies between the e-Waybill service and other ITS services.

- Information about the involved actors, e.g., name and address.
- Specifications of the consignment, e.g., type of goods, volume, weight, value, origin, and destination.
- Transport conditions, e.g., times for pickup and delivery.
- Information for law enforcement authorities (e.g., dangerous goods information for customs).
- Specification of additional documents used during transport, such as import and export declarations.

In addition, the actors involved in the transport of a consignment may enter any other information that they may consider useful. By studying the CMR convention and real-world examples of waybills, we have identified other types of information that may also be included, such as signatures of the different actors involved in the consignment.
We identified that a waybill provides, at least, the following functions for the actors involved in a consignment:

1. A waybill is a proof that there exists a contract for transport, which is important, since there should exist an agreement that specifies the conditions for transport.
2. A waybill shows which actors have been in control of the consignment, which actor is currently in control, and which actors will be in control in the future. When an actor (a carrier or the consignee) takes possession (and responsibility) of the consignment, the waybill is signed in order to declare that the consignment has been transferred to the new actor.
3. A waybill provides storage of information about a consignment, which is important for freight handling.

It is generally considered (see, e.g., Crainic et al. (2009); Johansson (2008)) that the functions provided by a waybill are functions 1 and 2. Since a waybill also contains important information about a consignment, our interpretation is that function 3 should also be considered, even though this is not commonly discussed in the literature. Another function, which is known as the right of disposal, concerns the right to prevent the consignment from being handed over to the consignee, unless this has been approved by the consigner. For example, if the payment for the consignment has not reached the consigner on time, the consigner can change the final destination of the consignment unless it is not already in possession of the final consignee. However, we have not considered the right of disposal function, because it only concerns some special situations, such as payment delays (Johansson, 2008).

3.4 Related Work

There exist several initiatives for replacing the traditional paper waybill with an e-Waybill, for an overview, see, e.g., Dubovec (2006). In this section, we discuss a number of existing e-Waybill systems for different modes of transport, as well as a conceptual initiative for how to achieve an e-Waybill that can be used as a single consignment document in multi-modal transport. In addition, we discuss existing work on synergies between ITS services.
3.4.1 Existing e-Waybill Solutions

The International Air Transport Association (IATA) implemented an e-Waybill model for air freight transport, which is referred to as an e-Air Waybill (IATA, 2012). The e-Air Waybill was designed in order to replace the paper documents that are attached with each air shipment with electronic messages. The e-Air Waybill uses the electronic data interchange (EDI) system and the enterprise resource planning (ERP) systems of the airlines that provide transport services. Actors can use a web-portal, an ERP system, or the EDI system in order to communicate with the ERP system of the airline that stores the e-Air Waybill. Therefore, the model is based on back-office to back-office communication.

A negotiable waybill used in transport by sea is known as a bill of lading (BOL). Mei and Dinwoodie (2005) argued for the implementation of an electronic version of the BOL, i.e., the eBOL, because of the fraud factor associated with the traditional paper-based BOL, and the often late arrival of a paper BOL to the consignee, who are not allowed to take possession of the consignment without showing the BOL. They introduced the concept of an Internet-Based Third-Party Internet Service Provider (IBTPISP), which is responsible for handling the eBOL. The focus of an IBTPISP, as a third party central function, is on organizational-based trust, which ensures to protect the interest of all stakeholders involved in a consignment. SEADOCs is another electronic alternative to the BOL. It was a joint project of the Chase Manhattan Bank and International Association of Independent Tanker Owners (INTERTANKO) and it uses a central registry for storing the eBOL. All actors involved in the consignment are supposed to communicate through this central registry (Dube, 1998).

One example of an e-Waybill used in road transport is DHL Express Waybill, which is used by the company DHL (see, e.g., Cane et al. (2012)). DHL is a carrier (transport service provider) who requires the consigner to fill out an electronic version of a waybill before the transport will take place.

For multi-modal transport, the e-Freight project suggested a multimodal e-Waybill that uses the e-Delivery infrastructure (Cane et al., 2012). The e-Delivery infrastructure consists of a network of e-Freight Access Points (EAPs), which are accessible via the internet. The e-Freight e-Waybill solution should not be located at a single location; instead it should be
scalable with the help of EAPs. In addition, the use of EAPs might help avoiding single points of failure, which could otherwise lead to difficulties in accessing the e-Waybill.

3.4.2 Synergy Between ITS Services

The literature contains several studies on synergy between ITS services. Balbo and Pinson (2010) proposed an agent-based approach to design a transportation regulation support system using functional synergies between an existing information system and a decision support system. Cane et al. (2012) considered ITS as a concept that is based on old and new technologies for transport management. They argued that the concept of ITS evolves with the realization of synergies between systems using ITS services and other systems. Mbiydzenyuy et al. (2008) proposed a method to assess functional synergies between ITS services used in road transport. They suggested that the total cost for service deployment could be reduced, by using functional synergy between services. Van der Perre (2006) presented the idea of a platform, which is capable of accommodating different services and which can support relevant communication media (cellular broadcasts and dedicated short range communication). Talib et al. (2010) argued for the need for a service-packaging platform, which is able to offer service providers the ability to create reusable service packages. This is possible through organizing existing service delivery functions or creating new ones. They introduced the notion of service packages and a pattern-based approach to service packaging, and they highlighted the requirements of a platform to enable service packaging. In addition, from the e-Waybill systems described in the literature, we identified possible synergies. For example, DHL provides the service e-Track (Santosa, 2004) for real time tracking of a consignment, which is a part of the e-Waybill system DHL Express Waybill.

3.5 e-Waybill Solutions

In this section, we present the e-Waybill solutions that we analyzed for information synergies with ITS services. In addition, we discuss the
connection between the e-Waybill solutions and the functions of a traditional waybill. As will be discussed in more detail below, we argue that all e-Waybill solutions that provide information storage capabilities, as well as read and write (update) access to the information, are able to provide all of the three waybill functions that were presented in Section 3.3. In addition, in our information synergy analysis, we considered the location of storage, and read and write access of the e-Waybill data, since different ITS services has different requirements with respect to location of input data. We consider the back-office and freight-level locations.

We identified the following six properties in order to specify the locations for storage, read and write access.

1. The e-Waybill information is stored in a back-office system.
2. The e-Waybill information is stored were the freight is, i.e., at freight level, which might imply that the information is stored in a hand-held device.
3. Read access is given to e-Waybill information stored at back-office.
4. Read access is given to e-Waybill information stored at the freight-level.
5. Access is given to write (update) e-Waybill information stored at back-office.
6. Access is given to write (update) e-Waybill information stored at the freight-level.

These six properties can be combined in $2^6 = 64$ ways in order to define different e-Waybill solutions. From the 64 possibilities, we consider 59 to be unrealistic, e.g., due to cases where no storage location is provided or when storage is provided at one location, while read and write access is provided only at the other location. This leaves us with five realistic solutions, which are presented in Table 3.1. For each of the solutions, we specify where (back-office and/or freight-level) the e-Waybill information is stored and where it can be read and written. In the column Read access to information, we summarize where the e-Waybill information can be read, since this is the most important property in our information synergy analysis.

Solution 1 stores e-Waybill information only at back-office, and read and write access to the e-Waybill is therefore only provided via connections to...
3.5. e-Waybill Solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Back-office Storage</th>
<th>Back-office Read</th>
<th>Back-office Write</th>
<th>Freight-level Storage</th>
<th>Freight-level Read</th>
<th>Freight-level Write</th>
<th>Read access to information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Back-office</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Back-office + Freight-level</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Back-office + Freight-level</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Back-office + Freight-level</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Freight-level</td>
</tr>
</tbody>
</table>

Table 3.1: e-Waybill solutions.

the back-office system. It should be mentioned that solution 1 corresponds to the solution that was proposed by IATA (2012). In solutions 2, 3, and 4, the e-Waybill information is stored both at back-office and at the freight-level, and read access is provided at both storage locations; however, they differ in where write access is given. For solution 2, write access (of e-Waybill information) is given both at back-office and at the freight-level. In solution 3, write access is given only at back-office, and in solution 4, which can be described as the inverse of solution 3 regarding write access, write access is given only at the freight-level. Finally, solution 5 corresponds to a typical paper waybill, i.e., the e-Waybill information is stored, and can be accessed, only at the freight-level. For the solutions that make use of storage both at back-office and at the freight-level (solutions 2, 3, and 4) there is a need for synchronization in order to keep both copies of the e-Waybill information up-to-date, however, for solutions 3 and 4, synchronization only need to occur in one direction. In addition, solution 2, which allows write access at both locations, is probably the most flexible solution. However, it requires conflict management in order to prevent inconsistency between the two copies of the e-Waybill information, since the e-Waybill potentially can be changed at both storage locations simultaneously.

We claim that each of our five e-Waybill solutions are able to provide the three main functions (of a waybill) that were discussed in Section 3.3. By requiring that the e-Waybill can be created only if there exists an agreement between the consigner and the carrier(s), it is able to serve as a proof that there exists a contract for transport (function 1). By making use of electronic signatures and authentication, the e-Waybill is able show which actors have been in control of the consignment and which actor is currently in control (function 2). In addition, it contains information about which actors will take over the control of the consignment in the future. Each of our five solutions provides storage capabilities (function 3). For functions 2 and 3,
we actually claim that an e-Waybill provide the functions in a better way than a traditional paper waybill is able to do. In most cases, electronic signatures provide better security than a traditional signature in order to verify the real identity of a person (who represents an actor), and an e-Waybill does not limit the amount of information that can be stored as much as a paper waybill does.

It should be noted that all access to the e-Waybill information is regulated by some kind of security mechanism, e.g., authentication, which prevents unauthorized actors from accessing the information. Different actors may have different types of read and write access, and a particular actor is typically only allowed to access parts of the e-Waybill information. For example, a driver may have both read and write access for some information types, while a customs officer is typically only allowed to read some types of e-Waybill information. In addition, for e-Waybill information stored at the freight-level, we assume that physical access to the location of the freight (e.g., a vehicle) is required in order to read or write e-Waybill information.

In particular for solution 5, which only stores e-Waybill information at the freight-level, it is relevant to mention that actors, who are in direct contact with the e-Waybill, are able to, and typically allowed to, make copies of the e-Waybill information. For example, the consigner and all involved carriers can make copies of the e-Waybill information before handing over the consignment to another actor. Such a copy reflects the state of the consignment at the particular point of time when it was made.

### 3.6 Analysis

In our information synergy analysis, we considered a subset of the ITS services that were identified by Jevinger et al. (2010) and Mbiydzenyuy et al. (2012). From the set of collected services, we removed duplicate services, as well as services with different names but identical functions. In our information synergy analysis, we considered the 20 services that are described in Table 3.2. We analyzed each of the services in order to identify what types of input information is required and what types of output is generated (see Table 3.2). The generated output was not considered in the synergy analysis, but is included in the table in order to facilitate the
understanding of the services.

We categorized the input information required by the ITS services into two categories of information (freight-level and back-office level) in order to explicitly illustrate that they need input that typically exist at different locations. The freight-level information category contains information types that normally are available at the location of the freight. Since freight is typically on-board vehicles, we included vehicle-related information in that category. In addition, we assume that all types of information that may be present in an e-Waybill belong to the freight-level category. The back-office information category contains information types that are normally accessed via a connection to a back-office system. In Table 3.2, we categorize the input required by each of the services based on our two information categories. For each of the services, the input entities that, according to our analysis, can be provided by an e-Waybill are written in italics.

We identified that all of the 20 ITS services require input that might be provided by an e-Waybill. By considering only the presence of information, and not taking the location for read access of the e-Waybill information into account, one could argue that there is a potential for information synergy between each of the services and each of the five e-Waybill solutions. That is, if a service needs input that can be provided by an e-Waybill, there is a possibility for information synergy regardless of where the e-Waybill information can be read. However, in our analysis, we consider a stronger type of synergy, where the possibility for information synergy between an ITS service and an e-Waybill solution depends on the storage location of the e-Waybill information.

<table>
<thead>
<tr>
<th>ITS Services</th>
<th>Required Input</th>
<th>Generated Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freight-level</td>
<td>Back-office level</td>
</tr>
<tr>
<td>E-call (EC)</td>
<td>Vehicle information, e.g., type and id, vehicle location, freight information, e.g., type and amount.</td>
<td>Information about an accident, e.g., location and the carried freight.</td>
</tr>
</tbody>
</table>
### Chapter 3. Information synergy between e-Waybill and ITS services

<table>
<thead>
<tr>
<th>Dynamic estimated time of arrival (ETA)</th>
<th>Freight and vehicle location, <em>freight destination.</em></th>
<th>Route related information, e.g., traffic and road conditions.</th>
<th>The estimated arrival time of a consignment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight mobility (FM)</td>
<td><em>Freight information,</em> e.g., <em>weight,</em> <em>value,</em> and <em>type,</em> freight location.</td>
<td>Road network information.</td>
<td>Information about freight movement.</td>
</tr>
<tr>
<td>Goods identification (GI)</td>
<td><em>Freight information,</em> e.g., <em>id,</em> <em>name,</em> <em>type,</em> <em>dimensions,</em> <em>amount,</em> and <em>weight.</em></td>
<td></td>
<td>Specification about goods, e.g., on-board a vehicle or in a container.</td>
</tr>
<tr>
<td>Information on extra-large cargo (XXL)</td>
<td><em>Freight information,</em> e.g., <em>weight and dimensions,</em> vehicle information, e.g., <em>weight and dimensions.</em></td>
<td>Road network information.</td>
<td>Information about road restrictions due to the carriage of extra-large freight.</td>
</tr>
<tr>
<td>Information on truck parking (ITP)</td>
<td><em>Freight destination,</em> vehicle destination.</td>
<td>Parking spot information, e.g., <em>entry/exit points,</em> <em>location,</em> <em>parking duration.</em></td>
<td>Real-time information about truck parking.</td>
</tr>
<tr>
<td>Navigation through a route network (NAV)</td>
<td><em>Freight and vehicle location,</em> <em>freight destination.</em></td>
<td>Traffic and road conditions, weather conditions, speed camera locations.</td>
<td>Route suggestion including specification of the route.</td>
</tr>
</tbody>
</table>
### 3.6. Analysis

| On-board safety and security monitoring (OSM) | Vehicle information, e.g., id and status, freight information, e.g., id, name, type, dimensions, amount, and weight, freight status. | Information about vehicle and freight safety status. |
| Real time track and trace of goods (RTT) | Freight location, freight information, e.g., id. | Real-time specification of freight location. |
| Remote declaration (RED) | Freight information, e.g., id, type, amount, origin and destination, vehicle information. | Real-time information about the vehicle and the freight (from a distance). |
| Road hindrance warning (RHW) | Freight origin and destination. | Current and expected traffic conditions, route specification. Information about obstacles on the road. |
| Sensitive goods monitoring (SGM) | Freight information, e.g., type, and amount, freight location and conditions. | Information about the location and status of sensitive goods. |
## Chapter 3. Information synergy between e-Waybill and ITS services

<table>
<thead>
<tr>
<th>Transport order handling (TOH)</th>
<th>Vehicle and freight location, freight information (for agreed and ongoing consignments), e.g., transport time window, amount, type, origin, and destination.</th>
<th>Description of order request(s).</th>
<th>Information about new transport orders, and already fulfilled and ongoing consignments.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight indication (WI)</td>
<td>Freight id and weight, vehicle information and location.</td>
<td>Route information.</td>
<td>Information about road restrictions and total weight of a vehicle.</td>
</tr>
<tr>
<td>Notify goods to load/unload (GLU)</td>
<td>Freight information, e.g., id, origin, destination, and actor information.</td>
<td></td>
<td>Information about goods to load/unload.</td>
</tr>
<tr>
<td>Notify missing/surplus goods (MSG)</td>
<td>Freight information, e.g., id and type, amount of freight to load or unload, vehicle information.</td>
<td></td>
<td>Information about missing or surplus goods.</td>
</tr>
<tr>
<td>Notify goods physical status (GS)</td>
<td>Freight information, e.g., id, type, and amount, freight temperature.</td>
<td></td>
<td>Information about the temperature of goods.</td>
</tr>
</tbody>
</table>
In order to enable a straightforward synergy analysis, we assumed that there are two storage locations that can be used to provide all input information required by an ITS service. Freight-level information is stored at the location of the freight, and back-office level information is stored in a single, back-office system. The latter has the implication that the back-office system needs to operate as an information repository, which provides various types of back-office level information to ITS services. In order to enable information synergy with an e-Waybill solution that stores information at back-office, it also needs to include e-Waybill information.

In Section 3.1, we introduced the concept of synergy between ITS services, and we discussed three types of synergies: functional, technical, and information synergy. Information synergy is achieved when two or more services share information, and it might exist in situations where, e.g., services are executed at the same location, or there exist communication

<table>
<thead>
<tr>
<th>Notify goods waiting (GW)</th>
<th>Freight information, e.g., id, type, origin, and destination, freight location.</th>
<th>Information about goods that is standing at the same location for a long time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notify lost goods location (LGL)</td>
<td>Freight information, e.g., id, type, amount, origin, and destination, freight location.</td>
<td>Information about the last known location of lost goods.</td>
</tr>
<tr>
<td>Notify goods unwanted location (GUL)</td>
<td>Freight information, e.g., id and type, freight location.</td>
<td>Information about goods that is forbidden to be placed at its current location.</td>
</tr>
</tbody>
</table>

Table 3.2: ITS services considered in the analysis.
links that connect services either directly with each other or with a shared information repository. For example, there may be information in the on-board unit (OBU) of a vehicle, which may be used by different ITS services. The services can make use of the information in the OBU, and achieve information synergy, either if they are implemented in the OBU or if they connect to the OBU.

In our synergy analysis, we focus on information synergy that involves the e-Waybill service, and in particular the situation where the e-Waybill provides information that may be used as input by other ITS services. We say that there is a possibility for information synergy between an e-Waybill solution and an ITS service if there is a communication link, between the e-Waybill information storage location and the ITS service, that has been established for transferring information that is not present on the e-Waybill. The synergy is realized when the already existing communication link is used for transferring e-Waybill information from the e-Waybill to the ITS service. The type of information synergy that was considered in our analysis is illustrated in Figure 3.1.

![Figure 3.1: Information synergy between an e-Waybill and an ITS service.](image)

In Figure 3.1, we separate the ITS service from the storage location in order to illustrate that ITS services may be executed at any location, i.e., not only at the locations where information is stored. A communication link between an ITS service and a particular storage location exists only if the service needs input that belongs to the information category represented by that location. It should be noted that, the service might have connections to one of the storage locations, or both of them, depending on which types of information it needs. Information synergy is possible if the e-Waybill
solution provides read access at, at least, one of the locations that is connected to the ITS service via a communication link. In the figure, we also include a synchronization link, which is used to synchronize the two copies of the e-Waybill information, and it is present only in those e-Waybill solutions where the information is stored both at the freight-level and at back-office, i.e., solutions 2, 3, and 4.

For ITS services that only require e-Waybill information as input, we argue that there exists a possibility for information synergy with all of the five e-Waybill solutions. The reason is that there exists no extra communication link for transferring other information, and that the communication link that needs to be used to transfer e-Waybill information can be established with whatever location that provides read access to the e-Waybill information. In the set of collected ITS services, there was one such service, i.e., Goods identification.

Based on what types of input is required by an ITS service, it is possible to categorize the 20 ITS services that were included in our analysis in two groups. Services that belong to the first category require both freight-level and back-office level input. In addition to e-Waybill information, they need both freight-level and back-office level input information. According to our definition of information synergy, there exist, for each of these services, communication links between the service and both of the storage locations (i.e., freight-level and back-office), which can be used to also transfer e-Waybill information. For these services, eight in total, there is a possibility for information synergy with each of the five e-Waybill solutions, since e-Waybill information can be transferred using one of the two already existing communication links. The second category contains services that only make use of information that belongs to the freight-level category. There were 12 services in this category, and by using the same type of reasoning as we did for the first category, we conclude that there is possible information synergy with those e-Waybill solutions that allow read access (of the e-Waybill information) at the freight-level storage location, i.e., solutions 2, 3, 4, and 5.

We conclude the analysis section by providing a short summary of the obtained results. We observed that e-Waybill solutions that allow read access to e-Waybill information, at least at the freight-level storage location (solutions 2, 3, 4, and 5), are able to provide better possibilities for
information synergy with ITS services, than the solution that only allow read access at back-office (solution 1). For services that need both freight-level and back-office level input, we argue that the e-Waybill solutions that store the e-Waybill information both at the freight-level and at back-office (solutions 2, 3, and 4) are more robust than the solutions that only store data at the freight-level, even though this could not be confirmed in our analysis. The reason is that they are less vulnerable to single points of failure.

3.7 Discussion and Concluding Remarks

In this paper, we have studied possible information synergies between the e-Waybill service and other ITS services. In our analysis, we have considered five different solutions for implementing the e-Waybill service, which differs in where the e-Waybill information is stored (at back-office and/or at the freight-level) and where read and write access, to the information, is provided.

Based on the results from our analysis, we conclude that e-Waybill solutions that store the e-Waybill information, at least, at the freight-level (solutions 2, 3, 4, and 5), enable better possibilities for information synergy than solutions that store information only at back-office (solution 1). The solutions that store the e-Waybill information both at the freight-level and at back-office (solutions 2, 3, and 4) require synchronization in order to ensure that both copies of the e-Waybill information are up-to-date. One of these solutions (solution 2) allows write access at both these locations, which is why it requires conflict management in order to maintain consistency between the two copies of the e-Waybill information. This solution may provide more robust write access than provided by the solutions that allow write access only at one location (solutions 3 and 4). However, the latter solutions do not suffer from possible inconsistencies, which might be caused by simultaneous updates of the e-Waybill information.

A possible implication of our study is that it may lead to the implementation of operational e-Waybill systems that enable high synergy with ITS services. This could contribute to a higher utilization of ITS services and more sustainable transport, e.g., in terms of reduced congestion and emissions, as well as increased safety. In addition, the method used in the analysis might
be used as a tool to support decisions regarding which type of e-Waybill solution is relevant to implement for a particular organization. For example, if a transport operator is interested in a certain set of ITS services, a similar analysis as we conducted could be made, however, by considering only the services that are relevant for the considered transport operator.

Our focus was on road transport, since we primarily studied road waybills in order to identify what types of information is typically included in a waybill, and in the analysis we considered ITS services for road transport. However, we have identified that the information included in waybills for other modes of transport, to a large extent coincide with the information present on road waybills. In addition, we argue that some of the studied ITS services should work equally well for other modes of transport, e.g., the service Notify goods unwanted location, which provides information (by sending notifications) about freight that is located at a location where it should not be. Therefore, we argue that the obtained results are valid also for other modes of transport. In fact, we believe that e-Waybill solutions that use storage both at back-office and at the freight-level could be a good basis for achieving a multi-modal electronic consignment document.

In the analysis, we chose not to consider aspects related to the quality of information, and we did not consider information synergy that appears when the ITS service is executed at the storage location of the e-Waybill information. The reason is that many ITS services are intended for multiple stakeholders that are active at different locations, and determining the execution location of an ITS service is often not possible. As mentioned in Section 3.6, we considered information synergy that is possible if the e-Waybill information that is needed as input to an ITS service can be transferred using an already existing communication link, i.e., a communication link that has been established for transferring other information than e-Waybill information. Despite the limitations of our study, we argue that the results are strong enough to draw conclusions regarding to what extent different solutions for implementing the e-Waybill service enable information synergy with ITS services.

Future work includes extending this study, e.g., by including aspects related to information quality in the analysis. Another possibility for future work is to analyze the technical requirements for each of the suggested e-Waybill solutions, and to study possible functional and technical synergies between
Chapter 3. Information synergy between e-Waybill and ITS services

the e-Waybill service and other ITS services.
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Technical requirements of the e-Waybill service

4.1 Introduction

An electronic waybill (e-Waybill) is a service that provides the functions of a paper waybill, and which is capable of storing, at least, the information present in a paper waybill (Bakhtyar et al., 2013a). An important purpose for using an e-Waybill is to enable faster (paperless) transfer of information during freight transport (see, e.g., (Pedersen et al., 2010)). In addition, e-Waybills contribute towards reducing the administrative overhead typically associated with paper waybills: paper waybills need physical storage space and sometimes require (mainly in transport involving multiple carriers) the same information to be written on several waybills. Furthermore, the authors in (Bakhtyar et al., 2013a) recently argued that the potential synergies between an e-Waybill and other services could lead to increased utilization of intelligent transport systems (ITS) services. In turn, this could lead to more sustainable transport, for example, by enabling more efficient use of vehicles and transport infrastructure.

There exist several examples of electronic replacements of the paper waybill. The International Air Transport Association (IATA) implemented an e-Waybill for air freight transport, which is referred to as an e-Air Waybill (IATA, 2012). Mei and Dinwoodie (2005) proposed an electronic version of the bill of lading, that is, the consignment document used in

Abstract

An electronic waybill (e-Waybill) is a service whose purpose is to replace the paper waybill, which is a paper document that traditionally follows a consignment during transport. An important purpose of the e-Waybill is to achieve a paperless flow of information during freight transport. In this paper, we investigate five e-Waybill solutions, that is, system design specifications for the e-Waybill, regarding their non-functional (technical) requirements. In addition, we discuss how well existing technologies are able to fulfill the identified requirements. We have identified that information storage, synchronization and conflict management, access control, and communication are important categories of technical requirements of the e-Waybill service. We argue that the identified technical requirements can be used to support the process of designing and implementing the e-Waybill service.
sea transport. For road transport, the company DHL implemented the DHL Express Waybill (see, (Cane et al., 2012)). Finally, a multi-modal e-Waybill, which is an important initiative for achieving the vision of using a single transport document during a consignment, was proposed in the e-Freight project (Cane et al., 2012). The e-Freight project also identified a number of implementation challenges, that is, accessibility, communication, security, ownership, and authentication, which should be considered when implementing their e-Waybill. As part of their analysis of synergies between an e-Waybill and other ITS services, five e-Waybill solutions are recently suggested by Bakhtyar et al. (2013a), which can be seen as abstract system design specifications for the e-Waybill service. The five solutions differ in where (at back-office and/or at the freight level) the e-Waybill information is stored, and where e-Waybill users are allowed to read and write e-Waybill information. A common property of the earlier e-Waybill initiatives is that they are based on storage of the e-Waybill information only at back-office (i.e., in a back-office system), whereas the solutions in (Bakhtyar et al., 2013a) also considers information storage by the freight.

In this paper, we contribute an extended analysis of the e-Waybill solutions provided in (Bakhtyar et al., 2013a). In particular, we identify and elaborate on the non-functional (technical) requirements of the solutions. We consider this to be important in order to support the implementation of an e-Waybill service that make use of storage both at back-office and by the freight. We regard the identification of the technical requirements of the e-Waybill service and the elaboration of technologies that can be used to implement the requirements as the main contribution of this paper.

The paper is organized in the following way. Our research methodology is presented in Section 4.2, followed in Section 4.3 by a discussion on the e-Waybill service and the recently proposed solutions for implementing the e-Waybill. The technical requirements for the e-Waybill solutions are identified in Section 4.4, followed in Section 4.5 by a detailed discussion on the identified technical requirements. The paper is concluded in Section 4.6.
4.2 Methodology

The requirements of a system are usually classified as functional and non-functional, where the functional requirements define what the system should do, and the non-functional requirements define how to achieve the functional requirements. Non-functional requirements can also be defined as attributes or constraints on a system (Glinz, 2007), and they may have a significant effect on the design and implementation decisions taken during the development of a system (Glinz, 2007). There exist several methods that can be used to identify the functional and non-functional requirements of a system. We used the structured analysis and design technique (SADT) method by Ross and Schoman Jr (1977), which is regarded as a classical work on requirements engineering, in order to identify the functional and non-functional requirements of the e-Waybill service (see also, Hansen and Lyytinen (2010); Kedad and Loucopoulos (2011)).

SADT suggests that the requirements of a system should be identified in a process involving three steps. The first step concerns identifying the context, and it should establish why the system is needed. The purpose of the second step is to identify what the system should do, by identifying what features are required in order to allow the system to operate in its context. The third step concerns identifying the non-functional (technical) requirements of the system, by determining how the system should be constructed.

The first two steps of SADT were implicitly addressed in previous work (Bakhtyar et al., 2013a). In this paper, the focus is on the third step, which we use in order to identify the technical requirements of the e-Waybill service. We derive these requirements by analyzing the implications of the functional requirements from the perspective of the five e-Waybill solutions suggested in (Bakhtyar et al., 2013a). Additionally, by studying the literature, we identify the existing technologies with potential to fulfill the technical requirements of the e-Waybill service. For each of the five e-Waybill solutions, we then elaborate on how the identified technologies are able to fulfill the technical requirements of the service. It should be mentioned that a functional requirement typically can be mapped into one or more technical requirement (Chung and do Prado Leite, 2009). We argue that this justifies our approach of using the functional requirements as a starting point for identifying technical requirements.
4.3 e-Waybill Service and Solutions

We define an e-Waybill as a service that provides the functions of a traditional paper waybill, and which is capable of storing, at least, the information present in a paper waybill. Furthermore, we refer to an e-Waybill solution as a design specification for the e-Waybill service. As mentioned above, the five solutions suggested by Bakhtyar et al. (2013a) differ in where the e-Waybill information is stored, and where read and write access are provided to the e-Waybill information. The e-Waybill information can be stored in an information system at the back-office (i.e., at the back-office level) and/or by the freight (i.e., at the freight-level), which is often inside the vehicle. It should be noted that access to information at the freight-level typically requires physical access to the freight. The two storage locations gives, together with the three properties of storage, and read and write access, the following six properties that can be used to define e-Waybill solutions:

1. The e-Waybill information is stored at back-office.
2. The e-Waybill information is stored by the freight, for example, in a hand-held device or on RFID tags.
3. Read access is given to e-Waybill information stored at back-office.
4. Read access is given to e-Waybill information stored by the freight.
5. Write access is given to e-Waybill information stored at back-office. It should be noted that the write access includes the possibility to update already written e-Waybill information.
6. Write access is given to e-Waybill information stored by the freight.

Based on these 6 properties, the authors in (Bakhtyar et al., 2013a) identified the five e-Waybill solutions that are specified in Table 4.1.

It is important to mention here that for e-Waybill solution 5, a copy of the e-Waybill should also be stored at the back-office; however, this copy of the e-Waybill is not synchronized with the e-Waybill stored by the freight. Hence, the up-to-date e-Waybill information is only present at the freight-level.
4.4 Requirements Identification

In this section, we present the technical requirements of the e-Waybill service, which we have identified by following the SADT method (see Section 4.2). The first and second steps of the method have been mainly addressed in (Bakhtyar et al., 2013a), and they are discussed in the two first subsections of this section. The third step, whose outcome is the main contribution of this paper, and in which the technical requirements are identified, is discussed in the third subsection of this section.

Table 4.1: The e-Waybill solutions.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Back-office Storage</th>
<th>Read</th>
<th>Write</th>
<th>Freight-level Storage</th>
<th>Read</th>
<th>Write</th>
</tr>
</thead>
<tbody>
<tr>
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<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

Step 1: Why is an e-Waybill service needed?

As discussed in Section 4.1, the e-Waybill service, as an electronic replacement of the paper waybill, has potential to contribute to a paperless flow of information in freight transport and faster flow of freight information. Additionally, the e-Waybill service may reduce the administrative costs that are typically associated with paper waybills, for example, since paper waybills need physical storage space, and since there are situations (mainly in transport involving multiple carriers) that require that the same information is written on several waybills. By utilizing synergies between ITS services, the e-Waybill service, if implemented with storage of the e-Waybill information both at back-office and at the freight-level, also has the potential to contribute to increased use of ITS services.

Step 2: What are the functional requirements of the e-Waybill service?

As an electronic replacement of the paper waybill, the e-Waybill service
should provide the same functions as the paper waybill:

1. It should be able to prove that there exists a contract for transport, which is important since there should exist an agreement specifying the conditions for transport.
2. It should be able to show which actors have been in control of the consignment, who is currently in control, and who will be in control in the future.
3. It should be able to store the essential consignment information.

We also consider authorized read and write access to the e-Waybill information as a functional requirement (requirement four) of the e-Waybill service, even though this is not directly implied from the functions of a paper waybill. The reason is that an e-Waybill, in particular when back-office storage is used, has the potential to be accessed by users without physical access to the storage medium, which is not the case for a paper waybill. Bakhtyar et al. (2013a) argue that the five considered e-Waybill solutions, which specify the locations for storage, and read and write access to the waybill information, are capable of providing the identified functions of the e-Waybill service. We have therefore chosen to use the five e-Waybill solutions provided in (Bakhtyar et al., 2013a) as input to the technical requirement specifications step (step 3 of SADT), which is presented in the next subsection.

**Step 3: What are the technical requirements of the e-Waybill service?**

As mentioned above, we based the technical requirement identification process on the identified functional requirements of the e-Waybill service and the three properties of storage, and read and write access, which are central in the considered e-Waybill solutions. The identified technical requirements are further discussed in Section 4.5.

There are several technical requirements concerning the third functional requirement, that is, that the e-Waybill should be able to store the essential e-Waybill information. Each of the five e-Waybill solutions specifies whether the e-Waybill information should be stored at back-office, by the freight, or at both of these locations. The types of storage medium needs to be chosen
4.4. Requirements Identification

in a way that it allows read and write access to the e-Waybill information at the location(s) where read and write access should be provided, respectively. In addition, the storage medium needs to be large enough to store all relevant e-Waybill information, as well as any other information that is considered relevant to store. To address the functional requirement of read and write access (the fourth requirement), the e-Waybill information may be read and written only by authorized actors, and there should exist some type of mechanism to enable authorized read and write access. Hence, we regard access control, including authentication control, as an important technical requirement of the e-Waybill. It might also be relevant to store the e-Waybill information in an encrypted form, which is important, for example, in situations where it is impossible to prevent physical access to the storage medium.

To address the first and second functional requirements of the e-Waybill, that is, it should be able to prove that there exists a contract for transport and it should be to show which actors been (currently is and will be) in control of the consignment, we also consider communication as an important category of technical requirements. In order to enable read and write access to the e-Waybill information, there needs to exist fast and reliable communication links between the e-Waybill information storage locations and the actors with access rights. The communication links may be permanently active, or active only when an actor or a system needs to access the information. When the e-Waybill information is stored both at back-office and by the freight, there also needs to exist communication links between the two e-Waybill information storage locations. Finally, it is important to emphasize that the communication links need to be secure enough to ensure that only authorized users are able to access the e-Waybill information in clear text, that is, in an unencrypted form.

For the e-Waybill solutions 2, 3, and 4 (where the e-Waybill information is stored, and can be read, both at the back-office and by the freight) there is a need for synchronization in order to make sure that an up-to-date version of the e-Waybill information is available for read access at both of the storage locations: the updates made at one location need to be made also at the other location. Conflict management is needed in solution 2, where write access is provided at both of the storage locations, in order to deal with conflicts that may occur due to simultaneous updates. In summary, we have identified
four categories of technical requirements, which we further elaborate on in the next section, that is, 1) information storage, 2) access control, 3) communication, and 4) synchronization and conflict management.

4.5 Discussion on the Technical Requirements

In this section, we provide a detailed discussion on the identified technical requirements of the e-Waybill service. In addition, we elaborate on existing technologies, which might be used to fulfill the identified requirements.

4.5.1 Information Storage

The type of e-Waybill information is necessary to take into account, when choosing the type of storage media to use, because different types of information puts different requirements on the storage media. Some of the e-Waybill information remains static throughout a transport, for example, goods id and type, as well as specification of the consigner and the consignee. The e-Waybill also includes dynamic information, for example, the information about who is currently in control of the consignment, which is updated whenever a new actor (e.g., a carrier) takes over the responsibility for consignment. Barcode labels would work for static e-Waybill information; however, the limited storage capabilities of barcode labels typically make it impossible to use them for storing all of the e-Waybill information. An option would be to use a barcode label to store only the e-Waybill identifier, while the remaining information could be stored in a handheld device. For dynamic information, a possible choice is to use RFID tags, which have larger storage capabilities than barcode labels. The e-Waybill information may be also stored, potentially in combination with other storage medias, in handheld devices, and in the On-Board Unit (OBU) of a vehicle or in similar systems, for example, in terminals. A handheld device with barcode or RFID tag reading capabilities can be used to scan the goods, and transmit information to other storage medias, such as an OBU. At back-office, for example, a customer order system or an Electronic Data Interchange (EDI) system (see, e.g., (Lankford and Johnson, 2000)), is capable of storing the e-Waybill information. In addition, the storage media
should have the capability to allow read and write access to the e-Waybill information. For the e-Waybill information stored at back-office, this can be achieved via an Internet connection. At the freight-level, there are different options for storing the e-Waybill information. For example, actors with physical access to the freight may connect to the e-Waybill using a handheld device with capabilities to read barcode labels or RFID tags. As mentioned above, information can also be stored in OBUs or in similar systems, which may be accessed using short distance wireless communication.

The storage media should have the capability to allow only legitimate actors to access the e-Waybill information. This can be achieved by using some kind of authentication control mechanism, for example, including an electronic signature. Access control mechanisms are further discussed in the next section. In order to further protect the e-Waybill information, there are situations where the information needs to be stored in an encrypted form. There exist several algorithms that can be used to encrypt and decrypt the e-Waybill information, for example, symmetric-key and asymmetric-key cipher techniques. At the back-office level, as well as in OBU’s and handheld devices, any type of state-of-the-art cryptographic techniques (see, e.g., (Pedersen et al., 2010)) can be used. An example of a technique that can be used to together with RFID tags is public-key cryptography, which was suggested in (Batina et al., 2007).

As mentioned above, the e-Waybill information may be stored by the freight using barcode labels, but their limited storage capabilities and non-line-of-sight, as well as the impossibility for multiple-tag simultaneous-reading from a short distance, make RFID more efficient than barcode labels (Wu et al., 2006). RFID tags are a possible alternative because of their storing, updating, communication, and information security capabilities. An e-Waybill contains sensitive information about a consignment, and RFID tags have been earlier used to store sensitive information, such as biometric data and electronic signatures, for example, in passports (Monnerat et al., 2007). Additionally, RFID tags have the capability to incorporate sensor readings, which makes it possible to use them in applications that require monitoring, asset management, and tracking (Li et al., 2008). Examples from the literature show that the integration of RFID and the Internet may enable supply chain management systems with capabilities such as inventory monitoring, and track and trace
Chapter 4. Technical requirements of the e-Waybill service

of goods (Delen et al., 2007; Wu et al., 2006; Zhou et al., 2007).

4.5.2 Access Control

There exist several mechanisms that can be used in order to control who should be allowed to access what resources, for example, role-based access control, task-based authorization control, and the fine-grained object approach (see, (Kang et al., 2001)). For each of the e-Waybill solutions specified in Table 4.1, there needs to be proper authentication and authorization mechanisms at each of the locations where the e-Waybill information is available for read and/or write access. For example, in e-Waybill solution 2, which allows read and write access at both the back-office and by the freight, authentication and authorization access control needs to be implemented at both locations.

Authentication concerns proving that a user is the person who he or she claims to be. For the e-Waybill, the access control mechanism must ensure that only legitimate actors or systems should be able to use the service. In addition, a particular actor or system should only be given access to read and write e-Waybill information based on what they are authorized to do. Traditionally, username and password are used to authenticate actors who want to access a system. Another way to ensure that only authorized users are given access to the e-Waybill information is to use an electronic signature, which can be used in order to guarantee that only genuine actors are able to write e-Waybill information. There should be a mechanism to prove the integrity of an electronic signature, in order to validate that a particular signature is associated with a genuine actor or system. A private-public key encryption mechanism can be used to implement an electronic signature, where the signature is encrypted using the private key of the signer and decrypted using a public key by the verifier. A certification authority (CA) could be responsible for handling the public keys of an actor or system, and in that way verify that a particular actor or system is the owner of a particular public key (Li et al., 2008).

For authorization control, there exist several models, which are all based on two authorization models, that is, mandatory and discretionary access control (see, e.g., (McCune et al., 2006; Osborn et al., 2000; Ray and Kumar, 2006; Yuan and Tong, 2005)). We believe that a customized authorization
mechanism should be developed primarily based on the preferences of the organizations using a particular e-Waybill system. The organization’s preferences are important to consider, because different organizations may have different policies for accessing the e-Waybill information. It should be up to the involved organizations to decide which e-Waybill information to be accessible by a particular actor.

4.5.3 Communication

For enabling the users to access the e-Waybill, there should exist communication links between the storage locations (where access is provided) and the actors with access rights. As will be discussed in the next subsection, for the e-Waybill solutions that store the e-Waybill information both at the back-office and by the freight, there also needs to exist a communication link for synchronization between the two storage locations. The communication links need to be active only when the e-Waybill information is accessed or synchronized.

The distance over which communication needs to occur may have implications on the type of communication link that could be used. The e-Waybill information stored at back-office may typically be accessed using an Internet connection. In this case the communication distance does not really matter, since the Internet is accessible worldwide. For actors with physical access to the freight, communication could occur directly using a handheld device or short-distance wireless communication, for example, Bluetooth and Wi-Fi. Short-distance communication can also be used for communication in case multiple types of storage medias are used at the freight level, for example, both RFID tags and an OBU. Remote communication, which is important for synchronization purposes, requires that the e-Waybill information is stored in a device with an Internet connection.

In order to prevent unauthorized access to the e-Waybill information, the communication links need to be secured. For short distance communication, there exist networking techniques that enable secure communication, including Wi-Fi, Bluetooth, and ZigBee (see, e.g., (Bakhache et al., 2013; Saponara et al., 2013)). For communication over the Internet, there is typically a need to secure the information using cryptographic techniques.
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4.5.4 Synchronization and Conflict Management

As mentioned in the previous subsection, there is a need for a communication link, for synchronization, between back-office and the freight-level, for those e-Waybill solutions that store e-Waybill information at both of the locations. Synchronization is important in order to make sure that up-to-date e-Waybill information is available at both storage locations.

In solutions 3 and 4, where the e-Waybill information may be written at only one location, at back-office in solution 3 and at the freight-level in solution 4, synchronization only requires replicating the up-to-date information from the location where write access is provided to the other location. In solution 2, write access is given both at back-office and at the freight-level, and simultaneous updates of the e-Waybill information may result in update conflicts. Therefore, there is a need for a conflict management mechanism.

Defining access rights (authorization) for different actors may be helpful in order to prevent conflicts, because limiting the access rights of the users as much as possible reduces the possibility of conflicts. As mentioned in Section 4.5.2, we believe that there is a need for a customized access control mechanism, since organizations typically have different actors with different roles. It should be up to the organizations involved in a consignment to define which parts of the e-Waybill information should be accessible, for read and write respectively, for a particular actor at a particular location. For example, a consigner may have access to the e-Waybill information only at the back-office, whereas a driver may only have access at the freight-level.

Another approach is to completely avoid update conflicts, for example, by using sessions (see, (Lee et al., 2004)) when updating the e-Waybill information. In this type of mechanism, only one actor (or system) is allowed to update (write) the e-Waybill information at the same time. Once an actor requests to update the e-Waybill information, a session manager locks the e-Waybill service for updates by other actors. If more than one actor wants to update the e-Waybill information at the same time, the session manager has a choice to use either a time-based or role-based access policy. In a time-based policy, the actors that request to update the e-Waybill information are placed in a queue, and in a role-based policy, importance is given to the role of an actor. In the latter case, a priority needs to be defined for each of a number of organizational roles.
4.6 Conclusion

We have identified and elaborated on the technical requirements for different system designs of the e-Waybill service, based on the properties of storing and accessing the e-Waybill information at the back-office and at the freight-level. The identified technical requirements are derived from the functional requirements of the e-Waybill service and they concern aspects related to information storage, access control, communication, and synchronization and conflict management. In addition, we have discussed existing technologies regarding how they are able to fulfill the identified requirements.

We have considered five e-Waybill solutions, which can be seen as abstract system design specifications for the e-Waybill service (see, Table 4.1). These solutions are of three types: solution 1 is a back-office solution, solution 5 is a freight-level solution, and solutions 2, 3, and 4 are both back-office and freight-level solutions, which differ only in where write access is given to the e-Waybill information. We conclude that there are technical requirements, which are common for all of the solutions, for example, the need to protect the e-Waybill information using cryptographic techniques and authorization control. There are also requirements that only concern some of the solutions, mainly synchronization and conflict management. For solutions 2, 3, and 4, where the e-Waybill information is stored (and read access is provided) both at back-office and by the freight, there is a need for synchronization in order to maintain up-to-date versions of the e-Waybill information at both locations. Solution 2 also requires a mechanism for resolving conflicts that may occur as a consequence of simultaneous updates. The reason is that solution 2 provides write access at both of the locations. For solutions 1 and 5, where the e-Waybill information is stored only at one location, there is no need for synchronization and conflict management. At back-office, where the e-Waybill information is typically stored in an information system, the identified technical requirements can be fulfilled using standard technologies. For example, access may be provided and controlled using an Internet connection and standard access control mechanisms. For information stored by the freight, there are typically more options regarding how to fulfill the technical requirements. The e-Waybill information may be stored, for example, directly on the freight (using barcode labels or RFID tags), in handheld devices, or in the OBU's of the vehicles that carry the
freight. It is also possible to use multiple storage medias, where electronic communication needs to occur in between. For example, barcode labels could be used to store static information about a consignment, and other storage medias could be used to store dynamic information. Short distance communication may be based on technologies, such as Bluetooth and Wi-Fi. Long distance communications links using the Internet need to exist in order to enable synchronization and conflict management and to allow remote actors to access the e-Waybill information. It is important to secure these communication links using cryptographic techniques, in order to prevent unauthorized access to the e-Waybill information. In Table 4.2, we summarize the identified technical requirements for each of the five e-Waybill solutions.

<table>
<thead>
<tr>
<th>Technical requirements</th>
<th>e-Waybill solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Encrypted information storage</td>
<td>yes yes yes yes yes</td>
</tr>
<tr>
<td>Static and dynamic information storage</td>
<td>yes yes yes yes yes</td>
</tr>
<tr>
<td>Information storage by the freight</td>
<td>no yes yes yes yes</td>
</tr>
<tr>
<td>Information storage at back-office</td>
<td>yes yes yes yes no</td>
</tr>
<tr>
<td>Read access control by the freight</td>
<td>no yes no yes yes</td>
</tr>
<tr>
<td>Write access control by the freight</td>
<td>no yes no yes yes</td>
</tr>
<tr>
<td>Read access control at back-office</td>
<td>yes yes yes yes no</td>
</tr>
<tr>
<td>Write access control at back-office</td>
<td>yes yes yes no no</td>
</tr>
<tr>
<td>Synchronization</td>
<td>no yes yes yes no</td>
</tr>
<tr>
<td>Conflict management</td>
<td>no yes no no no</td>
</tr>
<tr>
<td>Long distance communication links</td>
<td>yes yes yes yes no</td>
</tr>
<tr>
<td>Short distance communication links</td>
<td>no yes yes yes yes</td>
</tr>
</tbody>
</table>

Table 4.2: Technical requirements of the e-Waybill service.

The identified technical requirements may, to a large extent, solve the implementation challenges identified in the e-Freight project (see, (Cane et al., 2012)) for implementing the e-Freight multimodal e-Waybill. Cane et al. (2012) identified accessibility, communication, interoperability, security, ownership, and authentication as the main implementation challenges for their multimodal e-Waybill solution, which is also based on storage of e-Waybill information at different locations. Accessibility concerns having access to the e-Waybill information at the right time and place. The technical requirements, identified in this paper, regarding information storage have the potential to solve the challenge of accessibility by ensuring
4.6. Conclusion

that the e-Waybill information is accessible where it is stored. The communication challenge concerns the capability to exchange e-Waybill information between all the actors. This challenge is addressed by the technical requirements that concern access control and communication. The challenge of security is about authentication and authorization, and can be addressed by the technical requirements for read and write access control. The ownership of business data is about users having control of their own business data and it can be ensured by considering the technical requirements for encrypting the e-Waybill information and synchronization between the different e-Waybill information storage locations. It is our belief that the identified technical requirements can be used to support the process of designing and implementing the e-Waybill service. We argue that the organizational preferences also need to be considered in the design process, in particular concerning the choice of a proper access control mechanisms. However, in order to achieve acceptance of an e-Waybill service, we suggest that it, at least in its early versions, should allow the users to work in a similar way as they are used to work with a paper waybill. Therefore, the e-Waybill service should not require significant organizational changes for the involved actors. In addition, an organization interested in implementing the e-Waybill service could consider the technical requirements discussed in this paper in order to support the process of choosing which of the five e-Waybill solutions to use, as well as to choose which technologies to use when implementing the chosen e-Waybill solution extensions.
A simulation study of the electronic waybill service

5.1 Introduction

In this paper, our aim is to design and perform a simulation experiment for investigating the impact on process time for a potential electronic waybill (e-Waybill) application compared to a paper waybill as mostly used today. Different processes that occur during freight transport, such as verification and validation of freight’s status, or handover of responsibility, utilize different lengths of time depending on several factors, such as resource availability, load level (e.g., queue or no queue), type of network and products. The waybill is at the center of some of these processes and whether they are handled electronically or physically with pen and paper could have an impact on the resources utilization, in particular the time taken by the different processes for completion. One way to understand how resources are utilized is by simulating the different processes. An e-Waybill is an electronic version of the paper waybill, which can be used for different purposes during and after the transport, e.g., a receiver signed waybill may be used by the transport company as a proof that the order has been completed successfully. In an earlier study (Bakhtyar et al., 2013a), five different e-Waybill solutions were proposed. The solutions differ in where the e-Waybill information can be stored and updated. It was found that the e-Waybill solution where the information is stored, read, and updated both
Chapter 5. Simulation study of e-Waybill service

the back-office and in the vehicle can support greater number of intelligent transport systems (ITS) services when compared to the other e-Waybill solutions (Bakhtyar et al., 2013a). Therefore, in this paper, our focus is on the particular e-Waybill solution where both the copies of the e-Waybill, i.e., at the back-office and in the vehicle, are synchronized and hence a change in the e-Waybill at the back-office will be visible at the vehicle and vice versa.

A simulation experiment, if properly designed, is a cost-effective way of testing a model of the real world without losing too many details of the real world object under investigation. It should be noted here that, for the rest of this paper, we use the term waybill to represent both electronic and paper waybills. However, in certain situations, we use the terms paper waybill and e-Waybill whenever the focus is on those particular types of waybills. In particular, we use modeling and simulation to investigate:

- The processing time taken by a waybill at different nodes (processing time)
- The total time taken by a receiver signed waybill to reach back the transport company (i.e., invoicing time)

The focus of our model is on the waybill-centric processes that occur at the Transport Service Provider (TSP), and at the freight loading and unloading locations, which we refer to as nodes. In particular, our focus is on the waybill creation process at the TSP facility, and the waybill processing at different loading and unloading nodes. Traditionally, the waybill processing at nodes include the time taken to transfer a waybill from one actor to another, checking the waybill for any inconsistency, verifying that the freight and its conditions are similar to the specifications mentioned in the corresponding waybill, and updating the waybill, e.g., signature or comments.

The remainder of the article is organized as follows. In Section 5.2, we describe related work similar to our study. Next, In Section 5.3, we discuss the important steps in a real world transportation process. Based on Section 5.3, we present our simulation model in Section 5.4. In the next Section, i.e., Section 5.5, we implement our simulation model in an experiment involving a road network used by a medium-sized Swedish transportation company. Next, in Section 5.6, we present analysis of the results from our experiment.
Finally, in Section 5.7, we summarize our main conclusions and highlight directions for future research.

5.2 Related Works

In the literature, there are several studies that investigate the effects of information sharing in the supply chain; see, (Croom et al., 2007; Fawcett et al., 2009; Liu and Kumar, 2011; Sezen, 2008), for overviews. There also exist studies whose focus is on assessing the benefits of using e-Waybill solution in place of paper waybills. In a study (Mei and Dinwoodie, 2005), it is found that a savings of US $125 per document-set can be achieved when using electronic bill of ladings (eBoL) instead of a paper based bill of lading (BoL), which is a type of waybill (Mei and Dinwoodie, 2005). The study (Mei and Dinwoodie, 2005) found that different problems related to the use of BoLs are: delays in information gathering, typing errors, excessive paperwork, increased waiting time for authorization, high turnaround time, cost, and fraud factors. Additionally, the study found that the key benefits concerning eBOLs are: quick documentation processes, better management of information, and postal savings.

In another study (Fosso Wamba and Boeck, 2008), the effects of using different technologies for information flow (including creation and exchange of BoLs) in a retail supply chain are assessed. It is found that, using RFID (Radio-Frequency Identification) and EPC (Electronic Product Code) network, a saving of 355 seconds in process time can be achieved in different processes, such as data entry, generating document, and verifying data, performed on a BoL (Fosso Wamba and Boeck, 2008). The study that is most closely related to our work is by Pocuca et al. (2000). In this study, the authors perform a simulation experiment for two scenarios; one for paper documents, and one using electronic documents in a supply chain. The study (Pocuca et al., 2000) is aimed at identifying the value of e-commerce technologies in the supply chain. It is found that electronic documents reduces the transaction costs as it reduces the time required to create and obtain such documents as compared to paper documents. Additionally, the study has shown that, for a total of 103 documents in a supply chain, the electronic documents are 39% less expensive than the paper documents (Pocuca et al., 2000).
Chapter 5. Simulation study of e-Waybill service

The main difference between the focus of this paper and the related research discussed above is that none of the studies focus specifically on e-Waybill solutions for road transport. The study (Pocuca et al., 2000) focuses on all the documents (103 in total) that are used in a typical shipment. Further, the study focuses on maritime transport comprising of almost all the actors involved with handling the 103 shipment documents. We design and perform a simulation experiment to assess the resource utilization when using an e-Waybill instead of the traditional paper waybills in a road transport scenario. We believe that the results from our study will provide an evidence of the time saving effects when using an e-Waybill, which is currently missing in the existing studies on e-Waybill solutions for road transportation.

5.3 Real World Process

In executing a freight transport service, several interdependent activities need to be coordinated in order to maximize the efficiency of the service. Such activities are proceeded by; instantiation activities that are initiated by orders arrival, which are then followed by control and assurance activities that are aimed at managing the chain of control and responsibility assuring the transport operations and a feedback loop reaffirming the results of various undertakings.

Initialization-In most transport companies, when an order arrive, via email, phone, fax, word of mouth or other communication facilities, the following activities are performed.

1. The consigner may contact one or more transport service providers (TSPs) to negotiate the terms (usually the price) of the transport service and the type of services needed, e.g., origin, destination, lot size and so on.

2. Once an agreement between the consigner and a TSP is reached, a waybill (with 4 copies) is created by the TSP. The waybill has essential information about the consignment, such as freight specifications, origin, and destination.
3. Three copies of the waybill are then forwarded to a transport planner (TP), who maintains a record of all the trucks and the drivers, and one copy is transferred to the concerned department (usually a record keeping department). At this point, the waybill is ready to be assigned to a truck.

4. A truck may be assigned multiple waybills (i.e., a batch of waybills) by the TP for different reasons, e.g., the freight volume and weight may be low and there might be multiple consignee or consigners on the route that is to be traveled by the particular truck. A single waybill consist of three identical copies, i.e., one copy each for the driver, consigner, and the consignee. In the rest of this paper, we refer to this step as the batching process.

5. The truck (after the batch has been assigned to it) travels on a particular route, which consists of all the freight loading and unloading locations (nodes) specified in assigned waybills.

6. At the freight loading node (i.e., the consigner facility), the driver reports to the gate. Clearance operations, such as drivers license, vehicle id and type, are performed and copies of the waybill are transferred to a representative of the consigner.

7. The representative may inspect waybill information and the driver may inspect the freight. Once inspections are over, the freight is loaded and all the copies of the waybill are signed by the representative. The driver may enter additional remarks to the waybill, e.g., on the physical condition of the freight. A copy of the waybill is left to the representative and the driver drives to the next loading or unloading location.

8. The driver follows instructions from the back-office for the next nearest location to visit. In case of no instructions from the back-office, we assume that the driver checks the waybills for the next nearest location to visit. If the next location is a loading point then step 6 is repeated, otherwise step 9 is performed.

9. On reaching a consignee location (i.e., unloading node), different checks, such as driver id, license, vehicle id and type, are performed and copies
of the waybill are transferred to a representative of the consignee. The freight is unloaded and checked against the waybill by the representative. All the copies of the waybill are signed and any remarks may be written on it. A copy of the waybill is left to the consignee and the driver drives to the next loading or unloading location.

10. Steps 6-9 are repeated until the last order is completed by the truck. The driver then drives back to the TSP facility, i.e., the TSP node, along with the signed waybills for the completed orders.

Feedback and confirmation:

11. Upon reaching the TSP node, the signed waybills are handed over to the concerned department (usually the invoicing department).

12. The invoicing department sends a copy of the consignee signed waybill to the consigner via fax, email, or post in order to claim payment for the transport services.

13. Upon receiving of the payment, the order is considered to be completed.

5.4 The Model

In order to design a simulation model reflecting the scenario described above, the main activities relevant to a waybill have been considered thus; the initialization, control and assurance, and the feedback and confirmation components. In order to simulate the processes affecting waybill related operations in the identified components, different simulation entities have been considered: 1) the waybill itself shall be treated as a meta-entity on which several operations can be performed, such as create, and update. These entities are updated at different nodes, i.e., their values changes depending on the current node; 2) resources for processing waybill are also considered as important entities in the simulation since it is important in this study to generate information about time utilization for both e-Waybill and paper waybill.
5.4. The Model

The activities that are considered in our model are focused on the operations that can be performed on a waybill. These include: creation, batching, and assigning of a waybill at the TSP location, and the processing of the waybill at the freight loading and unloading locations. It should be noted that these activities are performed on a waybill by the resource. Upon completion of an activity, an event is generated, which changes the state of the system. The events are based on the activities, e.g., upon successful completion of the waybill creation activity, an event is generated to initiate the batching activity. In our model, the events are: waybill created, waybill batched, waybill assigned, and waybill reached loading location, waybill reached unloading location, and waybill reached TSP. In Table 5.1, we present the notations that we have used in our simulation model, which we illustrate using Algorithm 1.

<table>
<thead>
<tr>
<th>Notations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Total number of waybills/orders</td>
</tr>
<tr>
<td>i ∈ O = {1, 2, 3...n}</td>
<td>A set of orders arriving at the TSP</td>
</tr>
<tr>
<td>j ∈ W = {1, 2, 3...n}</td>
<td>A set of waybills</td>
</tr>
<tr>
<td>k</td>
<td>No. of nodes</td>
</tr>
<tr>
<td>Wij</td>
<td>Represents a waybill j for each corresponding order i, ∀ i ∈ O, j ∈ W Wij = 1 otherwise 0</td>
</tr>
<tr>
<td>B</td>
<td>Represents a batch of waybills</td>
</tr>
<tr>
<td>BT</td>
<td>Time taken to create a batch of waybills</td>
</tr>
<tr>
<td>M</td>
<td>Maximum number of waybills in a batch</td>
</tr>
<tr>
<td>Q</td>
<td>Waybill waiting time in queue</td>
</tr>
<tr>
<td>R</td>
<td>Represents staff (resources) for processing waybills</td>
</tr>
<tr>
<td>S</td>
<td>Waybill processing time at TSP</td>
</tr>
<tr>
<td>Ŝ</td>
<td>Waybill processing time at nodes</td>
</tr>
<tr>
<td>process(Wij)</td>
<td>A function to calculate processing and queue time of a waybill Wij for i ∈ O and j ∈ W</td>
</tr>
<tr>
<td>size(B)</td>
<td>A function to calculate no. of waybills in a batch</td>
</tr>
<tr>
<td>S(Wij)</td>
<td>Waybill service and queue time at TSP for i ∈ O and j ∈ W</td>
</tr>
<tr>
<td>Ŝ(Wij)</td>
<td>Waybill service and queue time at nodes for i ∈ O and j ∈ W</td>
</tr>
<tr>
<td>current(R)</td>
<td>Function to check status of Staff</td>
</tr>
<tr>
<td>TT(Wij)</td>
<td>Travel time of waybills, which is calculated by a function f(B) for i ∈ O and j ∈ W</td>
</tr>
<tr>
<td>T(Wij)</td>
<td>Travel time of electronic waybills (Equation 3) for i ∈ O and j ∈ W</td>
</tr>
<tr>
<td>T(Wij)</td>
<td>Travel time of paper waybills (Equation 2) for i ∈ O and j ∈ W</td>
</tr>
<tr>
<td>f(B)</td>
<td>Function to calculate travel time of waybills</td>
</tr>
</tbody>
</table>

Table 5.1: Processes and notations used in our model.
Algorithm 1 Our Model.

1: procedure WAYBILL (W)
2: \[ W_{ij} = 1 : i \in O \land j \in W \]
3: \( \text{size}(B) = \text{null} \)
4: \( \text{process}(W_{ij}) = \text{null} : i \in O \land j \in W \)
5: \( f(B) = \text{null} \)
6: \( \text{current}(R) = \text{false} \)
7: \( IT(W_{ij}) = BT(W_{ij}) = S(W_{ij}) = 0 : i \in O \land j \in W \)
8: \( Q(W_{ij}) = \hat{S}(W_{ij}) = 0 : i \in O \land j \in W \)
9: \( S = Q = 0 \)
10: for \( i \in O \) do
11: \( \text{while } W_{ij} > 0 \text{ do } \forall j \in W \)
12: \( \text{Call } \Rightarrow \text{process}(W_{ij}) \)
13: \( \text{process}(W_{ij}) \)
14: \{ \)
15: \( \text{if } \text{current}(R) = \text{false} \text{ then} \)
16: \( \text{current}(R) = \text{true} \)
17: \( S = \tau(W_{ij}) \)
18: \( \text{Increment } i \)
19: \( \text{current}(R) = \text{false} \)
20: \( \text{Return } S, Q \)
21: \( \text{else} \)
22: \( \text{if } \text{current}(R) = \text{true} \text{ then} \)
23: \( Q = \tau(W_{ij}) \)
24: \( \text{GOTO 15} \)
25: \} \)
26: \( \text{end if} \)
27: \( \text{end if} \)
28: \( \hat{S}(W_{ij}) = S + Q : j \in W, i \in O \)
29: \( BT = \sum_{j} W_{ij} : i \in O \)
30: \( \text{if size}(B) = M \text{ then} \)
31: \( TT(W_{ij}) = f(B) \)
32: \( \hat{S}(W_{ij}) = \text{process}(W_{ij}) \)
33: \( \text{end if} \)
34: \( IT(W_{ij}) = S(W_{ij}) + \hat{S}(W_{ij}) + BT + TT(W_{ij}) \)
35: \( \text{end while} \)
36: \( \text{end for} \)
37: \( \text{end procedure} \)
For a waybill $W_{ij}$, the total processing time (PT) is a sum of the processing time at the TSP and the processing at the loading and unloading nodes. It can be represented as:

$$PT = S + Q + BT + \hat{S}(W_{ij})$$ (5.4.1)

For the total travel time of a waybill, we assume that the nodes are statically located. Hence, the total travel time for a paper waybill consists of the travel time from node 1 to $k$ and back to node 1. Therefore, the total travel time for a paper waybill can be represented as twice the travel time between node 1–$k$.

$$T(W_{ij}) = 2 \times \sum_{l=1}^{k} T_l$$ (5.4.2)

In the case of e-Waybill, the total travel time will be the total travel time from node 1 to $k$ without the factor of 2. This is because the e-Waybills are synchronized and a change of status to the e-Waybill at node $k$ will result in updating the e-Waybill copy at the node 1.

$$\hat{T}(W_{ij}) = \sum_{l=1}^{k} T_l$$ (5.4.3)

The invoicing time for a waybill, i.e., $IT(W_{ij})$, is a sum of the total processing time at TSP, processing at different nodes, i.e., at freight loading, and freight unloading nodes, and the total travel time, which we calculate using Equation 5.4.2 in case of paper waybills and Equation 5.4.3 for e-Waybills. The total invoicing time for a paper waybill $IT(W_{ij})$ can be calculated using Equation 5.4.4, while for e-Waybill Equation 5.4.5 is used.

$$IT(W_{ij}) = S(W_{ij}) + \hat{S}(W_{ij}) + BT + T(W_{ij})$$ (5.4.4)
5.5 Experiment Setup

We implemented our model using the AnyLogic simulation tool for a network of 12 nodes, which is served by a medium-sized Swedish transportation company. The travel time between every pair of nodes was provided as an input to the model. In the customer orders database of the company, we observed that for a period of 10 days a total of 170 orders arrived. These orders were transported using one truck on a daily basis. Therefore, in our simulation setup we assumed the maximum batch size to be 17, i.e., a batch comprises of 17 waybills.

In Table 5.2, we summarize the above discussion and we present the parameters of our simulation experiment. We created three different scenarios based on different values of $\hat{S}$.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Paper Waybill</th>
<th>e-Waybill</th>
<th>Applicable Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>nodes (k)</td>
<td>12</td>
<td>12</td>
<td>All</td>
</tr>
<tr>
<td>Simulation run-time</td>
<td>2160 hours</td>
<td>2160 hours</td>
<td>All</td>
</tr>
<tr>
<td>Inter-arrival rate</td>
<td>30 min</td>
<td>30 min</td>
<td>All</td>
</tr>
<tr>
<td>$S$</td>
<td>uniform discrete [6, 100] minutes</td>
<td>uniform discrete [0.083, 50] minutes</td>
<td>All</td>
</tr>
<tr>
<td>$\hat{S}$</td>
<td>uniform discrete [30, 90] minutes</td>
<td>5 minutes</td>
<td>Scenario 1</td>
</tr>
<tr>
<td>$\hat{S}$</td>
<td>uniform discrete [240, 2880] minutes</td>
<td>1 minute</td>
<td>Scenario 2</td>
</tr>
<tr>
<td>$\hat{S}$</td>
<td>uniform discrete [1440, 4320] minutes</td>
<td>15 minutes</td>
<td>Scenario 3</td>
</tr>
</tbody>
</table>

Table 5.2: Simulation setup values.

In all of the three scenarios, for $S$, we used the time values for creating waybills based on the studies (Fosso Wamba and Boeck, 2008) and (Lertkitcha, 2012). For the time needed to process the waybills at different nodes, i.e., $\hat{S}$, the time values are based on different studies. The values of $\hat{S}$ are based on the study (Zec et al., 2001) for scenario 1, and (Sathasivam, 2009) for scenario 2 and 3. The study (Sathasivam, 2009) suggest two different values for $\hat{S}$ due to which we consider both the values in two different
5.6 Results and Analysis

We used the Welch method, as illustrated by Law and Kelton (2000), for calculating warm-up period of our simulation experiment. The method is based on executing several iterations and calculating the mean across the different iterations. The averages are then plotted and the truncation point is selected to be the point where the graphs flattens out (Sandıkçı and Sabuncuoğlu, 2006). The simulation experiment was initially executed for all the scenarios with different time periods of 24, 168, 336, and 1440 hours in order to verify the true stable state of the simulation. We found that different scenarios had a slight different warm-up period, e.g., in scenario 1 the simulation generated stable results after 5 batches (i.e., 85 waybills) were processed, while in scenario 3 the stable results were generated after processing batch 9 (153 waybills). Therefore, for our analysis, we collected results for all the scenarios after the processing of batch number 10. For each of the scenarios, the experiment was executed for a period of 90 days, i.e., 2160 hours.

In Table 5.3, for the initial 255 processed waybills in each of the scenario, we
present the mean invoicing time (for waybills) with a confidence interval (CI) of 95%. It can be seen that the difference between the minimum mean invoicing time for paper and electronic waybills is approximately 19 hours, while the maximum mean invoicing time can be as high as 1635 hours. In scenario 1, the difference between the mean invoicing time for paper and electronic waybills is 1161 minutes. Hence, a total of 65%, i.e., \((1161/1796)*100\), savings in invoicing time can be achieved when using e-Waybills in place of paper waybills. Similarly, a saving of 99% in the invoicing time can be achieved for each scenarios 2 and 3.

<table>
<thead>
<tr>
<th>Waybill Type</th>
<th>Scenario</th>
<th>No. of Waybills processed</th>
<th>Mean invoicing time with 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>1</td>
<td>4267</td>
<td>1796.79 ± 22.29 minutes</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1326</td>
<td>52000.53 ± 747.59 minutes</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>442</td>
<td>98872.29 ± 2020.80 minutes</td>
</tr>
<tr>
<td>Electronic</td>
<td>1</td>
<td>4284</td>
<td>635.69 ± 30.00 minutes</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4284</td>
<td>585.75 ± 27.69 minutes</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4284</td>
<td>792.53 ± 34.34 minutes</td>
</tr>
</tbody>
</table>

Table 5.3: Mean invoicing time for waybills.

For illustration purposes, consider Figure 5.1, which represent the mean invoicing time (of 15 batches) for paper and electronic waybills in scenario 1. It can be seen in Figure 5.1 that, in addition to the high difference in the mean invoicing time, the mean invoicing time of paper waybills fluctuates more often when compared to the invoicing time of e-Waybills, which is more stable. The mean invoicing time for paper waybills is between 1581–1984 minutes, while for e-Waybills it is between 532–745 minutes in scenario 1.

Additionally, we observed that in all the scenarios a total of 4320 orders arrived. In our simulation experiment, a waybill was created for every order received, therefore, in total 4320 waybills entered the system. Similarly, a waybill is ready for invoicing when the order has been fulfilled, i.e., the freight is loaded and unloaded at different nodes and the respective waybill for the freight is processed at the particular nodes. We found, for paper waybills, the number of orders fulfilled was different in the three scenarios,
i.e., 4267 in scenarios 1, 1326 in scenario 2, and 442 in scenario 3. In contrast to the paper waybills, 4284 orders were fulfilled in each of the scenarios for electronic waybills. The efficiency of the system, i.e., percentage of the ratio between orders received and fulfilled, is 99.17% for electronic waybills; whereas, the systems efficiency for paper waybills is 98.87%, 30.69%, and 10.23% in scenario 1, 2, and 3 respectively.

Furthermore, in Table 5.4, we present the monetary savings when using electronic waybills instead of paper waybills. The saving figure of US $0.4 per document is used in the table from a study by Hill (1989). In scenario 1, difference between the total number of processed paper and electronic waybills is significantly low, which leads to low savings. However, when comparing the number of paper and electronic waybills processed in scenarios 2 and 3, the number of electronic waybills processed is 3-10 times higher than paper waybills, which can lead to potential direct savings of US $1194 and $1536 respectively.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Paper Waybill</th>
<th>Electronic Waybill</th>
<th>Difference</th>
<th>Savings (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4267</td>
<td>4284</td>
<td>17</td>
<td>6.8</td>
</tr>
<tr>
<td>2</td>
<td>1326</td>
<td>4284</td>
<td>2985</td>
<td>1194</td>
</tr>
<tr>
<td>3</td>
<td>442</td>
<td>4284</td>
<td>3842</td>
<td>1536.8</td>
</tr>
</tbody>
</table>

**Table 5.4**: Savings in US$ when using an e-Waybill.
5.7 Conclusion

We have presented a simulation model for estimating the invoicing and processing time of waybills in road-based freight transportation. The model is implemented using the simulation tool AnyLogic for three different scenarios having different processing time for waybills at the nodes. We have analyzed the results from the simulation experiment, which was executed for a period of 90 days. The results indicate that a saving of 65–99% in invoicing time can be achieved using e-Waybills instead of paper waybills. However, for e-Waybills, the difference in invoicing time and the number of processed e-Waybills in the three scenarios is not significantly different even though the processing time increases 3–15 times. Similar to the number of waybills processed, the savings on electronic waybills is low in scenario 1 when compared to scenario 2 and 3. The overall systems efficiency is high for e-Waybills even when the processing time of waybills is increased 5-15 times in the three scenarios.

A possible limitation of our study is the limited number of nodes, where the waybills are processed. We have considered 12 nodes with only one TSP. Due to this limitation, the number of waybills processed at loading and unloading nodes are low in number as compared to the total number of waybills processed at the TSP. Therefore, a possible future work can be to consider more than one TSP for a particular number of loading and unloading nodes.

Acknowledgment

We would like to thank the Swedish road freight transport operator who made our research possible by providing consignment data. We would also like to thank Blekinge Institute of Technology (BTH) and the Swedish National Postgraduate School on Intelligent Transport Systems (NFITS) for supporting this research.
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A synergy based method for designing ITS services

6.1. Introduction

Abstract

In this paper, we propose a method for supporting the process of designing Intelligent Transportation System (ITS) services, which utilizes primarily functional synergies with already existing services. Using synergies between services will enable sharing of resources, such as, information entities, functions and technical resources, which in turn may lead to reduced costs for implementing services. The method is built around an existing service description framework, which is used to describe both existing services and the service to be designed. In order to illustrate the usage of the suggested method, we have applied it for designing a new ITS service, i.e., the Liability Intelligent Transport System (LITS) service. The purpose of the LITS service is to support the process of identifying when, where and why freight has been damaged, and which actor was responsible when the freight was damaged. The LITS service may lead to better quality control of consignments and may also facilitate the identification of which actor was responsible for the freight damage, which is of particular interest in multi-modal transport. By applying our service design method we were able to identify that three out of four functions of the LITS service already exist in other existing ITS services. Therefore, the LITS service can be designed based on synergies with these services.

6.1 Introduction

It has been suggested that the use of different types of Intelligent Transportation System (ITS) services might lead to positive effects on the execution of transport (Mbiydzenyuy et al., 2012). For example, ITS services might contribute to reduced congestion, decreased fuel consumption, and reduced amount of emissions, by enabling more efficient use of vehicles and infrastructure, as well as increased safety. However, it has been argued, that service usage is limited due to that service providers in general provide services only for their own terminals (Kim et al., 2007). Therefore, high service utilization during transport will require that the vehicle is equipped with several terminals, unless services are developed for open platforms that are shared by different service providers. In addition, it has been suggested that the utilization of synergies between ITS services can lead
to reduced implementation costs, which in turn might lead to a higher service utilization (Mbiydzenyuy et al., 2008). A possible way to benefit from synergies is to bundle multiple ITS services and distribute them as packages that are distributed for a shared platform. This would enable the same function to be implemented only once even though it is used by more than one service in the package.

We illustrate the concept of synergies between services by giving examples of functional, information, and technical synergies between the ITS services On-board Driver Monitoring and On-board Safety and Security Monitoring. The On-board Driver Monitoring service monitors and reports driver conditions in real time, e.g., driver’s actions and health. The On-board Safety and Security Monitoring service monitors the vehicle and the freight, e.g., in order to detect theft. A shared function of these services is determining the speed of the vehicle. Information about the vehicle, i.e., type, id, and size, is needed as input by both services. The services share the technical resource sensor to sense human presence, which is needed in order to identify presence of human(s) in case of an accident.

There exist several studies (Chandrasekaran et al., 2002; Talib et al., 2010; Van der Perre, 2006) in which synergies between ITS services are considered. Van der Perre (2006) presented the idea of a platform, which is capable of accommodating different services and which can support relevant communication media (cellular broadcasts and dedicated short range communication). Talib et al. (2010) argued for the need for a service-packaging platform, which is able to offer service providers the ability to create reusable service packages. This is possible through organizing existing service delivery functions or creating new ones. The authors introduced the notion of service packages and a pattern-based approach to service packaging. In addition, they highlighted the requirements of a platform to enable service packaging. Although there are numerous possibilities for utilizing on the synergies between different ITS services, there exists, at least according to the best of our knowledge, no study that explicitly considers how functional synergies can be used in order to designing new ITS services.

In this paper, we propose an ITS service design method for supporting the process of designing new ITS services by utilizing on synergies with existing services. By existing services, we here mean the services that were
identified during different projects by Jevinger et al. (2010); Mbiydzenyuy et al. (2008). The proposed method is built around the service description framework suggested in (Jevinger, 2012), which is used to generate uniform descriptions of both existing ITS services and the service to be designed. We illustrate the usage of the method by showing how it can be used to generate a design for a new ITS service, i.e., the Liability Intelligent Transport System (LITS) service. The purpose of the LITS service is to support the process of identifying why, when and where freight have been damaged, and in case of multi-actor transport, it should also support the identification of which actor should be held responsible for the damage. Since it is sometimes difficult to identify when freight damage has occurred, it might in multi-actor transport be difficult to identify who should be held responsible for the damage. Therefore, we believe that the LITS service might have an important role in future freight transport. By using a service to detect possible freight damage, based on the conditions for transport, it would be possible to identify the cause for damages that are not visible to a naked eye, e.g., a temperature deviation that has occurred for a short time.

In multi-modal transport, which typically involves multiple actors, there are two liability schemes that regulate the amount of penalty that should be paid by the actor(s) that is held responsible for freight damage, i.e., the Network Liability Scheme and the Uniform Liability Scheme (Daujotas, 2011; Eftestöö-Wilhelmsson, 2007). The major difference between these two schemes is how the amount of penalty is determined. In the Network Liability Scheme, the penalty is based on the transport mode (where the freight was damaged) while in Uniform Liability the penalty is identical for all modes of transport (Eftestöö-Wilhelmsson, 2007; Zanardi, 1999). Regardless of which scheme is adopted, there is a need to identify which actor was responsible for freight damage. We claim that the LITS service can contribute to addressing the problem of identifying the responsible actor for freight damages, which can make both of the liability schemes transparent.

The current paper is organized as follows. In Section 6.2, we present the service description framework that is used by our method to describe services. Then, in Section 6.3 we present our ITS service design method. In Section 6.4 we illustrate the method by showing how it can be used to design the LITS service. In Section 6.5, we finalize the paper by providing some concluding remarks and pointers to future work.
6.2 Service description framework

In this section, we briefly describe the service description framework (Jevinger et al., 2012), which suggests how to generate structured and uniform descriptions of ITS services. In our service design methodology, the framework is used to describe both existing services and the service to be designed. The framework defines how to decompose a service into different types of components (i.e., input entities, output entities, functions, triggers, and the locations where input and output entities are needed. These components describe what the service should do, what input it needs, and what output it produces.

A description that has been generated using the framework is based on various levels of detail and it is implementation (technology) independent. It uses two levels of specification, i.e., an abstract level (Level A) and a concrete level (Level B), where level B is a further specification of level A. Level A represents what tasks should be performed by the service, by specifying input and output entities, and in particular, when and where these entities are needed. Level B builds on the level A description, by describing how the service should fulfill the tasks specified in level A. This is achieved by specifying functions and triggers.

6.3 ITS service design method

In this section, we present our method for designing new ITS services by explicitly utilizing on, mainly functional, synergies with existing ITS services. As mentioned above, the service description framework by Jevinger et al. (2012), plays an integral role in the method, since it is used to generate uniform descriptions of both the service to be designed and the existing services. A pre-step, i.e., Step 0, to the service design method identifies relevant ITS services (which might enable synergies with the service to be design). This pre-step is an input to the service design method. In Figure 6.1, we specify our service design method.

Step 1 of the method concerns identifying the functional requirements of the “new” ITS service. This can be done in different ways, however, we have chosen not to specify any particular method for identifying
6.3. **ITS service design method**

0. Identify possible ITS services which may enable possible synergies with the new service.

1. Identify functional requirements of the new ITS service.

2. Create a structured description of the new service using service description framework.

3. Identify possible synergies with the existing ITS services.

4. Redesign the new ITS service based on the identified synergies.

Figure 6.1: Service design method.

Functional requirements, because we want the service design method to be flexible enough to allow for different types of approaches. Step 2 concerns identifying the components of the new service, by applying the service description framework. The components specified when applying the service description framework represent an initial design of the new service, where all the processing is performed by the service itself without making use of synergies with existing services. The purpose of step 3 is to identify all possible synergies between the new service and existing services (identified in step 0), by searching for functions and information entities in the existing services that can replace functions in the new service. In Step 4, the initial description (or design) of the new service is updated by realizing synergies with the existing services. In particular, synergies are achieved when one or more of the functions of the new service are replaced by new components, as a consequence of “borrowing” functions from existing services. For example, a function in the new service can be replaced by an input information entity, generated as output by an existing service, and a trigger that reacts to the input.
Chapter 6. A method for designing ITS services

6.4 Service design method applied on LITS service

In this section, we illustrate our ITS service design method by applying it in order to create a design of the so-called LITS service. The main purpose of this paper is to present an ITS service design method (based on synergies with existing services). Therefore, in rest of the paper, we limit scope of the LITS service. As discussed in Section 1, the LITS service should be able to detect various types of freight damage, which might be caused, e.g., by accidents, and temperature deviations. However, in the illustration of our method we limit the scope of the LITS service, to only consider freight damages related to temperature deviations.

The idea of monitoring the freight damage, which is an integral part of the LITS service, is not new. The literature contains several studies on freight damage detection during transport. Jedermann et al. (2006) proposed a service for monitoring agricultural products, Abad et al. (2007) introduced a service for monitoring fish products, Mahlknecht and Madani (2007) proposed a service to monitor the inside environment of a container for tracking changes, and Carullo et al. (2009) proposed a service for monitoring temperature-sensitive products. The LITS service, which is considered here, is different from the services discussed above, since they are not able to provide all functions of the LITS service.

Step 1. Identify functional requirements of the LITS service

We have used a scenario-based approach in order to identify the functional requirements of the LITS service, where we formulated and analyzed two scenarios that in different ways involve temperature related freight damages.

We have used a scenario-based approach, since scenarios are considered to be an effective way of identifying requirements of a system (Van Lamsweerde and Willemet, 1998). In the literature, scenarios have been used for different purposes. Scenarios can be used to illustrate behavior of a system in a certain environment. In the system design process, scenarios are used for design exploration, requirements elicitation and validation (Sutcliffe, 2003). Scenarios can also be used to illustrate real world examples (Sutcliffe, 2003). In this paper we have used scenarios to illustrate real world
examples of the incidents concerning freight damage during transport.

In our scenarios, we assumed that a consigner is sending freight to a consignee, and the transport involves multiple carriers \([c_1, c_2, c_3, \ldots, c_n]\). The carrier may represent different operators. The freight is assumed to be in perfect condition at the origin and are loaded into the vehicle by a carrier \(c_1\). The scenarios S1-S2 represent some incidents that may occur during a traditional freight transport process.

S1: While the vehicle is moving towards the destination, one package gets damaged due to rise in temperature in the storage environment of the freight. This deviation occurs for a short time causing freight damage, which is invisible to the naked eye. At a certain stop, \(c_1\) transfers the freight to \(c_2\) and since the damage is not visible, \(c_2\) accepts the freight for further transportation. This will result in a damaged freight at the end of transport.

S2: The precondition is that the freight must be placed in a temperature-controlled environment during transport. The carrier \(c_1\) reads the instructions from a waybill about the required storage temperature, which should be -20 degree centigrade, but \(c_1\) mistakenly sets the temperature to be 20 degrees. After traveling for some time, \(c_1\) realizes the mistake and corrects the temperature without checking whether the freight has been damaged. Later on, \(c_1\) transfers the freight to \(c_2\), who manually checks the freight temperature. If the temperature is suitable, \(c_2\) accepts the freight and proceeds with the transport until it eventually is handed over to the next carrier \(c_3\). When \(c_3\) arrives at the final destination, it is found out that the some of the freight has been damaged due to temperature deviations. It is unclear when and where the temperature deviation occurred and who was responsible for the damage.

From the incidents presented in the scenarios above, we derived the following functional requirements of the LITS service:

- **R1:** The service should be able to detect possible freight damages caused by temperature deviations for a longer time than allowed.
- **R2:** The service should be able to identify the timestamp for a possible freight damage.
- **R3:** The service should be able to identify the current freight location at the time of a possible freight damage.
• **R4:** The service should be able to identify the actor responsible for the transport at the time of possible freight damage.

• **R5:** The service should be able to store the information specified in R1, R2, R3, and R4.

• **R6:** The service should be able to create a report about the information specified in R1, R2, R3, and R4.

From the requirements above, we conclude that the service should have four categories of functions, i.e., monitoring, tracking, tracing, and reporting freight damages. Monitoring concerns detecting a freight damage. The service should be able to track when and where a damage occurred. It should be able to trace information related to the consignment and the actor involved at the time of damage. Finally the service should be able to store and report the output from the monitor, track, and trace functions to a storage location and user respectively.

**Step 2. Applying service description framework on the LITS service**

We applied the service description framework (see Section 6.2) on the LITS service in order to describe how to achieve the requirements R1, R2, R3, R4, R5, and R6. This will specify the relevant information entities (see Table 6.1), and the abstract level (see Table 6.2) and concrete level (see Table 6.3) descriptions of the LITS service.

<table>
<thead>
<tr>
<th>Information Entity (IE)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IE1</td>
<td>Unique id of the goods/packages</td>
</tr>
<tr>
<td>IE2</td>
<td>Current temperature of the environment in which goods are being stored</td>
</tr>
<tr>
<td>IE3</td>
<td>Ideal temperature for storing the goods</td>
</tr>
<tr>
<td>IE4</td>
<td>Maximum time goods can resist temperature deviations</td>
</tr>
<tr>
<td>IE5</td>
<td>Current location of the goods</td>
</tr>
<tr>
<td>IE6</td>
<td>Time when an actor was responsible for the transport</td>
</tr>
<tr>
<td>IE7</td>
<td>Actor id at the time of damage</td>
</tr>
<tr>
<td>IE8</td>
<td>Status of the goods, i.e., damaged or normal</td>
</tr>
<tr>
<td>IE9</td>
<td>Damage level</td>
</tr>
<tr>
<td>IE10</td>
<td>High/low temperature change</td>
</tr>
<tr>
<td>IE11</td>
<td>Timestamp of the possible damage occurrence</td>
</tr>
</tbody>
</table>

**Table 6.1:** IEs used in the service description of the LITS service.

At the abstract level, the relevant input entities to the service are IE1 and IE6. The service can operate in two ways. It can either acquire all the IEs by itself,
which we term EPull, or the IEs can be provided by the user, which we term EPush. Output IEs generated by the service are IE1, IE5, IE7, IE9, and IE11, which can be either reported by the service, i.e., EPush, or acquired by the user, i.e., EPull. The output IEs can be generated in the vehicle or at the back-office.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
Input IEs & Output IEs \\
\hline
What \in \{IE1, IE6\} & What \in \{IE1, IE5, IE7, IE9, IE11\} \\
Where \in \{back-office, vehicle\} & Where \in \{in vehicle, at back-office\} \\
\hline
\end{tabular}
\caption{Abstract level service description of the LITS service.}
\end{table}

The concrete level specifies the functions (i.e., the processes) that the LITS service should execute in order to achieve the abstract level output. In Table 6.3, it can be seen that the output IEs generated by each of the functions of the LITS service can be used by other functions of the service. The output entities generated by the $B_1$ function can be all used by $B_2$ and $B_3$. All the input entities required by $B_2$ are generated by $B_1$, and $B_3$ gets some input IEs from the output IEs generated by $B_1$ (IE1, IE8, and IE11) and some IEs from $B_2$ (IE5). Some of the input entities required by $B_4$ (IE1 and IE11) can be acquired from the output entities generated by $B_1$, $B_2$, or $B_3$.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
Functions & Input Entities & Output Entities \\
\hline
$B_1$ & IE1, IE2, IE3, IE4 & IE1, IE8, IE11 \\
$B_2$ & IE1, IE8, IE11 & IE1, IE5, IE11 \\
$B_3$ & IE1, IE4, IE5, IE8, IE10, IE11 & IE1, IE9, IE11 \\
$B_4$ & IE1,,IE6, IE11 & IE1, IE7, IE11 \\
\hline
\end{tabular}
\caption{Concrete level description of the LITS service.}
\end{table}

In this initial design of the LITS service, it executes by first detecting the goods status using function $B_1$. If a possible damage is detected, then the
timestamp of the damage occurrence and the current location of the freight are identified using $B_2$. The function $B_3$, identifies the damage level. Finally, the actor responsible for the freight at the time of freight damage occurrence is identified using $B_4$. The abstract level then generates the final output to a user to a storage location, such as, a database.

**Step 3. Identifying synergies with existing ITS services**

We conducted a search for functions (of the LITS service), and input to these functions, that can be (partially or completely) fulfilled through synergies with existing ITS services. Since some of the functions of the LITS service can have synergies with more than one service, there should be some sort of criteria for selecting the relevant services to consider. Services that are used to provide synergies with the new service can be selected based on, e.g., their costs or power consumption. In this paper, our criterion for selecting service(s) is based on the core function of the service. A core function is the main task performed by the service, i.e., the main purpose of a service. For example, the core function of a service Estimated time of arrival (ETT) is to predict the estimated arrival time of a vehicle. In addition to the core function, there may be other functions of the ETT service, such as, data storage. Hence, we have identified a number of services that can have synergies with the LITS service. However, we have selected only those services whose main function include any of the functions in the LITS service.

Function $B_1$, of the LITS service, already exists in the Notify goods physical status (GS) service. Therefore, the LITS service can use the $B_1$ function from the GS service. The GS service needs freight related information as input, such as, id, type, amount, and temperature. It generates output about the status of the freight based on temperature deviations. We found that the GS service can get some freight-related information from the e-Waybill service, i.e., goods id (IE1) and the required temperature for storing the freight (IE3) and the maximum time the freight can resist temperature deviations (IE4).

Function $B_2$ determines the current location of the damaged freight. This function can be provided by the Real-time track and trace of goods (RTT) service, which needs freight related input, such as, global positioning and freight identifier. The service generates real-time freight location. Instead
of implementing a separate $B_2$ function for the LITS service, it is possible to use the function from the RTT service. The $B_2$ function will execute only if the status of the goods is reported to be damaged by the $B_1$ function. The output entities generated by $B_1$ are input to the $B_2$ function.

Function $B_3$ can use the output generated by $B_1$ and $B_2$ functions. The function will execute only if the status of the goods is reported to be damaged by the $B_1$ function. Therefore, the output entities by the $B_1$ function are input to this function. The function also gets input based on the output information about the goods location from the $B_2$ function. The $B_3$ can also make use of information entities from the e-Waybill. Since the e-Waybill has information about the conditions for storing the freight, it can provide the input information entity IE4 to the $B_3$ function.

Function $B_4$ has synergies with the e-Waybill service, since the e-Waybill has information about the freight as well as when a particular actor was responsible for handling the freight, i.e., IE1 and IE6. The information entities IE1 and IE11 can be sent from the LITS service to the e-Waybill and the e-Waybill can return the information entity IE7 to the LITS service.

**Step 4. Redesigning the LITS service**

Based on the possible synergies identified in Step 3, we redesigned the LITS service as shown in Figure 6.2.

Figure 6.2 represents how the LITS service executes based on synergies with already existing ITS services. The first two functions of the LITS service, i.e., $B_1$ and $B_2$, can be provided by the GS and RTT services, since these are the core functions of these services respective. The third function $B_3$, i.e., identifying the freight damage level, gets input entities from the GS and RTT services, as well as, from the e-Waybill service. Finally, the $B_4$ function can be replaced with the e-Waybill service. The e-Waybill service gets input information entities IE1 and IE11 from the $B_3$ function of the LITS service and it generates output information entity IE7 that can be used by the LITS service as an output. The highlighted entities belong to the abstract level of the LITS service as the final output from the service. The final output generated by the service may be reported to the e-Waybill (to store) for later use or the output may be reported to the user of the service.
6.5 Concluding remarks

The main contribution in this paper is an ITS service design method, which can be used to design ITS services by explicitly utilizing on synergies with existing services. Since the service design method makes use of synergies with other services, a service designed using our service method could possibly lead to a reduced cost for implementing that service. Although the purpose of the proposed method is to design new ITS services, we believe, it can also be used to redesign existing services.

By applying the service design method in order to create a design of the LITS service, we verified that there exist components in other existing ITS services, such as, information entities and functions, which can be used by the LITS service. A general conclusion is that the LITS service can be designed using synergies with other ITS services, i.e., the e-Waybill, Real time track and trace (RTT), and Notify goods physical status (GS). Two
of the functions of the LITS service, i.e., the function to identify damage and the function to determine the current location of the goods can be provided by the GS service and the RTT service respectively. The third function, i.e., identifying who is responsible for the freight at the time of a possible damage, exists in the e-Waybill service and it can be provided by the e-Waybill service. Finally, the output information about the freight status can be stored by an e-Waybill service, therefore the e-Waybill can provide storage functionality to the LITS service for storing freight status information. Therefore the LITS service has synergies with the GS, RTT, and the e-Waybill service. The LITS service may have positive impacts in a transport process by detecting freight damage and the actor responsible for the damage. The LITS service may lead to better quality control of the freight being transported by monitoring and reporting the freight status in real-time and will also contribute in making the Network and Uniform liability schemes more transparent in case of a multi-modal transport.

In this paper, we have limited the scope of the LITS service by only considering freight damages related to temperature deviations. However, we believe this limitation will not affect our work, since it will be possible at a later stage to redesign and add more functions to the LITS service using the proposed service design method. A possible direction for the future development of the proposed method is develop criteria for selecting which services should be use to provide synergies with the service to be design (in Step 4).
Freight transport prediction using electronic waybills and machine learning

Abstract

A waybill is a document that accompanies the freight during transportation. The document contains essential information such as, origin and destination of the freight, involved actors, and the type of freight being transported. We believe, the information from a waybill, when presented in an electronic format, can be utilized for building knowledge about the freight movement. The knowledge may be helpful for decision makers, e.g., freight transport companies and public authorities. In this paper, the results from a study of a Swedish transport company are presented using order data from a customer ordering database, which is, to a larger extent, similar to the information present in paper waybills. We have used the order data for predicting the type of freight moving between a particular origin and destination. Additionally, we have evaluated a number of different machine learning algorithms based on their prediction performances. The evaluation was based on their weighted average true-positive and false-positive rate, weighted average area under the curve, and weighted average recall values. We conclude, from the results, that the data from a waybill, when available in an electronic format, can be used to improve knowledge about freight transport. Additionally, we conclude that among the algorithms IBk, SMO, and LMT, IBk performed better by predicting the highest number of classes with higher weighted average values for true-positive and false-positive, and recall.

7.1 Introduction

In freight transport, different types of documents accompany a consignment. A waybill contains essential information about a consignment. The information includes origin and destination of the consignment, information about the involved actors, and information about the type of freight. We believe, the information present in a paper waybill, if available in an electronic format, can be utilized in several ways in order to achieve greater benefits. For example, an electronic waybill (e-Waybill) can utilize synergies (i.e., share information) with different Intelligent Transportation Systems (ITS) services (Bakhtyar et al., 2013a), which can lead to reduced implementation cost of the services (Mbiydzenyuy et al., 2011). In this paper, we argue that the e-Waybill information may be utilized for building
knowledge about the freight movement between a particular origin and destination city.

Predicting the type of freight to be transported (from an origin to a destination) may be helpful in deciding the type of vehicle to be used for transportation, e.g., today reefers (i.e., refrigerated trucks) are used in case of frozen freight. For transport companies, having advanced information about the freight type may be helpful in deciding on the type of transport to use (provided that the origin and destination cities of an oncoming order are known). The information may also help the transport companies in demand forecasting for a particular type of freight. For public authorities, predicting the freight type (moving between different cities) may be helpful in ensuring that the infrastructure (between the freight's origin and destination city) is capable of meeting the actual freight to be transported, e.g., the road choice in case of dangerous goods.

The main purpose of this paper is to predict the type of freight that is moving between a particular origin and destination. To achieve the purpose, we have used a dataset that contains data from a customer ordering database of a Swedish transportation company. It must be noted here that the collected data (i.e., from a database) is, to a greater extent, similar to the data present in a paper waybill. Therefore, we can assume that the data present in the customer ordering database is, to a greater extent, similar to the data that can be provided by an e-Waybill. For predicting the freight type between cities, we have used the open-source tool Waikato Environment for Knowledge Analysis (WEKA). WEKA provides a collection of machine learning algorithms (in a graphical user interface) that can be applied on a dataset. In addition to the main purpose, the secondary purpose of this paper is to evaluate the different machine learning algorithms, which are applied on our dataset for predicting the freight type.

The paper is structured as follows: in Section 7.2, we describe the methodology for conducting the study, in Section 7.3, we present and explain the data pre-processing step, which was needed in order to remove missing values from the dataset, in Section 7.4, we present the preliminary experiment step, where different classification algorithms were applied on the dataset and the best-performing algorithms were selected. In Section 7.5, we describe the final experiment, which was conducted to evaluate the best three performing algorithms from the preliminary experiment step. In
Section 7.6, we present a discussion of the results and analysis of the final experiment and finally in Section 7.7, we discuss the concluding remarks to the paper.

7.2 Methodology

The methodology followed in this paper includes: data collection, data pre-processing, and computational experiments that were conducted in WEKA. For conducting the experiments, we used a dataset that included data from a customer ordering database of a transport company was used. We employed the case study method in evaluating the collected customer order data from the transport company located in Karlshamn, Sweden.

The order data consisted of 243 orders, which were completed during a period of one month. The data included freight origin, destination, weight, and type. In order to ensure confidentiality of the company and the order data, the cities names and the freight types have been replaced with unique identifiers in this paper. For each completed order, there exists a paper waybill. Therefore, to ensure that the collected data is similar to the data present in a paper waybill, the order data was compared with the corresponding data from the waybills.

To overcome the problem of missing values, we performed a data pre-processing step. Data imputation was used for replacing the missing values with realistic values. After conducting the pre-processing step, our dataset was complete and ready for experiments. We used the tool WEKA for applying different machine learning algorithms on the dataset. The main purpose was to predict the freight type based on the origin, destination, and weight of the freight. Therefore, we used classification algorithms in the experiments. The experiments were conducted in two phases. In phase 1 (preliminary experiment), we applied different classification algorithms on the dataset in order to identify the best-performing algorithms. Based on the results from the preliminary experiment, a final experiment was conducted in phase 2. In the final experiment, we selected the top three best-performing algorithms for a comparison and evaluation.
7.3 Data Pre-Processing

The dataset had four attributes, i.e., origin city, destination city, weight of the freight, and the freight type. Of the four attributes, the freight type is the class attribute. In summary, the dataset had the following characteristics:

- Total No. of attributes = 4
- All attributes = Origin City, Destination City, Weight, Freight Type
- Class attribute = Freight Type
- Total No of class attributes = 17
- Class attributes = G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, G12, G13, G14, G15, G16, G17
- Total no. of instances = 243

The 243 instances had 68 instances with missing values in the class attribute. In a dataset with only 243 instances, we considered this number of missing values to be high, and therefore, it was necessary to impute the missing values. To impute the missing values in a dataset, there exist different methods. In the literature, there exist different data imputation techniques such as, the following: ignoring instances with unknown feature values, most common feature value in class, mean substitution, regression or classification method, hot-deck or matching imputing, and treating missing feature values as special values (Kotsiantis et al., 2006). In our dataset, we could observe patterns between the instances with missing values. Therefore, we used the hot-deck imputation method. In this method, missing values are imputed through a process in which for an instance x with a missing value y” an instance with similar values of “x” is observed and the data present in place of “y” is selected and imputed against the missing value.

In our dataset, all the missing values belonged to the class attribute (i.e., the freight type). Additionally, most of the missing values belonged to instances where the origin and destination cities were similar. The imputation was done using three steps approach: first, we observed an instance with a missing value at the origin and destination cities. Second, the entire dataset was searched for origin and destination cities that matched with the origin
and destination of the missing value instance. Thirdly, if a match was found, the freight type value was taken from there and imputed against the missing value. There were cases where multiple matches were found for the same origin and destination cities with different freight type values. In such cases, the most frequently occurring freight type value was considered and imputed against the missing value. After all the missing values were replaced in the dataset, it was now ready for the experiments.

7.4 Preliminary Experiment

In our preliminary experiment, different classification algorithms were used on the dataset for predicting the type of freight moving between different cities. Before applying the algorithms in WEKA, we selected 10 folds cross-validation in the testing options since the dataset had 243 instances only and 10 folds cross-validation is considered to be useful on a dataset that is very small to be partitioned into separate training and testing (Witten et al., 2011). In the 10 folds cross-validation, a dataset is partitioned into 10 sets of equal sizes. The algorithm then trains on 9 datasets and tests on 1 of the dataset. This step of training and testing is repeated 10 times, and in the end mean accuracy of the tests is calculated (Witten et al., 2011).

Once the experiment was conducted, we selected the best-performing algorithms based on their accuracy, i.e., the number of instances correctly classified by a particular algorithm. The algorithms that performed with higher accuracy were Averaged one-dependence estimators (AODE), Sequential minimal optimization (SMO), k-Nearest Neighbors (IBk), LogitBoost, JRIP, Logistic Model Trees (LMT), and HyperPipes.

- AODE algorithm is a probabilistic classification learning algorithm. It is considered to be the most effective Naive Bayes algorithm due to its focus on addressing the attribute-independence problem of the popular Naive Bayes algorithm (Wu and Cai, 2011). AODE has been developed for the purpose of improving the accuracy of Naive Bayes (Jiang and Zhang, 2006).

- SMO was proposed for training support vector machines with a high speed. Support vector machines consist of a set of supervised learning
models for classification and regression problems (Shmilovici, 2005). Kernal functions, such as polynomial or Gaussian are used by SMO in order to implement the sequential minimal-optimization algorithm for training support vector machines (Hastie et al., 1998; Keerthi et al., 2001).

- IBk is an implementation of the k-nearest-neighbor classifier. A variety of different search algorithms can be used to speed up the task of finding the nearest neighbors. In IBk, predictions from more than one neighbor can be weighted according to their distance from the test instance, and two different formulas are implemented for converting the distance into a weight (Aha et al., 1991; Witten et al., 2011).

- LogitBoost is a boosting algorithm. In a boosting algorithm, a number of iterations are run over the data in order to find the simple regression function with the smallest error. The algorithm can be iterated until convergence. However, for optimal performance it is unnecessary to wait for convergence. This can be achieved by determining the appropriate number of boosting iterations through the expected performance measures until the performance stops to increase. The performance for a given number of iterations can be calculated using cross-validation (Friedman et al., 2000; Witten et al., 2011).

- JRip is an implementation of the popular RIPPER (repeated incremental pruning to produce error reduction) algorithm (Witten et al., 2011). It is a rules-based learner that determines propositional rules, which can be used to classify elements (Hindle et al., 2009).

- LMT is a supervised learning algorithm that combines decision trees and logistic regression. The algorithm uses LogitBoost algorithm in order to induce trees with linear-logistic regression models at the leaves (Witten et al., 2011).

- HyperPipes is considered to be a very simple algorithm, and it is used in discrete classification problems (Holden and Freitas, 2008). For each attribute in a training data, the algorithm records the range of values and calculates the ranges containing the attribute values of a test instance. The algorithm then chooses the category with the largest number of correct ranges (Witten et al., 2011).
7.4. Preliminary Experiment

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>AODE</td>
<td>79.83%</td>
</tr>
<tr>
<td>SMO</td>
<td>81.07%</td>
</tr>
<tr>
<td>IBk</td>
<td>82.72%</td>
</tr>
<tr>
<td>LogitBoost</td>
<td>79.83%</td>
</tr>
<tr>
<td>JRIP</td>
<td>75.30%</td>
</tr>
<tr>
<td>LMT</td>
<td>80.24%</td>
</tr>
<tr>
<td>HyperPipes</td>
<td>65.02%</td>
</tr>
</tbody>
</table>

Table 7.1: Algorithms with high accuracy.

7.4.1 Preliminary Experiment Results

The results of the preliminary experiment suggested that the best accuracy was by the algorithm IBk, and the algorithm with lowest accuracy was HyperPipes. To categorize the algorithms based on the results, the top three algorithms (based on high accuracy) were IBk, SMO, and LMT with an accuracy of more than 80%. The algorithms with accuracy between 70-80% were AODE, LogitBoost, and JRIP. The algorithm HiperPipes had the lowest accuracy of 65.02%. A summary of the results is presented in Table 7.1.

We selected the algorithms SMO, IBk, and LMT in phase 2 for the final experiment. The remaining algorithms, i.e., AODE, LogitBoost, JRIP, and HyperPipes, were analyzed based on their confusion matrices in order to identify the correctly classified classes.

All the three algorithms (except HyperPipes) were able to correctly classify the classes; G1, G3, G6, and G16. The HyperPipes algorithm was able to correctly classify the class G8 in addition to G1, G3, G6, and G16. The AODE algorithm was able to correctly classify 129 out of 138 instances for G1, 43 out of 53 instances for G3, 19 out of 21 instances for G6, and 3 out of 4 instances for G16. The LogitBoost and AODE algorithms produced similar results concerning G6 and G16 by correctly classifying the same number of instances. LogitBoost was able to correctly classify 132 out of 138 instances for G1 and 40 out of 53 instances for G3. Whereas, HyperPipes was able to correctly classify 15 out of 53 instances for G3, 6 out of 21 instances for G6, and 2 out of 3 instances for G8. For G1, the HyperPipes algorithm predicted the same number of instances as was predicted by LogitBoost. For G16, HyperPipes, LogitBoost, and AODE were able to correctly classify
Chapter 7. e-Waybills and machine learning algorithms

the same number of instances, i.e., 3 out of 4 instances. The algorithm JRip was able to correctly classify 124 out of 138 instances for G1, 38 out of 53 instances for G3, 17 out of 21 instances for G6, and 4 instances out of G16. Hence, the confusion matrices of the algorithms indicate that AODE, and LogitBoost performed equivalently by correctly classifying 194 out of 243 instances. The algorithm JRip was able to correctly classify 183 instances, while HyperPipes was able to correctly classify 158 instances out of the total 243. Thus, the HyperPipes algorithm correctly classified the lowest number of instances. However, HyperPipes was able to correctly classify more classes as compared to AODE, LogitBoost, and JRIP.

7.5 Final Experiment

For the final experiment, we used the Experimenter application in WEKA. The same dataset (from the preliminary experiment) was used in our final experiment. In the experiment type, 10 folds cross-validation was selected, which is the same testing option from the preliminary experiment. We present the results from the preliminary experiment in Table 7.1. We observe that the algorithms IBk, SMO, and FT have higher accuracy (i.e., more than 80%) as compared with the rest of the algorithms. Therefore, in the final experiment, we compared and evaluated the three algorithms based on their weighted average values for true-positive (TP) and false-positive (FP) rate, area under the curve (AUC), and recall.

TP rate is the number of correct classifications made by an algorithm, whereas FP rate is the number of incorrectly classified instances, i.e., predicting negative instances as positive (Witten et al., 2011). In the final experiment, we selected weighted average TP and FP rate in order to calculate the correct and incorrect classification rates of all the classes by the three algorithms.

AUC is the probability of randomly choosing and ranking a positive instance above a randomly chosen negative instance in a test data. The probability is based on the rankings by the classifier. In the best case, AUC is 1 and all the positive instances are ranked above all the negative instances. In the worst case, AUC is 0 and all the positive instances are ranked below the negative instances. In the case of random rankings, AUC is 0.5. Anti-learning is
expected to have been performed by the classifier if the AUC is significantly less than 0.5 (Witten et al., 2011). We selected AUC as a performance metric since the literature (see, e.g., Ling et al. (2003) and Bradley (1997)) suggests that AUC measure is better (as compared to accuracy) when comparing the performance different classification algorithms.

Recall can be defined as a ratio of the total number of instances classified correctly by the algorithm to the total number of actual instances (Hull, 1993; Witten et al., 2011). In the final experiment, we selected recall for evaluation of the algorithms since it can help in calculating the correctly classified instances as compared to the actual instances in the dataset.

### 7.6 Results and Analysis

We present results from the final experiment in Table 7.2.

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Algorithms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SMO</td>
</tr>
<tr>
<td>Weighted average TP rate</td>
<td>80%</td>
</tr>
<tr>
<td>Weighted average FP Rate</td>
<td>12%</td>
</tr>
<tr>
<td>Weighted average AUC</td>
<td>87%</td>
</tr>
<tr>
<td>Weighted average recall</td>
<td>80%</td>
</tr>
</tbody>
</table>

Table 7.2: Algorithms evaluation.

We can observe from the results that IBk has a higher weighted average TP rate than SMO and LMT, i.e., IBk could classify 82% of the instance correctly as compared to 80% and 79% by SMO and LMT respectively. Regarding incorrectly classified instances (i.e., weighted average FP rate), IBk (with the FP rate of 11%) outperformed SMO and LMT, which had weighted average FP rate of 12%, and 14% respectively. By analyzing the confusion matrices of the three algorithms, we observed that IBk performed better as compared to SMO and LMT by correctly classifying 6 out of the 17 classes. However, SMO and LMT correctly classified 5 out of the total 17 classes. The classified classes by each of the algorithms are presented in Table 7.3.

From Table 7.2, we can observe that the AUC of LMT is closer to 1 as compared to the AUC of SMO and IBk. This indicates that in most of the cases, the positive instances were ranked above the negative instances by
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<table>
<thead>
<tr>
<th>Algorithms</th>
<th>Correctly classified</th>
<th>Incorrectly classified</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMO</td>
<td>G1, G3, G6, G16</td>
<td>G2, G4, G5, G7, G8, G9, G10, G11, G12, G13, G14, G15, G17</td>
</tr>
<tr>
<td>IBk</td>
<td>G1, G3, G4, G5, G6, G16</td>
<td>G2, G7, G8, G9, G10, G11, G12, G13, G14, G15, G17</td>
</tr>
<tr>
<td>LMT</td>
<td>G1, G3, G5, G6, G16</td>
<td>G2, G4, G7, G8, G9, G10, G11, G12, G13, G14, G15, G17</td>
</tr>
</tbody>
</table>

Table 7.3: Classification of freight types.

LMT. Therefore, based on AUC, the algorithms LMT performed better than SMO and IBk. The weighted average recall value of IBk is higher than SMO and LMT. IBk has a weighted average recall value of 82%, which means 199 out of 243 instances were correctly classified by IBk. SMO, with 80% of weighted average recall value, was able to correctly classify 194 out of 243 instances. LMT, with a lowest weighted average recall value of 79%, was able to correctly classify 192 instances out of the total 243 instances.

In Figure 7.1, 7.2, 7.3, and 7.4, we present a comparison of the TP and FP rate, Recall, and AUC by IBk, SMO, and LMT for each of the class attributes. The TP rate comparison, in Figure 7.1, of the algorithms indicates that IBk performed better than SMO and LMT for the classes G1, G3, G4, and G5. The three algorithms had similar performance concerning the class G16, whereas SMO and LMT performed better than IBk.

![Figure 7.1: True Positive rate of IBK, SMO, and LMT.](image)

In Figure 7.2, a comparison of the FP rate of the three algorithms indicates that the algorithms performed equally well for the classes G6, G8, G10, and G13. However, for the classes G1 and G3, IBk performed better than both
SMO and LMT. The performance of SMO and IBK was equally better than LMT for the class G3. For the class G1, SMO and LMT had equally lower performance than IBk.

In Figure 7.2, we present a comparison of the three algorithms concerning recall values. It can be observed that IBk performed better than SMO and LMT for the class G1, G4, and G5. For the class G3, IBk has better performance than LMT but has an equivalent performance as SMO. For G6, IBk has lower performance than SMO and LMT, while the performance of all the three algorithms is the same for G16.

AUC comparison of the three algorithms is shown in Figure 7.4. The figure indicates that IBk performed better than SMO and LMT for the classes G6, G11, and G14. Whereas, for the classes G4 and G17, IBk lower performance than SMO and LMT. For the classes G1, G3, G7, G9, G11, G12, and G15, IBk performed higher than SMO but lower than LMT. For the classes G8, G10, and G13, IBk and SMO both performed equally higher than LMT, while IBk and LMT performed equally higher than SMO for the class G16. For the class G2, SMO performed better than IBk. However, the algorithm IBk may have performed anti-learning as the AUC is lesser than 5%.
The main purpose of this paper was to use machine learning algorithms for predicting the type of freight transported between different origin and destination cities. Based upon a dataset obtained from a Swedish transport company, we applied different machine learning algorithms on the dataset (in order to predict the type of freight transported). In addition, we selected the top three best-performing algorithms for evaluation based upon their performance.
values for weighted average true-positive, false-positive, AUC, and recall.

We conclude that overall the algorithm IBk performed better than the algorithms SMO and LMT. Based on weighted averages of their TP and FP rate, and Recall value, the algorithm IBk can be considered better than SMO and LMT. Under the same criterion, SMO is at the second place, i.e.; its performance was lower than IBk but better than LMT. However, based on the weighted average AUC value, LMT performed better than IBk and SMO. IBk performed better, based on the weighted average AUC value, than SMO. Of the total 17 classes, the algorithm IBk was able to correctly classify 6 classes, while SMO and LMT both were able to correctly classify 4 and 5 classes each respectively. Thus, IBk performed better than SMO and LMT by correctly classifying more classes. All of the correctly classified classes by LMT and SMO were correctly classified by the IBk. However, a comparison of SMO and LMT indicates that LMT was able to correctly classify one more class, i.e., G5. The classes G2, G7, G8, G9, G10, G11, G12, G13, G14, G15, and G17 were not correctly classified by any of the three algorithms. A common feature among the incorrectly classified classes is that all of them have less than or equal to three instances. However, having less than or equal to 3 instances, may not be the reason for incorrect classification since the class G5, which has 2 instances, was correctly classified both by IBk and LMT. A lesson learned from the incorrectly classified classes is to group the different classes based on some common features. The grouping of classes, we believe, will not only reduce the number of classes, but it may also increase the classification accuracy.

Additionally, we conclude that the data from a waybill, if available in an electronic format, i.e., in the form of an e-Waybill, can help in improving knowledge about the freight movement by predicting the freight type (transported between a particular origin and destination city). In addition, we conclude that different machine algorithms perform differently and produce different results when used for predicting the freight type (based on the freight's origin, destination, and weight). Predicting the freight type transported from a particular origin to a particular destination may help transport companies in improved decision making about the type of transport required for a particular origin and destination city of a future order. Additionally, predicting the freight type may lead to improved decision making such as, investment decisions and policy making.
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containing the infrastructure (between freights origin and destination), e.g., expanding road capacity or route choice in case of dangerous goods.

A possible limitation of this study is that multiple orders may be transported using a single vehicle and hence a vehicle may contain more than one type of freight. However, we believe that our results from this study can still be valid for the back-office level, i.e., by considering the order data in a database only and not focusing on the actual fulfillment of the orders by the vehicle. Potential future work to this paper would be to extend the features of the dataset in order to further strengthen the results achieved in this paper. The dataset can be extended with more attributes and features, such as the freight volume under transport and the routes travelled by a vehicle, which is used for transporting the freight, between a particular origin and destination.
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Paper VII

A data mining based method for route and freight estimation

8.1. Introduction

Abstract

We present a method, which makes use of historical vehicle data and current vehicle observations in order to estimate 1) the route a vehicle has used and 2) the freight the vehicle carried along the estimated route. The method includes a learning phase and an estimation phase. In the learning phase, historical data about the movement of a vehicle and of the consignments allocated to the vehicle are used in order to build estimation models: one for route choice and one for freight allocation. In the estimation phase, the generated estimation models are used together with a sequence of observed positions for the vehicle as input in order to generate route and freight estimates. We have partly evaluated our method in an experimental study involving a medium-size Swedish transport operator. The results of the study indicate that supervised learning, in particular the algorithm Naive Bayes Multinomial Updatable, shows good route estimation performance even when significant amount of information about where the vehicle has traveled is missing. For the freight estimation, we used a method based on averaging the consignments on the historical known trips for the estimated route. We argue that the proposed method might contribute to building improved knowledge, e.g., in national road administrations, on the movement of trucks and freight.

8.1 Introduction

It is commonly agreed that road freight transport contributes both positively (e.g., concerning economy and social welfare) and negatively (e.g., pollution, congestion, noise, and road accidents) to a society. An important challenge of today is to achieve an efficient and sustainable transport system, where the positive effects are maximized at the same time as the negative effects on the environment are minimized. A possible means to succeed with this challenge is to apply different types of policy instruments, such as taxes, fees, and infrastructure investments. However, significant changes to the transport system should not be done without first acquiring accurate information on the current system.

Large amounts of resources are spent yearly on collecting traffic data, e.g., in order to estimate the transport volumes and travel times on roads in congested areas. Still, there is often a large gap in the knowledge
concerning the transport system, in particular regarding the movement of individual vehicles and of freight. We argue that this gap is partly caused by the limitations of the technologies that are used for measurement. The dominating method in use, at least in the country of our study, is pneumatic tubes, which allows counting vehicles, as well as estimating vehicle types and traveling speeds. However, the method does not allow identifying vehicles, and the collected data can therefore not be used to determine how individual vehicles have traveled in the network. In addition, the data collection methods of today do not allow estimating what the observed vehicles carry.

The purpose of the current paper is to contribute to the development of methodology for building knowledge on the movement of trucks and freight in a transport network. In particular, we contribute a method for estimating the route a vehicle used and the freight carried by that particular vehicle, based on information about where the vehicle usually travels and the freight it usually carries. The method includes a learning phase and an estimation phase, where the learning phase uses historical data about the movement of a vehicle and the consignments allocated to the vehicle in order to generate estimation models for the route choice and consignment allocation. The estimation phase makes use of the generated estimation models to estimate the route and the carried freight, using only a sequence of vehicle positions as input, i.e., positions where the vehicle have been observed. Our work is based on the assumption that the vehicles traveling in a network, to a sufficiently large extent, can be identified along the roads, e.g., using road-side cameras that operate together with automatic number plate recognition software or vehicle-to-vehicle communication (e.g., using transponder technology). We believe that our research might be of interest for actors, mainly public road administrations, who are able to observe (and identify) a vehicle at different locations in a network, or who in other ways are able to collect information about vehicles positions. They also need historic data about the routes the vehicle usually uses and the freight it usually carries. Perhaps, these types of information could be collected using extended commodity flow surveys, where also route data is collected. Commodity flow surveys are conducted on a regular basis in some countries, e.g., in the US. In particular, the presented method can be useful in situations where the interest is on identifying the freight types and volumes and routes used by vehicles, in order to support the public policy
8.2. Related Work

There exist different types of freight transport analysis models for estimating freight transport under different conditions, and for supporting the design of the transport network. The dominating type of method is the so-called 4-step freight transport analysis models (De Jong et al., 2004), e.g., Swahn (2001) and Rich et al. (2009). However, it is often difficult to guarantee the quality of the vehicle and freight flow estimates that are generated using this type of models, e.g., since the quality of the input data used in the model might not be sufficiently good, and the models typically make several estimates, e.g., of vehicle types, traffic modes, transport chains, and routes, before arriving at the final vehicle and freight estimates. There also exist other types of models for the same purpose; see, De Jong et al. (2004), Chow et al. (2010), and Holmgren et al. (2012) for overviews.
Another field of related research is map-matching, where the purpose is to translate a sequence of vehicle locations into the correct route in a traffic network (see, e.g., Quddus et al. (2007) for an overview). Brakatsoulas et al. (2005), for example, propose and evaluate three map-matching algorithms that consider the trajectory nature of the GPS data and which have the ability to map a trajectory to a road network.

The most closely related work is by Froehlich and Krumm (2008); Simmons et al. (2006) and Bakhtyar and Henesey (2014). Froehlich and Krumm (2008) present different algorithms for predicting a driver’s route based on historical trip data for the same driver. They test the algorithms on data acquired for 250 drivers over a period of 15 days. In order to predict a driver’s route, they compare the first part of a driver’s current trip with the previously observed trips for the same driver. Simmons et al. (2006) propose an approach for predicting a driver’s intended destination and route by applying a hidden Markov model on observations of the driver’s driving habits. Through the use of online GPS observations for a driver, they manage to predict the destination and route for that particular driver using the proposed model. They claim that their model is able to achieve 98% accuracy in most cases. The work by Bakhtyar and Henesey (2014) concerns the estimation of freight types between terminals (i.e., the origin and destinations of consignments under transport). In particular, they present a comparison of classification algorithms for the considered problem. In Table 8.1, we present the difference between the work in this paper and the most closely related work.

<table>
<thead>
<tr>
<th></th>
<th>Estimation type</th>
<th>Transport type</th>
<th>Intended user(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Froehlich and Krumm (2008)</td>
<td>Route estimation</td>
<td>Passenger</td>
<td>Driver</td>
</tr>
<tr>
<td>Simmons et al. (2006)</td>
<td>Route estimation</td>
<td>Unknown</td>
<td>Driver</td>
</tr>
<tr>
<td>Bakhtyar and Henesey (2014)</td>
<td>Freight estimation</td>
<td>Freight</td>
<td>Public authorities</td>
</tr>
<tr>
<td>Our study</td>
<td>Route &amp; Freight estimation</td>
<td>Freight</td>
<td>Public authorities</td>
</tr>
</tbody>
</table>

Table 8.1: Our research compared to other closely related work.

The main difference between the focus of this paper and the related research discussed above is that we suggest building estimation (prediction) models for both freight and route. In particular, we propose a method that explicitly utilize on historical data (trips and freight data) in order to translate a set of vehicle positions into route and freight estimates. Another key difference between our work and the closely related work is the intended user; our aim is to support the decision making by public authorities.
8.3 A method for route and freight estimation

In this section, we present our method for building and using estimation models for the route used by a vehicle and of the freight carried on that particular route. The method includes a learning phase and an estimation phase. The learning phase uses historical data about the movement of the vehicle and the consignments allocated to a vehicle in order to build the estimations models: one model for the route choice and one model for the freight allocation. In the estimation phase, the estimation models are then used in order to estimate the route and freight using only a sequence of vehicle positions as input. The proposed route and freight estimation method is illustrated in Figure 8.1.

![Figure 8.1: Our method for route and freight estimation.](image-url)

8.4 Evaluation of the estimation method

We partly evaluated our route and freight estimation method in a study involving a medium-size Swedish road freight transport operator, who provided GPS data (from their fleet management system) and consignment
data (from their customer order system) for one of their trucks during a period of one month. We verified the correctness of the received data by comparing the waybills for the truck with the order data for the same truck. In addition, we installed monitoring equipment in the truck, and compared the collected data with the received GPS data. From the collected data we identified 1) the outbound trips in the GPS data and 2) which of the consignments that belonged to each of the outbound trips. We here define an outbound trip as a sequence of links, where the first link starts and the last link ends in the home terminal of the truck; each time the vehicle visits its home terminal, it initiates a new outbound trip. In the data processing phase, we grouped the locations of the pickup and deliveries in the consignment data so that all of the pickups and deliveries located in the same town were represented by one “terminal”, where freight may be picked-up or delivered. In total, we identified 18 bidirectional links (L1, ... ,L18) that connect the 18 terminals (N1, ... ,N18). In Figure 8.2, we illustrate the considered network. In total, the studied truck made 11 outbound trips along the 7 routes (described below as sequences of nodes). For future reference, we present the trips that belong to each of the routes, where trip 1 is oldest, trip 2 is second oldest, etc.

- **R1**: (trip 2) N1-N2-N3-N4-N5-N4-N3-N2-N1
- **R4**: (trip 1 and 4) N1-N7-N8-N9-N8-N7-N1
- **R6**: (trip 10) N1-N2-N3-N4-N3-N2-N1
- **R7**: (trip 11) N1-N2-N3-N4-N7-N8-N9-N10-N11-N12-N11-N10-N9-N8-N7-N4-N3-N2-N1

We grouped the transported freight into two categories: 1) food and consumption products and 2) non-food items. The food and consumptions products category includes fish, meat, vegetables, etc., and the non-food
freight consists of several types of products, e.g., transport equipment, furniture, and mail. The reason for using only two categories is that most of the studied consignments concern various types of food items and consumption products that could not be distinguished from each other. In addition, there was such a large variety among the other product types that it would not be possible to identify any patterns unless they were aggregated into one category.

It should be noted here that we had order data for a period of 25 days, whereas the GPS data covered 33 days. For this reason, we did not have any order data for R5, R6, and R7. However, in order to evaluate the route estimation phase of our model, we chose to keep R5, R6, and R7. In total, we had order data for six of the identified 11 trips, that is, trips 2, 3, 5, 6, 7, and 8.

### 8.4.1 Route estimation

As mentioned above, the route estimation should be made using only a set of vehicle positions, representing the links where the vehicle has been observed, as input. In particular, it should be able to work with high accuracy even if the vehicle has been observed only on a subset of the links along a route. It can be argued that each of the routes in our dataset defines a
class, and since the route estimation concerns estimating the most probable route (or class) from a set of vehicle observations (i.e., the links where the vehicle has been observed), we used supervised learning for the route estimation. In particular, we used the open source Waikato Environment for Knowledge Analysis (Weka) (Hall et al., 2009).

We considered different ways of representing the routes in the learning algorithms; we finally chose a route representation that explicitly specifies for each of the 18 links in the extracted network whether or not it is included in the route. Our representation of the identified routes is provided in Table 8.2, where each row represents a route, the first column is the route label (i.e., the class), and each of column 2-19 specifies if the corresponding link is in the route (value 1) or not (value 0). In order to evaluate our route estimation approach, we used the identified seven routes, as specified in Table 8.2, as the training set. The test set consists of all the routes that can be generated by removing one or more link from the seven routes, as will be detailed below.

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
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<th>L6</th>
<th>L7</th>
<th>L8</th>
<th>L9</th>
<th>L10</th>
<th>L11</th>
<th>L12</th>
<th>L13</th>
<th>L14</th>
<th>L15</th>
<th>L16</th>
<th>L17</th>
<th>L18</th>
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</thead>
<tbody>
<tr>
<td>R1</td>
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<td>R2</td>
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<td>R3</td>
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<td>R4</td>
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<tr>
<td>R5</td>
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<td>R6</td>
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<tr>
<td>R7</td>
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Table 8.2: Route representation in the supervised learning algorithms.

As mentioned above, the estimation (prediction) corresponds to identifying the correct route (or label) from a, typically, incomplete description of a route. An incomplete route description corresponds to the fact that the vehicle has been observed at one or more (but not at all) locations along a route. In other words, there are at least one link along the route for which there exist no observation. An incomplete route description corresponds to a row in Table 8.2, where one or more of the ones have been exchanged with zeros. In order to reduce the size of the test set, we did not include the links used by the vehicle when returning to the home terminal. However, in the freight estimation part, we still consider those links.

By requiring that an incomplete route description should contain at least one link, there are 5666 possible incomplete route descriptions for our seven routes. These 5666 instances constitute our test instances. For a route with \(n\)
8.4. Evaluation of the estimation method

links, there exist \( \binom{n}{k} \) ways to remove \( k \) links (or changing \( k \) ones to zeros). For example, for R1, which has 5 links, there are \( \binom{5}{1} = \binom{5}{4} = 5 \) ways to remove 1 or 4 links and \( \binom{5}{2} = \binom{5}{3} = 10 \) ways to remove 2 or 3 links.

We initially investigated each of the supervised learning algorithms provided by Weka, by classifying all of 5666 test instances. The algorithm *Naive Bayes Multinomial*, in particular the *Naive Bayes Multinomial Updatable*, performed best on the considered dataset with 61.4\% correctly classified instances. We therefore chose this algorithm to study in more detail. The *Naive Bayes Multinomial Updatable* is an updated version of the classical *Naive Bayes Multinomial* algorithm, which is mainly used for document classification (Witten et al., 2011). The *Naive Bayes Multinomial* views a document as a set of words by considering the word counts (i.e., words frequency). The *Naive Bayes Multinomial Updatable* also considers patterns in the words frequency in the document (McCallum et al., 1998; Razavi et al., 2010). Although 61.4\% seems rather low, it should be noted that the test set included the worst-case route descriptions, e.g., it includes for R5 (with 11 links) 11 instances with only one link, 55 instances with two links, and 165 instances with three links.

We divided our test set into 10 subsets: one subset with all incomplete route descriptions containing one link, one subset with all incomplete route descriptions containing two links, etc. From the confusion matrices generated for our 10 test subsets, we observed that the higher the number of links in the incomplete route descriptions, the higher the share of correctly classified instances will typically be. This can also be seen in Figure 8.3, where we show for each of the routes the share of correctly classified test instances with one link kept, two links kept, etc., for *Naive Bayes Multinomial Updatable*.

The routes R4 and R6, which had the least number of links (i.e., 3 links), were always correctly classified. Therefore, we chose not to display them in Fig. 3. The routes R1, R3, and R7 were always correctly classified for all incomplete route descriptions with at least 4 and 5 links respectively. The routes R2 and R5 (having 11 links each) showed an identical classification success pattern. The reason for this could be that these routes differ with only one link: R2 includes L18 but not L13 while R5 includes L13 but not L18. Both R2 and R5 can be classified correctly up to 91\% with 10 links present. The reason for not observing a higher classification success rate
than 91% is that R2 and R5 becomes identical to R3 when removing L18 and L13, respectively. In Fig. 3, it can be seen that the classification rate for R7 drops when the number of links are increased from 2 to 3. This is because 45% of the instances of R7 were incorrectly classified as instances of R4 and R6. The reason for this behavior is that there is a good match with R4 and R6 when removing all but three links from the description of R7. For example, all 18 incomplete representations of R7 with three links, where at least one of L1, L2, and L3 and none of L6, L7, and L8 are represented, will be misclassified as R6. Altogether, we argue that the presented results show that the supervised learning approach, in particular the Naive Bayes Multinomial Updatable algorithm, has potential to perform rather well for route estimation.

### 8.4.2 Freight estimation

The purpose of the freight estimation part of our estimation method is to estimate the freight types and corresponding weights carried by the vehicle along the estimated route. We chose to estimate the freight as the average of
8.4. Evaluation of the estimation method

the historical consignments for the outbound trips for the selected route. For example, if there are two outbound trips for a route with the same freight types, however in different amounts (lets say $x$ and $y$ kg), that are carried between the same origin and destination, we estimate the amount of freight carried by the vehicle as $(x+y)/2$ kg between the two locations. We used this approach as our freight estimation, since it is a straightforward way to estimate the carried freight, and it takes into account all the information about the consignments previously carried by the studied vehicle along a particular route.

We identified the consignments for a given trip in the order data set, by identifying those consignments that were loaded the same day as the outbound trip, and had loading and/or unloading locations that matched the sequence of terminals in the outbound trip. For some of the consignments, we were only able to identify a loading or an unloading location. We assumed that these consignments were loaded or unloaded, respectively, in the home terminal of the vehicle, i.e., node N1. We further assumed that some other trucks completed these orders. For the same reason as we had consignments assigned to the studied truck, which were partially completed by other trucks, there could be consignments assigned to other trucks that were partially completed by the considered truck. Therefore, we realized that there is risk that we underestimated the freight loaded on the truck. This was later on confirmed by the transport operator involved in our study.

In Figure 8.4, 8.5, 8.6, and 8.7, we present, for the purpose of illustration, our freight estimates based on the identified trips along R2 (trips 3, 6, and 8) and R3 (trips 5 and 7). In the figures, the links are presented on the x-axes and the amounts of freight (in kilograms) carried on each of the links are presented on the y-axes. Figure 8.4 and Figure 8.6 represent the amount of food and consumption products carried along R2 and R3, respectively. Figure 8.5 and Figure 8.7 represent the amount of non-food items on R2 and R3, respectively. It should be noted that we do not present freight estimates for R1, because we observed (and the company confirmed) that the order data for trip 1 was not representative for the studied truck.

In particular, the increases and decreases of the carried freight, which can be observed in the diagrams, clearly show how the truck is estimated to have carried the freight along the two routes. For example, for trip 3 and
6, we observed from Figure 8.4 that food freight was carried on L6, L7, L8, L9, L10, and L12 before the same type of freight is unloaded, i.e., on the nodes connected by L14, L15, L16, L17, and L18. It can be observed that on L18 and L18’, the freight weight decreases sharply. The reason for a steep decrease or increase on a particular link is due to the unloading or loading of large freight volumes (i.e., weight) before the vehicle enters the link. The same pattern can be seen on L18’ and L17’, where there is a steep increase in the freight weight.

**Figure 8.4:** Freight estimate diagrams for food freight for R2.

**Figure 8.5:** Freight estimate diagrams for non-food freight for R2.

For evaluation purposes, we presented the results from the freight
estimation to the manager of the transport company included in the study. He confirmed that the generated freight estimates for R2 and R3 correspond well with the typical pattern of the studied vehicle. He explained that the reason for the high difference in the non-food freight amount on trip 8 compared to trips 3 and 6 on route R2 (see, Figure 8.5) is due to a temporary load of 20 tons.

![Figure 8.6: Freight estimate diagrams for food freight for R3.](image)

![Figure 8.7: Freight estimate diagrams for non-food freight for R3.](image)
8.5 Concluding remarks

We have presented a method for route and freight estimation, which includes a learning phase and an estimation phase. The purpose of the learning phase is to build estimation models based on historical vehicle data; one model for route choice and one model for freight allocation. The purpose of the estimation phase is to estimate what freight (types and weights) was carried by the vehicle along an estimated route. We partly evaluated the proposed method in a study involving a medium-size Swedish road freight transport operator. We conclude that the method has potential to provide good route and freight estimations, as long as there exist sufficient amounts of historical vehicle movement and consignment data, as well as current vehicle observations. In addition, we conclude that more detailed data (typically found in fleet management and ordering systems) is needed when building the prediction model, whereas only positions (typically sparse) along the road is needed in order to estimate routes. We used supervised learning for the route estimation, i.e., the Naïve Bayes Multinomial Updatable algorithm, which performed rather well for route estimation. For freight estimation, we estimated the freight carried by the vehicle along a particular route as the average of the consignments that previously have been observed on the outbound trips for the route.

A possible limitation of the suggested method, which estimates the route and freight in two sequential steps, is that incorrect route estimations might lead to incorrect freight estimations. However, our evaluation indicate that it is possible to achieve a rather accurate route classification using supervised learning, unless very little information is known about the movement of the vehicle. As the method operates in two steps, i.e., first the route is estimated, and then the freight is estimated, we find it reasonable to assume that the performance of the method to a large extent depends on the choice of model components for the route and freight estimation, respectively.

Even though there is a risk of transferring errors between the route and freight estimation models, we argue that there are also desirable features of the approach. Mainly, a two-step (sequential) approach, where the interface between the steps is clearly defined, enables to replace only one of the estimation models (either route or freight) and keep the other one. The possibility to independently choose models for the two steps is an
important reason that we suggest using an approach where route and freight is estimated sequentially.

An interesting direction for future work is to estimate freight types and volumes on routes for which there exist no order data. Additionally, the proposed method needs to be evaluated in more detail, in particular, the freight estimation part of the approach, which we only evaluated through expert opinion.

In addition, it is relevant to study whether it is best to create one estimation model for each vehicle of a company, or if it is better to cluster vehicles so that prediction models represent multiple vehicles. It is also relevant to study the possibility to include, in the estimation models, that consignments may be transferred between vehicles, which in our study led to an underestimation on carried freight for some links.

Acknowledgements

The presented research was conducted within the project Arena3, which was led by NetPort Karlshamn, and funded by the Regional Council of Blekinge, the Swedish Governmental Agency for Innovation Systems, the Swedish Transport Administration, and the Swedish Transport Agency. In addition to the above, we would like to thank the Swedish road freight transport operator who made our research possible by providing consignment and vehicle movement data, and by allowing us to monitor one of their trucks. We would also like to thank the Swedish National Postgraduate School on Intelligent Transport Systems (NFITS) for supporting this research.
Appendix

Terms used in this thesis

• **AODE**: *Averaged One-Dependence Estimators* is a probabilistic classification learning algorithm. It is considered to be the most effective Naive Bayes algorithm.

• **AUC**: *Area Under the Curve* is a graphical plot that illustrates the performance of a classifier as its discrimination threshold is varied. The curve is created by plotting the true positive rate against the false positive rate at various threshold settings.

• **BOL**: *Bill of Lading* is a transport document in maritime transport issued by a carrier. The document has details about a shipment and gives title of that shipment to a specified party.

• **CA**: *Certification Authority* is an entity that issues digital certificates, which certifies the ownership of a public key by the named subject of the certificate in order to ensure trust.

• **CAF**: *Customized Access Framework* is a part of the cloud-based Logistic Mall. CAF implements a Software-as-a-Service (SaaS) layer in order to provide logistics applications and services to a customer company of the Logistics Mall.

• **CMR**: Convention on the Contract for the International Carriage of Goods by Road is an agreement signed in 1956. It addresses
various legal issues concerning transportation of cargo by road. The agreement is also known as CMR convention and it has been ratified by the majority of European states.

• **DHL**: *Dalsey, Hillblom & Lynn* is a 4PL service provider.

• **e-Air Waybill**: *Electronic Air Waybill* is a solution proposed and used by IATA for replacing the paper air waybills with an electronic solution.

• **EAPs**: *e-Freight Access Points* are communication facilities exposing data of an organization to other parties based on an agreed profile, which may include message standards and security mechanisms. EAPs is essential part of the e-Freight project.

• **eBOL**: *Electronic Bill of Lading* is an electronic solution for replacing the traditional paper-based bill of lading.

• **ebXML**: *electronic business using eXtensible Markup Language* is an initiative by OASIS for replacing the EDI. It enables a global electronic marketplace in which enterprises of any size, and in any location, could safely and securely transact business through the exchange of XML-based messages over the internet.

• **EC**: *E-call* service provides information about an accident, e.g., location of the accident or good type in the vehicle. Users of this service are drivers, emergency units, traffic controllers, environmental agents and goods owners.

• **e-CMR**: *Electronic CMR* is an agreement signed by member states of UNECE in 2008. In this agreement the member states agreed on the use of an electronic CMR document (i.e., a waybill).

• **EDI**: *Electronic Data Interchange* is an electronic exchange of business information using a standardized format. It can also be a system that allows the electronic exchange of information in standardized format between organizations.
• **e-Freight**: was a European project that aimed at replacing paper documents in freight transport with an electronic solution.

• **EPC**: *Electronic Product Code* is a universal identifier that gives a unique identity to a specific physical object.

• **ERP**: *Enterprise Resource Planning* is business software that enables the collection, storage, management, processing, and interpretation of data related to business activities in an organization.

• **ETA**: *Dynamic Estimated Time of Arrival* is a service that predicts the arrival time of goods for a specific destination. Users of this service are goods owners and dispatchers.

• **e-Track**: It is a real-time track and trace service by DHL. The service enables tracking and tracing of cargo.

• **EU**: *European Union*.

• **e-Waybill**: *Electronic Waybill* is a service presented in this thesis. The service is aimed at achieving the purpose of a paper waybill, supporting ITS services, and enabling knowledge building concerning freight flows.

• **FM**: *Freight Mobility* is a service that provides freight related information such as type of goods, capacity, origin, destination, etc. Users of this service are transport planners, infrastructure investment agencies and infrastructure owners.

• **FP**: *False Positive* is an error in data reporting in which a test results improperly by indicating presence of a condition.

• **GI**: *Goods Identification* is a service that helps in identification of goods by providing goods related information. Users of this service are good owners, gate controllers, terminal operators, custom officers and emergency units.

• **GLU**: *Notify goods to load/unload* is a service that provides information about goods to load or unload on-board. Users of this service include drivers, gate agents, loading/unloading agents and goods owners.
• **GPS:** *Global Positioning System* is a satellite-based navigation system developed by the U.S. Department of Defense. The system provides location and time information to a GPS receiver.

• **GS:** *Notify goods physical status* is a service that provides information about the physical status (i.e., temperature) of the goods. Users of this service are drivers and goods owners.

• **GW:** *Notify goods waiting* is a service that provides information about the goods that are standing for too long in the same location. Users of this service are drivers, goods owners, traffic control agents, environmental agents and infrastructure operators.

• **GUL:** *Notify goods unwanted location* is a service that provides information about the goods that are forbidden to be placed in a certain location. Users of this service are drivers, goods owners, gate controllers, loading/unloading agents and warehouse agents.

• **IATA:** *International Air Transport Association* is a trade association for the worlds airlines. At present, IATA represents approximately 260 airlines.

• **IBTPISP:** *Internet-Based Third-Party Internet Service Provider* is the concept of a third party organization that is responsible for handling the electronic Bill of Lading. The focus of an IBTPISP is on organizational-based trust, which ensures to protect the interest of all stakeholders involved in a consignment.

• **IBk:** An Implementation of the k-Nearest Neighbors Algorithm.

• **IEx:** Information Entity x, e.g., x=3, Information Entity 3. An information entity in this thesis can be either an input information entity or an output information entity.

• **INTERTANKO:** *International Association of Independent Tanker Owners* is an association for independent tankers’ owners, non-oil companies and non-state controlled tanker owners, for the safe shipping of oil
and chemicals. The association offers a forum for discussing policies concerning tankers.

- **IRU**: *International Road Union* is an organization representing the world road transport. The organization was founded in Geneva on 23 March 1948 and it supports the interests of road vehicle operators to ensure economic growth through sustainable mobility of people and goods by road worldwide.

- **IS**: *Information System* is an organized system that can be used for collecting, organizing, storing, processing, and communicating information.

- **ITP**: *Information on Truck Parking* is a service that provides information about available parking space. Users of this service are drivers and parking infrastructure providers.

- **ITS**: *Intelligent Transport Systems* are advanced information and communication technologies that are used in transportation for providing innovative services relating to different modes of transport.

- **JRIP**: An implementation of the popular RIPPER (Repeated Incremental Pruning to Produce Error Reduction) algorithm.

- **KL-Net**: *Korea Logistics Network* is a Korean logistics network in which formal business transactions flows between logistics-related parties. It was introduced due to the absence of support for the ports and the transport operators in Korea Trading Network.

- **KT-Net**: *Korea Trading Network* was introduced in the year 1990. KT-Net uses an EDI network for exchange of logistics information within the maritime community. In addition to issuing electronic bill of ladings, KT-Net covers the scope of licensing, insurance, customs clearance, request for shipment etc.

- **LITS**: *Liability Intelligent Transport System Service* is a service proposed in this thesis. The service is designed to detect freight damage and identify the actor(s) responsible for the damage.
• **LMT:** *Logistic Model Tree* is a supervised learning algorithm that combines decision trees and logistic regression. The algorithm uses LogitBoost algorithm in order to induce trees with linear-logistic regression models.

• **MMP:** *Mall Market Place* is a component of the cloud-based platform known as Logistic Mall. Mall Market Place provides logistics IT services and applications.

• **MSG:** *Notify missing/surplus goods* is a service that provides information about the missing or surplus goods. Users of this service are drivers, gate agents, loading/unloading agents and goods owners.

• **NAV:** *Navigation through a route network* is a service that helps in deciding about a road choice in a network of roads towards the destination. User of this service is a driver who needs up-to-date information about a road choice.

• **OASIS:** *Organization for the Advancement of Structured Information Standards* is a global non-profit organization working for the development and adoption of standards for security, Internet of Things, energy, and other areas.

• **OBU:** *On-Board Unit* is a system mounted on vehicles. The system has capabilities, such as it can communicate with other devices over a short-range and it can be used to collect driving information.

• **OSM:** *On-board Safety and Security Monitoring* is a service that provides information about the vehicle and goods safety status. Users of this service are drivers, goods owners and vehicle inspectors.

• **PDA:** *Personal Digital Assistant* is a hand-held device for personal information management.

• **RFID:** *Radio-Frequency Identification* is the use of radio waves to read and capture information stored on a tag (known as RFID-tags) attached to an object.
Appendix . Terms used in this thesis

- **RTT**: *Real time Track and Trace of goods* is a service that provides real time information about the location of goods. Users of this service are goods owners, dispatchers, and traffic controllers.

- **RED**: *Remote Declaration* is a service that provides real time information about the goods and the vehicle from a distance, i.e., before the vehicle has reached the gates. Users of this service are goods owners, gate agents, loading/unloading agents, tax agents, customs, and consignment inspectors.

- **RG**: *Route Guidance* is a service that provides information about the use of a specific route or a choice of routes. Users of this service are drivers and infrastructure owners.

- **RHW**: *Road Hindrance Warning* is a service that provides information about any obstacle on the road and the possible ways to reduce the effect of that obstacle. Users of this service are drivers and fleet operators.

- **SaaS**: *Software as a Service* is a licensing model for software. In this type of model, the software is hosted online and it is licensed to the users on a subscription basis.

- **SADT**: *Structured Analysis and Design Technique* is a method proposed in 1977 for identifying the functional and non-functional requirements of a system.

- **SDF**: *Service Description Framework* is a framework that can be used to describe an ITS service by decomposing the service into entities and functions.

- **SEADOCS**: A project proposed in 1986 for achieving the purpose of electronic solution for negotiable Bill of Lading in maritime transport.

- **SGM**: *Sensitive Goods Monitoring* is a service that provides information about the location and status of sensitive goods. Users of this service are authorities in charge of sensitive goods.
• **SMO**: Sequential Minimal Optimization is an algorithm for training support vector machines with a high speed. The algorithm was developed in 1998 at Microsoft Research.

• **TOH**: Transport Order Handling is a service that provides information about new incoming transport orders and the already fulfilled orders. Users of this service are drivers and transport planners.

• **TP**: True Positive rate is the proportion of positives that are correctly identified.

• **TSP**: Transport Service Provider provides transport services, such as vehicles and drivers, for freight transportation.

• **UBL**: Universal Business Language is a library of standard electronic XML business documents. It was developed by Organization for the Advancement of Structured Information Standards.

• **UN**: United Nations.

• **UNECE**: United Nations Economic Commission for Europe.

• **US**: United States.

• **VAN**: Value Added Network is a private network hired by a company to facilitate electronic data interchange and/or other network services, such as message encryption, secure email and management reporting.


• **WEKA**: Waikato Environment for Knowledge Analysis is an open-source software developed at the University of Waikato, New Zealand. The software provides a collection of machine learning algorithms.

• **WI**: Weight Indication is a service that provides information about road restrictions and total weight of the vehicle. Users of this service are drivers and inspection agents.
Appendix . Terms used in this thesis

- **XML**: *eXtensible Markup Language* is a markup language that defines a set of rules for encoding documents in a format which is both human and machine readable.

- **XXL**: *Information on XXL Cargo Transportation* is a service that provides information about the measures that need to be taken for successful transportation of XXL cargo over a specific route. Users of this service are drivers, infrastructure owners and traffic controllers.

- **ZigBee**: It is a low-powered and high-level communication protocol. ZigBee is intended to be simpler and less expensive than other protocols, such as Bluetooth and Wi-Fi.
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ABSTRACT

In freight transportation, a waybill is an important document that contains essential information about a consignment. The focus of this thesis is on a multi-purpose electronic waybill (e-Waybill) service, which can provide the functions of a paper waybill, and which is capable of storing, at least, the information present in a paper waybill. In addition, the service can be used to support other existing Intelligent Transportation System (ITS) services by utilizing synergies with the existing services. Additionally, information entities from the e-Waybill service are investigated for the purpose of knowledge-building concerning freight flows.

A systematic review on state-of-the-art of the e-Waybill service reveals several limitations, such as limited focus on supporting ITS services. Five different conceptual e-Waybill solutions (that can be seen as abstract system designs for implementing the e-Waybill service) are proposed. The solutions are investigated for functional and technical requirements (non-functional requirements), which can potentially impose constraints on a potential system for implementing the e-Waybill service. Further, the service is investigated for information and functional synergies with other ITS services. For information synergy analysis, the required input information entities for different ITS services are identified; and if at least one information entity can be provided by an e-Waybill at the right location we regard it to be a synergy. Additionally, a service design method has been proposed for supporting the process of designing new ITS services, which primarily utilizes on functional synergies between the e-Waybill and different existing ITS services. The suggested method is applied for designing a new ITS service, i.e., the Liability Intelligent Transport System (LITS) service. The purpose of the LITS service is to support the process of identifying when and where a consignment has been damaged and who was responsible when the damage occurred. Furthermore, information entities from e-Waybills are utilized for building improved knowledge concerning freight flows. A freight and route estimation method has been proposed for building improved knowledge, e.g., in national road administrations, on the movement of trucks and freight.

The results from this thesis can be used to support the choice of practical e-Waybill service implementation, which has the possibility to provide high synergy with ITS services. This may lead to a higher utilization of ITS services and more sustainable transport, e.g., in terms of reduced congestion and emissions. Furthermore, the implemented e-Waybill service can be an enabler for collecting consignment and traffic data and converting the data into useful traffic information. In particular, the service can lead to increasing amounts of digitally stored data about consignments, which can lead to improved knowledge on the movement of freight and trucks. The knowledge may be helpful when making decisions concerning road taxes, fees, and infrastructure investments.