An Integration Platform for Synchromodal Transport

Prince Mayurank Singh

AN INTEGRATION PLATFORM FOR SYNCHROMODAL TRANSPORT

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PROEFSCHRIFT

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यक्षः – धन्यानामुत्तमं किंस्वित् धनानां स्यात् किमुत्तमम्।
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युधिष्ठिरः – धन्यानामुत्तमं दाक्ष्यं धनानामुत्तमं श्रुतम्।
लाभानां श्रेय आरोग्यं सुखानां तुष्टिरुत्तमा॥

यक्षः प्रश्न, अरण्य पर्व, ३११ – ३१२, महाभारत ।

*Yaksha: What is the epitome of good behaviour, of all wealth,
of all gains and of all happiness ?*

*Yudhishthira: Generosity is the epitome of good behaviour,
learning is the epitome of all wealth.
Health is the epitome of all gains and
contentment is the epitome of all happiness.*

Yaksha Prashna, Aranya Parva, 311-312, Mahabharat.

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20th August 2018

Summary

Transportation sector plays an important role in the growth of national economies. Advances in information technology have facilitated new collaboration opportunities among transport companies. Ubiquitous and faster internet now enables transport companies to access real time data about events in a transport network. New collaboration opportunities and access to real time data, have given rise to new transport practices.

Synchromodal Transport (SmT) or Synchromodality, is a new transport practice, where the route and transport mode for transporting cargo is chosen dynamically, i.e., while the cargo is in-transit. If a disruption event occurs, causing a delay in transportation, the cargo may be shifted to another transport mode.

Existing research over SmT is biased towards routing and capacity planning challenges posed by SmT. Data integration challenges posed by SmT, have not received their due attention from researchers. The primary data integration challenge is the integration of contextual events data and transport planning data. This dissertation provides a solution to data integration challenges posed by SmT, by designing a **Synchromodal Transport Integration Platform (SmTIP)**.

I, designed SmTIP based on the results of three research activities. The first research activity is SmT stakeholders' interview, which resulted in a list of requirements for SmTIP. The second research activity is analysis of SmT practices, which resulted in a list of relevant contextual events and processes for a SmT scenario. The third research activity is studying the state-of-the-art in integration platform design, which resulted in a reference architecture for integration platforms.

I, then, developed a prototype based on SmTIP. The prototype integrates transport data and contextual events data, enables dynamic transport planning and in case of a disruption event, changing the transport mode of cargo. When representatives from transport companies used SmTIP prototype, their responses induced improvements in SmTIP design.

This dissertation is useful for transport companies, researchers in transportation sector and information technology sector. Transport companies can get acquainted with, SmT processes, relevant contextual events, data integration challenges posed by SmT and how to overcome them.

Researchers in transportation sector, can use this dissertation as an introduction to SmT. It will help them understand SmT scenario, SmT processes and relevant disruption events. Documented responses of transport companies' representatives during SmTIP validation will help researchers in the future improvement of SmTIP and in designing validation experiment setups. This dissertation enhances SmT research. It fills the research gap of SmT data integration challenges by: (1) identifying the data integration challenges, (2) listing the requirements for SmTIP, and (3) designing SmTIP to overcome them.

Researchers and practitioners in information technology, can use the reference architecture for integration platforms to address data integration challenges in different application domains. For that purpose, the refinement of the reference architecture to SmT domain, as shown in this dissertation, may be used as a guide.

Samenvatting

De transportsector speelt in vele landen een belangrijke rol bij economische activiteiten en de groei van de nationale economie. Vooruitgang in informatietechnologie heeft nieuwe samenwerkingsmogelijkheden tussen transportbedrijven mogelijk gemaakt. Alomtegenwoordig en sneller internet biedt nu vervoersbedrijven toegang tot real-time gegevens over de status en gebeurtenissen in een transportnetwerk. Nieuwe samenwerkingsmogelijkheden en toegang tot real-time gegevens hebben geleid tot nieuwe vervoerspraktijken.

Synchromodaal Transport (SmT), of **Synchromodaliteit**, is een nieuwe vervoerspraktijk, waarbij de route en modaliteit voor het transport van lading dynamisch wordt gekozen, d.w.z. terwijl de lading onderweg is. Als het transport wordt vertraagd door het optreden van een verstoringsegebeurtenis kan de lading worden verplaatst naar een andere transportmodaliteit.

Bestaand onderzoek naar synchromodaliteit is vooral gericht op problemen met betrekking tot routing en capaciteitsplanning. Gegevensintegratieproblemen als gevolg van synchromodaliteit hebben tot nu toe geen of weinig aandacht gekregen van onderzoekers. De primaire uitdaging bij gegevensintegratie voor synchromodaliteit is de integratie van gegevens over contextuele gebeurtenissen en gegevens over transportplanning. Dit proefschrift draagt bij aan een oplossing voor de uitdagingen op het gebied van gegevensintegratie voor synchromodaliteit, door een **Synchromodal Transport Integration Platform (SmTIP)** te ontwerpen.

SmTIP is gebaseerd op de resultaten van drie onderzoeksactiviteiten. De eerste onderzoeksactiviteit betreft het interviewen van SmT stakeholders, wat resulteerde in een lijst met vereisten voor SmTIP. De tweede onderzoeksactiviteit is de analyse van SmT werkwijzen, wat resulteerde in een lijst met contextuele gebeurtenissen en processen voor een SmT-scenario. De derde onderzoeksactiviteit omvat de studie van state-of-art integratieplatformen, wat resulteerde in een referentiearchitectuur voor integratieplatforms.

Ik heb toen een prototype ontwikkeld op basis van SmTIP. Het prototype integreert transportgegevens en gegevens over contextuele gebeurtenissen, maakt dynamische transportplanning mogelijk en verandert de transportmodaliteit van lading in het geval van een relevante verstoringsegebeurtenis. Het prototype is vervolgens gedemonstreerd aan een aantal transportbedrijven en op basis van verzamelde reacties van de bedrijven verder verbeterd.

Dit proefschrift is nuttig voor transportbedrijven, onderzoekers in de transportsector en informatietechnologie. Transportbedrijven kunnen kennis maken met de inrichting van SmT-processen, het detecteren en gebruiken van contextuele gebeurtenissen, en het integreren van gegevens die relevant zijn voor SmT.

Onderzoekers in de transportsector kunnen dit proefschrift gebruiken als inleiding tot SmT. Het zal ze helpen om SmT-scenario, SmT-processen en relevante verstoringsegebeurtenissen te begrijpen. Gedocumenteerde reacties van transportbedrijven tijdens de SmTIP-validatie zullen onderzoekers helpen bij de toekomstige verbetering van SmTIP en bij het ontwerpen van validatie-experimenten. Dit proefschrift draagt bij aan SmT-onderzoek door: (1) de uitdagingen voor gegevensintegratie te identificeren, (2) de eisen met betrekking tot SmTIP te definiëren, en (3) een SmTIP te ontwerpen. Onderzoekers en praktijkmensen in de informatietechnologie kunnen de referentiearchitectuur gebruiken voor het adresseren van uitdagingen op het gebied van gegevensintegratie in verschillende toepassingsdomeinen. Voor dat doel kan de verfijning van de referentiearchitectuur voor het SmT-domein, zoals beschreven in dit proefschrift, als leidraad worden gebruikt.

List of Abbreviations

aPaaS	application Platform as a Service
AIS	Automatic Identification System
ANWB	Algemene Nederlandse Wielrijdersbond
API	Application Programming Interface
DSRM	Design Science Research Methodology
ETA	Estimated Time of Arrival
FMS	Fleet Management System
GPS	Global Positioning System
IS	Information Systems
IT	Information Technology
ITS	Intelligent Transport System
LSP	Logistic Service Provider
NL	The Netherlands
NS	Nederlandse Spoorwegen
RAfIP	Reference Architecture for Integration Platforms
SLR	Systematic Literature Review
SmT	Synchromodal Transport
SmTIP	Synchromodal Transport Integration Platform
SMEs	Small and Medium-sized Enterprises
SOA	Service Oriented Architecture
TMS	Transport Management System
WMS	Warehouse Management System

Glossary for Synchronomodal Transport

Carrier	A business entity which owns vehicles and provides transportation services to freight forwarders. A carrier transports consignments. Also called a 3PL (3rd party logistics service provider).
Consignment	A collection of shipment segments, assembled by a freight forwarder and given to a carrier for transport.
Consignor	A business entity who wants its shipments to be transported.
Contextual Event	An event which affects the behaviour of a system.
Demand Aggregation	An activity performed by a planner, of dividing shipments into shipment segments, followed by, combining shipment segments to form consignments.
Disruption	A situation caused by an event, wherein the transport plan of a consignment is delayed.
Event	Something which happens in an environment.
Freight Forwarder	A business entity which accepts transport requests from consignors, arranges transportation for their shipments and gets paid for it. It also arranges related activities like, container handling and storage, on behalf of the consignor. Also called a 4PL (4th party logistics service provider).
Leg	The path between two consecutive terminals in a route plan.
Logistic Service Provider	A generic and overarching term used for any business entity involved in the transportation of goods.
Modality	A transportation mode, i.e., waterway, roadway, railway and airway.
Plan/Transport Plan	The resulting document of a planning activity.
Planner	An employee working at a freight forwarder responsible for making transport plans for transporting consignments.
Planning	The activity performed by a planner wherein he devises a route plan, chooses carriers and decides times at which each carrier should transport a consignment.
Route	A path connecting two or more terminals and all geographic points along that path. Terminals can be connected via different modalities, therefore a route can be a road route, waterway route or railway route.
Route Plan	An aggregation of different individual routes chosen by a planner to transport a consignment. A route plan may involve one or more modalities and one or more carriers.
Shipment	A container or a collection of containers to be transported from a pick-up location to a drop-off location.
Shipment Segment	A shipment of more than one container may be divided into two or more parts by a planner. Each part thus made, is a shipment segment.
Terminal	A facility where vehicles can pick up and drop-off containers. Terminals have container handling facilities, i.e., moving containers from one vehicle to another

and storage facilities.

Transportation

The activity of moving goods from one location to another.

Vehicle

A movable resource used by the carrier for transporting consignments.

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Part I

Introduction

Chapter 1

Introduction

In order to make an apple pie from scratch, you must first create the universe.

- Carl Sagan

American physicist (1934-1996)

The core of many businesses depends on transportation. Raw materials are shipped in and finished products are shipped out to customers¹. Today, equipped with Internet, customers demand high levels of customer service [107, 174], e.g., real time order tracking, a precise time of arrival, etc. Fulfilling such demands is getting increasingly difficult for transport companies [86, 164, 190]. For timely delivery of products and maintaining a high level of customer service, transport companies are compelled to increase the flexibility of their business processes by using multiple transport modes and contextual data [3, 124].

However, customer demands is just one of reasons responsible for transport companies to adapt their business processes. There are other contributing factors, prominent among them are as follows. Firstly, government initiatives, regulations and environmental laws, e.g., on CO₂ emissions, tax benefits on sustainable transport practices and reducing dependence on road transport (see Fig. 1.1), all provide reasons for adapting transport processes [1]. Secondly, increasing competition in transportation sector, as new entrants use latest technologies for service improvements, force a reconsideration of business processes [58, 59]. Thirdly, the global shift of transportation sector towards a *service-based-information-intensive* business requires a redesign of business processes too [32, 57, 172]. Finally, easy access to contextual events data (weather, traffic-disruptions, accidents, etc.) makes its usage in route planning, a competitive advantage [165], which facilitates further improvement in transport business processes. All these factors in combination are triggering transport companies to change their **business-as-usual** approach and adopt new, smarter transport practices [4, 133]. As a result, transport

This chapter is based on the following peer reviewed article
Developing a Service Oriented IT Platform for Synchronodal Transportation [164]

¹here, *customer* implies a business entity.

Market share of transport modes in EU

Figure 1.1: Market share of transportation modes in EU (European Union) is highly skewed in favor of road transport and the use of trucks. Source: Eurostat (as of 2012)

companies need to switch from a **planning and control** approach to a **sense and respond** approach [195].

At first glance, it seems transport companies should be able to make this transition easily, since the core business activity (i.e. transportation) still is the same. However, previous studies point towards a different scenario, implying that transport companies face numerous challenges in their transition towards smarter transportation practices [133, 168].

This dissertation is about *Synchromodal Transport* (SmT). SmT is a new transport practice, where the route and transport mode for transporting cargo is chosen dynamically, i.e., while the cargo is in-transit. If a disruption event occurs, which causes a delay in transportation, the cargo may be shifted to another transport mode. SmT facilitates transport companies to adopt a sense and respond approach. This dissertation presents research conducted between February 2014 and March 2018 to study SmT, discover data integration challenges posed by SmT, and design an integration platform to solve them. Specifically, the integration of contextual events data with transport planning data. By designing an integration platform for SmT, this dissertation facilitates the transition of transport companies towards SmT.

1.1 Synchromodal Transport (SmT)

Synchromodal Transport (SmT) was first conceptualized by TNO², in 2010 [104, 180] and has been studied primarily in the BENELUX countries [1, 133, 167]. Assuming that during the transportation of a shipment³, multiple transport modes are available, SmT prescribes dynamic routing of shipments [37]. It uses real-time contextual events data, like road works, weather forecasts and infrastructure (un)availability as parameters for

²www.tno.nl.

³*shipment* is a common term used in transportation sector and is synonymous to freight, haul, goods, cargo, order and load.

dynamic routing. The benefits of SmT include, optimal use of resources, lesser CO₂ emissions and on-time delivery of shipments [37, 136, 148]. In this section, I introduce SmT by providing a definition, but, a in-depth discussion over SmT is left for Chapter 4, which is dedicated to studying SmT in detail.

Synchromodal Transport (SmT) entails dynamic transport planning. Shipments may be switched over transport modes dynamically in order to avoid disruptions, optimize resource usage and reduce waiting times. SmT supports sustainable transport via reduced CO₂ emission and timely delivery of shipments. The whole transport process is thus, more flexible.

A SmT pilot study was conducted in The Netherlands on the transport corridor Rotterdam-Moerdijk-Tilburg (NL) by Barge Terminal Tilburg⁴, Oosterhout Container Terminal⁵ and Freightlive⁶ [148]. It yielded positive and encouraging results in favor of SmT. The pilot study consisted of optimal usage of three transport modes, road (by trucks), rail (by freight trains) and inland waterways (barges). Previous researchers advocating SmT as a solution to current (and future) transportation challenges, include Agbo. et al. [1], Lu. [104], Pfoser et al. [133], van Rissen et al. [146], Roth et al. [154], Singh et al. [167] and Vanelslander et al. [193]. In addition to the typical challenges in transportation sector (e.g. fragmented markets, localization of demand, fierce competition, etc. [59]), transport companies face further challenges while transitioning towards SmT. These barriers include data integration problems, data privacy concerns, lack of appropriate physical infrastructure and outdated data sharing policies [133, 167, 197]. Overcoming these barriers requires special systems, like, integration platforms, business analytics tool, business process management tools. However, transport SME's have limited funds, IT portfolio and skilled personnel. Therefore, the chances of them lagging behind in the transition towards SmT are high. This dissertation is about solving data integration problems related to SmT, faced by transport SME's, by designing a SmT Integration Platform (SmTIP).

1.2 Goal structure and Design Problem

1.2.1 Main Stakeholder Goal

Main stakeholder goals are the highest level goals which a research project aims to achieve. The main stakeholders for this dissertation are freight forwarders⁷. Freight forwarder goals are at two levels. The higher level goal is — To perform new and better transport practices. The lower level goal is — To perform Synchromodal Transport for flexible transportation process. Since main stakeholder goals are motivated from their social context, therefore in Fig. 1.2 (Goal structure) freight forwarders' goals are listed as social context goals.

⁴www.gvtintermodal.com/terminals/barge-terminal-tilburg

⁵www.rietveldlogisticsgroup.nl/container-terminal/

⁶www.freightlive.eu/freightlive.html

⁷Freight Forwarders or 4PLs aggregate transportation services from different carriers and offer it to consignors as one integrated service [156]

Figure 1.2: Goal structure of a design science project [211] (left). Goal structure for this dissertation (right).

Higher level main stakeholder goal — To perform new and better transport practices.

Lower level main stakeholder goal — To perform Synchromodal Transport (SmT) for flexible transportation process.

1.2.2 Artifact Design Goal

The artifact design goal for this dissertation is as follows (Fig 1.2):

To design a Synchromodal Transport Integration Platform (SmTIP).

1.2.3 Design Problem

To formulate the design problem for this dissertation, I used the template for formulating design science research problems, prescribed by Wieringa in [211].

Improve flexibility of transport process, by designing a Synchromodal Transport Integration Platform, that integrates real time contextual events data and transport planning data, so that freight forwarders can perform Synchromodal Transport.

The design problem for this research is solved by answering four sub-questions, RQ1, RQ2, RQ3 and RQ4, which follow the design science research cycle [211]. RQ1, RQ2 and RQ4 are knowledge questions and are

therefore answered by collecting and analyzing data. RQ4 satisfies the knowledge goal of this dissertation. RQ3 is a design problem and is therefore solved by designing an artifact, namely SmTIP. RQ3 satisfies the artifact design goal of this dissertation.

- **RQ1:** What is the current state of research in SmT?

Rationale: Studying existing research is important for understanding SmT concept. Delineation of SmT w.r.t similar transportation practices/concepts will facilitate better understanding of SmT.

- **RQ1.1** What is SmT?
- **RQ1.2** How is SmT different from Multimodal, Intermodal and Co-modal Transport?
- **RQ1.3** What are the main research themes in SmT?
- **RQ1.4** What are the success factors for SmT?

- **RQ2:** What are stakeholders' requirements for Synchromodal Transport Integration Platform (SmTIP).

Rationale: Stakeholders' requirements will determine SmTIP functionalities. RQ2 is further divided into 5 subquestions as follows.

- **RQ2.1** Who are the stakeholders in SmT?
- **RQ2.2** What are stakeholders' goals?
- **RQ2.3** What is the state of practice in transportation sector?
- **RQ2.4** What are stakeholders' requirements for SmTIP?
- **RQ2.5** What is the desired state of practice in a SmT scenario?

- **RQ3:** (stated as a design problem) Design a SmT Integration Platform (SmTIP), using best practices in integration platform design.

Rationale: Studying state-of-the-art technologies is necessary for using best practices in integration platform design in designing SmTIP. RQ3 is further divided into 2 subquestions which are as follows.

- **RQ3.1** What are the best practices in integration platform design?
- **RQ3.2** How to design SmTIP?

- **RQ4:** Does SmTIP contribute to main stakeholder goals?

Rationale: How good (or bad) is SmTIP w.r.t stakeholder goals. RQ4 is further divided into 2 subquestions which are as follows.

- **RQ4.1** Do stakeholders find SmTIP useful?
- **RQ4.2** Which stakeholder goals are met by SmTIP?

1.3 Research Methodology

I used the Design Science Research Methodology (DSRM) by Wieringa [211] for this research. DSRM consists of a design cycle and an engineering cycle. The design cycle consists of three steps, namely, *problem investigation*, *treatment design* and *treatment validation*. The design cycle is part of a larger cycle, the engineering cycle, in which the result of the design cycle — a validated treatment — is transferred to the real world, used, and evaluated. This dissertation is divided in 5 parts. The first and last part are Introduction and Conclusion, respectively. Part 2, Part 3 and Part 4 are based on the three steps of the design cycle, which they cover, i.e., Problem Investigation, Treatment Design and Treatment Validation, respectively. The research methods used by me for this research, along with the list of chapters in which they are discussed is given in Table 1.1.

- This chapter, Chapter 1, Introduction, lays the foundation for this dissertation by (1) defining SmT, (2) stating freight forwarders' goals, the design problem and (3) mentioning the research methods and chapters of this dissertation.
- Chapter 2, Background, summarizes the state of SmT research and related works.
- Chapter 3, Stakeholder Analysis, analyzes the design problem via stakeholder interviews. It lists the stakeholders requirements for SmTIP.
- Chapter 4, Synchromodal Transport (SmT) Scenario, discusses a SmT scenario in detail, presents an ontology for SmT and models SmT processes.
- Chapter 5, Reference Architecture for Integration Platforms, describes the use of a pattern mining method to design a Reference Architecture for Integration Platforms (RAfIP).
- Chapter 6, Synchromodal Transport Integration Platform (SmTIP), uses the RAfIP to design a Synchromodal Transport Integration Platform (SmTIP), the artifact for this dissertation.
- For SmTIP validation, I performed two validation cycles. Chapter 7, SmTIP Validation 1, describes the setup, conduction and results of the first validation cycle.
- Chapter 8, SmT Prototype, elaborates the development of a SmTIP prototype.
- Chapter 9, SmTIP Validation 2, discusses the setup, conduction and results of the second validation cycle.
- Chapter 10, Conclusion and Future Work, concludes this dissertation, re-visits main research results and recommends topic for future research.

Table 1.1: Research questions vs. Dissertation chapters vs. DSRM Step vs. Research Method used

Research Sub-question	Chapter	DSRM Step	Research Method
RQ1.1 What is SmT?	Ch. 1	Problem Investigation	Literature Review
RQ1.2 How is SmT different from Multimodal, Intermodal and Co-modal Transport?	Ch. 2	Problem Investigation	Literature Review
RQ1.3 What are the main research themes in SmT?	Ch. 2	Problem Investigation	Literature Review
RQ1.4 What are the success factors for SmT?	Ch. 2	Problem Investigation	Literature Review
RQ2.1 Who are the stakeholders in SmT?	Ch. 3	Problem Investigation	Literature Review & Stakeholder Interviews
RQ2.2 What are stakeholders' goals?	Ch. 3	Problem Investigation	Literature Review & Stakeholder Interviews
RQ2.3 What is the state of practice in transportation sector?	Ch. 3	Problem Investigation	Literature Review & Stakeholder Interviews
RQ2.4 What are stakeholders' requirements for SmTIP?	Ch. 3	Treatment Design	Stakeholder Interviews
RQ2.5 What is the desired state of practice in a SmT scenario?	Ch. 4	Treatment Design	Literature Review & Stakeholder Interviews
RQ3.1 What are the best practices in integration platform design?	Ch. 5	Treatment Design	Pattern Mining
RQ3.2 How to design SmTIP?	Ch. 6	Treatment Design	Artifact Design
RQ4.1 Do stakeholders find SmTIP useful?	Ch. 7	Treatment Validation	Case Based Experiment
	Ch. 8	Treatment Validation	Prototype Development
	Ch. 9	Treatment Validation	Case Based Experiments
RQ4.2 Which stakeholder goals are met by SmTIP?	Ch. 7	Treatment Validation	Case Based Experiment
	Ch. 8	Treatment Validation	Prototype Development
	Ch. 9	Treatment Validation	Case Based Experiments

1.4 Conclusion

This chapter lays the foundation for this dissertation. It formulated the design problem, research questions and introduced the research methodology. The next chapter, Background, starts the first step of the DSRM, Problem Investigation.

Part II

Problem Investigation

Chapter 2

Background

The important thing in Science is not so much to obtain new facts, as to discover new ways of thinking about them.

-William Bragg

English physicist (1862-1942)

This chapter analyzes the design problem, based on the results of a systematic literature review (SLR). The methodology followed for the SLR is elaborated in Sec. 2.1. Sec. 2.2 discusses the state of SmT research based on SLR articles. Sec. 2.3 summarizes the state of the art in context aware systems and relates it to SmT research. Lastly, Sec. 2.4, Conclusion, closes the chapter, highlighting the main results.

2.1 Systematic Literature Review Methodology

To answer RQ1.2, RQ1.3 and RQ1.4, research articles over SmT, published between 2010 and 2016¹, were collected. The databases used were: Google Scholar², IEEE Xplore³, JSTOR⁴, SpringerLink⁵, Web Of Science⁶, Emerald Insight⁷, Science Direct⁸, Scopus⁹, EBSCO-Elite¹⁰ and DBLP¹¹.

This chapter is based on the following peer reviewed articles
Big Data Interoperability challenges for logistics [166]
Synchromodal Transport: Pre-requisites, activities and effects [167]

¹The SLR was conducted in March-June 2016

²<https://scholar.google.nl>

³<https://ieeexplore.ieee.org/Xplore/home.jsp>

⁴<https://jstor.org>

⁵<https://link.springer.com>

⁶<https://webofscience.com>

⁷<https://emeraldinsight.com>

⁸<https://sciencedirect.com>

⁹<https://scopus.com>

¹⁰<https://ebSCO.com>

¹¹<https://dblp.uni-trier.de>

Initially, I used the search string *Synchromodal** which produced some false positives, e.g., articles over synchro-modal learning environments and optics. I, then, refined the search string to: *Synchromodal* AND (transport* OR logistic*)*. Additional search constraint was the language, i.e., English. Some databases had restrictions over search coverage, e.g., full text, abstract or/and title. For each database, I conducted the most elaborate search possible. The search resulted in 137 articles. To select relevant articles from these, three rounds of selection criteria were applied.

Round 1 — Inclusion. In Round 1, the inclusion criteria were (a) article is about logistics/transport, and (b) article is published in a peer reviewed publication. Criterion (b) was more relevant for Google Scholar since in other databases, the search results were, by default, from peer reviewed publications. In Round 1, 87 articles were included.

Round 2 — Exclusion. If the meaning of SmT was not sufficiently clear in an article, then that article was excluded. This was done, to remove articles where the term Synchromodal Transport occurs without explanation. The list of excluded articles was then reviewed by another researcher and any disagreements were resolved by a meeting. After Round 2, 31 papers were excluded, leaving a list of 56 papers.

Round 3 — Exclusion. Duplicate articles were excluded. 26 articles were duplicates, therefore, the final list consisted of 30 articles. The complete list of articles can be found in Appendix A. Further on, I will refer to them as, SLR articles.

2.2 SmT Research

This section provides an overview of the state of SmT research, based on SLR articles, and is divided into four subsections. First, I present a comparison of relevant terminologies used in SLR articles and their relationship with SmT. Then, I provides a classification of SmT research themes. ICT is one of the research themes in SmT. Thereafter, project results and industry standards relevant for this dissertation are discussed. Finally, SmT success factors are studied and ICT is identified as a critical success factor.

2.2.1 SmT and related terminology

Many terms are used to describe contemporary transport practices. The most used terms are, Multimodal Transport (MM), Intermodal Transport (IM) and Co-modal Transport (CM). Other, relatively lesser used terms include, Bi-Modal Transport and Smart Transport. Reading these terms, evokes the following questions. *Firstly*, how do these terms differ and *secondly*, what is the use and relevance of adding another term, i.e. *Synchromodal Transport*, to the list? SteadieSeifi et al. in [178], Tavasszy et al. in [181], Pleszko in [136], Lu in [104], Rossi in [153] and Reis in [143] have objectively addressed the above questions. They have delineated and clarified the meaning of these terms. Furthermore, they justified the introduction and usage of the term, Synchromodal

Transport (SmT). After studying SLR articles (which included the articles by aforementioned authors), I concluded that these terms represent overlapping concepts and continuous maturity in transport practices. The overarching term is Multimodal Transport from which the remaining three terms are derived. Each term represents a specific dimension (transport practice) within multimodal transport. The definition of the terms and their relationship are shown in Table 2.1 and Table 2.2, respectively. Table 2.1 and Table 2.2 together answer R.Q1.2, *How is SmT different from Multimodal, Intermodal and Co-Modal Transport?*

Table 2.1: Definition of terms

Abbreviation	Term	Definition [167]
UM	Unimodal Transport	Use of a single transport mode
MM	Multi-modal Transport	Use of two or more transport mode
IM	Inter-modal Transport	The movement of goods in the same load carrying unit which successively use several transport modes without handling of goods.
CM	Co-Modal Transport	Use of different transport modes on their own and in combination
SmT	Synchromodal Transport	Strategic switching between different vehicles and/or different transport modes while a consignment is in transit based on contextual events.

Table 2.2: Relationship between terms. (See Glossary for the definition of a Consignment)

Unimodal Transport		Multimodal Transport			
		Sequential		Parallel	
Static	Dynamic	Static	Dynamic	Static	Dynamic
Unimodal	Synchromodal	Intermodal	Synchromodal	Co-Modal	Synchromodal

Sequential : the use of different transport modes in sequence for one consignment

Parallel : the use of different transport modes in parallel for one consignment

Static : static planning, i.e., transport plan for a consignment is not changed while it is in transit

Dynamic : dynamic planning, i.e., transport plan for a consignment may be changed while it is in transit

2.2.2 SmT Research Themes

Ambra et al. in [4] studied and classified SmT research in three broad themes, (a) Conceptual, Introductory or Literature Search - CIL (b) Information and Communication Technology - ICT and (c) Models. Fig. 2.1 (left pie-chart) shows an adapted version of that classification. I renamed the theme Models to Operational Research and added a new theme i.e. Facilitating Mechanisms, for better analysis of their results.

SLR articles (Appendix A), when classified according to the above themes present a different picture, Fig. 2.1 (right pie-chart). The dominating research theme in the findings of Ambra et al., is Operations Research while

according to my SLR, the dominating research theme is Conceptual, Introductory and Literature Search. The number of articles in the research theme ICT were the same in both studies.

The difference between the findings can be attributed to; (a) different search terms; *Dynamic/flexible fleet transport* by Ambra et al. and *Synchromodal* AND (transport* OR logistic*)*, by me, and (b) unclear article selection activity by Ambra et al. They state in [4] that articles “from authors we knew about based on informal connections” were also included. Consequently, the articles studied by Ambra et al. and me were different; giving rise to different results. SmT research themes, representative topics and example research articles in each theme are show in Table 2.3. SmT ICT research will be discussed in Sec. 2.3. By identifying four major research themes in SmT research, Fig. 2.1 answers R.Q1.3 *What are the main research themes in SmT?*

As an aside, SLR articles shed light on prominent institutes involved in SmT research. Delft University of Technology, Delft¹² had the most publications, i.e., 6, followed by Erasmus University, Rotterdam¹³ and TNO. Majority of SmT research is from Dutch institutes. Factors that may have contributed towards the concentration of SmT research in NL are, government support [124, 185], a strong Dutch economy, Rotterdam port [185] & an elaborate inland waterway network. Nevertheless, some SLR articles were from Austrian [140], British [127], Danish [128], German [49] and Polish [136] research institutes. This indicates proliferation of SmT concept in research communities outside NL.

Figure 2.1: Classification of SmT research themes by Ambra et al. [4] (left) and Singh et al. [167] (right)

2.2.3 SmT Projects and Industry standards

The most comprehensive SmT projects found in literature are from, Impulse Dynamisch Verkeersmanagement Vaarwegen (IDVV) program in NL [148]. The IDVV program (2011-2013) was a two year program with 3 tracks, Track 1: Basic Vessel Traffic Management (VTM) services, Track 2: Single window for inland navigation and

¹²www.tudelft.nl

¹³www.eur.nl

Table 2.3: SmT research themes, representative topics and example research articles in each theme

SmT Research Theme	Representative topics	Example research articles
Operational Research (OR)	Scheduling, ETA calculations, Planning Algorithms	1. Anticipatory Scheduling of Freight in a Synchromodal Transportation Network [151]. 2. Service network design for an intermodal container network with flexible due dates/times and the possibility of using subcontracted transport [145].
Information and Communication Technology (ICT)	Interoperability, Data models, Big Data Usage, Integration Platform	1. Interoperability challenges for context aware logistics services—the case of synchromodal logistics [165]. 2. Control Tower Architecture for Multi and Synchromodal Logistics with real time data [76].
Facilitating mechanisms (FM)	Mind Shift, Serious Gaming	Synchro mania—design and evaluation of a serious game creating a mind shift in transport planning [15].
Conceptual, Introductory, Literature Search (CIL)	Challenges, Critical Success Factors, Explanatory research, Literature reviews	1. Should we keep on renaming a +35-year-old baby? [143] 2. Synchromodal Transport: Prerequisites, Activities and Effects [167].

Track 3: Logistic challenges. In total, 17 projects were initiated [212]. In track 2 of the IDVV program, logistic companies, knowledge institutes and the Dutch government worked together on 13 innovative projects to improve the role of waterway in NL. Amongst these projects were three SmT projects: (1) Development of a Synchromodal Planning Tool, (2) Synchromodal Control Tower and (3) Synchromodal Cool Port Control Tower. Though, all three projects yielded positive results in favour of SmT, details over SmT processes, contextual data used, etc. are not found in literature.

In [104], Lu presents a list of European Union (EU) funded SmT projects. A more elaborate list of projects facilitating SmT, can be found in [41]. It is not feasible to discuss all of them here. After studying the findings of previous SmT projects, I concluded that, they do not focus on the integration of transport and contextual data. Also, they do not show how to use contextual data for smart transport practices, like dynamic planning¹⁴. Rather, they focus on the standardization of data sharing among transport partners in a transport chain. An appropriate example is, One Common Framework¹⁵ [130] which proposes standardized message templates for message exchanges among transport companies. One Common Framework combines the results of eight European (logistics) project. They are Freightwise, e-Freight, Integrity, Smart CM, SMARTFREIGHT, EURIDICE, RISING and DiSCwise. The goal of the One Common Framework is to standardize the communication between partners in a logistics chain. Though, the common framework elaborates about stakeholders, informa-

¹⁴transport plan for a consignment may be changed while it is in-transit

¹⁵full name; One common framework for Information and Communication systems in transport and logistics

tion systems and business processes in a logistic chain, it's focus is neither SmT nor the use of contextual data in transportation. Therefore, dynamic planning and the integration of contextual events data with transport planning data is not covered in the One Common Framework. Though, it does consider events, but these events are what I will call, *logistics events*, i.e., events providing the location of a consignment, e.g., scanning of consignment code and location sharing.

GET Service project [33] provides an approach to use contextual data for transport planning. The proposed data model for integration of contextual and transport data, may be reused for SmTIP. Although, SmT is not the focus of the GET service project, yet, the approach followed in the project, over integration of contextual and transport data, is relevant for SmT.

The Logistic Interoperability Model (LIM) by GS1 [67] is an industry standard for logistics sector, which provides a logistics vocabulary, list of standard logistics events, standard business processes and guidelines for communication in a logistic chain. GS1's LIM facilitates end to end visibility of a consignment from procurement till final delivery and financial settlement. By studying the LIM standard document, I understood the state of the practice in transportation sector. Still, as with One Common Framework, in LIM too, dynamic planning and the use of contextual data is not the focus.

I reached similar conclusion after studying EPCIS¹⁶, another standard by GS1. EPCIS is a standard for collection, storage and sharing of logistic events. Data about consignments is collected by scanning devices and stored in an EPCIS data repository using EPCIS data format. The EPCIS repository is used by partners in a logistic chain to query for specific logistic events (e.g., is the consignment already loaded in the vehicle?, is the consignment at the warehouse?). Partners in a logistic chain can subscribe to EPCIS repository for regular event updates.

A relevant industry standard is, TNO ontology for logistics¹⁷, namely, LogiCo, LogiServ and LogiTrans. The ontology may be extended and applied to SmT, as it facilitates the integration of contextual and transport data (discussed further in Sec. 4.3).

2.2.4 Success Factors for SmT

SLR articles over SmT success factors were by van Riessen et al. [146], Putz et al. [140] and Roth et al. [154]. Additional relevant articles (published after SLR was completed) include Pfoer et al. [133] and Agbo et al. [1], wherein Agbo et al. provided an overview of SmT success factors based on previous research. Fig. 2.2 shows SmT critical success factors (vertical-axis) and their incidence in SmT literature (horizontal-axis) based on their study. ICT/ITS¹⁸ technologies are frequently denoted as critical success factor (CSFs) for SmT, by researchers. This is evident from the high incidence of ICT/ITS technologies as CSFs in research articles. This dissertation

¹⁶<https://www.gs1.org/epcis/epcis/1-1>

¹⁷TNO Ontology and Vocabulary. <http://ontology.tno.nl/www.tno.nl>

¹⁸ITS-Intelligent Transport Systems

is about data integration challenges for SmT, which falls under ICT/ITS technologies. Fig. 2.2 answers RQ1.4 *What are the success factors for SmT?*

Figure 2.2: Incidence of terms indicating critical success factors for SmT in a total of 37 research articles as found by Agabo et al. in [1]

- SmT Pre-requisites — After studying SLR articles, I identified requirements for a successful SmT implementation. Further on in this dissertation, I will refer to them as, SmT pre-requisites. They are listed in Table 2.4, along with constituent concepts extracted from SLR articles. These pre-requisites must be fulfilled by a freight forwarder for performing SmT. SmT pre-requisites can be divided into three categories, Policies, Physical Infrastructure and Information Technology (IT).
 1. Policies — SmT requires new and improved policies at two levels, government level (e.g., funding for infrastructure developments, tax incentives for sustainable transport, lenient laws for transport SMEs, etc.) and at enterprise level (mutual trust development, co-operation instead of competition, simpler data sharing policies, etc.).
 2. Physical Infrastructure — Physical infrastructure includes, warehouses and depots at ports/terminals, cargo handling capability at ports/terminals, maintenance of transport corridors, etc. Appropriate physical infrastructure is critical for SmT. E.g., in the absence of multimodal transport hubs, transport mode switch would not be possible.
 3. Information Technology (IT) — In the absence of appropriate IT infrastructure freight forwarders cannot access real time contextual events data. IT co-ordination between transport companies is a pre-requisite for data sharing.
- SmT Effects — Study of SLR articles also provided a list of SmT effects. SmT effects are potential benefits for SmT stakeholders from a successful implementation of SmT. They are listed in Table 2.5, along with constituent concepts extracted from SLR articles.

SmT Pre-requisites	Constituent concepts
Policies	Integrate policies with partners, Integrate governance with partners, Policy for decision making, Legal requirements, like ownership, insurance etc. to be formalized, Central network orchestrator rights, Data sharing policy, Data usage policy, Increased co-operation
Physical Infrastructure	Integrated transport systems, Integrated infrastructure, Co-ordination of logistic chains, Integrated services, Holistic view of transport network, Aggregation of different modes into a coherent service
Information Technology	Integrating IT systems, Advanced ISs, Access to real time contextual events data, Access to partner data, Data sharing

Table 2.4: SmT Pre-requisites and constituent concepts based on SLR articles

SmT Effects	Constituent concepts
Supply Chain Improvements	Structured combination of transport modes, Better supply chain visibility, Synchronized combination of transport modes, Increased efficiency, Optimal alignment, Increased reliability, Integrated transport solutions, Better traceability, Increased flexibility, Possibility of last minute changes
Better resource utilization	Reduction in empty container trips, Reduction in waiting time and buffer time, Better utilization of resources, Reduction in work pressure for planners
Environment benefits	Environment friendly, CO ₂ emission reduction, Sustainable, Reduced pressure on roads, Sustainable use of different modalities
Cost Reduction	Reduce cost, More profit

Table 2.5: SmT Effects and constituent concepts based on SLR articles

2.3 SmT ICT Research

This section discusses current ICT developments over context aware systems and relates them to SmT. There are three subsection; i.e., (1) Sec. 2.3.1, Data Collection, discusses contextual data collection from external data sources, (2) Sec. 2.3.2, Data Analysis, discusses the extraction of information from contextual data, and (3) Sec. 2.3.3, Data Usage, discusses the use of contextual data for business activities.

2.3.1 Data Collection

Contextual data for a context aware system may be provided by diverse data sources. Common examples of data sources, are, sensors, RFID readers and web services. Other sources include, CCTV cameras, mobile apps and internet browsers. Data sources providing contextual data to a system may, together be called, *devices*. Initially, context aware systems used sensors and RFID readers, only, as devices. Standardized and specific protocols were used for communication between devices and a central processing unit. Due to limited communication range of sensors, the geographic area covered by the devices was limited, implying that a context aware system's network was relatively small. Thanks to Internet and new communication technologies, the size of a context aware system's network, is now, practically, unconstrained. New devices, like CCTV cameras, mobile apps and internet browsers etc. can now be used for contextual information. Using adapters, devices can now connect to the Internet and monitor contexts, globally. Contemporary research articles use the term,

IoT¹⁹ network, to refer to a network of devices, which provides contextual data, enabling seamless monitoring of a system's context. A context aware system along with its IoT network is called an, **IoT system** [51]. For connecting to devices and collection of data, there are 6 standard communication technologies, used by IoT systems, i.e., WiFi, WiFiMAX, LR-WPAN, Mobile communication, Bluetooth and LoRaWAN [142]. The choice of communication technology and computing hardware for an IoT system, depends the network's setup, i.e., which devices are used, where the devices are located, how fast the communication should be, computation power required for data analysis, data size and so on. E.g., in the Health IoT system [217] the Health Box monitors the health of a patient via different sensors. To connect with the sensors (short-range), it uses the WiFi communication technology and Internet connectivity (long range) for data analysis, data storage.

A study of SLR articles revealed that data collection methods for SmT have not been studied adequately. Most freight forwarders collect contextual data manually [164]. Planner are assigned the task to collect contextual data via infrastructure providers' websites and phone calls to carriers [11] (Appendix B, Stakeholder Interviews). Though sensors and APIs to carrier websites are used for data collection, it is about logistic events, i.e., track and trace. The potential use of IoT systems for SmT has not been explored yet.

2.3.2 Data Analysis

Ontology and data models facilitate the analysis of contextual data. Ontology can be device specific, e.g., W3C Semantic Sensor Network, or application domain specific, e.g., SAREF²⁰. W3C Semantic Sensor Network (SSN) ontology is an ontology for describing sensors and their observations, involved procedures, features of interest and observed properties. SAREF is an ontology for contextual data collection in the smart home application domain [116]. For context aware systems requiring fast and complex event processing, special infrastructure and technology for data storage & analysis is required. Complex event processing applications are then used, along with traditional platforms, (like, Java Beans, JAX-RS logic) to facilitate real-time data analysis. Similarly, when the size and frequency of data collected by devices is considerably large, big data analytics application are used. They are cloud-scalable solutions and use technologies such as Apache Hadoop, to provide highly scalable mapreduce analytics over data [116]. The collection, analysis and usage of data can also be done remotely, which has given rise to cloud **IoT solutions**. IoT solutions, like FIWARE²¹, OpenIOT²², simplify data collection & data analysis, through a suit of APIs and components. A typical suit consists of standards, proprietary data model, protocols, ontologies and data analysis function(-alities). FIWARE consists of a central component for linking contextual data, the Core Context Management. Different suits (called enablers in FIWARE) can be added to the Core Context Management component for data analytics. For example, The Kurento enabler facil-

¹⁹Internet of things

²⁰Smart Appliances REference ontology

²¹www.fiware.org

²²www.openiot.eu

itates real time processing of media streams and supports the transformation of CCTV cameras into sensors to detect suspicious activity. Similarly, The Cosmos enabler facilitates (big) data analysis over contextual data and allows easy integration with big data storage infrastructure. Other examples of relevant IoT solutions include, ThingWorx, Nimbits [142].

Contemporary SmT literature rarely addresses the extraction of useful information from contextual data. The primary reason is, small to medium sized freight forwarders use planners' expertise for contextual data analysis, whereas, large freight forwarders use in-house applications (e.g. DHL Resilience 360) or proprietary software. Though, the use of IoT solutions for logistics in general, has been proposed in literature, but their use in SmT is yet to be explored. Furthermore, the use of existing ontology (e.g. TNO LogiCo, LogiServ, LogiTrans) in a SmT scenario is promising but has not been addressed in literature yet. A relevant study is by Frehe et al. [50], where the authors provide an overview of the use of contextual data analysis approach for better decision making in transportation sector. They based their results on a literature search and interviews with transport companies.

2.3.3 Data Usage

The goal of analyzing contextual data is to make better decisions. Better decision making should be studied based on the respective application domain. Therefore, below, I summarize my conclusions after studying research articles (Table 2.6) over the use of contextual data in transport domain [166]. The main transport activities which benefit from contextual data analysis include; (a) Transport Planning (b) Resource capacity planning (strategic, i.e., long term and operational, i.e., daily) (c) Monitoring (d) Track and Trace and (e) Risk evaluation and resilience planning. Wedgwood and Howard, in [203], list three areas for better decision making based on contextual data, (i) Customer analytics and loyalty marketing (ii) Capacity and pricing optimization and (iii) Predictive maintenance analysis. Other relevant studies over the topic include, Jeske et al. [90] and Hu et al. [81], where the use of contextual data for demand prediction, optimizing transport cost and intelligent warehousing is addressed.

As a practical example, consider the Retail Control Tower Project [166]. In this project, a large retail supermarket chain, in NL, uses traffic data for optimal route planning and better ETA prediction, of its trucks to supermarket stores. The collection and analysis of the data is outsourced to an IT company, which uses live traffic data feed from Tom-Tom²³ and road accident information from mobile apps. Based on data analysis, a dashboard shows the live location of trucks and their status to a planner, at the supermarket's office. Using the dashboard, the planner can better plan transport operations, optimize loading of trucks and monitor the ETA of trucks at stores, in real time.

DHL uses contextual data, to predict, pre-empt events and assess their impact on transport plans. To this end,

²³www.tomtom.com

DHL uses DHL's Resilience 360, a risk management solution based on contextual data [166]. All disruptions on the transport network, their cause and location are displayed on a map in real time to the planner. Using this information, planners at DHL can re-plan disrupted consignments.

Although, current SmT literature does not discuss modeling and detection of disruption events, situation modeling languages for context aware systems [23, 24] can be used to detect relevant events in a SmT scenario.

Table 2.6: Articles used for a state-of-the-art study over the use of contextual data in the transport domain

Ref.	Data Source	Usage	Related Transport Activity
[6]	GPS data, RFID scans	Monitoring and Tracking of cargo	Monitoring, Track and Trace
[50]	Fuel Sensors, GPS data	Optimize refueling	Monitoring
	Websites	Better Price Negotiation	Transport (Pre)-planning
	Driver's work pattern	Resilience, Reduce accidents	Planning, Monitoring
	Board Computers	Advise to driver, Maintenance scheduling	Monitoring
	GPS data, Board computer on trucks	Minimizing waiting time, Resource Allocation	Monitoring, Disruption Handling
[90]	Social Media, Blogs, Weather	Risk evaluation, Resilience	Disruption Handling
[172]	Board computer on trucks	Driver behaviour, monitoring, Idling of trucks, Maintenance of trucks	Monitoring, Track and Trace
[203]	Consignment data, Traffic data	Resource Allocation	Transport Planning, Demand Aggregation

2.4 Conclusion

This chapter reported on the state of SmT research based on the results of a systematic literature review. R.Q.1.2 was answered by Table. 2.2 which illustrates the relationship between SmT and other related terms. R.Q.1.3 was answered by Fig. 2.1 which shows the research results of two studies over current SmT research themes. R.Q.1.4 was answered by Fig. 2.2 in which critical success factors for SmT were compared. After studying relevant industry standards, I concluded that dynamic planning and the integration of contextual data with transport planning data is not addressed sufficiently. The study of current ICT development in context aware systems provided solution direction for developing SmTIP, e.g. use of contextual data from websites, extending ontologies in transport domain for data integration in SmTIP and the use of contextual data for dynamic planning. The next chapter, Stakeholder Analysis carries forward the Problem Investigation step of DSRM and answers R.Q.2 via stakeholder interviews.

Chapter 3

Stakeholder Analysis

*All truths are easy to understand once they are
discovered; the point is to discover them.*

-Galileo Galilei

Italian physicist (1564-1642)

This chapter describes stakeholder analysis for this research. It lists main stakeholders' requirements for SmT integration platform (SmTIP) and answers R.Q.2 (What are stakeholders' requirements for SmTIP?). Sec. 3.1, describes how stakeholder interviews were planned and conducted. R.Q.2.1 to R.Q.2.4 are answered in Sec 3.2 to Sec 3.5, sequentially. The title of a subsection is representative of the research question answered in that subsection. They are answered based on stakeholders' responses during stakeholder interviews (Appendix B).

3.1 Stakeholder Interviews

For this dissertation, twenty-one interviews with SmT stakeholders were conducted, between March 2014 and September 2017¹ (Appendix B). The objective of these interviews was to discover SmT stakeholders, their requirements for SmTIP and the state of practice in transportation sector. Each stakeholder interview was approx. one hour long. It was preceded by a short introduction, to trigger a discussion and to clarify the objective of the interview.

To prepare a questionnaire for stakeholder interviews, I started with RQ2 and its constituent sub-questions. I divided the sub questions into two themes, Theme 1 consisting of RQ2.1, RQ2.2 & RQ2.4 and Theme 2 consisting of RQ2.3 & RQ2.5. Theme 1 covers, SmT stakeholders, stakeholder goals and requirements for SmTIP. Theme 2

This chapter is based on the following peer reviewed article
Interoperability challenges for context aware logistics services - The case of Synchronodal Logistics [165]

¹requirement gathering and artifact design were carried out in parallel

covers, the current state of practice in transportation sector and the desired state of practice in a SmT scenario. Thereafter, I divided each theme into sub themes, which are essential aspects to be studied in a theme. The sub themes in Theme 1 were SmT stakeholders, Stakeholder goals and Stakeholder requirements. The sub themes in Theme 2 were Shipment characteristics, Planning activity, Use of contextual data, Use of modalities, Contextual Events and IT application. Finally, I formulated questions to obtain information from stakeholders over each sub theme. By adopting the above approach of preparing the questionnaire, each question in the questionnaire is directly related to my research questions, via themes and sub themes. In case during interviews, stakeholder responses gave rise to new questions, they were added to the questionnaire under corresponding sub theme. The complete questionnaire when all stakeholder interviews were completed, is given in Table 3.1.

Table 3.1: Questionnaire for stakeholder interviews

Theme	Sub theme	Questions
Theme 1	SmT stakeholders	S.1 Who, according to you, are the stakeholders in SmT?
	Stakeholder goals	S.2 Are you aware about SmT concept and practice? S.3 What is your opinion about SmT practice? S.4 What are your goals w.r.t SmT ?
	Stakeholder requirements	S.5 How will an integration platform aid in SmT? S.6 What are the characteristic activities of SmT? S.7 What are your requirements for a SmT integration platform?
Theme 2	Shipment characteristics	SH.1 When a shipment is received, does this shipment always have the same data format? SH.2 What are the data fields of a shipment request? SH.3 What data fields are needed for transport planning ? SH.4 Which data is needed about the freight characteristics? SH.6 Are different modalities combined for transport of a shipment?
	Planning activity	P.1 How is transport planning done? Manual or via a planning software? P.2 How many planners are employed? P.3 Do you think your company requires a planning software? P.4 Which planning application/software is currently used for planning? What are the optimization parameters? P.5 Does the planning application/software use real time events, disruptions, consignments in-transit? P.6 Does planning application/software provide feedback, for example, color coding to see the status of transport? What kind of feedback? P.7 What are the steps that you take to create a transport plan?
	Use of contextual data	D.1 Which data sources do you use for real time data? D.2 Are there specific consignments for which real time data is essential?
	Use of modalities	M.1 Which transport modalities are being used? M.2 Which factors influence the decision to use a certain transport mode for a consignment ? M.3 Do certain modalities have more preference than others?
	Contextual events	E.1 Do you monitor real time events in the transport network? E.2 What do you consider a disruption? E.3 Which types of disruptions occur the most? E.4 What is the current disruption handling policy? E.5 Is there a threshold for a disruption to trigger disruption handling? E.6 In case of a delay when do you inform the consignor about the delay? E.7 What are current disruption handling options ? E.8 Is it possible to transfer a consignment at a partner carrier in case of a disruption? E.9 Which factors are considered for re-planning? E.10 What according to you is an optimal disruption handling process?
	IT applications	IT.1 Which software/applications are currently being used? IT.2 What is the current data storage policy? IT.3 What are security mechanism for data security and privacy? IT.4 What are the current mechanisms for data sharing with carriers?

3.2 SmT stakeholders

Before I discuss the results of stakeholder interviews, a short (and relevant) introduction of transportation sector in Europe.

Transportation, globally, is a highly fragmented business sector and this fragmentation is quite pronounced in Europe [125, 221]. It manifests itself via the presence of hundreds of transport related businesses in Europe [68], each delivering its services to multiple logistic chains. E.g., container handling companies, last mile delivery services, skippers, brokers, warehouses, customs, data providers, government agencies and so on [165]. These businesses together form a *logistics ecosystem* [75]. Collaboration and outsourcing is a notable feature of European logistics ecosystems owing to regional/national alliances, diverse customer segments, differences in technological maturity, existence of (local) consortia and virtual clusters [59].

To begin with stakeholder interviews, I started with known stakeholders in SmT, i.e. freight forwarders, which lead to the discovery of new stakeholders; who were subsequently, also interviewed until no new stakeholder could be identified. Table 3.2 lists all SmT stakeholder identified by me; they were transport companies, infrastructure providers, customers, researchers, data providers, manufacturing companies, consultants and governments. Out of these, the stakeholders interviewed by me were transport companies, infrastructure providers, researchers and consultants.

3.3 SmT stakeholders' goals

Stakeholders usually do not have a list of goals ready, which can be used in artifact design. Instead, stakeholder goals have to be discovered by researcher(s) via interaction with the stakeholders. Furthermore, at times stakeholders themselves are unaware of their *actual* goals, which become clear only during discussions, scenario building exercises, brainstorming sessions, interviews and presentations. All these steps are thus methods of goal discovery [2] and in this dissertation I used interviews and presentations for SmT stakeholder goal discovery. SmT stakeholder goals, thus discovered, are listed in Table 3.3.

This dissertation will focus on freight forwarders' goals, since they were identified by me as the main stakeholders in SmT. Further on in this dissertation, the term *stakeholder goal*, will refer to freight forwarders' goals (until stated otherwise).

Table 3.2: SmT stakeholders

Stakeholder	Stakeholder Type	Explanation
Transport companies	Freight Forwarders	Freight Forwarders or 4PL aggregate transportation services from different carriers and offer it to shippers as one integrated service [156]. They can be understood as <i>brokers</i> in logistics ecosystem since they perform match making of transportation demand and transportation supply. Owning little to no vehicles and infrastructure they survive in the logistic ecosystem by means of a network of business contacts, a strong ICT infrastructure and domain knowledge [156].
	Carriers	Carriers are transportation companies, who receive transportation requests from freight forwarder & shippers, fulfill it using their vehicles and get paid. Also refereed to as 3PLs.
Infra. Providers	Port Authorities	Deep sea ports (e.g. Port of Rotterdam) and Inland ports (e.g. Port of Seville) are managed by port authorities. They are responsible for all ports operations and provide additional services like storage, cargo handling, trans-shipment, anchorage, etc.
	Infra. Maintenance	Infrastructure maintenance companies are responsible for the upkeep and repair of roads, railway tracks and inland waterway systems. In most cases, provincial and union governments via their respective ministries perform this role. At times this role can also be contracted to private companies.
	Terminals Operators	At inland terminals like Hengelo and Venlo, terminal operations are managed, overseen by Terminal Operators. E.g. Combi Terminal Twente in Hengelo and ECT Hutchison Ports, Venlo.
	Cargo Handlers	Cargo handling companies work at ports, warehouses, inland terminals and provide container loading-unloading services. They play a critical role in modal-shift of cargo containers.
	Warehouses	As the name suggests warehouse companies own and operate warehouses. They provide storage and cargo handling services. Strategic location of warehouses can be an important enabler for SmT [159].
Customers	Shipper	The business entity who requests transport service and ships cargo. In SmT the shipper is both an important initiator and an important beneficiary of SmT.
	Receiver	The receiver of the cargo sent by the shipper.
Researchers	Research Groups	Researchers working on SmT or similar topic like Humanitarian Logistics, Intermodal Transport, Smart City logistics, to name a few.
	R&D Dept.	R&D departments of logistics companies like DHL, FedEx.

contd...		
Data providers	Traffic data	Road Traffic data providers source data from vehicles (and sensors along roads) and provide it free (or with a fee) to the public at large or companies. E.g., Google and Tom-Tom. Tom-Tom sells floating car data to companies for analytics. Similarly, the mobile app. <i>Flitsmeister</i> (www.flitsmeister.nl) provides data about traffic jams and accidents on road to users of the app and also to companies for analytics [165].
	Infra. providers	All stakeholder listed under Infra. providers above, publish data, like availability of port, railroad maintenance, warehouse availability, etc. on their websites or via dedicated interfaces. Transport companies access and use their data for route planning.
	Carriers	Carriers provide locations, availability and eTAs of vehicles to partners and other stakeholders involved in a transport chain.
	Government	Government Agencies like <i>Rijkswaaterstaat</i> (in NL) provide open data regarding the status and availability of infrastructure. E.g. vaarweginformatie.nl provides status messages over locks, bridges etc. on the inland waterway network in NL. Similarly, RIS (River Information System) portal financed by the EU allows information transfer service between skippers and infrastructure authorities. (See www.ris.eu).
	AIS Data	Websites like MarineTraffic.com collect AIS (Automatic Identification System) data from ships, barges, boats and provides them using a freemium model to general public.
Manufacturing	IT h/w companies	Hardware companies which manufacture IT devices used in transport sector, like, temperature sensors, RFID readers, GPS devices etc. are important stakeholders. The multitude of data formats, technologies and proprietary interfaces lead to interoperability and integration problems.
	Vehicle Manufactures	As a result of the (global) push towards efficient and sustainable logistics, vehicle manufactures would soon need to take into account the related IT requirements during manufacturing. Most trucks manufactured and used in Europe today, have an inbuilt GPS device and a dedicated communication system connecting the truck 24X7 with its office thereby allowing easy track and trace services.
Consultants	BP Consultants	Business Process consultants help logistic companies assess, evaluate, improve and optimize their business processes. Such consultants play an important role in facilitating a mind-shift towards SmT in logistic companies.
	IT consultants	IT consultancy companies help logistics companies adopt new IT capabilities. Software companies which build software for transport sectors (like dashboards, control tower s/w, analytics s/w) are classified under IT consultants.
Government	National Gov.	There is a continued push for more sustainable transportation by governments all over the world. Primary goals include, reducing CO ₂ emissions, reducing traffic congestion and minimizing reliance on trucks. Government (and government agencies) are therefore an important stakeholder towards newer and efficient transport practices. Government backed agencies frequently initiate projects to enhance partnerships between research institutes and transport companies to initiate efforts for sustainable logistics. E.g. TNO, Rijkswaterstaat [148].
	European Union	At a meta-governance level, the European Union has the same goals and vision w.r.t to transportation sector, as mentioned above.

Table 3.3: SmT stakeholders' goals

Stakeholder	Stakeholder Goals
Freight Forwarders	F.1 Smarter transport practices F.2 Competitive Advantage F.3 End-to-end visibility of transport chains F.4 Business growth F.5 Sustainable Transport Practices F.6 Handle disruptions better F.7 More profit F.8 A secure data policy
Infra. Providers	I.1 Provide better facilities at terminals/hubs. I.2 Faster cargo handling I.3 Less expenditure on infrastructure maintenance
Customers	C.1 Faster shipment delivery C.2 Real time track and trace C.3 Real time updates about shipment state/condition C.4 Precise ETA
R&D Institutes	R.1 Solving data integration challenges R.2 Creating dynamic planning algorithms R.3 Predicting disruption events R.4 Precise calculation of ETA R.5 Creating better routing algorithms
Data Providers	D.1 Solution to data integration challenges D.2 Greater coverage of real time transport data D.3 Analytics over contextual data
Manufacturing	M.1 Requirements for smart devices which can be embedded in vehicles
Consultants	C.1 Better integration of different data sources C.2 Mind shift in favour of SmT
Government	G.1 Reduction in CO ₂ emission G.2 Reduced traffic congestion G.3 An integrated transport network G.4 Economic growth G.5 Sustainable development

3.4 Current state of practice for a freight forwarder

Freight forwarders' responses during stakeholder interviews were used to sketch the current state of practice for a freight forwarder, as will be described below and is also shown in Fig. 3.1 (An enterprise architecture model of a freight forwarder). I chose enterprise architecture (EA) modeling to model the state of practice of a freight forwarder in Fig. 3.1. EA modeling was chosen because it provides an overview of business, application and technology architecture of an enterprise [82, 115, 163, 182] (here, freight forwarder), which fits well with the goal of this section.

Transportation of a consignment from pick-up location to the drop-off location consists of two short hauls and one or more long haul(s). The first and second short hauls are from the pick-up location to a terminal and from a terminal to the drop-off location, respectively. The transportation of a consignment between terminals is referred to as long haul. Short haul uses trucks and reefers while barges, freight-cars and deep sea vessels are used for long haul.

- The planning activity is the main business process performed by planners. At some freight forwarders, it is performed manually by the planners. Other business processes include, (a) contracting — formulating a legal contract with the consignor for transportation of shipment, (b) transport — the transportation of a consignment and (c) monitoring — of consignment for track and trace services. If a freight forwarder uses its own vehicles for short hauls, it is referred to as in-house transport. The long haul is always contracted to a carrier.

The monitoring process implies tracking the location of consignments (via business interfaces; email, telephone, websites) to provide track and trace services to the consignor. According to freight forwarders' responses to questions E.4, E.7, E.9 and E.10 (Table 3.1 and Appendix B), dynamic routing based on contextual events is rarely done. The primary reason is that capacity booking at carriers is done weeks (usually 4-5 weeks) in advance. Last minute changes are very costly, require considerable co-ordination and at times prove counter productive. On the other hand, the planners indicated that they would like to have access to more contextual events data for planning.

- Freight forwarders use two main IT applications, a financial system and a Transport Management System (TMS). The financial system is used for accounting, contracting and invoicing purposes. The TMS is used for receiving shipment requests from consignors, planning and contacting carriers. In some cases, the TMS can be as simple as an MS Excel sheet, as revealed during stakeholder interviews.

Planners may use contextual data during planning but it is rarely used for dynamic planning of consignments. The planners are aware of the availability of relevant contextual events data and its potential use in (dynamic) planning. The main challenges identified by planners for dynamic planning were varied data sources, different data formats and combination of data from different sources. E.g. ETA information for deep sea vessels and barges has to be mined from websites of respective carriers, which is a

cumbersome task [11]. Data security and privacy concerns constrain data sharing between carriers and freight forwarders. Frequently, ETA of vehicles is known by carriers, still, it is not shared with the freight forwarders owing to data privacy concerns. This is yet another road block for dynamic planning of consignments. Below, is the response of a planner when asked about the current disruption handling policy. The planner elaborates over a situation wherein a deep sea vessel bringing containers at a port is delayed (ETA is delayed) or its status is unknown (ETA unknown).

TextBox 3.1. A planner's response to question E.4 (Table 3.1), during a stakeholder interview.

Q. (E.4): What is the current disruption handling policy?

A: *"We just send the truck, and ask them to wait. May take a few minutes or even a full day. We don't have information which can be relied upon; as the updating is slow, I mean, from the port's side. Even when the trucks are there sometimes they have to wait a long time before they are loaded; you know; many incidences we can't take into account like, delay when waiting for its turn. Usually, we plan for such delays and provide a cushion; I mean; everyone does that. Its not ideal or efficient way to work. This lag could be removed if we have more information; it follows to other orders also, like a chain."*

- On being asked about SmT, most planners reported to be aware of SmT but could not identify SmT processes. Yet, consensus was noticed over some characteristic properties of SmT like, dynamic planning, use of real time data and switching transport modes for a consignment. The planners indicated that if a consignor specifies a certain transport mode for the shipment, then the shipment can not be shifted to another modality, so the liability of SmT partially also lies on the consignor.

Figure 3.1: Enterprise architecture model of a freight forwarder using ArchiMate 3.0 notation [183]

3.5 Requirements for a SmT Integration Platform (SmTIP)

Interviews with SmT stakeholders (Appendix B) provided information about their current state of practice, the challenges faced by them and the desired state of practice in a SmT scenario. I did content analysis of the stakeholder responses to extract requirements for SmTIP.

Additionally, I consulted the articles from the systematic literature review and listed the processes to be performed in a SmT scenario (see [167]). SmTIP should enable the planner to perform these processes. By combining content analysis results and SmT processes, I obtained a list of requirements for SmTIP. In Table 3.4, I list the top level functional requirements for SmTIP according to freight forwarders, the main stakeholders. Top level functional requirements were iteratively decomposed to low level requirements until every low level requirement represented one atomic functionality to be provided by SmTIP. This resulted in a detailed list of functional requirements for SmTIP (Appendix C).

I then mapped SmTIP requirements to freight forwarders goals to obtain Table 3.5. As can be seen in the table, freight forwarder goal, F.6, i.e., Handle disruption better, has most functional requirements associated with it, i.e., six. On the other hand, freight forwarder goal, F.5, i.e., Sustainable Transport Practices has no functional requirement associated with it. One way to interpret the above observation is that, Handling disruption better is the most important goal for freight forwarders while Sustainable transport practices is (relatively) the least important goal for freight forwarders. The above statement is a hypothesis whose validity has to be tested. Goal F.5 may be related to non functional requirements of SmTIP. Non-functional requirements of SmTIP are not discussed in this dissertation and are left for future research. Table 3.6 show the mapping of freight forwarder goals to SmTIP requirements

Table 3.4: Top level SmTIP Functional Requirements

Req. No.	Top level SmTIP Functional Requirements
R1	Supports the planner to play the role of a central logistics provider
R2	Shows the entire transport chain to the planner
R3	Should allow the planner to use smart planning applications
R4	Supports the planner to change the already made planning in real time
R5	Supports the planner to switch consignment between transport modes
R6	Supports the planner to aggregate demand in order to get the best transport offer
R7	Be able to give the planner, carrier and consignor an integrated transport system
R8	Be able to make a synchronized combination of transport modes and services to the planner, carrier and consignor
R9	Should enable the planner to cope with disruptions regarding every transport mode
R10	Should enable the planner to distinguish user roles and their rights to view, add, edit and delete data
R11	Analytics
R12	Should use contextual data for planning
R13	The planner should be notified of contextual events

Table 3.5: Freight Forwarder Goals vs SmTIP Functional Requirements

Freight Forwarder Goals	SmTIP Functional Requirements
F.1 Smarter transport practices	R3, R4, R11, R12.
F.2 Competitive Advantage	R8, R11, R13.
F.3 End-to-end visibility of transport chains	R1, R2, R7, R8.
F.4 Business Growth	R6.
F.5 Sustainable Transport Practices	
F.6 Handle disruptions better	R4, R5, R7, R8, R9, R12, R13.
F.7 More profit	R6, R11.
F.8 A secure data policy	R10.

Table 3.6: SmTIP Functional Requirements vs Freight Forwarder Goals

SmTIP Functional Requirements	Freight Forwarder Goals
R1 Supports the planner to play the role of a central logistics provider	F3
R2 Shows the entire transport chain to the planner	F3
R3 Should allow the planner to use smart planning applications	F1
R4 Supports the planner to change the already made planning in real time	F1, F6
R5 Supports the planner to switch consignment between transport modes	F6
R6 Supports the planner to aggregate demand in order to get the best transport offer	F4, F7
R7 Be able to give the planner, carrier and consignor an integrated transport system	F3, F6
R8 Be able to make a synchronized combination of transport modes and services to the planner, carrier and consignor	F2, F3, F6
R9 Should enable the planner to cope with disruptions regarding every transport mode	F6
R10 Should enable the planner to distinguish user roles and their rights to view, add, edit and delete data	F8
R11 Analytics	F1, F2, F7
R12 Should use contextual data for planning	F1, F6
R13 The planner should be notified of contextual events	F2, F6

3.6 Conclusion

This chapter reported on the results of stakeholder interviews and answered the research questions, as follows:

R.Q.2.1, *Who are the stakeholders in SmT?* is answered via Table 3.2, where a detailed list of SmT stakeholders is given. I identified eight stakeholders for SmT and, freight forwarders were selected as the main stakeholders.

R.Q.2.2, *What are stakeholder goals?* is answered via Table 3.3, where a list of stakeholder goals is given.

R.Q.2.3, *What is the state of practice in transportation sector?* is answered only for the main stakeholders, i.e., freight forwarders. The business processes and IT applications of a typical freight forwarder, are modeled using an enterprise architecture model, in Fig. 3.1.

Finally, R.Q.2.4, *What are the stakeholder requirements for a SmTIP?* is answered in Sec. 3.5 where, based on freight forwarders responses during interviews, a list of SmTIP functional requirements is given. For a detailed list of SmTIP functional requirements, refer to Appendix C.

This chapter concludes the first step of design science research methodology for this research, i.e., Problem Investigation and paves the way for the next step, i.e., Treatment Design.

Part III

Treatment Design

Chapter 4

Synchromodal Transport (SmT) Scenario

*No matter what you look at, if you look at it closely
enough, you are involved in the entire universe.*

*-Michael Faraday
English physicist (1791-1867)*

This chapter provides a closer look over SmT. In Sec. 4.1, I describe SmT in practice using a SmT scenario and in Sec. 4.2, I discuss contextual events in a SmT scenario. Then, in Sec 4.3, I present an **Ontology** for **SmT**, abbreviated as OntoSmT, an ontology made by me. OntoSmT allows consistent interpretation of SmT concepts and facilitates the integration of contextual events data with transport data. In Sec. 4.4, I model events and disruptions in a SmT scenario. Disruptions in SmT are modeled using a Situation Modeling Language (SML) [24]. Then, in Sec. 4.5, I enumerate SmT processes and position them in a freight forwarders' enterprise architecture. Finally, a conclusion of the chapter is given in Sec. 4.6.

4.1 A SmT scenario and Assumptions in a SmT Scenario

4.1.1 A SmT scenario

An illustrative example: Consider Consignment C1 (Fig. 4.1), to be transported from Amsterdam to Dortmund by a freight forwarder and Fig 4.1(a) is the plan created by a planner at the freight forwarder. Amsterdam is the pick up location, Dortmund is the drop-off location and intermodal terminals Rotterdam & Venlo constitute the long-haul. Suppose, the planner, receives an event notification about Rotterdam - Venlo railway section.

This chapter is based on the following peer reviewed article
Smart logistics: An enterprise architecture perspective [168]

The event notification is that the Rotterdam-Venlo train segment is closed for 3 days due to an accident (Fig. 4.1(b)). If the transport plan shown in part (a) is followed, the consignment may be stuck at Rotterdam terminal for up to 3 days. Not only such a situation constitutes a delay, but, also causes monetary loss to the freight forwarder. The freight forwarder would have to pay for storing the consignment at Rotterdam terminal, till the Rotterdam-Venlo train segment is operational again.

In a SmT scenario, anytime after receiving the event notification (of rail segment closure) and prior to the consignment being loaded on the freight car at Rotterdam terminal, the planner may replan (change the route and/or transport mode) the consignment. Via replanning, the planner avoids the delay caused due to the closure of Rotterdam-Venlo rail segment. The planner may choose one of the following re-planning approaches:

Approach 1. The planner decides to transport the consignment via inland waterway from Rotterdam to Enschede¹ (long-haul) and from Enschede to Dortmund via truck, as shown in Fig 4.1,(c)). This leads to a new plan for consignment C1.

Approach 2. The planner decides to split Consignment C1 in two parts at Rotterdam terminal, i.e., Consignment C2 and Consignment C3. One part, consignment C3,² is transported via Rotterdam to Enschede using inland waterway and the other part, Consignment C2, follows the original plan (Fig 4.1,(d)).

Changing transport plans dynamically based on contextual events, as shown above, is the essence of SmT. Here, it is important to note that SmT involves not just dynamic routing, but might also lead to a change in the carrier(s) and modality. Above, I have shown two approaches of re-planning only to highlight the options available to the planner. Further on in the dissertation, I do not distinguish between the two approaches, and together mention them as *dynamic planning*.

4.1.2 Assumptions in a SmT scenario

A SmT scenario makes many assumptions, which are implicit in the SmT scenario described above. *Firstly*, a consignor must permit the freight forwarder to use any available modality and vehicle for transporting his shipment(s). *Secondly*, SmT assumes that the freight forwarder has such a business contract with carriers that allows it to cancel/change a transport service request any time, with minimum penalties. In the above example, the freight forwarder cancels his transport request to Carrier 2 and Carrier 3 in Fig. 4.1(c) and changes it in Fig. 4.1(d). *Thirdly*, SmT assumes that the freight forwarder can request transport services from carriers in real time, i.e., no pre-booking requisites exists. *Fourthly*, all terminals are intermodal terminals with appropriate container handling infrastructure for all modalities. *Lastly*, via dynamic planning, a freight forwarder achieves some goal (stakeholder goal), e.g., more profit, competitive advantage, etc. Thus, as indicated by the aforementioned assumptions, SmT assumes and requires, an idealized logistics ecosystem.

¹an example route

²based on requirements of the cargo, e.g., urgency

Figure 4.1: A SmT Scenario

4.2 Contextual Events in a SmT Scenario

Figure 4.2: Different locations of a consignment between Pick-Up and Drop-Off

To find out relevant contextual events in a SmT scenario, I studied existing research over context and contextual information, for any system. The environment of any system has many (tangible and intangible) entities, e.g., a user (tangible) or a route (intangible). In system design, **context** of a system implies entities in the system's environment which have an influence on its functionality [39]. The state of any such entity, at any given time, is represented by its property/attribute, e.g., mood, hair color in the case of a person and distance, traffic flow in case of a route. Together, the values of all attributes, of all entities in a system's context constitutes a *context state*, at any given time. The value of these properties/attributes, of all entities together is called *contextual information* for the system. A change in the value of these properties is a *contextual event*. A context-aware system: (a) senses its context state, (2) adapts its functionality according to it and (3) may change its context state by changing the properties/attributes of its context entities. Which entities should be included in a system's context, during system design, depends upon the design goal [40].

Applying the above in a SmT scenario, the *system* is a consignment. Context entities are *Containers*, *Vehicles* and *Routes* and their properties are *contextual information*. Therefore, any change in the property/state of a container, a vehicle or a route is a *contextual event*.

To clarify the above argument, consider Fig. 4.2, which is a reproduction of Fig. 4.1(a). Between Amsterdam and Dortmund, Consignment C1, at any given time, will have (exactly) one of the seven possible locations, indicated by numbers in Fig. 4.2. The possible locations are, (1) at Amsterdam terminal, (2) in-transit between Amsterdam and Rotterdam, (3) at Rotterdam terminal, (4) in-transit between Rotterdam and Venlo, (5) at Venlo terminal, (6) in-transit between Venlo and Dortmund, and, (7) at Dortmund terminal. At each location, from 1 to 6, events about the containers in Consignment C1, events about vehicles³ and events about routes⁴ are contextual events. When Consignment C1 is at Amsterdam Terminal, Location 1, the pick up truck may be late (vehicle-event) and/or a route, say, Rotterdam—Venlo could have a disruption event (route-event). Similarly, when the consignment is in transit between Amsterdam and Rotterdam, Location 2, the freight car's arrival at Rotterdam Terminal may be delayed and/or the route Venlo to Dortmund may have a disruption event. All the

³Truck of Carrier 1, Freight Car of Carrier 2, Truck of Carrier 3

⁴Amsterdam—Rotterdam, Rotterdam—Venlo, Venlo—Dortmund

above events may warrant dynamic planning for Consignment C1.

4.3 OntoSmT: An ontology for synchromodal transport

The SmT scenario discussed in Sec. 4.1 indicates complex communication between freight forwarders and carriers. Besides carriers, freight forwarders also communicate with infrastructure providers⁵. For meaningful communication, consistent interpretation of SmT concepts is essential. Separately, freight forwarders have to integrate contextual event data and transport (planning) data to determine, which consignments are/will be delayed and to what extent.

To enable, (1) consistent interpretation of SmT concepts and, (2) integration of contextual events data with transport data, I developed OntoSmT, an **Ontology** for **SmT**. For background knowledge over terms and concepts used in transportation sector, I consulted existing researches including, GS1 Core business vocabulary [67], GS1 Logistics Interoperability Model (LIM) [68], Itria et al.⁶ [87], GET Service project report [33], Iacob et al.⁷ [83], Bol Raap et al.⁸ [11], TNO Logistics Core Ontology (**LogiCO**)⁹, TNO Logistic Service Ontology (**LogiServ**)¹⁰ and TNO Transport Ontology (**LogiTrans**)¹¹. OntoSmT builds upon LogiCo, LogiServ and LogiTrans.

4.3.1 LogiCo, LogiServ, LogiTrans

1. LogiCO is a core ontology, which provides the main elements for the logistics domain, as well as mappings (through annotations) to the international standards under the United Nations rules for Electronic Data Interchange for Administration, Commerce and Transport (UN/EDIFACT).
2. LogiServ models business activities (such as Transport, Transshipment, Load, Discharge, Storage, Consolidation, Deconsolidation, etc.) and their properties as the basis for specifying logistic services. LogiServ is an extension of LogiCO.
3. LogiTrans defines the transport order that specifies user requirements for transporting a cargo from one place to another. LogiTrans is an extension of LogiCO.

4.3.2 OntoSmT Classes

The object and data properties of selected OntoSmT classes are shown in figures 4.3 to 4.12. First, I list OntoSmT classes which are extensions of existing ontologies (1-4, below), followed by OntoSmT classes which are reused,

⁵omitted from the scenario description for sake of simplicity

⁶Identification of critical situations via Event Processing and Event Trust analysis

⁷Towards a reference architecture for fuel-based carbon management systems in the logistics industry

⁸The design of a common data model for generic synchromodal cargo-tracking in logistics using web scraping and big & open data

⁹<http://ontology.tno.nl/logico/>

¹⁰<http://ontology.tno.nl/logiserv/>

¹¹<http://ontology.tno.nl/transport/>

as-is, from LogiCo (5-10, below), and, finally OntoSmT classes which are not an extension of existing ontologies, i.e., are added new. (11-24, below).

- The following OntoSmT classes are extensions of classes defined in the ontologies mentioned in Sec. 4.3.1:
 1. `OntoSmT:Shipment` — denotes a shipment as defined in the glossary. `OntoSmT:Shipment` is an extension of `LogiTrans:Consignment`. (Fig. 4.3).
 2. `OntoSmT:TransportActivity` — denotes the activity of transporting a consignment from one location to another. `OntoSmT:TransportActivity` extends `LogiTrans:TransportActivity` (Fig. 4.4).
 3. `OntoSmT:Container` — denotes a standardized shipping container, designed and built for inter-modal freight transport. `OntoSmT:Container` extends `LogiCo:Container` (Fig. 4.5).
 4. `LogiCo:Vehicle` — denotes a vehicle as defined in the glossary. It extends `LogiCo:TransportMeans` (Fig. 4.6).

Figure 4.3: OntoSmT classes Shipment and Shipment Segment

- The following classes are reused, as-is, from LogiCo.
 5. `LogiCo:Consignor` — denotes a consignor as defined in the glossary.
 6. `LogiCo:Carrier` — denotes a carrier as defined in the glossary.
 7. `LogiCo:Modality` — denotes a mode of transport as defined in the glossary.
 8. `LogiCo:Terminal` — denotes a terminal as defined in the glossary.
 9. `LogiCo:Location` — denotes the relative location of an entity.

Figure 4.4: OntoSmT class Transport Activity

10. `LogiCo:Space Region` — denotes the specific dimensional space that defines the absolute location of an entity.
- The following classes in OntoSmT are added new.
 11. `OntoSmT:FreightForwarder` — denotes a freight forwarder as defined in the glossary.
 12. `OntoSmT:ShipmentSegment` — denotes a shipment segment as defined in the glossary (Fig. 4.3).
 13. `OntoSmT:Consignment` — denotes a consignment as defined in the glossary (Fig. 4.7).
 14. `OntoSmT:DemandAggregation` — denotes the activity of combining individual shipment segments to form consignments, as defined in the glossary.
 15. `OntoSmT:Route` — denotes a route as defined in the glossary (Fig. 4.8).
 16. `OntoSmT:Planner` — denotes a planner as defined in the glossary.
 17. `OntoSmT:Planning` — denotes a planning activity as defined in the glossary.
 18. `OntoSmT:Plan` — denotes a plan as defined in the glossary (Fig. 4.9).
 19. `OntoSmT:Event` — denotes an event as defined in the glossary (Fig. 4.10).
 20. `OntoSmT:ContainerEvent` — denotes an event which informs about the state of a cargo inside a container (Fig. 4.10).
 21. `OntoSmT:RouteEvent` — denotes an event which inform about state of a route, e.g., roadworks, traffic jams, accidents, etc. (Fig. 4.10).
 22. `OntoSmT:VehicleEvent` — denotes an event which informs about the state of a vehicle (Fig. 4.10).
 23. `OntoSmT:DisruptionEvent` — denotes an event which leads to a disruption (Fig. 4.11).
 24. `OntoSmT:ComplexEvent` — denotes an event formed after aggregating two or more related events

Figure 4.5: OntoSmT class Container

(Fig. 4.12).

The validation of OntoSmT is left for future research. For this dissertation, OntoSmT is described textually and by using class diagrams. Future researchers may describe OntoSmT via OWL¹² or any other language.

¹²<https://www.w3.org/OWL/>

Figure 4.6: OntoSmT class Vehicle

Figure 4.7: OntoSmT class Consignment

Figure 4.8: OntoSmT class Route

Figure 4.9: OntoSmT class Plan

Figure 4.10: OntoSmT classes Event, Container Event, Vehicle Event and Route Event

Figure 4.11: OntoSmT class Disruption Event

Figure 4.12: OntoSmT class Complex Event

4.4 Modeling events and disruptions in a SmT Scenario

This section is dedicated to modeling events and disruptions in a SmT scenario using a situation modeling language (SML), proposed by Costa et al. in [24]. Firstly, in Sec. 4.4.1, 4.4.2 and 4.4.3, I model container events, vehicle events and route events, respectively. Then, in Sec. 4.4.5 to Sec. 4.4.7, I model disruptions due to each event type. Fig. 4.13, is an example representation, showing the use of SML and OntoSmT to model situations.

Figure 4.13: SML and related notations as used in this dissertation

4.4.1 Container event

A container event is the change of a physical property of cargo inside a container, which is measured by a sensor. Examples of physical properties measured by sensors include temperature, humidity and pressure. Monitoring of cargo's physical properties is relevant when biological, perishable, medicinal or chemical cargo is being transported. If cargo's properties change beyond an acceptable limit, it may lead to a delay and in some cases

may lead to a change in the transport plan. A container event is represented by `OntoSmT:ContainerEvent`. `OntoSmT:ContainerEvent::isAbout` refers to the container in which the cargo is being transported. `OntoSmT:ContainerEvent::measuredProperty` is the physical property measured by the sensor and `OntoSmT:ContainerEvent::hasValue` is its measured value. Using SML, Fig. 4.14 models a container event.

Figure 4.14: Situation 1. A container event modeled using SML

4.4.2 Vehicle event

An event involving a vehicle, can delay a consignment and may require dynamic planning. E.g., freight car delayed by 5 hours, truck break down, etc. A vehicle event is represented by `OntoSmT:VehicleEvent`. `OntoSmT:VehicleEvent::isAbout` refers to the corresponding vehicle and `OntoSmT:VehicleEvent::hasDelay` is the delay associated with the event. Using SML, Fig. 4.15, models a vehicle event.

Figure 4.15: Situation 2. A vehicle event modeled using SML

4.4.3 Route event

An event on a route can delay a consignment and may require dynamic planning. In our running example of consignment C1 (Fig. 4.2), events on Amsterdam-Rotterdam road, Rotterdam-Venlo railway or Venlo-Dortmund road may delay the consignment. A route event is represented by `OntoSmT:RouteEvent`.

`OntoSmT:RouteEvent::isAbout` refers to the corresponding route and `OntoSmT:RouteEvent::hasDelay` is the delay associated with the event. Using SML, Fig. 4.16, models a route event.

Figure 4.16: Situation 3. A route event modeled using SML

4.4.4 Disruptions in a SmT scenario

A disruption is a *situation* in which a consignment is delayed beyond its allowed delay. Allowed delay for a consignment is decided by the planner, to account for minor (and unavoidable) delays such as, traffic jams, delayed customs clearance of containers, etc. The allowed delay for a consignment, is a property of the class `OntoSmT:Consignment`, i.e., `OntoSmT:Consignment:allowedDelay`. Allowed delay per consignment is a practical approach used by planners to decide upon minor and major delays.

In Fig. 4.2, when consignment C1 is at Location 1, an event notification about Rotterdam — Venlo rail segment being closed for 3 days is a route event, about railway route Rotterdam - Venlo. It leads to a situation wherein consignment C1 may be stuck at Rotterdam terminal for 3 days, which is (say), more than its allowed delay. Events which delay a consignment beyond its allowed delay, are called **disruption events**.

Suppose, for our example, Duisburg-Frankfurt railway route was also closed for 3 days. Though, it is a route-event, but, consignment C1 will not be transported via this route. Therefore, it does not delay the consignment. The planner, nevertheless, has to determine whether other consignments are delayed due to this route-event. This implies that for every route event, the planner has to check which consignments are delayed and to what extent, i.e., within or beyond the allowed delay. Consignments which are delayed beyond the allowed delay, are *disrupted consignments* and warrant dynamic planning.

4.4.5 Disruptions due to container events

A container event reports the value of cargo's physical property during transportation, in a container. If the value is beyond an acceptable limit, then, the cargo may need shifting to another container/vehicle and/or an inspection of cargo. Either of these situations lead to a delay in transport. I model this situation in Fig. 4.17

using temperature as the physical property and the acceptable limit as 5 degrees. Since, a consignment is a collection of containers, therefore, a container event can be mapped to a consignment.

Figure 4.17: Situation 4. Disruption due to a container event

4.4.6 Disruptions due to vehicle events

A consignment and a vehicle are related in two ways.

1. Vehicle carrying a consignment — In Fig. 4.2, between Amsterdam and Rotterdam, the truck is carrying the consignment. Similarly, between Rotterdam and Venlo, the freight car is carrying the consignment. The situation of a vehicle carrying a consignment is modeled in Fig. 4.18.
2. Pickup vehicle for a consignment — A vehicle, planned to pick up a consignment at a terminal/pick-up location, is a pickup vehicle. E.g., In Fig. 4.2, when consignment C1 is on the truck between Amsterdam and Rotterdam, its pickup vehicles are the freight car (for Rotterdam—Venlo leg) and truck (for Venlo—Dortmund leg). When consignment C1 is on the freight car between Rotterdam and Venlo, its pickup vehicle is the truck (for Venlo—Dortmund). The situation of a consignment having pickup vehicles is modeled in Fig. 4.19.

If a vehicle carrying a consignment is delayed or breaks down, it *directly* delays the consignment. If a pickup

Figure 4.18: Situation 5. Vehicle carrying a consignment

vehicle is delayed or breaks down, it *indirectly* delays the consignment. In both these situations, the delay may be beyond the allowed delay, thereby, leading to a disruption. The corresponding situations are modeled in Fig. 4.20 and Fig. 4.21, respectively.

4.4.7 Disruptions due to route events

Fig. 4.22 shows the five possible situations due to a route event. Situation A and Situation C, are similar situations, since the route-event is about a route, planned for the consignment, but the consignment is still not on that route (future situation). Situation D and Situation E are not relevant since the route event can not delay the consignment. Therefore, only Situation B and Situation C (or A) are of interest.

Fig. 4.23 relates a vehicle and a route by modeling a situation when a vehicle is on a route. Fig. 4.24 models the situation, when a consignment is disrupted due to route event on its current route (Situation B). Fig. 4.25 model the situation, where a consignment is disrupted due to a route event on a planned/future route (Situation A/C).

The difference between Fig. 4.24 and Fig. 4.25 is the **temporal relationship** between *Route-Event* and *Vehicle on Route*. While, in Fig. 4.24 the *Route-Event* occurs **during** *Vehicle on Route*, in Fig. 4.25 the *Route-Event* occurs **before** *Vehicle on Route*.

Figure 4.21: Situation 8. Disruption due to a delayed pickup vehicle

Situation A: Consignment at a terminal, route event on the next route

Situation B: Consignment in transit, route event on the same route

Situation C: Consignment in transit, route event on the next route

Situation D: Consignment at a terminal, route event on the previous route

Situation E: Consignment in-transit, route event on the previous route

Figure 4.22: Five possible situations due to a route event

Figure 4.23: Situation 9. A situation model for a vehicle driving on a route

Figure 4.24: Situation 10. A situation model for disruption due to a route event on a route, where the consignment currently is.

Figure 4.25: Situation 11. A situation model for disruption due to a route event on a future route

4.5 SmT Processes

Figure 4.26: SmT Processes using ArchiMate 3.0 notation. Routing implies determining the route for a transport plan. Routing is a constituent functionality of Smart Planning. But, since Routing is not specific to SmT it is not considered a SmT process. Still, it is shown here for completeness

SmTIP should enable planners to perform SmT. After studying SLR articles (Sec 2.1) and stakeholder interviews (Sec. 3.1), I deduced that for SmT a freight forwarder must perform six processes, i.e., Event Prediction, Demand Aggregation, Smart Planning, Negotiations, Disruption Handling and Dynamic Switching (Fig. 4.26, SmT Processes). In a SmT scenario Smart Planning, Demand Aggregation and Event Prediction processes will be performed by a software. Therefore, I have modelled them as *business functions*. In Disruption Handling, Dynamic Switching and Negotiation processes some tasks would be performed by the planner manually while others, would be automated. Therefore, these three processes are modelled as *business processes*.

1. Event Prediction — implies using historical and real time contextual event data to predict contextual events. In a SmT scenario, a freight forwarder uses event prediction for preemptive transport planning and disruption handling. Andrej et al. in [35] used AIS data to predict the arrival of deep sea vessels at ports. Based on such predictions, freight forwarders can, for instance, plan the pickup time for consignments, more precisely. Consequently, the waiting time of pickup vehicles at ports/terminals is reduced. The process model for event prediction is left for future research.
2. Demand Aggregation — implies combining shipment segments to form consignments (Fig. 4.27). Via demand aggregation, a planner no longer has to make a separate transport plan for each shipment, rather, he can optimize vehicle's capacity by combining shipments and shipment segments.

If a consignor does not specify a particular modality for transporting his shipment, then the freight forwarder may use any transport mode, based on price, demand, vehicle availability and contextual data. Booking shipments, without specifying a particular transport mode is called, *mode-free booking*. Demand

Figure 4.27: Demand Aggregation. Shipment 1 and a shipment segment from Shipment 2 are combined to form Consignment 1. By demand aggregation, the planner utilizes the full available capacity of the freight car

aggregation process can be performed by an application or manually by a planner (Fig. 4.29).

3. Smart Planning — implies using a route planning application to make optimized transport plans (Fig. 4.29). The smart planning application optimizes various parameters, including, distance, time, demand, cost, etc., uses contextual data and produces a list of transport plans for a consignment. From this list, a planner chooses one transport plan for the consignment.
4. Disruption handling — encompasses all actions taken by a planner to avoid a delay due to a disruption event. To re-plan a disrupted consignment (i.e. dynamic planning), the planner may use a smart planning application or can do it manually. Fig. 4.28 models the disruption handling process, showing both options.
5. Negotiations — due to dynamic planning, a consignment's original pickup time, drop-off time and transport mode, may change. The planner then has to confirm whether the consignor agrees to the changes. In case of disagreement, the planner has to select a different plan. Again, consignor agreement is sought. This process may be repeated, until an agreement is reached. It is possible, that the consignor disagrees with any change to the original plan. The complete process of dynamic planning, seeking agreement from consignor, choosing another plan in case of disagreement, is called *Negotiation*. In Fig. 4.28 (bottom), the negotiation process involving manual planning is highlighted in red.
6. Dynamic Switching — refers to the specific case of disruption handling, where, the modality of a consignment is changed to avoid a delay.

Figure 4.28: Disruption Handling process performed by the planner using SmTIP (top), Disruption handling for one order (middle) and dynamic planning process performed by the planner using SmTIP (bottom). Negotiation process involving manual planning is highlighted in red.

Figure 4.29: Smart Planning Function of the Smart Planning application (top), Internal business process of a carrier (middle) and Manual Demand Aggregation process performed by the planner using SmTIP (below)

SmT stakeholders often use many similar terms for SmT processes. This leads to confusion. Therefore, to avoid confusion I have gathered such terms (from SLR articles and stakeholder interviews) and have listed them in Table 4.1 against the SmT process they refer to.

Table 4.1: SmT Processes

SmT Process	synonymous terms used by SmT stakeholders
Event Predictions	Prediction on infrastructure state, Using historic data for demand prediction, Using historic data for event prediction
Demand Aggregation	Bundling, Aggregate demands, Consolidation of load, Synchronization of demands
Smart Planning	Dynamic Planning, Better Planning, Real time decision making, Choice based on current circumstances, Best transport selection at all times, Real Time adaptation, Ability to decide at real time
Disruption Handling	Coping with disruptions, Handling uncertain circumstances, Coping with delays
Negotiations	Negotiate over time window, Negotiate over modality
Dynamic Switching	Real Time switching, Intermediate transfers, Switching between modes

4.5.1 Relationship among Pre-requisites, Processes, Effects and Stakeholder Goals

After having described and modeled SmT processes (Fig. 4.28 and Fig. 4.29), I can now summarize the relationship between SmT pre-requisites, SmT processes, SmT effects and SmT stakeholder goals as follows:

1. SmT Pre-requisites need to be *met* for performing SmT Processes *leading* to SmT Effects.
2. SmT effects *realize* SmT stakeholders' goals.

The relationships among them (Fig. 4.30, Relationship between SmT pre-requisites, SmT processes, SmT effects and SmT Stakeholder goals) provides a holistic understanding of SmT. Freight forwarders can use the above relationships for refining their goals w.r.t SmT. In Fig. 4.30, SmT effects are modeled as *Drivers*, which realize freight forwarders' goals, modeled as *Goals*. SmT processes are modeled as business process which realize (*realization relationship*) SmT effects. SmT pre-requisites are modeled as requirements which positively influence (*influence relationship*) SmT processes. To clarify, Better Resource Utilization (a SmT effect) realizes freight forwarder goal of More Profits which is realized by Demand Aggregation and Smart Planning (SmT processes). Demand Aggregation and Smart Planning processes can only be performed with advanced software for access and analysis of contextual data (a SmT Pre-requisite) [167].

4.5.2 Enterprise Architecture Model of a freight forwarder for SmT

To illustrate the main business processes, applications and technology infrastructure required for SmT, Fig 4.31 shows the desired (to-be) enterprise architecture of a freight forwarder, for SmT. The changes w.r.t to current (as-is) enterprise architecture model of a freight forwarder (Fig. 3.1), have been highlighted. At the business level (in yellow), are two new business processes, Smart Planning and Disruption Handling. At the application

Figure 4.30: Relationship between SmT Pre-requisites, SmT Processes, SmT Effects and stakeholder goals

level (in blue), SmTIP is added. To save the planner from using two applications simultaneously, i.e., TMS **and** SmTIP, SmTIP imports the functionalities of existing TMS (shown via the *serves* relationship between TMS and SmTIP). Some functionalities of the TMS might be adapted for a SmT scenario or even disabled, since SmT propose a different way of working. At the technology level (in green), contextual data and contextual data sources have been added.

Figure 4.31: An enterprise architecture model of a freight forwarder for SmT

4.6 Conclusion

This chapter provided a closer look over SmT using a SmT scenario. OntoSmT, an ontology for SmT, facilitating the integration of transport (planning) data and contextual events data was developed. Contextual events in a SmT scenario are container events, vehicle events and route events. They may lead to situations in which consignments are delayed beyond an allowed delay. Such situations are called disruptions. Disruptions in a SmT scenarios were modeled using situation modeling language (SML).

SmT consists of six processes: Event Prediction, Demand Aggregation, Smart Planning, Negotiations, Disruption Handling and Dynamic Switching. SmT processes and the enterprise architecture of a freight forwarder for SmT were also modeled. Together, they answer R.Q.2.5 *What is the desired state of practice in a SmT scenario?* The results discussed in this chapter will be used to design SmTIP in Chapter 6, Synchromodal Transport Integration Platform. The next chapter, is about discovering best practices in integration platform design.

Chapter 5

Reference Architecture for Integration Platforms

Science, however, is never conducted as a popularity contest, but instead advances through testable, reproducible, and falsifiable theories.

-Michio Kaku

American physicist (1947-)

This chapter answers R.Q.3.1; *What are the best practices in integration platform design?* The answer is a Reference Architecture for Integration Platforms (RAfIP) to capture and represent such practices. It was designed based on the results of a pattern mining method. The method is used to discover design patterns for integration platform design. Firstly, in Sec. 5.1, I introduce pattern mining for architectural design patterns. Then in Section 5.2, I discuss a pattern mining method and its results.

5.1 Pattern Mining

Knowledge about best practices in integration platform design may not be acquired by studying any single integration platform. Rather, they can be established only after studying a (well-chosen) sample of integration platforms. Best practices in integration platform design manifest themselves as recurring architectural design patterns [179]. Design patterns help solution architects employ knowledge, best practices and experience of experts in the field, rather than re-inventing the wheel as an inexperienced designer would [17, 21, 121, 177].

This chapter is based on following peer reviewed article
Reference Architecture for Integration Platforms [169]

Figure 5.1: A Pattern Mining Method (adapted from [177])

Extracted architectural design patterns together form a *reference architecture*. Reference architectures (RAs) are a collection of architectural design patterns. They allow solution architects to design a high level architecture of a system using best practices and proven problem solving approaches [13, 52, 108, 176, 179]. In this dissertation, I will use the reference architecture to be discussed in this chapter, to design SmTIP.

5.2 Using a pattern mining method

For extracting architectural design patterns from existing integration platforms, I used a pattern mining method (Fig. 5.1, A Pattern Mining Method) proposed by Stal in [177]. I chose this method because, it was devised and used by Stal in a similar setting, with a similar objective (i.e., to mine inherent design patterns from different software architectures), as in this dissertation. I have used an adapted version of the original method. The adaptations made by me, further align the original method to the overall goal of this chapter. This section describes the application of the method to extract design patterns for integration platform design.

5.2.1 Step 1: Identify recurring problems

The first step of the pattern mining method concerns identifying recurring problems for which design patterns are desired. The problem for my pattern mining method is RQ3.1.

5.2.2 Step 2: Define solution space

The second step of the pattern mining method concerns defining a solution space for solution candidates. I defined the solution space for my pattern mining process as; every integration platform designed in the last five years, in any business domain; e.g., smart cities [5], bio-informatics [53], health care [187], etc.

5.2.3 Step 3: Select candidates

The third step of the pattern mining method concerns selecting relevant candidates from the solution space. To find every integration platforms in the solution space, a SLR was conducted by me, according to the guidelines

Figure 5.2: Result of the study search and selection criteria

for conducting SLR in software engineering by Kitchenham et al. [92]. To achieve maximum search coverage, four electronic databases were used, i.e., (i) Scopus, (ii) Web of Science, (iii) IEEE Xplore and (iv) SpringerLink. The search term used was *integration platform*. The search was conducted during December 2016 - February 2017. Further constraints applied on the search were as follows:

- (a) year of publication, 2010-2016. To exclude obsolete works and include latest integration platforms.
- (b) search term was applied on title only, to reduce false positives.
- (c) language, English.

The search resulted in a total of 378 articles¹, on which the following exclusion criteria were applied (See Fig. 5.2).

1. *Exclusion criteria 1: Removal of duplicates.* Duplicate results from the list of 378 articles were excluded. 176 articles were found duplicate and hence were removed. Remaining articles, 202.
2. *Exclusion criteria 2: Restrict to Information Systems (IS) domain.* Articles not belonging to IS domain were removed, as they were false positives. E.g., articles such as, “*Silicon photonic integration platform for optimal communications and other applications*” were removed. This decision was made by reading the title of the articles. 68 papers were false positives. Remaining articles, 134.
3. *Exclusion criteria 3: Full text access.* For further analysis, full text access to these 134 articles was required. 26 articles were unavailable. After repetitive attempts for access to these articles were unsuccessful, they were finally dropped from the list of candidate articles. Remaining articles, 108.
4. *Exclusion criteria 4: Removal of Noise.* In 108 remaining articles, there were many short articles where the integration platform was not discussed adequately. These articles were considered as *noise*. Such articles lacked proper justifications (and explanations) for the design choices made. Therefore, from the list of 108 articles, articles which were shorter (or equal to) 5 pages, excluding references, were removed. There were 37 such articles. Remaining articles, 71.
5. *Exclusion criteria 5: Integration platform figure.* Only those articles which had an architecture diagram of the designed integration platform, showing constituent architectural components, were included in the

¹174 from Scopus, 103 from Web of Science, 80 from IEEE Xplore and 21 from Springer Link

final list of candidate articles. The rationale behind this selection criterion is to exclude those articles from further analysis which lack clarity or are ambiguous about the components of the designed integration platform. An architectural diagram considerably reduces such an ambiguity. By applying exclusion criteria 5 on the list of 71 articles, 40 articles were excluded (Fig. 5.2), which left a final list of 31 articles listed in Table 5.1. They are the solution candidates for subsequent steps of my pattern mining method.

I classified the candidate articles based on their business domain (Table 5.2). The rationale behind such a classification is to establish that the candidate articles cover different business domains. Table 5.2 confirms that conjecture. Thus, design patterns extracted from the candidate articles would incorporate best practices across business domains, rather than incorporating prevalent best practices in any specific business domain(s).

Table 5.1: List of candidate articles

Ref.	Article
[5]	iQAS: An integration platform for QoI assessment as a service for smart cities
[20]	Context-oriented Data Acquisition and Integration Platform for Internet of Things
[22]	An Integration Platform for private assisted homes
[31]	Research on Application Information System Integration Platform in Medicine Manufacturing Enterprise
[34]	SMART GROUND Project: SMART data collection and integration platform to enhance availability and accessibility of data and information in the EU territory on secondary raw materials
[48]	An integration platform for heterogeneous sensor systems in GITEWS - Tsunami Service Bus
[53]	Requirements for data integration platforms in biomedical research networks: a reference model
[60]	A Service-Oriented Integration Platform to Support a Joined-Up E-Government Approach: The Uruguayan Experience
[61]	An event-driven integration platform for context-aware web services
[62]	Towards a compliance-aware inter organizational service integration platform
[63]	A reference architecture for integration platform supporting cross organizational collaboration
[80]	A GISservice-based transportation information resources integration platform
[95]	Contextual Information Integration platform for humanitarian relief
[97]	Human centric data model and data integration platform enabling personalized product service systems for health care
[99]	Towards a reference architecture for an Integration Platform for Diverse Smart Object Technologies
[100]	Business processes oriented heterogeneous systems integration platform for network enterprises
[102]	Towards an Integration platform for bioinformatics services
[118]	A simulator integration platform for city simulations
[135]	A cloud service integration platform for web applications
[141]	Semantic integration platforms
[155]	Indoor Navigation Integration Platform for Firefighting purposes
[171]	The Urban Data Re-Use and Integration Platform for Australia: Design, Realisation and Case Studies
[187]	An ontology enhanced SOA-based home integration platform for the well being of inhabitants
[201]	Cloud-based government procurement information integration platform
[205]	Research on an Information Application Integration platform based on SOA and web service
[213]	HIP: Health Integration Platform
[214]	Analysis for information integration platform for warships
[215]	A cloud based information integration platform for smart cars
[216]	A service oriented simulation integration platform for hierarchical manufacturing planning and control
[218]	Design and Development of a Clinical Data Exchange System based on Ensemble Integration Platform
[219]	Research on Home-Textile Enterprise-oriented comprehensive management integration platform and its application

Table 5.2: Classification based on research domain

Domain	Candidate Papers
Health care	[22], [97], [187], [213] and [218]
Services	[61], [62], [135] and [155]
Disaster Mgmt.	[48], [80], [95] and [155]
Smart Cities	[5] and [118]
E-gov.	[60] and [201]
Biomedical	[53] and [102]
Generic Devices	[20] and [99]
Vehicles	[135] and [214]
Other domains	[34], [63], [100], [141], [171] and [205]

5.2.4 Step 4: Identify abstraction levels

The fourth step of the pattern mining process concerns identifying abstraction levels in the selected solution candidates. After studying each integration platform in the candidate articles, I identified three abstraction levels in each of them, i.e., logical, functional and technical. The **logical** level is the highest abstraction level. At the logical level each integration platform can be viewed as being composed of a number of layers or tiers. Examples from the candidate articles include; [80] (Application and Service Layer, Information and Process Analysis Layer, Information Conversion Layer), [95] (Service Tier, Context Tier, Interface Tier) and [187] (Application Layer, Service Composition Layer, Adapter Layer). After the logical level, the next abstraction level is the **functional** level. At the functional level, each layer can be viewed as being composed of modules or components. The focus at the functional level is to study the function of these components as a whole. After the functional level, the next abstraction level, is the **technical level**. It is the lowest level of abstraction, where components in each layer are identified and studied individually.

5.2.5 Step 5: Identify design patterns at each abstraction level

The fifth step in the pattern mining method is to identify design patterns in each of the abstraction levels, which were identified in the previous step.

At the logical level, I identified a **Service Oriented Architecture (SOA) pattern** in most integration platforms. This means that most integration platforms had three layers: a service/business layer, an application layer and a data layer. Sixteen out of the thirty-one integration platforms exhibited a SOA architectural design pattern.

At the functional level, I identified patterns in each of the three layers mentioned above. At the service layer, I identified a **Service Design Pattern**. At the application layer, I identified a **Enterprise Service Bus (ESB) design pattern** and at the data layer, I identified a **Extract Transform Load (ETL) design pattern**.

A *service design pattern* exposes the functionality of a system via services and user interfaces. The users of the system are human actors, applications or both. An application can search and connect to a service (provided

by the system) by using a service catalog which describes the service itself, how to connect to it, format of query messages and format of response messages. Human users use the system's services via dashboards and pages/windows.

In an *ESB* design pattern, applications connect to each other via an enterprise wide service bus (ESB). An ESB enables interoperability, loose coupling among applications and manages application interactions [93, 94].

An *ETL* design pattern refers to three sequential steps, i.e. extract, transform and load, performed over data. It consists of accessing data from data sources, performing transformations/calculations over the data and loading it into a database [47].

At the technical level, I identified three recurring architectural components in the service layer, nine recurring architectural components in the application layer and six recurring architectural components in the data layer. Two architectural components, i.e., security mechanism and user roles, frequently occurred in candidate integration platforms but do not belong to any specific layer. Fig. 5.3 summarizes the finding of Step 5.

Design Pattern at Logical Level		Design Pattern at Functional Level	Design Pattern at Technical Level
SOA	Service Layer	Service Design Pattern	Dashboard
			Platform Management Tool
			Web Services
	Application Layer	ESB Design Pattern	Enterprise Service Bus
			Event Processing Module
			Workflow Management Module
			Business Rules
			Data Source Manager
			Analytics and Decision Support
			Computations
			Diagnostics
			Platform Manager
	Data Layer	ETL Design Pattern	Adapters
			Data Bus
			Data Filtering
			Meta Data
			Data Conversion and CDM
			Database
	Cross Layered	No observable pattern	Security Mechanism
			User Roles

Figure 5.3: Design patterns identified at logical, functional and technical levels.

5.2.6 Step 6: Document identified design patterns

The sixth step of the pattern mining process is to document the design patterns identified in the fifth step. In this section, I document the design patterns at technical level, i.e. individual architectural components since they are the main building blocks in integration platform design.

Data Layer

Outside the data layers (beyond system boundary) lie data sources which can be devices, e.g. sensors ([22, 48, 97]), databases ([219]), applications ([118]) or a combination of these ([5]). To connect to these sources a communication link is required e.g., Bluetooth, RFID, etc.

1. **Adapters.** Adapters enable connections to data sources. Each data source (or a group of similar data sources) may require a dedicated adapter for connection, owing to differences in vendor technologies and communication protocol(s). In [5], different adapters are used for sensors, APIs and datasets. The connection link to the data sources can be via a physical link or wireless (as in [155] and [213]).
2. **Data Bus.** A data bus is a device level common connection point for all data sources. In [215], an integration platform for smart cars is designed. CAN (controller area network) bus is a common connection point for all electronic devices in a car. In the same integration platform, another bus (IT data bus) collects information from other data sources like mobile phones, GPS and a 3G module.
3. **Data Filtering.** Depending upon the intended use of data, filters can be applied before the data is used or stored, to extract relevant data (e.g., [5]). These filters are contained in the Data Filtering component, which is a common component of the *ETL* design pattern. Data filtering rules/policies can be changed depending on intended use of data. E.g., the *iFormatReader* in [48] applies a filtering mechanism by parsing the messages received from the sensors and mapping them to an internal data model. Those parts of the messages which do not map, are removed, thereby reducing the data stream to relevant data only. In some cases, data filtering is used to remove erroneous and anomalous readings from a data set, as in [22], where filtering is used to filter raw data by using mathematical models to avoid erroneous readings. Other commonly used terms for data filtering are data cleaning, data cleansing and content filter.
4. **Meta-data.** Meta-data is simply *data about the data*, appended to any data describing its type, source or intended use (e.g., in [20]). One commonly used technique for appending meta data is to first store all meta-data in a XML file. Then, dynamically choosing the correct meta data to append, based on *if-then-else* logic, where original data fields are used as constructs. E.g., in [214], an information integration platform for warships is designed. The platform consists of a meta-data database and a meta-data management module. The data sources are sensors, devices and processors which are distributed throughout a warship. Depending on the sources of the data, the meta data management modules appends the incoming data with appropriate meta-data. Meta-data for each corresponding data source is stored in the meta-data database.
5. **Data Conversion and Common Data Model (CDM).** The use of a CDM is to provide a common representation for data from different data sources [11]. E.g., in [218], data from different medical institutes is

converted to HL7 (Health Level-7)² for storage and transfer to different users. Similarly, in [171], data sets from remote data providers are converted to a common format used by other components of the designed platform. A common data model can also be referred to as a canonical data model (e.g. [102]) or unified data model (e.g. [214]) or unified data form (e.g. [80]). A data conversion module is often used for additional data transformations besides conversion to CDM. In Healthcare Integration Platform (i.e. [213]), a data processing module is responsible for processing of gathered data. The processing may include techniques like, compression/decompression, Fourier transform, Gabor transforms, encryption, etc.

6. Database (DB). Most candidate integration platforms have a local, dedicated database, which could be connected to external heterogeneous databases, as observed in [100]. An internal DB enables easier, faster and safer retrieval of data. At times, storing data about events is an important task of an integration platform, as in [155], where an Indoor Navigation Integration Platform (INI) is developed for fire-fighters on rescue missions. INI gathers data from diverse mobile (e.g. GPS) and static devices (e.g. building plan) and creates the best route for the fire firefighters in the building. An important functionality of INI is operation recording, which is used as evidence in case of accidents. The operation recording is saved in an integrated internal database. Besides storing data from external sources, an integration platform database also stores local data, like the list of devices to connect, data filtering rules and meta-data. Applications may access data from the database via an enterprise service bus.

Application layer

1. Enterprise Service Bus. Internal applications have access to the database via an enterprise service bus (ESB) (also called service bus). An ESB is the central connection point for all applications in an enterprise. Asynchronous communication, data buffer and message queues are some of the additional functions of the service bus ([102, 214]). An ESB can be commercial one, e.g. MS Biztalk or open-source, e.g., Mule ([187]).
2. Event processing (EP) module. An event processing module makes a deduction about its context and events that may occur or might have occurred [42]. Business rules, models, algorithms [87] and ontologies aid this module. E.g., in [22] (integration platform for private assisted house), data from various sensors in a house is collected. Based on this data, the integration platform decides if the patient is safe or does he needs assistance. An example of event processing in the form of a simple if-then-else scenario is, *if the location sensor detects activity in the bathroom, with a sudden change in posture (also detected by a sensor), and a horizontal posture of the body, then possibly the patient has fallen in the bathroom and requires assistance.* In [61], customized web services are provided to users based on their current situation i.e., context. Determination of a users situation is done by a complex event processing (CEP) engine which receives contextual data from the ESB and detects the situations in which users are.

²HL7 is the most widely accepted standard for transfer of clinical data

3. Workflow management (WFM) module. A workflow is a series of processes which are executed to achieve a desired result in case of an event. A workflow could use internal and external applications, human interaction or request for additional information. Based on the result of event processing module, the workflow management (WFM) module initiates an appropriate workflow. An example explaining the working of WFM is given in [187], an integration platform for smart homes. The example directly quoted from that text in [187] is as follows:

“An inhabitant sets the standard maximum time for taking a shower in the bathroom in his profile to 60 minutes. Given that each room in the smart home (including the bathroom) is equipped with several infrared sensors for detecting the inhabitant’s presence, the home automation system can detect the most current location of the inhabitant as well as the duration of his presence in that particular room. The inhabitant cooked food using an electric stove, then left the kitchen for taking a shower. 60 minutes has passed and he has not left the bathroom yet. The home automation system detects this anomaly, turns off the electric stove, then activates an alarming system in the bathroom for a notification to the inhabitant that he has been taking a shower more than the maximum normal duration and the electric stove has been turned off.” In this example, turning off the stove and activation of the alarm are the desired results, and constitute a workflow. They are triggered, based on the event, which in turn is based on the data collected from the sensors.

4. Business Rules. Business rules are policies of an enterprise. Based on these policies the WFMS invokes different processes when pre-determined events occur (or do not occur).
5. Data source manager. This module is directly linked to the data bus and enables easy update, repair, diagnosis and maintenance of connected data sources.
6. Analytics and Decision Support. The analytics and decision support module can have different functions based on specific system requirements and goals. One such function can be analyzing contextual data to predict the future state of the environment. Different mathematical operations can also be applied on the data to derive information and aid the user of the platform in decision making (e.g. the use of simulations models in [80]). E.g., in [218], the data mining and analysis module, allows the user to analyze patient records and monitor progress.
7. Computation. The computation module performs computation on the data. The computation results are shown to the user and/or stored for future analysis. Based on these computation results, different processes can be initiated by the user.
8. Diagnostics. The diagnostics module monitors the overall working of the platform. It monitors the performance of devices and applications connected to the integration platform and saves that data for future analysis. In the case of malfunctioning device(s), the diagnostic module runs pre-saved scripts or procedures to fix the fault. When it is not possible to fix the fault automatically an appropriate user (e.g. admin) is alerted. In some specific implementations, load balancing and scalability functions can also be associ-

ated with the diagnostic module, to ensure that excessive connections and load do not cause breakdown of the integration platform.

9. Platform Manager. The platform manager uses the diagnostic module. The platform manager can be assessed by the admin via an interface. Apart from diagnostics, the platform manager may be used to view, edit and update the data sources connected to the integration platform.

Service Layer

The service layer exposes the functionalities of an integration platform to the outside world via three architectural components, i.e., Platform management tool (PMT), Dashboard/Pages and Web Service Module. PMT & Dashboard have human users while the Web Service Module has internal and external applications as users.

1. Dashboard/Pages. The dashboard displays information on the working of the applications to the end users. Examples of displayed information includes, health records ([187]), status of a consignment, disruption notifications, weather reports, query results, etc. A dashboard aims to provide complete visibility and control over all applications and data sources of the integration platform.
2. Platform Management Tool. Platform Management tool (PMT) is the user interface for the Platform Manager architecture component (in the application layer). It allows a user with appropriate permissions to perform administrative functions.
3. Web Services Module. External applications can use the integration platform's functionalities via a Web Service module (WSM). E.g. in [5], the integration platform for smart cities, provides four web services (via an API gateway) to smart city stakeholders. WSM may allow public (via Internet) or limited (via Intranet) access. This module can also have additional functions like web services usage statistics and security.

Cross Layered Components

Cross layered components are those architectural components which do not belong to any design pattern. Yet, they were found in almost all solution candidates.

1. Security Mechanisms. In candidate integration platforms, security mechanisms existed mostly at entry and exit points of data. This corresponds to the basic level of security in a system, data access control (i.e., authentication and authorization). E.g., in [218], only certain medical institutions are authorized to upload patient data. To view their medical records patients have to login via a password on a web interface. In some candidate integration platforms, the communications channels and protocols included security features, while in others a registry of accepted services, data sources, is kept to restrict data

from unreliable sources. Furthermore, a security management module was not found in any candidate solution³.

2. Roles. Users of an integration platform can have one or more roles, and permission rights are specific to user roles. Basic user roles to be considered during design of an integration platform are Data Provider, Data Consumer and an Admin. However, depending on the specific application domain, other user roles, each with different permissions can be derived from these basic roles [62]. It is for the admin to define appropriate permissions for each user role.

The pattern mining method is thus complete and has produced a list of architectural components representing best practices in integration platform design. These architecture components, along with Fig. 5.4, (RAfIP - A Reference Architecture for Integration Platforms), together answer R.Q.3.1.

³A security management module governs how security of a system is administered and how security breaches are reported [14].

Figure 5.4: RAfIP - A Reference Architecture for Integration Platforms

5.3 Conclusion

In this chapter, I demonstrated the use of a pattern mining method to extract architectural components from thirty one integration platforms across different business domains. My premise for designing RAfIP is as follows. Just as in software development the same code snippet can be used for recurring computations in a program, similarly, same architectural component(s) can be used for recurring design problem in similar application scenarios. The extracted architecture components, embody the best practices in integration platform design. Together they form a reference architecture for integration platforms (RAfIP).

Researchers and practitioners in information technology, can use RAfIP to address data integration challenges in different research domains. Examples of such domains include smart cities, humanitarian logistics and disaster management. These and similar research domains are characterized by: *(a)* numerous data sources, *(b)* data integration challenges, *(c)* need for real time decision making and *(d)* requiring complex event processing. While adapting RAfIP to design domain specific integration platforms, some components might be combined, split into smaller manageable components or become avoidable. Such specific design decisions, however, depend on the respective domain and the requirements of the to-be-designed integration platform. For SmT domain such design decisions become apparent in the following chapter, in which RAfIP is used as a template to design SmTIP.

Chapter 6

Synchromodal Transport Integration Platform (SmTIP)

Eureka.

-Archimedes

Greek physicist (287-212 B.C)

This chapter reports on the design of SmTIP. First, in Sec 6.1, I discuss SmTIP's environment then in Sec 6.2, I design SmTIP architectural components using the Reference Architecture for Integration Platforms (RAfIP), discussed in the previous chapter. The layout of Sec 6.2 follows the layout used in Sec 5.2.6, i.e., data layer followed by the application layer and then the service layer. Finally, in Sec 6.3, Conclusion, I summarize the results of this chapter. This chapter answers R.Q. 3.2 i.e., *How to design SmTIP?*

6.1 SmTIP's Environment

To discuss SmTIP's environment, I refer back to Fig. 4.31, An enterprise architecture model of a freight forwarder for SmT. The environment of SmTIP consists of planner(s), freight forwarder's database, transport management system (TMS) of the freight forwarder and contextual data sources. SmTIP's interaction with each entity in its environment is discussed below.

1. Planner — The planner interacts with SmTIP via SmTIP pages on a computer screen. Through SmTIP pages, he receives information (e.g., event notification, consignment status), provides input data and per-

This chapter is based on following peer reviewed articles
SmTIP: A Big Data Integration Platform for Synchromodal Transport [170]

forms SmTIP process tasks, e.g., reviews plan, informs consignors of delayed ETA. The set of all SmTIP pages, together, enable the planner to perform all SmT processes.

2. Freight forwarder's database — SmT processes need transport data, e.g., list of shipments, list of carriers, routes, etc., used for transport planning. I assume that transport data already resides in the freight forwarder's database and SmTIP connects to the database via a data connector. Transport plans made using SmTIP are stored in the freight forwarder's database. Thus, the data connector between SmTIP and the freight forwarder's database provides two-way communication.
3. TMS of the freight forwarder — A transport management system (TMS) is used by a freight forwarder to perform basic transport processes [18] (Fig. 3.1., Enterprise architecture model of a freight forwarder). In a SmT scenario, if the planner has to use SmTIP in addition to existing TMS, then, frequently switching between the two applications may negatively affect his efficiency. Thus, in order to provide a single application to the planner, SmTIP imports TMS functionalities via APIs.
4. Contextual data sources — SmT requires contextual events data about containers, vehicles and routes. To access data from data sources (Table 6.1, Contextual Data Sources for SmTIP) different connection protocols are needed. Furthermore, data from the sources, may have different data formats (e.g., XML, JSON, .txt, etc.) [165, 166, 173].

SmTIP connections with contextual data sources present three different design choices. They are, (1) SmTIP connects to all contextual data sources directly, (2) SmTIP connects to contextual data source via another application and (3) hybrid approach, i.e., a combination of the previous two. In the **hybrid approach**, SmTIP connects to some data source directly, while to others via another application. An example for (2) is the use of an *ETA web scrapper* [11]. An ETA web scrapper automatically scans numerous websites (of carriers and infrastructure providers) to determine the ETA of vehicles (ships/barges). Since the hybrid approach provides a broader choice for collecting contextual data, therefore I recommend the use of the hybrid approach during SmTIP development.

Table 6.1: Contextual Data Sources for SmTIP

Contextual Data	Web resources	Applications	Sensors
Route Events	3rd party websites Carriers' websites Infra. provider websites		
Vehicle Events	Carriers' websites	Carriers' TMS	GPS/Board Computers/AIS on vehicles
Container Events			Sensors on containers

I conclude this subsection by modeling the message flows between SmTIP and entities in its environment (Fig. 6.1) for a simplified disruption handling process (Fig. 6.2).

Figure 6.1: Message flows during disruption handling process.

Figure 6.2: Simplified disruption handling process used for showing message flows between SmTIP and SmTIP's environment entities

6.2 SmTIP Architecture

Figure 6.3: SmTIP Architecture modeled using ArchiMate 3.0 notation

Fig 6.3 shows SmTIP architecture modeled using ArchiMate 3.0. To design it, I used RAfIP (Ch. 5). Other supporting resources used for SmTIP design were, functional requirements for SmTIP (Table. 3.4), OntoSmT (Fig. 4.3 - Fig. 4.12) and the enterprise architecture of a freight forwarder for SmT (Fig. 4.31). SmTIP uses a SOA design pattern and has three logical layers, SmTIP data layer, SmTIP application layer and SmTIP service layer. I have divided this section into three subsections, each corresponding to one layer of SmTIP, in the same order as in Sec 5.2.6, i.e., data layer followed by the application layer and then the service layer. Cross layered components, i.e., security mechanism and user roles, were not considered in SmTIP design and are left for future research. SmTIP instantiates RAfIP. In other words, the reference architecture was *refined* to the SmT scenario which produced SmTIP. The adaption led to the refinement of technical level components' functionalities. Some components were renamed for better alignment with SmT context. To illustrate the adaption of RAfIP to SmTIP clearly, it is discussed layer-wise, i.e., for each layer separately.

6.2.1 SmTIP Data Layer

Figure 6.4: SmTIP data layer in ArchiMate 3.0 notation, refined from RAfIP data layer

SmTIP data layer (Fig. 6.4) is refined from RAfIP data layer. When compared to the ETL design pattern, the **extract** part maps to SmTIP adapters. They request and receive data from external data sources. The **transform** part maps to SmTIP data converter, SmTIP data mapper and SmTIP data filter, which together convert different data formats to XML and map them to the SmTIP data model. The **load** part maps to SmTIP events database.

1. **SmTIP Adapters** - SmTIP adapters are of two types: APIs and Data connectors. SmTIP APIs connect to contextual data sources (see Table 6.1, Contextual Data Sources for SmTIP). Data connectors connect to freight forwarder's database. SmTIP APIs receive contextual data over TCP/IP. When connecting to web services the messaging protocols can be SOAP and REST over HTTP. The corresponding data format for request and response messages are HTML, XML or JSON. When connecting to a carrier's TMS, the SmTIP API uses a secure application layer connection protocol, TLS or FTP over TCP/IP. The corresponding data format for request and response messages are HTML, XML, or JSON. When connecting to sensors, the SmTIP API uses a sensor specific connection and transport protocol over TCP/IP. The SmTIP data connector connects to the freight forwarder database and the data formats include GS1 EDI-XML, JSON, XML.

Regarding SmTIP APIs, the mechanism for requesting contextual data requires attention. There are two mechanisms, a pull mechanism and a push mechanism. In the pull mechanism, SmTIP APIs requests data from a data source only when it is required by an SmTIP module. Whereas, in a push mechanism, SmTIP adapters subscribe for periodic notifications. The data is thus, pushed to the SmTIP API by the data source. An example of push mechanism is a live feed subscription from RIS (River Information System)¹ [157, 186] or TIS (Train Information System)². In cases where data update is frequent or data is critical (ETA of vehicles), SmTIP adapter uses a push mechanism while in other cases a pull mechanism is used. For instance, ETA and location of a barge is important for a planning, therefore, for this data, the SmTIP API uses a push mechanism. On the other hand, weather data is relatively less important and thus a pull mechanism may be used.

2. SmTIP Data Converter

The SmTIP data converter converts data from contextual data sources to XML³. This is performed by the SmTIP data converter. Both, open source and proprietary middleware solutions, like, eMagiz⁴ are available for conversion of different data formats to XML, and either may be used as SmTIP data converter.

3. SmTIP Data Mapper

SmTIP data mapper maps contextual data and transport data to SmTIP data model. A class diagram for SmTIP data model is shown in Fig 6.5. The entities in SmTIP data model are OntoSmT classes. Entity attributes and entity-relationships are based on data properties and object properties of respective OntoSmT class. Fig. 6.5, only shows those classes which are defined in OntoSmT and specified in the glossary. Other classes like planner, costs, etc., are not included in Fig. 6.5. Such classes already exist in the freight forwarders database and therefore can be re-used, appended to SmTIP data model.

Since OntoSmT (and therefore, SmTIP data model) has been developed after consulting GS1 LIM (Lo-

¹RIS incorporates a publish/subscribe middleware to which users, such as SmTIP, can subscribe by specifying their information need.

²<http://tis.rne.eu>

³XML is the most used data format providing easy interoperability with other data formats

⁴www.emagiz.com

Figure 6.5: SmTIP Data Model class diagram using UML notation. Entities in SmTIP data model are OntoSmT classes. Entity attributes are data properties of respective OntoSmT class. Entity-relationships are based on OntoSmT classes' object properties. Entity with blue outline, was not defined in OntoSmT.

gistics Interoperability Model) vocabulary⁵, therefore any data model based on GS1 LIM may easily be appended or mapped to the SmTIP data model. Such a mapping makes it easier for freight forwarders using GS1 LIM to adopt SmTIP data model.

4. SmTIP Data Filter

Contextual data from a data source may contain fields or sections which are not relevant for SmT. Those fields have to be filtered out. E.g., when SmTIP APIs request ANWB web service for route events, the corresponding ANWB response covers **all** events on **all** road segments in NL. Planners are primarily interested in road segments (routes) connecting terminals and ports. Therefore, events about minor road segments in cities/towns are not relevant. From the ANWB response the SmTIP data filter selects relevant road segments and filters out the remaining data. Filtering mechanisms can be static, i.e., *hard coded* during design time in SmTIP data filter or dynamic, i.e., *editable* by the planner during runtime. Taking our example of road events above, in dynamic filtering, the planner specifies routes where road events are relevant. Consequently, events on routes, except those specified by the planner, are filtered out. Later, if the planner changes the specified route, the filtering mechanism is also updated.

In case of route events, filtering is based on start and end location of the route event. In case of vehicle ID and container events, filtering is based on vehicle and container ID.

5. SmTIP Events Database

SmTIP has a dedicated database for storing events data. The SmTIP event database is designed using

⁵standard vocabulary for concepts used in logistic domain

EPCIS repository⁶ as guideline. Just as an EPCIS repository allows storage and querying for logistics events, the SmTIP event database enables storage and querying for contextual events.

6.2.2 SmTIP Application Layer

Figure 6.6: SmTIP application layer in ArchiMate 3.0 notation, refined from RAfIP application layer

The SmTIP application layer (Fig. 6.6) is refined from RAfIP application layer and uses the ESB architectural design pattern. The components of ESB design pattern were refined by me for a SmT scenario which led to the following SmTIP modules.

1. **SmTIP Event Handler.** The SmTIP event handler has four functions that are performed sequentially for each event⁷.
 - (a) **SmTIP Event De-duplicator** — Identical contextual events reported by multiple data sources are combined to form one event instance by the SmTIP Event De-duplicator. For two or more contextual events to be identical all properties of `OntoSmT:Event` except `OntoSmT:hasEventID`, `OntoSmT:hasDescription`, `OntoSmT:recordedOn` and `OntoSmT:recordedBy` have to be identical. When identical events are reported by different data sources, `OntoSmT:recordedBy` property is not identical. Any two events can not have the same EventID, therefore

⁶<https://www.gs1.org/standards/epcis>

⁷the volume and velocity of event data may cause scalability issues [165], though they were not considered by me in SmTIP design

OntoSmT:hasEventID would be different. Furthermore, the data sources may record identical events at different times and add different descriptions, making properties

OntoSmT:hasDescription and OntoSmT:recordedOn different.

- (b) **SmTIP Event Aggregator** — SmTIP Event aggregator aggregates related events to create complex events. SmTIP event aggregator joins container events from containers in the same consignment using the `OntoSmT:Container_Event:isAbout::ContainerID` property of container event and `OntoSmT:Consignment::hasContainers` of consignment. In the case of vehicle events, the SmTIP aggregator aggregates events about the same vehicle using the

`OntoSmT:Vehicle_Event:isAbout::VehicleID` property of a vehicle event.

In the case of route events, events on the same route are aggregated together. Consider the following route events, EventID 123 and EventID 456, in Fig. 6.7. EventID 123 reports the closure of Rotterdam-

Figure 6.7: The aggregation of two route events to form a complex route event by SmTIP Event Aggregator

Amsterdam railway segment for 3 days and EventID 456 reports heavy snow in the Rotterdam region. These two events though not identical, yet are related to the accessibility of the Rotterdam terminal. They are aggregated to form a complex route event, Event ID789 (Fig. 6.7). The original events and the complex event are all stored in the SmTIP event database. Determining a complex event's data properties, based on aggregating events, require further study of SmT scenarios, and for this reason is left for future research. A detailed discussion of generic event aggregation techniques is not required here either, as they have been studied before, e.g., by Etzion and Niblett in [42]. Off-the-shelf software solutions like Apache Flink may be used as SmTIP event aggregator.

- (c) **SmTIP Event Filtering** - After duplicate events have been combined and related events are aggreg-

gated, resulting events can be broadly categorized as follows:

- I. Category 1 - Events which may delay consignments. The planner is notified about such events and related delays. Category 1 events are of two types:
 - Category 1.1 - Events which delay any consignment beyond the allowed delay, leading to disruption situations. E.g., ETA of pick-up barge at terminal delayed by 17 hours⁸. Category 1.1 events are disruption events.
 - Category 1.2 - Events which delay consignments, but within an allowed delay, therefore, re-planning based on such events is either not possible or not feasible. E.g., ETA of pick-up barge at a terminal delayed by 10 minutes.
- II. Category 2 - Events which do not delay consignments and therefore do not lead to disruption situations. Such events may still be stored in SmTIP events database (for analytics), but the planner is not notified about them. E.g., traffic jam on A35 cleared—traffic flowing smoothly, vehicle departed from terminal, etc.

The SmTIP event filter classifies events into Category 1 and Category 2, based on event filtering rules.

Event filtering rules use the `OntoSmT:Vehicle_Event::hasDelay`,

`OntoSmT:Route_Event::hasDelay`, `OntoSmT:Event::hasProbability`,

and `OntoSmT:Event::hasEventType` properties events. Fig. 6.8 shows two event filtering rules.

`RuleEventFilterRule1` classifies events with priority 0 as category 2 events. `RuleEventFilterRule2` classifies traffic jams as category 2 events. One or more filtering rules might apply to an event, as for event `IDX87` shown in Fig. 6.9. It reports a traffic jam and has priority 0, thus, `EventFilterRule1` and `EventFilterRule2` apply to it.

```
rule "EventFilterRule1"
when
  OntoSmT:Event::hasPriority == '0'
then
  set OntoSmT:Event::hasCategory == '2'
end
```

```
rule "EventFilterRule2"
when
  OntoSmT:Event::hasEventType == 'Route_RoadSegment_TrafficJam'
then
  set OntoSmT:Event::hasCategory == '2'
end
```

Figure 6.8: `EventFilterRule1` (top) filters out events with priority value as zero, and classifies them as category 2 events. `EventFilterRule2` (bottom) filters out Traffic Jams, and classifies them as category 2 events.

- (d) SmTIP Event mapper - The input to the SmTIP event mapper is a list of Category 1 events. To re-iterate, Category 1 events **may** lead to disruptions. The SmTIP Event Mapper determines **which** consignments are disrupted. For this, it uses SmTIP Disruption Rules. The output of the SmTIP

⁸Here, the assumption being that a delay of 17 hours for pick-up is greater than the allowed delay for the consignment.

```

OntoSmT:Event::hasEventID :   IDX87
OntoSmT:Event::hasPriority :   0
OntoSmT:Event::hasDescription : Traffic jam on A35 near Borne, approx. delay 30 minutes
OntoSmT:Event::hasEventType::Route_RoadSegment_TrafficJam
OntoSmT:Event::recordedOn: 13/01/2018
OntoSmT:Event::recordedBy: ANWB website
OntoSmT:Event::startTime: 13/01/2018
OntoSmT:Event::endTime : 13/01/2018
OntoSmT:Event::hasStartGeoLocation : Borne
OntoSmT:Event::hasEndGeoLocation: Borne

```

Figure 6.9: A route event for which EventFilterRule 1 and EventFilterRule2, both are applicable. This event is therefore classified as a category 2 event.

event mapper is a list of disrupted consignments and associated disruption events.

Fig. 6.10 shows a taxonomy of events in a SmT scenario and the functions of the SmTIP event handler.

2. **SmTIP Disruption Rules.** SmTIP disruption rules detect situations. Below, I list SmTIP disruptions rules for every situations modeled in Sec. 4.4 (Modeling events and disruptions in a SmT Scenario). The rule snippets in pseudo code are given in Appendix D.

- Situation detection rule 1 — matches a container event to a specific container. Detects situation 1 modeled in Fig. 4.14
- Situation detection rule 2 — matches a vehicle event to a specific vehicle. Detects situation 2 modeled in Fig. 4.15.
- Situation detection rule 3 — matches a route event to a route. Detects situation 3 modeled in Fig. 4.16.
- Situation detection rule 4 — detects the situation where the temperature of a cargo (in a container) is higher than the required temperature. See situation 4 modeled in Fig. 4.17.
- Situation detection rule 5 — detects the situation where a vehicle is carrying a consignment. See situation 5 modeled in Fig. 4.18.
- Situation detection rule 6 — matches a consignment with its pick up vehicle. Detects situation 6 modeled in Fig. 4.19.
- Situation detection rule 7 — detects disruption due to a vehicle event, about the vehicle carrying the consignment. Detects situation 7 modeled in Fig. 4.20.
- Situation detection rule 8 — detects disruption due to a vehicle event, due to a PickUp Vehicle. Detects situation 8 modeled in Fig. 4.21.
- Situation detection rule 9 — matches a route with a vehicle driving on that route. Detects situation 9 modeled in Fig. 4.23.
- Situation detection rule 10 — detects a disruption due to a route event on a route (where the consignment currently is). Detects situation 10 modeled in Fig. 4.24.
- Situation detection rule 11 — detects disruption due to Route event on a planned route. Detects

situation 11 modeled in Fig. 4.25.

3. **SmTIP Workflow Module.** The SmTIP Workflow Module (WFM) realizes SmT processes. The input for SmTIP WFM are SmT process diagrams (Fig. 4.28 and Fig. 4.29). I had chosen Business Process Modeling Notation (BPMN) to model SmTIP processes, since BPMN processes can be converted to executable code.
4. **SmTIP Smart Planning Module.** The SmTIP Smart Planning Module optimizes various parameters like: cost, modalities, delays, open shipments, stoppages and halt times, to create a list of transport plans [83, 113, 150, 151]. The planner then chooses a plan from that list. When a smart planning module is used, Demand Aggregation is performed by the optimization algorithms in the module.
5. **SmTIP Analytics Module.** Analytics software provide insights for improved decision making. This also applies to analytics systems in transportation and logistics sector [220]. SmTIP analytics module, helps the planner in decision making by analyzing data and suggesting a suitable decision. Studies have shown that when planners are aided in decision making by analytics module(s), they tend to make better decisions [36].
6. **SmTIP Diagnostics Module.** The SmTIP diagnostics module periodically checks whether data sources are up and running. If some data sources not available, it raises a warning message.
7. **SmTIP Management Module.** The SmTIP management module is the system management module for SmTIP. E.g., if the planner requests to mute all event notification for route events on A1 (a Dutch highway) for 1 day, SmTIP management module fulfills the request by making changes in the SmTIP Event Handler and SmTIP Pages. Modifications to the default workflow of SmTIP are made via the SmTIP Management Module. In its absence, such modification would have to be hard coded in SmTIP each time, thereby negatively affecting the usability of SmTIP.
8. **SmTIP Enterprise Service Bus.** SmTIP Enterprise Service Bus (ESB) follows SOA principle of loose coupling. In a SOA application, an ESB provides agile and flexible communication among interacting applications [101]. The SmTIP ESB removes the need for point to point connectivity among SmTIP modules. It supports different interaction styles among SmTIP modules, i.e., (a)synchronous request/response, messaging, queuing and publish/subscribe. ESBs are available as commercial products by different vendors. They may be used as SmTIP ESB.

6.2.3 SmTIP Service Layer

The SmTIP service layer (Fig. 6.11) is refined from RAfIP service layer. It uses the service design pattern. Human actors use SmTIP functions via SmTIP pages. External applications can access SmTIP functions via SmTIP Services.

1. **SmTIP Pages.** SmTIP Pages expose SmTIP functionalities. A planner uses SmTIP Pages to perform SmTIP process tasks, input data and view information. One of the SmTIP pages is a dashboard. It gives an

overview of all transport plans and their status. I supervised a requirement gathering exercise to collect requirements for a SmT dashboard [200]. In the exercise, planners were interviewed to extract requirements. The interviews resulted in a list of twenty two requirements. The top three (most important) requirements were:

- (a) The dashboard should show all events that may lead to disruptions.
- (b) The dashboard should be able to notify the planner about disruption situations.
- (c) The dashboard should be able to show all shipments and their status.

The SmTIP management tool is the front end of the SmTIP management module. It is a set of SmTIP Pages which enable a system administrator to perform management and administrative tasks. E.g., add/remove data sources, change security settings, add user roles, update user passwords, grant access to external applications, etc. Additionally, planners may use the SmTIP management tool to set user preferences, like, custom event notification settings and UI layout.

2. **SmTIP Services.** SmTIP services expose (selected) SmTIP functionalities and resources. An example of SmTIP functionality which may be provided to external applications is data analytics (performed by SmTIP Analytics module). An example of SmTIP resource which may be provided to external applications is event data (stored in SmTIP Event Databases). A direct connection (remote procedure call [14]) between an external application and a SmTIP module is not a good design choice, as it increases its vulnerability to risks. Therefore, access to external applications is granted via a SOAP/REST web service interface where appropriate security measures can be included. For studying data sharing policies, in a transport scenario, results of the SELIIS project [161] may be referred to.

Figure 6.10: A taxonomy of events in a SmT scenario showing the functions of the SmTIP event handler.

Figure 6.11: SmTIP service layer in ArchiMate 3.0 notation, refined from RAfIP service layer

6.3 Conclusion

In this chapter, I refined the RAfIP to design SmTIP (Fig. 6.12).

Design Pattern at Logical Level		Design Pattern at Functional Level	Design Pattern at Technical Level	SmTIP Modules				
SOA	Service Layer	Service Design Pattern	Dashboard	SmTIP Dashboard	SmTIP Pages			
			Platform Management Tool	SmTIP Management Tool				
			Web Services	SmTIP Services				
	Application Layer	ESB Design Pattern	Enterprise Service Bus	SmTIP ESB	ED EA EF EM			
			Event Processing Module	SmTIP Event Handler				
			Workflow Management Module	SmTIP Workflow Module				
			Business Rules	SmTIP Disruption Rules				
			Data Source Manager	not relevant				
			Analytics and Decision Support	SmTIP Analytics Module				
			Computations	SmTIP Smart Planning Module				
			Diagnostics	SmTIP Diagnostic Module				
			Platform Manager	SmTIP Management Module				
	Data Layer	ETL Design Pattern	Adapters	SmTIP Adapters	SmTIP APIs		Data Connector	
			Data Bus	not relevant	SmTIP Data Model			
			Data Filtering	SmTIP Data Filter				
			Meta Data	not relevant				
			Data Conversion and CDM	SmTIP Data Converter				
Database			SmTIP Events Database					
Cross Layered	No observable pattern	Security Mechanism	not considered					
		User Roles	not considered					

Legend
ED - SmTIP Event De-duplicator
EA - SmTIP Event Aggregator
EF - SmTIP Event Filter
EM - SmTIP Event Mapper

Figure 6.12: Adaption of RAfIP components in a SmT scenario leading to SmTIP modules. I found RAfIP components Data Source Manger, Data Bus and Meta Data less relevant for a SmT scenario. Security Mechanisms and User Roles in a SmT scenario are left for future research.

Modules in SmTIP data layer connect to data sources, filter relevant data and store it in an events database. Modules in SmTIP Application layer integrate transport data and events data. Using situation detection rules, disruption situations and disrupted consignments are determined. SmTIP Service layer consists of pages which enable a planner to perform SmTIP process tasks, input data and view information. SmTIP Architecture, Fig. 6.3, is the answer to R.Q.3.2 — *How to design SmTIP?* This chapter concludes the treatment design step for this dissertation. The following chapters illustrate the development of a SmTIP prototype and SmTIP validation using the prototype.

Part IV

Treatment Validation

Chapter 7

SmTIP Validation 1

*What we observe is not nature itself, but nature
exposed to our method of questioning.*

-Werner Heisenberg

German physicist (1901-1976)

In treatment validation step of DSRM, interaction between the treatment prototype and its context is studied. For SmTIP validation, a SmTIP prototype was developed by me using Mendix aPaaS (to be discussed in Sec. 7.1).

To validate that SmTIP allows a planner to perform SmT processes, I performed 13 experiments with 27 users. The first experiment was conducted with a group of 15 users, **together**, and used SmTIPv1 (first version of SmTIP prototype). The next 12 experiments were conducted with 12 users **individually**, and used SmTIPv2 (second version of SmTIP prototype). All 13 experiments are Case Based Experiments [211]. The first experiment corresponds to validation round 1 and the next 12 experiments correspond to validation round 2. Further on in this dissertation, I refer to validation round 1 as, SmTIP validation 1 and validation round 2 as, SmTIP validation 2. Each validation round is an empirical research cycle. Just as a design cycle is used to answer design questions, similarly, an empirical cycle is used to answer knowledge questions.

This chapter covers SmTIPv1 Architecture (Sec. 7.2) and describes the first validation experiment. Results from the first experiment were used to redesign SmTIPv1 producing a new version of the SmTIP prototype, i.e., SmTIPv2 (to be discussed in Chapter 8). The knowledge question for SmTIP validation 1 and SmTIP validation 2 is — R.Q 4: Does SmTIP contribute to main stakeholder goals? The corresponding knowledge goal is — To know whether SmTIP, when used by stakeholders, satisfies the stakeholder goals (Fig. 1.2, Goal structure). For setup, conduction and analysis of experiments, I used the checklist for conducting empirical research by Wieringa [211], which consists of six parts. Each part relates to one aspect of a validation experiment. For

SmTIP validation 1, each of these parts is discussed as separate subsection in Sec 7.3, but first, in Sec. 7.1, I briefly describe Mendix aPaaS, used to develop SmTIPv1.

7.1 Mendix®

SmTIPv1 has been developed as a web application using Mendix®. Mendix is a cloud based aPaaS (application platform as a service) tool for building web applications. For SmTIP prototype development, a licensed copy of Mendix v6.6.0 (2016 release) was installed on a HP® machine running Windows 7® operating system. I chose an aPaaS tool to develop SmTIPv1 since by using an aPaaS, essential modules in any application development like databases, runtime service buses, user interface templates can be imported and re-used. Therefore, it is not required to implement such modules from scratch; though application specific modification to the imported modules may be required. Using an aPaaS tool for application development considerably reduces the time and effort needed for developing a new application.

I chose Mendix because it covers the complete life cycle of application development, right from capturing stakeholder requirements¹ to end user feedback when the application is live. Therefore, using Mendix assured easy referencing and tracking of SmTIP stakeholder requirements during prototype development. Furthermore, Mendix provides a model-driven application development environment enabling faster application development.

Any application developed using Mendix aPaaS has one or more *modules*. A Mendix module is a self-contained unit providing specific functionality. It is (ideally) loosely coupled with other modules in the application. A Mendix module could thus be exported as a service, even isolated from the application for testing/version updates, without effecting the functionality of other modules. Each Mendix module can have its own data model² and user access rules (for security). The building blocks of a Mendix module are as follows:

- **Domain Model.** In Mendix, a data model is referred to as a domain model. A domain model has Entities, Attributes and Associations. Entities are representations of real and abstract things, while objects are instances of entities. Entities have attributes of specified data types, including string, binary, integer, boolean, date and time. Further, entities have relationships with each another, called associations. Associations are of three types: *1-to-1*, *1-to-many* and *many-to-many*.
- **Microflows.** In Mendix, application logic is realized using microflows. Microflows are a model-based approach to implementing logic, which otherwise would have been implemented via program code [111]. A microflow is an aggregation of events, flows, gateways, activities and artifacts. Complex application logic can be created by combining simple microflows to form complex microflows.
- **Pages.** Mendix pages are a front-end for users and are used to collect data and display information.

¹called user stories in Mendix

²called domain model in Mendix

Mendix provides templates for pages which are used to design an application's pages. Mendix pages use widgets to display information in specific layouts and formats.

- **Security.** Mendix uses the concept of *user roles* and *access rules* to implement application security. Security is applied at two levels: application level and module level. At the application level *user roles* are used, with authentication and authorization rules. At the module level, user role permissions are refined to determine *module-specific user roles*. *Access rules* for user roles are CRUD (create, read, update, delete) permissions and permissions to execute microflows.

7.2 SmTIPv1 Architecture

In SmTIP v1, I implemented the following SmTIP modules: SmTIP Adapters, SmTIP Data Mapper, SmTIP Data Model, SmTIP Data Filtering, SmTIP Workflow Module and SmTIP Pages. The functionalities of SmTIP Data Converter, SmTIP Event Database and SmTIP Enterprise Service Bus are provided by Mendix run time. The complete architecture of SmTIPv1 is shown in Fig. 7.1, where modules that were not implemented are blurred. Due to unavailability of freight forwarder's database and transport data, they are simulated for SmTIPv1. Local storage of the machine hosting SmTIPv1, is thus used as the freight forwarder's database. Transport data is created manually and stored in the local storage. Moreover, containers and carrier's vehicles were unavailable for SmTIPv1, therefore, container events and vehicle events are not considered. For route events, publicly available events from free and open data sources are used as contextual events. Freight forwarder's TMS was not considered for SmTIPv1. This however, does not affect the performance of SmTIPv1, as the main functionality of a TMS, i.e., providing data and user interface for transport planning, is implemented in SmTIPv1.

7.2.1 SmTIPv1 Data Layer

For SmTIPv1 Data Layer, I will discuss the data model, only. Since, the complete data model for SmTIPv1 is too lengthy to be put on one page, therefore Fig. 7.2, Fig. 7.3 and Fig. 7.4 show three relevant parts of SmTIPv1 data model, along with (explanatory) annotations next to the entities. While developing SmTIPv1, the glossary as used in this dissertation was still being worked upon and was not complete. Therefore, the entities in SmTIPv1 had different names than the objects they model. E.g., Shipments were modeled by the Order entity, Consignors by the Client entity, Carriers by the LSP entity and Terminals by the Location entity.

7.2.2 SmTIPv1 Application Layer

SmTIPv1 workflow module implements simplified SmT processes using microflows and pages. The microflow shown in Fig. 7.5, when triggered, informs the planner about plans having associated rail events. It matches

all locations included in a plan against all locations having rail events. If such a plan exists, then its *Remarks* attribute is updated to indicate associated rail events.

7.2.3 SmTIPv1 Service Layer

SmTIPv1 Pages are implemented using Mendix Pages. Fig. 7.6 (Add/Edit new Location page), Fig. 7.7 (Add/Edit new Plan page) and Fig. 7.8 (Events page showing Road works and Traffic jams on A2 highway) are examples of relevant SmTIPv1 pages used by the planner.

SmTIPv1 modules together realized selected functional requirements of SmTIP, i.e., R1, R2, R4, R5, R6 partially, R8 partially, R9, R12 and R13 (see Sec. 3.5, Requirements for a SmT Integration Platform). Remaining requirements were not implemented in SmTIPv1. Below, I enumerate the SmTIPv1 functionalities which were used in the SmTIP validation 1 experiment.

- F1.** Using SmTIPv1, a planner can divide shipments into shipment segments, form consignments and perform demand aggregation process.

SmTIP modules used: SmTIP Adapters, SmTIP Data Mapper and SmTIP Pages.

- F2.** Using SmTIPv1, a planner can make plans for consignments, involving multiple routes, modalities and carriers. F1 and F2 satisfy stakeholder requirements R1, R2 and R8, which require that by using SmTIP, a planner can function as a central transport orchestrator.

SmTIP modules used: SmTIP Data Model and SmTIP Pages.

- F3.** Using SmTIPv1, a planner can request and receive all events on Dutch roads provided by the ANWB web service, all events on Dutch railways provided by the NS web service and weather information provided by the Accuweather³ web service. This functionality satisfies stakeholder requirement R12, which requires the use of contextual data for transport planning.

SmTIP modules used: SmTIP Adapters, SmTIP Data Converter, SmTIP Data Mapper, SmTIP Workflow Module and SmTIP Pages.

- F4.** Using SmTIPv1, a planner can change the transport plan of consignments delayed by disruption events. In SmTIPv1, disruption events and disrupted consignment are manually identified by a planner. This functionality satisfies stakeholder requirement R9, which prescribes disruption handling.

SmTIP modules used: SmTIP Adapters, SmTIP Workflow Module and SmTIP Pages.

³www.accuweather.com

Figure 7.1: SmTIPv1 architecture, modules that were not implemented are blurred

Figure 7.2: A section of SmTIPv1 Data Model, showing the Order entity and its associations with other entities

Figure 7.3: A section of SmTIPv1 Data Model, for all road events

Figure 7.4: A section of SmTIPv1 Data Model, for all railway and waterway events

Figure 7.5: Workflow. All rail events for a plan

Number	<input type="text" value="12"/>
Local location ID	<input type="text" value="EN12"/>
Stop type	<input type="text" value="Intermodal Hub"/>
Owner detail	<input type="text" value="Twente Terminal b.v"/>
Rail	☒ Yes ☐ No
Barge	☒ Yes ☐ No
Road	☒ Yes ☐ No
Available	☒ Yes ☐ No
Available from	<input type="text" value="5/5/2017"/>
Address	<input type="text" value="Enschede"/>
Latitude	<input type="text" value="0.00"/>
Longitude	<input type="text" value="0.00"/>
Description	<div><div>Intermodal Hub close to German border, contact info:</div><div></div></div>

Figure 7.6: Add/Edit new Location page

Made on	<input type="text" value="mm/dd/yyyy"/>
Updated on	<input type="text" value="mm/dd/yyyy"/>
Plan number	104
Made by	<input type="text"/>
Remarks	<div><div></div><div></div></div>
Order	<input type="text"/>
Locations	<input type="text"/>

Figure 7.7: Add/Edit new Plan page

A2	aWegen					
A10	aWegen					
A12	aWegen					
A29	aWegen					
A44	aWegen					
A59	aWegen					
A73	aWegen					
N267	nWegen					

Road Works						
Search		Delete				
Msg nr	From	To	Location	Seg start	Seg end	Start
108259853	knp. Batadorp	knp. De Hogt	A2 Eindhove...	Eindhoven	Maastricht	1/11/2018

Traffic Jams						
Search		Delete				
Msg nr	From	To	Location	Seg start	Seg end	Start
108262329	knp. Deil na...	knp. Deil na...	A2 Utrecht ri...	Utrecht	's-Hertogen...	

Figure 7.8: Events page showing Road works and Traffic Jams on A2 highway (NL)

7.3 SmTIP Empirical Cycle 1

For setup, conduction and analysis of SmTIP validation 1 experiment I used the checklist for conducting empirical research by Wieringa [211]. It consists of seventeen points divided into six parts. Each subsection below corresponds to one part of the checklist. I have used continuous numbering for the seventeen points in the checklist.

7.3.1 Research Context

1. Knowledge Goals — The knowledge goals for SmTIP empirical cycle 1 are at two levels. The lower level knowledge goal is to answer the question — *Do SmTIP modules facilitate SmT activities?* The lower level knowledge goal aims to investigate the validity of SmTIP design.

The higher level knowledge goal for SmTIP empirical cycle 1 is — *To know whether SmTIP, when used by stakeholders, satisfies the stakeholder goals.* The higher level knowledge goal aims to investigate the contribution argument [211], i.e., by facilitating SmT activities SmTIP contributes to the stakeholder goals.

2. Improvement Goals — Since SmTIP empirical cycle 1 is part of the overall design cycle for this research, the improvement goal is, to improve SmTIPv1.
3. Current Knowledge —
 - (a) SmT stakeholders, Sec. 3.2.

Figure 7.9: Conceptual framework for SmTIP empirical cycle 1. (a), (b), (c) relate to the respective knowledge questions in Sec. 7.3.2

- (b) SmT stakeholders' goals, Sec. 3.3.
- (c) Requirements for a SmTIP, Sec. 3.5.
- (d) SmT Processes, Sec. 4.5.
- (e) SmTIP Architecture, Sec. 6.2.
- (f) SmTIPv1 Architecture, Sec. 7.2.

7.3.2 Research Problem

4. Conceptual Framework — Fig. 7.9, shows the conceptual framework for SmTIP empirical cycle 1, based on current knowledge.
5. Knowledge Questions — I made the following knowledge questions for SmTIP empirical cycle 1. Questions (a), (b) and (c) investigate the relationships between concepts in the conceptual model and are shown in Fig. 7.9.

- (a) Does SmTIPv1 facilitate SmT processes/activities?
- (b) Do SmTIPv1 functionalities satisfy stakeholder requirements?
- (c) Do the stakeholders find SmTIPv1 useful?
- (d) What additional functionalities should SmTIPv1 have?
- (e) What improvements can be made in the experiment setup?

Answer to question (a) satisfies the lower level knowledge goal, while answers to question (b) & (c) satisfy the higher level knowledge goal. Answers to questions (d) & (e) satisfy the improvement goal.

6. Population — Planners working at freight forwarders.

7.3.3 Research Design and Validation

7. Objects of study (OoS)

- 7.1. Acquisition of OoS — In case-based experiments OoS is the validation model [211]. The validation model for SmTIP empirical cycle 1 consists of (a) 15 test subjects⁴ having prior knowledge of SmT,

⁴five planners working at freight forwarder companies and ten researchers playing the role of a planner

(b) SmTIPv1, (c) ANWB web service, (d) NS web service, (e) Accuweather web service and (f) a list of shipments, carriers and terminals to simulate transport data. The test subjects were informed that they are part of a validation experiment and their participation is voluntary. Ethical guidelines [191] for conducting experiments were followed.

7.2. Construction of the sample — From the population, subjects having prior knowledge or prior research experience over SmT were chosen as test subjects. Another factor considered was test subjects' closeness to the experiment location, i.e., Enschede (NL).

8. Treatment Design — The treatment consisted of three parts; (a) Ten minute introductory presentation given by me. Via the presentation, the test subjects were informed that during the experiment they have to play the role of a planner working at a freight forwarder. The test subjects were also briefed over the tasks they have to perform, related SmT processes (see Table 7.1) and SmTIPv1 functionalities, (b) Thirty minute hands-on session during which test subjects performed five tasks using SmTIPv1 (Table 7.1). The tasks were to be performed by test subjects individually and in sequence, T1 to T5. and (c) Twenty minutes feedback session in which test subjects were asked knowledge questions and their feedback was noted by me. Each test subject was given the same five tasks to perform. The treatment instruments used were: test subjects' laptop, text hand-out of treatment tasks, username-password for logging into SmTIPv1, a beamer for introductory presentation, a shipments file, list of carriers file, list of terminals file (all three files in a USB stick) and a room where the experiment took place. Every test subjects was treated equally and was free to ask questions during the experiment.

The transport data file provided to the test subjects was made by me before the experiment and served as the control mechanism for the experiment. The origin and destination of all shipments were such that there were pre-known and on-going road or rail disruption events. This was established by me before the experiment. In other words, treatment part (b) consisted of a stimuli, in which I provided test subjects with shipments, whose transport routes had events leading to delays during transportation. The test subject were asked to consider the events as disruptions and re-plan the shipments.

9. Measurement Design — A feedback session was conducted for obtaining test subject responses.

(a) Constructs to measure — Test subject responses to knowledge and improvement questions.

(b) Data sources — Test subjects.

(c) Measurement Instrument — Pen and notebook.

(d) Measurement schedule — Post test.

(e) Storing of data — Test subject responses to knowledge questions were written down. The feedback session was not audio or video recorded.

(f) Ethics — Test subjects were informed that their responses would be used in this dissertation but their identity would not be made public.

Table 7.1: Treatment tasks, corresponding SmTIP requirement and SmT Process

No.	Task Description	SmTIP Requirement	SmT Process
T1.	Connect to local storage and retrieve the list of shipments, terminals and carriers	R2. Shows the entire transport chain to the planner	No specific SmT processes
T2.	Create a transport plan using different shipments, modalities, terminals and carriers	R8. Be able to make a synchronized combination of transport modes and services for the planner, carrier and consignor	(Manual) Demand Aggregation
T3.	Retrieve events on road and rail network in NL and weather forecasts for the routes provided	R12. Should use contextual data for planning	Disruption Handling
T4.	On the consignment page identify delayed consignments	R9. Should enable the planner to cope with disruptions regarding every transport mode	Disruption Handling
T5.	Re-plan disrupted consignments to avoid disruptions	R9. Should enable the planner to cope with disruptions regarding every transport mode	Disruption Handling

7.3.4 Inference Design and Validation

10. Inference Design — The primary data source for inferences is test subject responses. The secondary data source is my notes during the experiment.
- 10.1. Descriptive Inference Design — I used content analysis to describe and analyze the test subject responses.
- 10.2. Abductive Inference Design — My theory at this point is that, (a) SmTIPv1 fulfills SmTIP requirements, (b) SmTIPv1 contributes to stakeholders' goals and (c) the stakeholder goals derived by me via stakeholder interviews truly represents their goals. Nevertheless, I am aware that test subjects could have different expectations from SmTIPv1 which might reflect in their feedback during the feedback session.
- 10.3. Analogic Inference Design — No assumption can be made for test subjects responses. Yet, there is enough similarity between test subjects chosen for the experiment and others in the same role in the transport domain. Therefore, they are expected to give similar responses. Furthermore, this experiment should provide answers to improvement questions, which will be used for improvements in SmTIPv1.

7.3.5 Research Execution

11. What happened? — All fifteen test subjects were present for the validation experiment. After the initial presentation, the test subjects were provided a web-link, which they used to run SmTIPv1 on their own laptops. They logged into SmTIPv1 using the username and passwords provided to them. While test subjects performed treatment tasks, two errors were reported by them,

- (a) If one test subject deleted data on his SmTIPv1 instance, it got deleted from all instances of SmTIPv1 running on every test subjects' laptops. Since SmTIPv1 was deployed on the cloud, the runtime created 15 parallel instances of the SmTIP, one for each test subject, all using the same runtime database.
- (b) In SmTIPv1, each disruption-consignment tuple is unique, but in real life, a disruption event can affect more than one consignment. Thus, the datamodel of SmTIPv1 required redesign, such that multiple disruptions could be associated with one consignment and one disruptions could be associated with multiple consignments.

Time allotted for the hands on session was insufficient for some test subjects and they were not able to finish all five tasks. Yet, the session did not fail as I was able to extract useful feedback from the test subjects during the feedback session. One test subject left mid-way during the hands-on session because she had another appointment. While most test subjects actively participated in the feedback discussion, few remained passive and provided limited inputs during the feedback session.

7.3.6 Data Analysis

12. Description

12.1. Data Preparation — Test subject's responses to all knowledge questions are given in Appendix E. Notes taken during the feedback session were elaborated by me after the experiment was complete. For referring to test subject responses, I gave each response an identifier. E.g., S8Q(c) is the response of Test Subject 8 to Question (c). By using an identifier the test subject identity is protected.

12.2. Data Interpretation — I used content analysis for data interpretation. Test subjects responses to Q(a) (Does SmTIPv1 facilitate SmT processes?) did not point to a definitive answer. All test subject had expectations about SmT processes and they compared SmTIPv1 against those. However, different test subjects had different expectation. For example, some expected pro-active prediction of disruptions (S8Q(a)) while others expected cooperation between partners in a transport chain (S10Q(a)). While on the one hand, SmTIPv1 did enable test subjects to get contextual events, on the other hand, test subject suggested additional information is needed to decide whether an event is/could be a disruption (See S11Q(a)).

Test subjects responses to Q(b) (Do SmTIPv1 functionalities satisfy stakeholder requirements?) provided additional functionalities which SmTIPv1 should have, e.g., analytics. Test subject responses were about what *cannot* be done using SmTIPv1, e.g., S2Q(b).

Test subjects responses to Q(c) (Do the stakeholders find SmTIPv1 useful?) suggest that they did not find it useful for SmT. In their opinion SmTIPv1 complicates the workflow of the planner (see S1Q(c)), as some tasks (of disruption handling process) are manual tasks while others are automated. Frequent switching between manual and automatic tasks for a process was considered unnecessary complication by test subjects. Furthermore, test subjects found it difficult to see the added value of

SmTIPv1, after performing the tasks. Such responses could also indicate that SmTIPv1 Pages are complicated and the test subjects find them difficult to navigate. Additionally, the overall goal of performing the experiment tasks should be made more explicit to the test subjects via the introductory presentation.

Test subject responses to Q(d) (What additional functionalities should SmTIPv1 have?) gave new requirements for SmTIP. They were random order generation, live tracking of consignments and historic data analysis.

Test subject responses for Q(e) (What improvements can be made in the experiment setup?) provided ways to improve future validation experiment, e.g., using an example case (S3Q(e)) and using assistance for taking notes during the feedback session (S11Q(e)).

13. Statistical Conclusions — I conducted one experiment with descriptive responses from test subjects, thus no statistical conclusions could be drawn.
14. Explanations — The absence of a SmT scenario as an example before the tasks, left the test subject questioning the goal of performing experiment tasks. The relationship between the experiment tasks and the experiment objective was not sufficiently clear to the test subjects, which is reflected in their feedback. Since I did no expectation management before the experiment (e.g., via the introductory presentation), all the test subjects expected SmTIPv1 to be an industry-ready application. During the experiment they found SmTIPv1 suitable for research purposes, which explains their negative evaluation of SmTIPv1's usefulness. Based on their expectations, they also suggested additional requirements, which is a known effect of prototyping.

SmTIPv1's Pages are different from (various) TMSs pages encountered by test subjects in their daily work environment. Since test subjects' are accustomed to the user interface (graphics, page layout and navigation) of known TMSs, a different user interface (SmTIPv1 pages) for performing similar tasks could be perceived as a complication. This might have influenced test subjects' opinion about SmTIPv1's usability. Test subject have background knowledge of SmT, which may determine their opinion about the feasibility of SmT. This in turn may influence their evaluation of SmTIPv1's usability.

15. Generalizations. The following generalizations can be made based on the explanations above.
 - Different users of SmTIPv1 will have different expectations from SmTIPv1.
 - SmTIPv1 complicates the workflow of a planner for SmT processes, requiring a planner to switch between manual and automated tasks.
 - Planners find user interface of SmTIPv1 confusing. As a solution, user interface design of TMSs used by planners can be studied and SmTIPv1 pages can be designed with similar layout and navigation. A familiar user interface may positively influence the usefulness of SmTIPv1.
16. Answers — Below, I present the answers to the knowledge questions for this empirical cycle.
 - (a) SmTIPv1 facilitates SmT processes, but only for demonstration purpose.

- (b) Though, new requirements were provided by the test subjects yet they did not provide feedback over SmTIPv1 w.r.t the original stakeholder requirements. Thus, this question was left unanswered.
- (c) The stakeholders did not find SmTIPv1 useful.
- (d) New functionalities suggested by the stakeholders included, analytics support, live track and trace on map, automatic generation of shipment data, disruption prediction, addition of more contextual data sources and data mining.
- (e) Improvements for experiment design suggested by stakeholder included, (1) making the goal and scope of the experiment clearer at the start of the experiment, (2) introductory presentation to be shorter (c) more time allocation for hands on session and (4) use of an assistant to help in taking notes during feedback session. These improvements were noted down for future reference.

7.3.7 Research Context

- 17. Contribution to knowledge goal — Answers (a), (b) & (c) above (item 16) contribute to the knowledge goal of this empirical cycle.
- 18. Contribution to improvement goal — Answers (d), (e) above (item 16) contribute to the improvement goal of this empirical cycle.

7.4 Conclusion

This chapter described SmTIPv1 development and SmTIP validation 1. SmTIPv1 was developed using Mendix aPaaS. Mendix enabled faster development of SmTIPv1 as some Mendix components were adapted and re-used as SmTIP modules. For example, the Mendix runtime service bus was reused as SmTIP ESB and Mendix pages were adapted to SmTIP pages. Four SmTIP modules were implemented in the data layer i.e., *SmTIP Adapters*, *SmTIP Data Model*, *SmTIP Data Mapper* and *SmTIP Data Filtering*, one in the application layer, i.e., *SmTIP Workflow Module* and one in the service layer, i.e., *SmTIP Pages*. Then, an validation experiment was conducted for SmTIP validation using SmTIPv1. During the experiment, fifteen test subjects used SmTIPv1 to perform five tasks corresponding to demand aggregation and disruption handling process of SmT. After the experiment, knowledge questions were asked to the test subject and their responses were noted. Test subjects responses indicate that SmTIPv1, facilities SmT activities for demonstration purposes only, complicates the workflow of the planner and needs additional functionalities. Explanation for test subject response were, prior opinion about SmT feasibility, expectation of an industry ready application and new requirements for SmTIP. Test subjects responses led to a re-design of SmTIPv1 modules, which produced SmTIPv2, to be discussed in the next chapter, i.e., Chapter 8, SmTIP Prototype.

Chapter 8

SmTIP Prototype

What I cannot create, I do not understand.

-Richard Feynman

American physicist (1918-1988)

This chapter describes the development of SmTIPv2. SmTIPv2 development used the feedback of test subjects from SmTIP validation 1 (Sec. 7.3.6 and Appendix E). Sec. 8.1, discusses the main improvements in SmTIPv2 w.r.t SmTIPv1. Thereafter, Sec. 8.2 provides an overview of SmTIPv2 architecture. Sec. 8.3, Sec. 8.4 and Sec. 8.5 discuss individual layers of SmTIPv2. Finally, Sec. 8.6 provides a recap and concludes the chapter.

8.1 Improvements in SmTIPv2

1. Additions to the data model. After SmTIP validation 1, I concluded that SmTIPv1's data model causes some limitation in its functionalities. The absence of a *Route* entity in SmTIPv1 data model implies that the planner has to create a route by selecting terminals, for every new plan. This workflow does not correctly model a planner's workflow in a SmT scenario. In a SmT scenario, planners select pre-defined routes, with known distances, costs and travel time per modality. A *Route* entity was added to SmTIPv2 data model. SmTIPv2 allows the planner to select a route from pre-defined routes for each transport activity. The planner can add/edit new routes (See Fig. 8.1).

Another entity added to SmTIPv2 data model is *Vehicle* entity. The planner can view available vehicles from carriers and choose a vehicle for each transport activity.

2. In SmTIPv1 the main activity of the planner is to create a plan for orders, then divide individual plans into schedules. This workflow, again, does not model a planner's activity in a SmT scenario. In a SmT scenario, a planner creates transport activities for transporting consignments, based on available resources

The screenshot displays two parts of the SmTIPv2 web application. The top part is the 'Add/Edit Route' form, and the bottom part is the 'Routes Overview' table.

Add/Edit Route Form:

- Route name:** AMS-VEN
- Stop:** Amsterdam, Eindhoven, Venlo, Rotterdam
- Num stop:** 4
- Terminals enroute:** A list of terminals with an 'Add Stop' button and navigation controls (1 to 4 of 4).
- Sequence of Terminals:** A list of terminals with 'Stop name' labels: Amsterdam, Rotterdam, Eindhoven, Venlo.
- Buttons:** Save, Recreate Route, Cancel.

Routes Overview Table:

Route name	Disrupted	Delay
AMS-VEN	No	0
AMS-VENLO	No	0
ANT-ROT	No	0
VEN-ROT	No	0
EIN-VEN	No	0
AMS-EIN	No	0

Additional details for the selected route (AMS-VEN):

- Start point: Amsterdam
- First stop: Rotterdam
- Second stop: Eindhoven
- End point: Venlo
- Num stop: 4
- R distance: 248

Figure 8.1: SmTIPv2 Page for adding/editing Routes (top), Routes Overview Page (bottom)

(e.g. vehicle availability, costs, etc.). Consequently, in SmTIPv2 following additions are made, a *Transport Activity* entity in the data model, a *Transport Activity Overview Page* and a *New/Edit Transport Activity Page*. The planner can add planned start and end time for transport activities. In SmTIPv2 a *Plan* is an aggregation of transport activities, implying that a *Plan* is an aggregation of multiple shipments, carriers, vehicles, routes and modalities. This is consistent with a SmT scenario, as discussed in Sec. 4.1.

3. Addition of SmTIP Event Handler and SmTIP Rules modules.
4. Rather than showing all road, rail events to the planner, SmTIPv2 shows only those events which delay consignments beyond the allowed delay. i.e. disruption events. SmTIP business rules were added in SmTIPv2, to check if an event is a disruption event.
5. The names of the entities in SmTIPv1 data model did not align with the concepts they model in a SmT scenario. Therefore, the entities in the SmTIPv1 data model were renamed according to the glossary for SmT. Order entity was renamed to Shipments, Clients to consignors, LSPs to Carriers and Locations to Terminals.
6. In SmTIPv1, after logging in, the planner directly views the Order Overview page. Thus, the planner has no overview of the all functionalities provided by SmTIPv1. A dashboard, having icons for different

functionalities, was added in SmTIPv2 as the landing page for the planner after logging in.

7. The concept of a Mendix module as a self-contained functional unit aligns with the concept of a SmTIP module. Adhering to SOA principles, SmTIP modules were modeled as an independent functional units. Therefore, in SmTIPv2, individual SmTIP modules are implemented as separate Mendix modules.

By incorporating the above improvements SmTIPv2 better satisfies the SmTIP functional requirements. Owing to item 1 and 2 above, SmTIPv2 better satisfies requirements R1, R2, R6 and R8, which require that by using SmTIP, a planner can function as a central transport orchestrator. Owing to item 3 and 4 above, SmTIPv2 better satisfies R9, R12 and R13, which prescribe the use of contextual data for disruption handling. Remaining functional requirements are not implemented in SmTIPv2 and are left for future research. Items 5, 6 and 7 contribute towards usability and software quality improvements, respectively (non-functional requirements).

8.2 SmTIPv2 Architecture

Figure 8.2: SmTIPv2 architecture using ArchiMate 3.0 notation. Modules that were not implemented are blurred.

8.3 SmTIPv2 Data Layer

1. **SmTIPv2 Adapters.** SmTIPv2 adapters are of two types: (a) APIs and (b) data connectors.

- (a) **APIs** — SmTIPv2 connects to data sources via APIs, implemented in Mendix. The data sources used in SmTIPv2, along with respective events, connection protocol and data format, are shown in Table 8.1. SmTIPv2 acquires data from data sources via a *pull* mechanism, i.e., by issuing a HTTP GET

Table 8.1: Data Sources used for route events in SmTIPv2, along with respective events, connection protocol and data format. All data sources used in SmTIPv2 are web services.

Data Source	Events	Con. Protocol	Data Format
Nederlandse Spoorwegen (NS)	Railway disruptions, Railway works	REST	XML
Rijkswaterstaat	Waterway Information	SOAP	XML
MarineTraffic	Deep Sea Vessel location, eTA at port	REST	JSON
ANWB	Road Data	REST	JSON
AccuWeather	Weather Data	REST	JSON

message in the case of a REST web service and by issuing a SOAP request message in case of a SOAP web service. Each data source has one dedicated API. Since each data source is a web service, each API consists of a service call and an import schema.

- (i) *Service call*: A service call to request event data is implemented using a microflow. The service call is a GET message (for REST web services) or a SOAP request message (for SOAP web service). Additionally, authentication is required for connecting to the NS, Rijkswaterstaat & MarineTraffic web services.
- (ii) *Import Schema*: Each web service provides a schema in the web service description to interpret the web service response. For the MarineTraffic, ANWB and Accuweather web services, a `json` import schema is provided, while for the NS and Rijkswaterstaat web services an `.xsd` schema is provided.
- (b) **Data connectors** — SmTIPv2 data connector accesses transport data from local storage, using file import. The connector consists of two components:
- (i) *Import file*: This is a microflow that imports a `.xml` data file, selected by the user, from local storage.
- (ii) *Import Schema*: This is a `.xsd` schema file, which provides the schema of the file to be imported. The schema is unique for each file.

2. **SmTIPv2 Data Model and SmTIPv2 Data mapper.** Based on events data from data sources, the SmTIP data model was updated with the addition of new entities, as shown in Fig. 8.3. The updated SmTIP data model thus made, is the SmTIPv2 data model. Data mapping in SmTIPv2 is the conversion of event (and transport) data to SmTIPv2 data model using the *Import Schema* of APIs and data connectors. The mapping is performed in two ways:

Figure 8.3: A section of the updated SmTIP data model showing the new entities added to the model. Entities with black outline are used to explain SmTIPv2 functionalities in this chapter.

- (a) Entity mapping — In entity mapping a new data object is created for every object in the event data. E.g., consider Fig. 8.4, which shows the mapping of a route event to the SmTIPv2 Road Works entity, employing the entity mapping approach. *JsonObject_4* is mapped to *A_Road_Work* entity in SmTIPv2 data model. There can be many *JsonObject_4* entities in a single response message. For every such entity a new *A_Road_Work* entity is created. This is indicated by the $[0..*]$ association between *Road-Works* and *JsonObject_4*. Furthermore, *FromLoc_2* and *ToLoc_2* are converted to appropriate entities in the SmTIP data model, i.e. *Works_From_Loc* & *Works_To_Loc* respectively.
 - (b) Using Microflow — Data mapping can also be achieved via microflows. The benefit of using microflows over entity mapping is that the attributes of one object (in event data) can be mapped to attributes of multiple entities in the SmTIPv2 data model. This is handy when importing transport data. If a file in local storage contains both consignor and shipment data, then it can be imported using microflows, and subsequently mapped to SmTIPv2 data model, ensuring that consignor objects are mapped to consignor entity, and shipments objects are mapped to shipment entity.
3. **SmTIPv2 Data Filtering** In SmTIPv2, data filtering functionality is included in the data mapper module. Below, I discuss how event data fields are mapped to the SmTIPv2 data model. Remaining fields, not mapped the data model, are consequently filtered out.
- (a) The AccuWeather web service response includes *RealFeelTemperatureShade* value and *AirandPollen* value, which is irrelevant information for a SmT scenario. On receiving event data from Accuweather,

Figure 8.4: Data mapping using entity mapping

the data mapper does not map them to any attribute of Event entity, thus filtering them out. The remaining data fields to be stored are *temperature*, *text report for day weather* and *text report for night weather*.

- (b) The response from the ANWB web service consists of three types of information, namely, traffic jams, road works and radar readings. SmTIPv2 Data Mapper filters out the radar reading and traffic jams data.
- (c) From the Rijkswaterstaat RIS web service response, fields like *subject_code*, *target_group* and *communication* fields are filtered out.
- (d) From the NS web service¹ response, Data Mapper maps *period*, *trajectory* and *id* of planned and unplanned railway disruptions. All other data fields, e.g., reason of disruptions and advice to avoid disruption are filtered out.

I did not implement a dedicated data filtering module in SmTIPv2 because data filtering via entity mapping as explained above is both simpler and faster. To explain this point, let's assume that, I had chosen to implement a dedicated data filtering module in SmTIPv2. In that case, firstly, the complete response from a data source had to be stored in SmTIPv2 Events Database. Then, data filtering module had to se-

¹The NS web service provides planned and unplanned disruption information for the passenger rail network. This is different from disruption information on a cargo rail network. The latter information is not provided by NS, but instead by rail-road infrastructure and management companies, like Pro-Rail. Nevertheless for the purpose of prototype development the NS service was used.

lect relevant data fields and the remaining data fields may be deleted. Finally, selected data fields would be mapped to the SmTIPv2 data model by the Data Mapper. Instead of the above three steps, the current implementation in SmTIPv2 achieves Data Filtering and Data Mapping in one step, thereby reducing calls to the SmTIP Event Database (better performance). Yet, I do not claim that the above approach of not implementing a dedicated data filtering module is ideal for every application scenario. In scenarios where the potential use of some data fragments (in the response from a data source) is still being studied/researched, it is pertinent to store and retain the complete response in the database. In such scenarios a data filtering module would only filter the data required currently, leaving the remaining data intact for potential future usage.

4. **SmTIPv2 Event Database.** During the first run of a Mendix application, a local database is created by Mendix. The local database created for SmTIPv2 during first run acts as the SmTIPv2 Event Database, where event data is stored.

8.4 SmTIPv2 Application Layer

SmTIP modules implemented in the SmTIPv2 Application Layer are SmTIP Event Handler, SmTIP Disruption Rules and SmTIP Workflow Module. While the SmTIP Smart Planning Module, SmTIP Analytics Module, SmTIP Diagnostic Module and SmTIP Management Module are left for future work, SmTIP ESB functionality is provided by the Mendix runtime.

1. **SmTIPv2 Event Handler.** While I was working on SmTIPv2 development, I had discussions with planners. The discussions led to the clarification that for transport planning it is important to relate route events with Terminals, rather than relating them to routes. According to planners, planning is done terminal to terminal, since it is at terminals that containers are picked-up, dropped-off, stored or handled (modality change). Therefore, planners interpret route events as - *what is the delay due to this event for reaching a certain terminal*. E.g., in case of an accident on the Amsterdam-Rotterdam highway, the planners are more interested in knowing the delay caused due to the accident (in reaching terminals Amsterdam and Rotterdam) and less interested about the actual location of the accident on the highway. To model this situation, I defined a new situation, Situation 12, in which a Route Event affects two terminals. If `OntoSmT:RouteEvent::hasStartLocation` or `OntoSmT:RouteEvent::hasEndLocation` equals `OntoSmT:Terminal::hasAddress`, then `OntoSmT:RouteEvent` affects `OntoSmT:Terminal`. The corresponding rule for Situation 12 is;

- Situation detection rule 12 — detects a situation when an event affects a Terminal by causing a delay on the route leading to/from the terminal. While the rule in pseudo code is given in Appendix D, its implementation in SmTIPv2 is shown in Fig. 8.5 for a road work event.

Figure 8.5: Implementation of the situation detection rule to detect situation 12 in SmTIPv2. Situation 12 is a situation where a route event potentially affects two terminals.

SmTIPv2 Event Handler has three² constituent modules: SmTIPv2 Event De-duplicator, SmTIPv2 Event Filter and SmTIPv2 Event Mapper.

- (a) **Event De-duplicator** - SmTIP event de-duplicator combines identical contextual events from multiple data sources. However, in SmTIPv2, each type of route event is reported by exactly one data source. E.g., road events are reported by the ANWB web service only, rail events are reported by the NS web service only. Still, duplicate events could be encountered as described below.

Each time ANWB web service is called, it returns a list of road events. Events which are still continuing from the previous web service call are reported again by ANWB. Therefore, the same event **may** be reported by the ANWB web service more than once. The same is true for the NS web service. In such scenarios, where the same event is reported multiple times by a data source,

`OntoSmT:Event:hasEventID` can be used for de-duplication of events.

Fig. 8.6 shows the de-duplication of route events by SmTIPv2 Event De-duplicator. Firstly, road work events are retrieved from the SmTIPv2 event database and a list is created. Then, the union of the list is taken with itself, which removes the duplicate events. A similar method is used for de-duplication of railroad events.

Figure 8.6: De-duplication of route events by SmTIPv2 Event De-Duplicator

- (b) **Event Filtering** - SmTIP prescribes using `OntoSmT:Event` data properties, i.e., `OntoSmT:Event::has Value`, `OntoSmT:Event::hasProbability` and `OntoSmT:Event::hasEventType` for filtering out Category 2 events (see Fig. 6.10, A Taxonomy of events in a SmT scenario).

In SmTIPv2, there are two approaches to implement event filtering. In the first approach, all events are stored in SmTIP events database and then Category 2 events are deleted based on the `EventType` data property. In the second approach, while issuing the service call request for events, Category 2 events are not requested. The latter approach, similar to the SmTIPv2 data filtering discussed above, is simpler and faster. Therefore, I used it for SmTIPv2 Event Filtering as illustrated in Fig. 8.7.

- (c) **Event Mapper** - SmTIPv2 event mapper consists of microflows and rules. Fig 8.8, shows an example, where a list of terminals for each consignment is created and every event for each terminal is

²SmTIPv2 Aggregator is left for future work.

Name	Primitive Type	Occure...	Custom Name
(Object)		1	Root
dateTime	String	1	DateTime
roadEntries		1	RoadEntries
(Object)		0..*	JsonObject
road	String	1	Road
roadType	String	1	RoadType
events		1	Events
trafficJams		1	TrafficJams
roadWorks		1	RoadWorks
radars		1	Radars

Figure 8.7: Event Filtering in SmTIPv2. Road Events have three Event Types: trafficJams, roadWorks and radar reading. trafficJams and radar readings are classified as category 2 events

retrieved from the database. Then, a rule (Fig. 8.9), is used to determine events leading to disruptions. If the rule response is positive (Boolean 1) then a disruption event is created and related to the consignment. Fig. 8.8 and Fig. 8.9 together implement the disruption detection rule for Situation 11 (i.e., Consignment disrupted due to Route event on a planned route, see Appendix D).

Figure 8.8: Implementation of situation 11

- SmTIPv2 Disruption Rules.** SmTIP disruption Rules in SmTIPv2 are implemented using Mendix *Rules*. A Mendix rule is a special microflow used for condition checking. The return value of a Mendix rule is a boolean, which indicates the result of the condition evaluation. If the rule evaluates to true, the return value is Boolean 1, else, the return value is Boolean 0. Rules are used in SmTIPv2 to determine whether an event leads to disruptions based on event data properties. Fig. 8.9 determines whether a road work's duration is longer than 3 days. The generic condition checked by the rule is whether `Event1:hasDelay > Consignment1 : allowedDelay`, where `allowedDelay` is taken as 3 (days) and `$hasDelay:` is calculated as the duration (in days) of the road works. Additionally, SmTIPv2 Rules are used to avoid the same event being added as a disruption more than once, as shown in Fig. 8.10.
- SmTIPv2 Workflow Module.** The SmTIPv2 workflow module implements simplified SmT processes (Fig. 8.11) using microflows and pages. A manual planning process is performed by the planner using the New/Edit Transport Activity page (Fig. 8.12) and a Route Overview Page. The New/Edit Transport Activity page allows the planner to select a route for a transport activity and the Route Overview Page is

Figure 8.9: Disruption Rule for situation 11

Figure 8.10: Duplicate Disruption Rule

used to view all events for the selected route.

The Demand Aggregation process is performed by the planner using the Shipment Overview Page and the New/Edit Consignment Page. The Shipment Overview page allows the planners to divide Shipments into Shipment Segments and the New/Edit Consignment page allows the planner to make a consignment using Shipment Segments.

Figure 8.11: Simplified SmT processes for SmTIPv2

New/Edit Transport Activity

Transport Activity ID

TA-15

Carrier

Groen Transport

Vehicle

RT6756

Reg no

RT6756

Max capacity

500

Current load

0

Vehicle type

Freight_Car

Status

☒ Planned
 ☐ InTransit
 ☐ Disrupted
 ☐ Delayed
 ☐ Complete

Route

Route1

Planned start time

5/23/2018, 8:00 AM

Planned end time

5/24/2018, 12:00 PM

Expected start time

1/23/2019, 11:00 AM

Expected end time

5/24/2018, 3:00 PM

Actual start time

mm/dd/yyyy hh:mm AM/PM

Actual end time

mm/dd/yyyy hh:mm AM/PM

route delay (min)

180

Route ID

Route1

Start Location

Amsterdam

End Location

Venlo

Consignment

Search

Delete

1 to 3 of 3

Shipment SegmentID	Parent Shipment ID	hasCargo	noOfContainers
OR1-1	OR1	Metal scrap	50
OR2-1	OR2		0
OR1-2	OR1	Metal scrap	50

Add Consignment

Delete Consignment

Save Transport Activity

Cancel

Figure 8.12: New/Edit Transport Activity Page

8.5 SmTIPv2 Service Layer

The only SmTIP module implemented in the service layer is SmTIP Pages. SmTIP Management Tool and SmTIP Services are left for future work. SmTIPv2 Pages are implemented using Mendix Pages. Mendix Pages are the end-user interface for a Mendix application and use different *widgets* to display information and collect data from the user. Fig 8.13 shows SmTIPv2 Dashboard page for the planner. The dashboard consists of three rows.

1. Using icons in the first row the planner can access respective pages to view (a) Consignments and their status (icon: Consignments), (b) all events (icon: Events), and (c) disruption events (icon: Disruption Events).
2. Using icons in the second row the planner can access respective pages (a) to make a transport plan (icon: Make Plan) (b) make a consignment (icon: Make Consignment) (c) start a negotiation with a consignor (icon: Negotiation Manager).
3. Using icons in the third row the planner can access respective pages to view (a) Consignors (icon:Consignors) (b) Carriers (icon:Carriers) and (c) Routes (icon:Routes).

8.5.1 Demand Aggregation

For making a consignment, the planner first access the Shipment icon from the dashboard which opens the **Shipment** overview page. He selects a shipment and clicks on Edit Shipment button to divide the shipment into shipment segments. Then, he clicks the Consignment icon from the dashboard to open the **Consignment** page, where the planner clicks on **New Consignment** button to make a new consignment and add previously made shipment segments. Similarly, an existing consignment can be edited by the planner by selecting a consignment and clicking the **Edit Consignment** button.

8.5.2 (Re-)Planning

For making a transport plan, the planner performs the following steps

1. Clicks the icon Make Plan from the Dashboard, which open the New Plan page.
2. Clicks on Add Transport Activity button to add a transport activity which opens the New/Edit Transport Activity page as shown in Fig. 8.12.
3. Selects the Carrier, Route, Consignment and Planned Times for the activity and saves it. The planner is then re-directed to the previous page.
4. Back on the New Plan page, the planner selects and adds the newly created transport activity to the plan.
5. Adds all transport activities for a transport plan in similar manner.

6. Clicks on the Save Plan button, to save the plan.

Anytime during the creation of the transport plan the planner can save the Plan and start editing it at a later stage.

8.5.3 Getting Contextual Events.

On the Terminals Overview page or the Route overview page, the planner clicks on Get Events button. Then, by clicking on a particular Terminal or a Route the planner can view all the events associated with that terminal or route. Fig. 8.14, shows the Terminals page after clicking Get Events button by the planner. The columns show respective events for each terminal. Fig. 8.15, 8.16 and 8.17 show road, rail and waterway events for Amsterdam on 15th, 12th and 12th June 2018, respectively.

Figure 8.13: Dashboard-Home Page for the planner in SmTIPv2 prototype

Figure 8.14: Terminals Page, showing events for each terminal. By clicking on a Terminal name, the planner can view all related events.

Road Events	
Event ID	131118652
Seg start	Amsterdam
Seg end	Utrecht
Start	6/15/2018
Stop	6/16/2018
Reason	Dicht. Van 15 juni 2018 23:00 uur tot 16 juni 2018 05:00 uur.
Event ID	130891063a
Seg start	Amsterdam
Seg end	Hoorn
Start	6/11/2018
Stop	6/16/2018
Reason	Dicht. Van 11 juni 2018 20:00 uur tot 16 juni 2018 05:00 uur.
Event ID	130891063b
Seg start	Hoorn
Seg end	Amsterdam
Start	6/11/2018
Stop	6/16/2018
Reason	Dicht. Van 11 juni 2018 20:00 uur tot 16 juni 2018 05:00 uur.

Figure 8.15: A section of Events Page showing Road Works for Amsterdam on 15th June 2018

Planned Rail Events		Unplanned Rail Events
Event ID	Event Period	Event Trajectory
11 1 2 of 2 11	11 1 2 of 2 11	11 1 2 of 2 11
ID	Periode	Trajectory
2018_STATW_rsd_esn_26mei_26jul	Roosendaal-Antwerpen C.-Puurs	vanaf zaterdag 26 mei
2018_es_edo_9_14jun	Enschede-Dortmund Hbf	zaterdag 9 tot en met donderdag 14 juni

Figure 8.16: A section of Events Page showing Planned Rail Events for Amsterdam on 12th June 2018

Search	Delete	Select all
Contents	Source	Reason
Het vorige bericht Rijkswaterstaat.2...	E-mail 04-06-2018 RWS Midden Nederland – District Zuid, VP Wijk	REPAIR
Het vorige bericht Rijkswaterstaat.2...	E-mail 10-06-2018 RWS Oost Nederland – District Oost, CMIJ	REPAIR
Het vorige bericht Rijkswaterstaat.2...	E-mail 25-05-2018 RWS Oost Nederland – District Oost, 50	WORK

Figure 8.17: A section of Events Page showing Rijkswaterstaat RIS messages for Amsterdam on 12th June 2018

8.6 Conclusion

This chapter described the development of SmTIPv2 based on learning from SmTIP validation 1. Main improvements in SmTIPv2 include, an updated data model, implementation of SmTIP Event Handler and implementation of SmTIP Business Rules. Consequently, SmTIPv2 satisfies SmTIP functional requirements more comprehensively. Every component in each layer of SmTIPv2 was discussed in respective sections. SmTIPv2 integrates contextual event data with transport (planning) data and enables a planner to perform SmT processes, Demand Aggregation, Disruption Handling and Dynamic Switching. The following chapter, uses SmTIPv2 for SmT validation 2.

Chapter 9

SmTIP Validation 2

The opposite of a correct statement is a false statement. But the opposite of a profound truth may well be another profound truth.

-Niels Bohr

Danish physicist (1885-1962)

After developing SmTIPv2, I made another attempt to answer R.Q.4, i.e., *Does SmTIP contribute to stakeholder goals?* This attempt is SmTIP validation 2 for which SmTIPv2 was used. SmTIP validation 2 considered test subjects' responses from SmTIP validation 1 for experiment setup improvement. For consistency and easy comparison between SmTIP validation 1 and 2, I again used the checklist for empirical research by Wieringa [211].

9.1 SmTIP Empirical Cycle 2

Each subsection below corresponds to one part of the empirical cycle checklist. Similar to SmTIP Empirical Cycle 1, I have used continuous numbering for the seventeen points in the checklist.

9.1.1 Research Context

1. Knowledge Goals — The knowledge goals for SmTIP empirical cycle 2 are at two levels. The lower level knowledge goal is to answer the question — *Do SmTIP modules facilitate SmT activities?* The lower level knowledge goal aims to investigate the validity of SmTIP design.

The higher level knowledge goal for SmTIP empirical cycle 2 is — *To know whether SmTIP, when used by*

stakeholders, satisfies stakeholder goals. The higher level knowledge goal aims to investigate the contribution argument, i.e., by facilitating SmT activities SmTIP contributes to stakeholder goals.

2. Improvement Goals — In the context of this dissertation, SmTIP empirical cycle 2 is the last validation cycle. The improvement goal is to provide a direction for further improvement of SmTIPv2 by future researchers.
3. Current Knowledge —
 - (a) SmT Stakeholders, Sec. 3.2.
 - (b) SmT stakeholders' goals, Sec. 3.3.
 - (c) Requirements for a SmTIP, Sec. 3.5.
 - (d) SmT Processes (activities), Sec. 4.5.
 - (e) SmTIP Architecture, Sec. 6.2.
 - (f) SmTIPv2 Architecture, Sec. 8.2.
 - (g) Test subject responses - SmTIP Empirical Cycle 1, Appendix E.

9.1.2 Research Problem

4. Conceptual Framework — In SmTIP empirical cycle 1, I postulated that test subjects' opinion about SmT may affect their opinion about SmTIPv1's usefulness. Therefore, for this empirical cycle the conceptual framework is updated. *Opinion about SmT* is added as a property of actor Freight Forwarder. The relationship between Opinion about SmT and SmTIPv2's usefulness is included in the measurement design for this empirical cycle.

Usefulness of a system has been defined by Seffah et al. in [160] as “whether a software product enables users to solve real problems in an acceptable way”. Further, Nielsen in [123] defines usefulness as - whether the system can be used by users to achieve some desired goal (Model of Attributes of System Acceptability). Based on these complementary definitions, I concluded that a useful system is one, which provides functions enabling its users to perform their tasks and achieve their goals. Usefulness of SmTIPv2 measures - can planners use SmTIPv2 to perform SmT processes and achieve their goals for SmT? Usefulness of a system is composed of two concepts, *usability* and *utility* [123].

Usability of SmTIPv2 measures the extent to which SmTIPv2 can be used by planners to perform SmT processes with effectiveness, efficiency and satisfaction. Usability is composed of following five components [106, 123]:

- (a) Learnability — how easy is it for planners to perform a SmT process when using SmTIPv2 for the first time?
- (b) Efficiency — once planners are accustomed with SmTIPv2, how quickly can they perform SmT processes using SmTIPv2?
- (c) Memorability — if planners return to using SmTIPv2 after a period of not using it, how easily can

Figure 9.1: TAM [28, 29] (top) and results of Lacka & Chong [96] (bottom)

they re-establish proficiency?

(d) Errors — while planners use SmTIPv2, how many error does SmTIPv2 exhibit?

(e) Satisfaction — indicates how pleasant is it for planners to use SmTIPv2?

Utility, according to Nielsen [123] is “the question of whether the functionality of the system in principle can do what is needed.” Thus, utility of SmTIPv2 measures - does SmTIPv2 models a SmT scenario by integrating transport and contextual data.

A widely used model to study the usefulness of information systems is the Technology Acceptance Model (TAM) [28, 29]. TAM theorizes that, the *actual use* of a system (by users) is determined by users’ *behavioral intentions* towards system use. Behavioral intentions are themselves jointly determined by the user’s *attitude* towards using a system and the system’s *perceived usefulness*. Additionally, the *perceived ease of use* of a system by the users, determines their attitude towards using the system and its perceived usefulness (Fig. 9.1, top).

The concepts of usefulness, usability, utility by Nielsen and perceived usefulness, perceived ease of use, behavioral intention to use in TAM are related [96]. The concept of Usefulness by Nielsen and Perceived Usefulness in TAM are used interchangeably in IS literature. Both these concepts refers to a user’s perception - whether he can achieve his goals by using a given system. Similarly, Usability as defined by Nielsen and Perceived Ease of Use in TAM, both refers to a user’s perception of effort needed to use a technology for achieving desired goals.

Lacka and Chong in [96] have empirically tested the relationships between usefulness, usability, utility

and TAM for the use of social media sites by B2B marketing professionals. They first extended TAM by adding two new constructs, perceived usability and perceived utility. Via their empirical study they found that (Fig. 9.1 (bottom)) : (a) intention to use impacts actual use of social media sites; (b) perceived usefulness impacts intention to use social media sites; (c) perceived usability impacts intention to use social media sites; (d) learnability impacts perceived usability of social media sites; (e) memorability impacts perceived usability of social media sites; (f) perceived utility impacts intention to use social media sites and (g) perceived utility impacts perceived usefulness of social media sites. Still, their results did not indicate that other usability components; i.e., efficiency, errors and satisfaction, impact perceived usability of a system.

Another model to study the acceptance of information systems is Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. [196]. It combines eight different technology acceptance models and presents a unified view over technology acceptance by users. TAM is among the models used by Venkatesh et al. for UTAUT. It prescribes four constructs which determine technology acceptance. They are; *performance expectancy*, *effort expectancy*, *social influence* and *facilitating conditions*. The perceived usefulness construct of TAM is a part of the performance expectancy construct of UTAUT, where, performance expectancy is defined as “the degree to which an individual believes that using the system will help him or her to attain gains in job performance” [196]. The perceived ease of use concept of TAM is a part of the effort expectancy construct of UTAUT, where effort expectancy is “defined as the degree of ease associated with the use of the system” [196].

For this empirical cycle, learnability, efficiency, errors and utility of SmTIPv2 will be measured¹. By measuring them, I aim to measure the (a) behavioral intention of planners to use SmTIPv2, as in TAM and (b) performance expectancy and effort expectancy as in UTAUT.

5. Knowledge Questions — The knowledge questions for this empirical cycle are refined versions of the knowledge questions from the previous empirical cycle. Questions (a) and (b) from the previous empirical cycle were combined to form one question, i.e., Does SmTIPv2 models a SmT scenario? Question (c) from the previous empirical cycle was expanded to three questions, covering the learnability, efficiency and errors of SmTIPv2. Questions (d) and (e) from the previous empirical cycle were dropped for this empirical cycle. Two additional questions were added in this empirical cycle to measure the knowledge and opinion of test subjects.

- (a) What is the learnability of SmTIPv2 ?
- (b) What is the efficiency of SmTIPv2?
- (c) How many errors does SmTIPv2 exhibit?

¹memorability and satisfaction are left for future research

- (d) Does SmTIPv2 models a SmT scenario?
 - (e) Does prior knowledge of SmT influence usefulness of SmTIPv2?
 - (f) Does a positive opinion about SmT influence usefulness of SmTIPv2?
6. Population — Planners working at freight forwarders.

9.1.3 Research Design & Validation

7. Objects of Study (OoS) — The OoS consists of (a) SmTIPv2, (b) a test subject playing the role of a planner, (c) ANWB web service, (d) NS web service.
- 7.1. Acquisition of OoS — I contacted five planners and ten researchers and requested for an individual validation experiment. Three planners and nine researchers agreed to the request for an experiment, making the total number of test subjects (and validation experiments) twelve.
- 7.2. Construction of the sample — I conducted twelve individual experiments, one each with the twelve test subjects. There was no overlap between the test subject chosen for SmTIP empirical cycle 1 and those chosen for SmTIP empirical cycle 2. This was done to ensure that test subject responses are not influenced by their previous experience with SmTIPv1.
8. Treatment Design — I explained SmT to the test subjects using the SmT scenario, described in Sec. 4.1 and then asked them to perform two tasks, which are described below:

Task 1 - The first task for the test subject was *Demand Aggregation* and to create a transport plan. Prior to the task, the meaning of shipments, shipment segments, consignments, transport activity and transport plan was explained to the test subject.

To start Task 1, the test subject opens the shipment page, which shows shipments to be transported (pre-entered in SmTIPv2 by me before the experiment). The test subject divides the shipment into shipment segments, makes a consignment and views it on the *Consignment Overview* page.

The test subject then opens the *New/Edit Plan* page and make a transport activity for the consignment, on a specific route, using a specific modality, provided by me. The test subject then views the plan by opening the *Plan Overview* page. This concludes Task 1.

SmTIP Pages used in Task 1 — Shipment Overview page, Consignment Overview page, New/Edit Plan page, Transport Activity page, Plan Overview page.

SmTIP modules used in Task 1 — SmTIP Data Mapper, SmTIP Data Model and SmTIP Pages.

Control for Task 1 — The test subject was asked to choose a specific route and a specific modality for the transport plan. There were on-going route events for that route and modality. On the day of the experiment, I had to determine a such route.

Task 2 - The second task for the test subjects was *Disruption Handling*. Prior to the task, the meaning of events, disruptions and disruption handling process was explained to the test subject. To start Task 2, the test subjects opens the *Route Overview* page and imports events for all routes. Ongoing route

events are automatically related to routes and consignments on those routes. The test subject views this by opening (and refreshing) the *Routes Overview* page. The test subject, then, reviews the events for the route chosen in Task 1. He is asked to consider the event(s) on the route chosen in Task 1 as disruption event(s) and re-plan the consignment. The test subject opens the New/Edit Transport Activity Page and, (a) chooses a different route for the transport activity and (b) chooses a different vehicle for the transport activity and (c) saves the new transport activity. This concludes Task 2.

SmTIP Pages used in Task 2 — Route Overview page, Consignment Overview page, Events page, New/Edit Transport Activity page, New/Edit Plan page.

SmTIP Modules used in Task 2 — SmTIP Adapters, SmTIP Data Converter, SmTIP Data Mapper, SmTIP Data Filtering, SmTIP Events Database, SmTIP Event Handler, SmTIP Workflow Module, SmTIP Pages.

Control for Task 2 — Asking the test subject to consider events on the planned route as disruption events.

The treatment instrument used for the tasks were a meeting room, (my) laptop on which the SmTIPv2 was run, Internet connection to connect to event data sources. Every test subject in each of the twelve experiments, was given the same tasks and in the same order, i.e., Task 1 followed by Task 2.

9. Measurement Design — As an improvement over SmTIP empirical cycle 1, for this empirical cycle, I designed a questionnaire to record test subject responses. The questionnaire consisted of ten questions and has two sections (Table 9.1). The test subjects filled the questionnaire after performing the experiment tasks.

Section 1 — consists of eight task-specific questions, four for each task. The first three questions for each task, measure Learnability, Efficiency and Errors of SmTIPv2 for that specific task, respectively. The fourth question measures Utility of the task. (See Table 9.1).

Section 2 — consists of two questions. The first question was about the test subject's SmT knowledge before starting the experiment and the second question was about the test subject's opinion regarding SmT. The complete questionnaire can be found in Appendix E. A print-out of the questionnaire was given to the test subject after he had completed both tasks, and was requested to fill it.

To ensure compliance with ethical guidelines for conducting experiments, the test subject was informed that his responses would be used in this dissertation. He was free to opt out from filling-in the questionnaire, though, none of the test subjects decided to do so. Also, to protect test subject's identity, they were not required to write their name or affiliation on the questionnaire. The test subjects were informed that their identity would not be made public.

Table 9.1: Measurement Design Overview

Question	Measured Construct	of Task	Scale
Question 1.1	Learnability	Task 1	Ordinal Scale
Question 1.2	Efficiency	Task 1	Ordinal Scale
Question 1.3	Error	Task 1	Ratio Scale
Question 1.4	Utility	Task 1	Ordinal Scale
Question 1.5	Learnability	Task 2	Ordinal Scale
Question 1.6	Efficiency	Task 2	Ordinal Scale
Question 1.7	Error	Task 2	Ratio Scale
Question 1.8	Utility	Task 2	Ordinal Scale
Question 2.1	SmT Knowledge	n.a.	Ordinal Scale
Question 2.2	SmT Opinion	n.a.	Ordinal Scale

9.1.4 Inference Design and Validation

10. Inference Design — The data source for inferences are the filled in questionnaire obtained at the end of each experiment. After all experiments were completed, I entered all test subject responses in an MS Excel sheet for an overview of the responses.
 - 10.1. Descriptive Inference Design - I used content analysis for making inferences based on test subject responses. Test subject responses were divided into positive and negative responses. Strongly Agree and Agree were considered as *positive responses*. Disagree and Strongly Disagree were considered as *negative responses*.
 - 10.2. Abduction Inference Design - My theory at this point is that, (a) SmTIPv2 fulfills SmTIP requirements, (b) SmTIP contributes to stakeholders' goals and (c) the stakeholder goals derived by me via stakeholder interviews truly represented their goals.
 - 10.3. Analogic Inference Design - Not all test subjects are representative of the populations, however, their responses can be used for further improvement of SmTIPv2.

9.1.5 Research Execution

11. What happened — The average time taken by test subjects to perform the task and fill in the questionnaire was approx. 30 minutes. Some test subjects had a different understanding of terms like, shipment, consignment and disruption. Therefore, considerable explanation was needed for the concepts used in the tasks and *why* I have named them such. Test subjects frequently needed help for navigating through SmTIPv2 pages.

9.1.6 Data Analysis

12. Descriptions — The test subject responses over learnability of Task 1 and Task 2 do not provide a definitive answer, since in both cases the number of positive responses and negative responses are equal (Fig. 9.2).

The test subjects' responses reveal that SmTIPv2 does not contribute to increasing the efficiency of demand aggregation activity (9 negative responses). On the other hand, SmTIPv2 does contribute to increasing the efficiency of the disruption handling activity (9 positive responses).

Test subject reported encountering more errors while performing Task 2 then Task 1.

The test subjects' responses also reveal that the utility of demand aggregation activity using SmTIPv2 as marginally positive (7 positive responses). On the other hand, the utility of disruption handling activity using SmTIPv2 is clearly negative (9 negative responses). I summarize the results as follows:

Demand Aggregation using SmTIPv2 — neither easy nor difficult to learn, does not contribute to increasing the efficiency of demand aggregation process, correctly models the demand aggregation process for a SmT scenario (Fig. 9.2).

Disruption Handling using SmTIPv2 — neither easy nor difficult to learn, contributes to increasing the efficiency in of disruption handling process, does not model the disruption handling process for a SmT scenario (Fig. 9.2).

13. Statistical Conclusions — I did not make any statistical analysis based on test subject responses.
14. Explanations — Negative responses for SmTIPv2's utility w.r.t demand aggregation and disruption handling may partly be a result of test subjects considering SmT an unfeasible concept. This is supported by the test subjects' responses to Question 2.2 in the questionnaire. Three test subjects responded *Disagree* to Question 2.2, which indicates that they do not consider SmT applicable in a transport scenario. Two of them also disagreed (or strongly disagreed) with SmTIPv2's utility w.r.t Demand Aggregation and Disruption Handling processes.

Another explanation for low utility is that the events chosen for disruption handling (Task 2) were not considered as disruption events by the test subjects. Therefore, the test subjects considered disruption handling for those events unnecessary. This may have led the test subjects to question the benefit of the disruption handling process.

A low learnability of SmTIPv2 could be a result of an inefficient layout of SmTIPv2 pages, which test subjects might (still) find difficult to navigate.

No correlation could be deduced between prior SmT knowledge and SmTIPv2 usefulness since all test subjects reported having prior knowledge of SmT.

15. Generalizations — Some planners at freight forwarder consider SmT as unfeasible, since, currently the incentives/returns (monetary or customer satisfaction) are limited, difficult to achieve and not quantified. Thus, it is not clear to planners how SmT contributes to more profits, which is the primary goal of planners.
16. Answers — Below I present the answers to the knowledge questions for this empirical cycle
 - (a) No conclusion could be drawn about the learnability of SmTIPv2.
 - (b) SmTIPv2 does not contribute to increasing the efficiency of demand aggregation process but does

Figure 9.2: Test subject responses

- contribute to increasing the efficiency of disruption handling process.
- (c) SmTIPv2 exhibits more error for disruption handling than for demand aggregation.
 - (d) SmTIPv2 properly models the demand aggregation process for a SmT scenario but does not properly model the disruption handling process correctly.
 - (e) No conclusion could be drawn about the relationship between a test subject's prior knowledge of SmT and his response to the question on SmTIPv2's usefulness.
 - (f) A prior opinion about SmT does influence the usefulness of SmTIPv2 as it influences the utility of task performed using SmTIPv2.

9.1.7 Research Context

17. Contribution to knowledge goal — Since (a) test subjects were able to use SmTIPv2 to perform SmT processes as designed by me and (b) SmTIPv2 functioned as expected during the experiment, I conclude that SmTIPv2 modules facilitate SmT activities. SmTIPv2's contribution to stakeholder goals can not be concluded with certainty. The learnability and efficiency of SmTIPv2 need improvement.
18. Contribution to improvement goal — For the next validation of SmTIPv2, more complex events should be used as disruption events. In both empirical cycles, events used by me as examples of disruption events, were eventually considered too simple by the test subjects, to warrant a change in existing transport plans. In both empirical cycles, the transport data used for the tasks, was provided by me. For future validation, the planner may be allowed to enter transport data himself. Whether doing this influences test subjects responses to efficiency and utility of SmTIPv2 should then be investigated.

9.2 Conclusion

This chapter described SmTIP validation 2, the second validation cycle for this research. In this validation cycle SmTIPv2 was used - having two new modules, SmTIP Event Handler and SmT Rules. Using learning from SmTIP validation 1, the number of tasks were reduced, tasks were explained with the help of a SmT scenario, individual experiments were conducted and test subjects responses were measured using a questionnaire. The test subjects performed Demand Aggregation process and Disruption Handling process using SmTIPv2. Their responses indicate that SmTIPv2 models the demand aggregation process correctly and increase the efficiency of the disruption handling process. The main take away for future works are: (1) further study of disruption situations in a SmT scenario from the planner's perspective and (2) consulting planners during the design of SmTIP pages for better learnability of SmTIP.

Part V

Conclusion

Chapter 10

Conclusion and Future Work

I do not think there is any thrill that can go through the human heart like that felt by the inventor as he sees some creation of the brain unfolding to reality... such emotions make a man forget food, sleep, friends, love, everything.

- Nikola Tesla

Serbian physicist (1886-1943)

In this dissertation, I have provided a solution to data integration challenges posed by SmT by designing a Synchromodal Transport Integration Platform (SmTIP). I designed SmTIP based on the results of three research activities. The first research activity was SmT stakeholders interviews, which resulted in a list of requirements for SmTIP. The second research activity was the analysis of SmT transport practices, which resulted in a list of six SmT processes. The third research activity was study of the state-of-art in integration platform design, which resulted in a reference architecture for integration platforms. SmTIP (1) integrates contextual event data with transport planning data (2) identifies disruption situations and (3) allows the planner to perform SmT processes.

In Sec 10.1, I re-visit the research questions and summarize the answers. Then, I discuss the contribution of this dissertation to SmT research and practice in Sec 10.2. Lessons learned during the research and open questions for future research are given in Sec 10.3 and Sec 10.4, respectively.

10.1 Answers to research questions

I started this dissertation with a design problem, viz., *Improve flexibility of transport process, by designing a Synchronomodal Transport Integration Platform, that integrates real time contextual events data and transport planning data, so that freight forwarders can perform Synchronomodal Transport*. To answer the design problem, I had formulated four research questions. All research questions were answered in this dissertation. Below, I summarize the answers.

RQ.1 *What is the current state of research in SmT?*

R.Q.1 was answered via a systematic literature review. SmT state of research was studied from three perspectives, i.e., (1) meaning of SmT, (2) SmT research themes and (3) success factors for SmT. I found out that there are many overlapping terms being used in the transportation sector. Their interpretation varies depending upon individual researchers, which often leads to confusion. The overarching term is Multimodal Transport and SmT is but, one dimension of it. Hence, I defined a categorization of terms in Chapter 2 and those terms are consistently used throughout this dissertation. I concluded that, the dominant research themes in SmT are operations research and conceptual research. Smart transport planning and strategic use of ICTs have been identified by researchers as critical success factors for SmT.

RQ.2 *What are stakeholders' requirements for Synchronomodal Transport Integration Platform?*

R.Q.2 is answered via stakeholder interviews. I categorized SmT stakeholders into eight categories (Table 3.2). Freight forwarders were identified as the main stakeholders in SmT. Based on stakeholder interviews, I concluded that SmT consists of six processes, (SmT Processes, Sec 4.5). They are event prediction, demand aggregation, smart planning, disruption handling, negotiations and dynamic switching. SmTIP should enable the planner to perform these six processes. Thirteen functional requirements for SmTIP were extracted from literature and stakeholder interviews, which were then decomposed into smaller functional requirements (Appendix C).

RQ.3 *Design a SmT Integration Platform (SmTIP) using best practices in integration platform design.*

SmT requires integration of contextual event data and transport data. I developed OntoSmT: an ontology for SmT to enable data integration. Then, I defined events & disruptions in a SmT scenario using OntoSmT classes. Disruption situations were modeled using a situation modeling language (SML). To design SmTIP using best practices in integration platform design, I used a pattern mining method for extracting architectural design patterns found in contemporary integration platforms. Extracted architectural design patterns were, SOA¹ design pattern, ETL² design pattern, ESB³ design pattern and service design pattern. These design patterns represent the state-of-the-art in integration platform design. SmTIP was designed based on these design patterns.

RQ.4 *Does SmTIP contribute to main stakeholder goals?*

¹service oriented architecture

²extract-transform-load

³enterprise service bus

To answer R.Q.4, two SmTIP validation rounds were carried out. A total of thirteen case based experiments were conducted using two versions of SmTIP prototype, i.e., SmTIPv1 and SmTIPv2. During validation experiments, the SmTIP prototypes successfully integrated events data and transport data. They enable test subjects to perform SmT processes as defined in Sec. 4.5. Yet, these validation rounds could not confirm that SmTIP contributes to stakeholder goals, since, the test subjects in both validation rounds did not find the SmTIP prototype useful. Nevertheless, SmTIP modules fulfill SmTIP functional requirements provided by the stakeholders. For future validation of SmTIP, more complex events should be used in validation experiments to simulate disruption events.

10.2 Contributions to research and practice

10.2.1 Contribution to research

1. This dissertation enhances SmT research. It fills the research gap of SmT data integration challenges by: (1) identifying the data integration challenges, (2) listing the requirements for a SmTIP, (3) designing a SmTIP to overcome them.
2. Researchers in transportation sector can use this dissertation as an introduction to SmT. It will help them understand SmT processes, SmT scenarios and relevant disruption situations. Freight forwarders' requirements for SmTIP (Ch. 3) may be reused by researchers in similar research projects to design applications for SmT.
3. The stakeholder responses during interviews (Appendix B) provide an overview of contemporary transport practices. They may be used to write a comprehensive state-of-the-art document over transportation sector.
4. Reference Architecture for Integration Platform (RAfIP) (Ch. 4) provides an architecture of a generic, domain-independent integration platform. Just as I refined RAfIP to design SmTIP, similarly, researchers can use RAfIP to design integration platforms in other domains. For that purpose, the refinement of the reference architecture to a SmT scenario, as shown in this dissertation, may be used as a guide.
5. The responses of transport companies' representatives during SmTIP validation will help researchers in the future improvement of SmTIPv2 and in designing new validation experiment setups.
6. OntoSmT aids in the integration of transport and contextual data for a SmT scenario and can be reused for developing new applications for SmT.
7. SmT prerequisites, processes and effects, as discussed in this dissertation, contribute to better understanding of SmT.
8. At the highest level, by designing an integration platform for SmT, this dissertation contributes to EU's research efforts towards a sustainable, integrated and synchromodal transport network.

10.2.2 Contribution to practice

In this dissertation, I have specified and modeled SmT processes. They may be used by planners for demand aggregation and disruption handling.

Using this dissertation, transport companies can get acquainted with SmT processes, data integration challenges posed by SmT and how to overcome them. Currently, there is no application using which SmT disruption handling processes can be simulated. SmTIPv2 aims to fill this gap. While Sychromania [15] and Cargo Rail Challenge [189] study the generic decision making processes in SmT, SmTIPv2 (primarily) studies the disruption handling process.

10.3 Lessons learned

Firstly, researchers and practitioners should use consistent terminology to describe SmT processes. Consistent terminology would help to converge future SmT research and allow better interpretation of existing research. *Secondly*, user interface and workflow of TMSs used by planners should be studied as a part of requirement specification. The results must then be used in SmTIP prototype development. If planners experience the same *look and feel* while using SmTIP prototype, as with their TMSs, then it will positively influence the learnability of SmTIP prototype. *Thirdly*, the choice of treatment tasks for SmTIP prototype validation experiments requires attention. If treatment tasks are complex, requiring considerable work by the test subject, then he/she loses interest in the experiment. Subsequently, he/she might adopt passive involvement or even opt out of the experiment. On the other hand, if the tasks are too simple then the test subjects will not find SmTIP prototype useful. The latter was observed during SmTIP validation 1 and 2, when test subjects were asked to consider road works and railway events as disruption events. *Fourthly*, planners' inputs should be sought while modeling disruption situations and disruption handling process. Incorporating planners' views during the design process would positively affect the utility of SmTIP. *Fifthly*, SmTIP prototype should quantify and display the benefits of performing SmT processes to the planners. This triggers their interest in SmTIP. Possible ways to display benefits are, profit in terms of Euros saved, lesser CO₂ emissions per consignment, greater capacity utilization in terms of percentage or any other relevant indicator. *Finally*, there exist numerous definitions of usefulness, usability and utility. The interpretation of these concepts varies among different research domains. Therefore, their interpretation for SmTIP validation, should be well-motivated and strictly from IS research domain.

10.4 Future Work

F.Q.1 *How can disruption situation models be improved ?*

Rationale — The disruption models I used in this dissertation take into account the delay caused by events. According to planners, are there additional factors which determine a disruption? How to model such factors? Planners, based on their experience, can at times foresee bottlenecks and disruption events. How can the expertise of planner be included in modeling disruptions?

F.Q.2 *Does contemporary SmT research consider the perception of SmT by freight forwarders, carriers and infrastructure providers?*

Rationale — How has their perception/opinion about SmT changed over the years? Does contemporary SmT research align with their opinion? This is important for practical implementation of SmT, determining its feasibility and identifying new challenges.

F.Q.3 *Do SmT effects depend on freight forwarder's profile? In what way?*

Rationale — SmT effects may depend upon a freight forwarder's profile; where profile includes company size, IT portfolio, partner alliances, geographic location, etc. This is important for determining the feasibility of SmT activities.

F.Q.5 *Do managers and planners have similar opinions about SmT?*

Rationale — Managers at freight forwarder are responsible for strategic decision making. Planners are responsible for operational decision making and route planning. Their opinions about SmT could be different. While managers could consider SmT essential for strategic and long term gains, planners may perceive SmT processes as complications of current processes. Consequently, there opinions about SmTIP prototype's usefulness may vary.

F.Q.7 *Who are the right test subjects for SmTIP validation?*

Rationale — Though planners are the main users of SmTIP, it might be that managers may better assess the benefits of using SmTIP. Also, are IT consultants (for transport companies) relevant test subjects? They could provide useful inputs over SmTIP prototype's usability.

F.Q.8 *Does SmTIP undermine the job prospect of a planner?*

Rationale — Planners could view applications like SmTIP negatively, as their possible replacements. For future SmTIP validation, it is pertinent to investigate if planners fear applications like SmTIP. If true, appropriate steps could be taken to address and remove such fears.

F.Q.9 *How to address conflicting stakeholder goals in SmT?*

Rationale — SmT stakeholders may have conflicting goals. A relevant example is the dynamic switching process, which implies a change in transport mode while a consignment is in-transit. Dynamic switching is applicable only when the consignor agrees/allows a modality change during transit. Situations may occur wherein the freight forwarder wants to dynamically switch the transport modality but, the consignor does not agree. Possible motives for the consignor's decision include: security of cargo, possible

damage during cargo handling, etc.

The result of the negotiation process depends on a win/win situation for the consignor and the freight forwarder. E.g., the consignor receives his shipment earlier and freight forwarders saves costs. A SmT scenario in which consignors, carrier and freight forwarders have conflicting demands has not been adequately studied, yet. Currently, in such situations planners make a decision based on their expertise and intuition.

Appendices

Appendix A

Candidate articles of Systematic Literature Review

No.	Author(s)	Year	Article
1	van Rissen, B., Negenborn, R.R. & Dekker R.	2015	Synchromodal Container Transportation: An overview of current topics and research opportunities
2	Singh, P.M. & van Sinderen, M.J.	2015	Interoperability challenges for context aware logistics services- The case of synchromodal logistics
3	Putz, L., Haider, C., Haller, A. & Schauer, O.	2015	Identifying key enablers for synchromodal transport chains in Central Europe
4	Singh, P.M.	2014	Developing a service oriented IT platform for synchromodal transportation
5	Hofman, W.J.	2015	Control tower architecture for multi and synchromodal logistics with real time data
6	Pleszko, J.	2012	Multi variant configuration of supply chains in the context of synchromodal transport
7	Lu, M.	2014	Synchromodality for enabling smart transport hubs
8	SteadieSeifi, M., Dellaert, N.P., Nuijten, W., van Woensel T., & Raoufi R.	2013	Multimodal freight transportation planning: A literature review
9	van Rissen, B., Negenborn, R.R., Dekker R. & Lodewijks, G.	2015	Service network design for an internal container network with flexible transit times and the possibility of using subcontracted transport
10	Oonk, M.E.	2014	Smart logistic corridors and the benefits of intelligent transport systems
11	Roth, M., Klarmann A. & Franczyk, B.	2013	Future Logistics - Challenges, requirements and solutions for logistics network
12	Klievink, A.J., Van Stijn, E., Hesketh, D., Aldewereld, H., Overbeek, S., Heijmann, F. & Tan, Y.H.	2012	Enhancing visibility in international supply chains: The data pipeline concept

No.	Author(s)	Year	Article
13	Overbeek, S., Klievink, A.J., Hesketh, D., Heijmann, F. & Tan, Y.H.	2011	A web-based data pipeline for compliance in international trade
14	Lu, M. & Borbon-Galvez, Y.	2012	Advanced logistics and supply chain management for intelligent and sustainable transport
15	Reis, V.	2015	Should we keep on renaming a +35 year old baby?
16	Panagakos, G. & Psaraftis, H.	2014	How green are the TEN-T core network corridors.
17	Eftestål-Wilhelmsson, E., Bask, A. & Rajahonka, M.	2014	Intermodal transport research: A law and logistics literature review with EU focus.
18	Harris, I., Wang, Y. & Wang, H.	2014	ICT in multimodal transport and technological trends: Unleashing potential for the future
19	Van Riessen, B., Negenborn, R.R., Dekker, R. & Lodewijks, G.	2014	Impact and relevance of transit disturbances on planning in intermodal container networks using disturbance cost analysis
20	Oudani, M., Alaoui, A.E.H & Boukachour, J.	2014	An efficient genetic algorithm to solve the intermodal terminal location problem
21	Vanelslender, T., Hintjens, J., Kuipers, B. & van der Horst, M.	2012	Driving forces and challenges for the Flemish-Dutch delta for 2040: A multi actor analysis
22	de Keizer, M., van der Vorst, J.G.A.J., Bloemhof, J.M. & Haijema, R.	2015	Floriculture supply chain network design and control: Industry needs and modeling challenges
23	van den Berg, R. & de Langen, P.W.	2014	An exploratory analysis of the effects of modal split obligations in terminal concession contracts
24	Flitsch, V., Herz, N., Wolff, J. & Baird, A.J.	2014	Maritime policy in the North Sea region: Applications of the cluster approach
25	Hofman, W.J. & Bastiaansen, H.J.M.	2014	Roadmap towards a smart logistics ecosystem
26	Szkopiński, J. & Jacyna, M.	2014	The railway system transformation - Implementation of the interoperability requirements on the rail network
27	van Damme, D.A	2013	Towards a vision of good transport in 2040: dealing with volatility
28	Beyer, A. & Verhaeghe, L.	2014	Co-operation between waterways and railways, an unnatural alliance rail strategic development of river ports in the greater Paris region
29	Grefen, P. W. P. J. & Dijkman, R. M.	2013	Hybrid control of supply chains: A structured exploration from a systems perspective
30	Kourtit, K., Nijkamp, P. & Partridge, M. D.	2015	Challenges of the new urban world

Appendix B

Stakeholder interviews

The objective of this Appendix is to enable the reader understand the basis on which stakeholder goals (Table 3.3), SmTIP requirements (Table 3.4), enterprise architecture model of a freight forwarder (Fig. 3.1) and a synchromodal scenario (Fig. 4.1) were designed. The first eight interviews (B.1 - B.8) are presented in a question-response format and a summary is provided (B.9) for the remaining interviews. To preserve the privacy and identity of interviewees and individual stakeholder companies, some data has been repressed, like, the name of the interviewee, name of the stakeholder company, names of the projects the interviewee is working/has worked on. Repressing such data does not affect the knowledge provided by interviewee response. For setup, conduction and documentation of some interviews, I was helped by Christiaan Visscher, Erik D. van der Kuil, Frank Bloo and Thierry Sterrenburg.

B.1 Freight Forwarder 1

This interviews was conducted with a planner of a freight forwarder company which specializes in the transport of large industrial machine parts. It is a medium sized company and is situation in the NL.

SH.1. When a shipment is received, does this shipment always have the same data format?

No, actually shipments do not have the same data format, but mostly we receive them via email. Often, an excel sheet is provided in the attachments of the email which has all shipment information.

SH2. What are the data fields of a shipment request? and SH3. What data fields are needed for transport planning?

If we need more information about a shipment we have to contact our client. But, for recurring clients we have fixed data fields which we need, like, description, weight, dimensions, pickup and delivery location,

earliest and latest pickup date-time, earliest and latest delivery date-time, loading instructions. Any extra remark is usually included in the email.

P.1. How is transport planning done? Manual or via a planning software?

We use a software, MODALITY, for transport planning. You can say that the real planning is done by our planners with the help of MODALITY.

P.2 How many planners are employed?

There are 17 planners working in our company.

P.4. Which planning application is currently used for planning? What are the optimization parameters?

Our planners use MODALITY for planning. It is not an optimization software nor a planning software.

P.5. Does the planning application use real time events, disruptions, consignments in-transit?

Using MODALITY our planners can track consignments and view their next stops. Actually, I can show you our planners using the system after this meeting. Some improvements are planned for MODALITY. Currently, we can know exactly where a particular consignment is and which carriers are involved for its transport.

P.6 Does the system you currently use provide feedback, for example colour coding to see the status of a transport? What kind of feedback?

Yes, it is there. Color coding is used for showing the status of a consignment. Delayed consignments are highlighted in red.

D.1 Which data sources do you use for real time data? and D.2 Are there specific consignments for which real time data is essential?

The real time data we currently use are the location and progress of trucks. If we are using the trucks from carriers then we get their locations by contacting them. From our trucks, location is provided by the board computer system of the truck.

M.1 Which transport modalities are currently being used?

We transport all our consignments via road using specialized trucks.

E.2. What do you consider a disruption?

For us a long standing traffic jam, bad weather conditions/forecasts are disruptions. When an escort vehicle for escorting our trucks doesn't show up, or is late, then it is also a disruption for us.

E.4. What is the current disruption handling policy?

We just send the truck, and ask them to wait. May take a few minutes or even a full day. We don't have information which can be relied upon; as the updating is slow, I mean, from the port's side. Even when the trucks are there sometimes they have to wait a long time before they are loaded; you know; many

incidences we can't take into account like, delay when waiting for its turn. Usually we plan for such delays and provide a cushion; I mean; everyone does that. Its not ideal or efficient way to work. This lag could be removed if we have more information; it follows to other orders also, like a chain.

E.6 In case of a delay when do you inform the shipper about the delay?

We do not automatically inform the shipper of the delay. I am not sure that they would like to know of every delay. We have a time window within which we must deliver the consignment. Usually, the time window provides us with some cushion but, if there is a massive delay we have to inform the shipper.

E.7 What factors are considered in re-planning?

The mandatory rest time of drivers is taken into account in case of re-planning, according to the Arbeidstijdenwet. Arbeidstijdenwet is a law which prescribes mandatory rest time for drivers between continuous driving assignments. Apart from this, all shipment details used during planning, are reused.

E.10 What according to you is an optimal disruption handling process?

Optimal disruption handling should be able to automatically recognize events which may cause disruptions, communicate it to our planners and enable them to make changes so that they can resolve the disruption, before it occurs. I am not sure if that can be implemented. The input of a planner during a disruption situation is important for disruption handling, therefore I think that it cannot be totally automated.

B.2 Freight Forwarder 2

This interview was conducted with a planner at a freight forwarder. It is a large company situated in the NL and having international operations. It uses all four modalities for transporting shipments. The interview was conducted in Dutch.

P.1 How is transport planning done? Manual or via a planning software?

Via een transport management system, zitten wel manueel processen om heen. Zoals communicatie. Het volgen van en aansturen transport operaties, ongeacht welke kwaliteit wordt gedaan door het systeem. We hebben planners en het verschilt per afdeling. Schatting voor de totale organisatie is 15-20 planners. Voor planning, gebruiken we KEWILL met toegevoegde eigen intelligentie.

P.5 Does the planning application/software use real time events, disruptions, consignments in transit?

Nee, wel track and trace standaarden en statusmeldingen, die zitten in lijstjes per orde zodat je wel kunt zien of het via planning verloopt, maar niet fysiek op een kaart. Je wil namelijk vooral weten of het in de pas loopt of niet. Dat kan ook met een lijstje in je TMS wat dat slim weergeeft en op acteert. Het geeft wel inzicht als je een kaartje hebt, maar is niet noodzakelijk. Het is meer noodzakelijk dat je weet wat de status is. Intermodaal is slecht beschikbaar, er is weinig data, we zijn afhankelijk van de openheid van leveranciers. Voor ons is de route niet van belang we geven het uit aan een carrier, bij dedicated transporteurs kunnen we op het GPS systeem kunnen inloggen. Kunnen ze eventueel extra freight toevoegen

SH. 1. When a shipment is received, does this shipment always have the same data format?

Verschillend, edi, email, excel, klant specifieke portals. Andere vormen zijn bijna uitgestorven. Sommige kunnen we inlezen andere moeten we zelf overnemen. Er zijn wel standaarden maar daar houdt niemand zich aan.

SH.3 What data fields are needed for transport planning?

Laad Referenties, specialistische zaken, ADR, zijkant lading, over het freight - lengte, hoogte, breedte, gewicht, huidige locatie, temperatuur.

P.7 What are the steps that you take to create a transport plan?

Eigenlijk is het zo; Aanvraag — Matchen — Shipment verwerkings process — plansysteem — optimalisatie deel geautomatiseerd, deel planner. Planners weten heel van de markt en net wat dingetjes die je niet geautomatiseerd kunt doen. Bij klanten zijn vaak afwijkingen die niet in business rules te vangen zijn, waarmee de planner net wat beter kan omgaan dan het systeem.

E.1 Do you monitor real time events in the transport network?

Ja, het weer, traffic, road blocks en zo. Bijna nog alles handmatig. Bij bepaalde verbindingen en overgangs verbindingen, zijn er stakingen, hoog en laag water stand. Zorgen dat er voldoende ruimte in de planning

is aan de voorkant, dan op de rand gaan werken. Actuele info kan altijd veranderen en dan zit kan je opeens vast zitten

D.1 Which data sources do you use for real time data?

Brancheverenningen, infra beheerders, de markt, belangrijkeschakelpunten, collegas, word allemaal handmatig gedaan.

D.2 Are there specific consignments for which real time data is essential?

In het algemeen, niet specifiek voor een order

M.1. Which transport modalities are being used?

Alles behalve pijpleidingen. Spoor, binnenvaart, deep/short sea, weg (ook bestelwagen) en luchtvaart.

M.2 Which factors influence the decisions to use a certain transport modality for a consignment?

Meest gunstige combi van doorlooptijd/prijs. Voor het short tijd: lucht en weg. Voor het laange tijd: Water and spoor. In algemeen, milieuvriendelijker en goedkoper, frequentie, doorlooptijd, schedule, closings, slotboeking wel of niet.

E.7 What are current disruption handling options?

Short term, is moeilijk om te veranderen. Mid en long term disruption handling impliceert modal-switch. Eerst overleg met de klant, i.v.m de extra kosten die kunnen ontstaan. Kijken wat er in de keten kan. Theoretisch kun je wel switchen (tussen modaliteiten), maar in praktijk vaak niet. Het netwerk van andere modaliteiten. Moet van vergelijkbare kwaliteit zijn, doorlooptijd. Je moet ruimte bij een andere carrier hebben ander krijg je merge en dit extra kosten, kan wel doorleggen misschien aan de klant maar die zijn daar natuurlijk niet blij mee. Als iets niet op tijd is voor een afgegeven planing. Kan om weken gaan, kan om uren gaan. Ligt aan modaliteit type of lading. Lokaal bufferen kan disruption in ogen van de klant voorkomen.

E.2 What do you consider a disruptions?

Traffic Jam/Snow, Het hangt van het vervoermode af. Deep sea vervoer - vessel wisseling/douane (papier niet in orde) kan duerde dagen of weken. Luchtvaart - afhandeling half uur tot anderhalve dag. Weg - congestion/ te krap plannen. Het heet cascade effect of spill over effect. Spoor - Kapot spoor/wachten op elkaar (rood sign) /machinist of locomotief wissel duurt lang/ planning spoorbeheerder/intercity krijgt voorrang; trein path missen (30 min tot half dag). Voor het binnevaart; hoog laag water/afhandeling haven/sluizen (kapot).

E.6 In case of a delay when do you inform the consignor about the delay?

Afhankelijk van de situatie. Soms is een telefootje genoeg. Informeren via telefoon en mail. Deels is geautomatiseerd, afhankelijk van partners en keten. Als het geautomatiseerd is gaat het vaak via portals, maar ze krijgen ook een mail. Daardoor hoeven ze niet constant de portal in de gaten te houden. Ook

wordt het vaak bepaald samen in overleg met de klant, hoe ze willen worden geïnformeerd. Vaak moeten ze zelf achter vertragingen komen, soms krijgen ze wel een geautomatiseerde notificatie/mail, maar is vaak te laat.

E.8 Is it possible to transfer a consignment at a partner carrier in case of a disruption?

Ja, dat gebeurt wel, het is heel verschillend hoe lang dat van te voren moet. Vaak in dagdelen tot een paar uur.

E.9 What factors are considered for re-planning?

Zelfde zaken als bij aanmenen, kan het past het, kan de leverancier het aan, ADR, zijladen, kwaliteit, partij en zo.

E.10 What according to you is an optimal disruption handling process?

Ten eerste, onderscheid maken tussen: Strategisch, tactische en operationele vertraging, per type een tijd horizon afspreken. Tweede, tactische voldoende plan horizon, veel meer via geautomatiseerde systemen informatie voor hebben. Paar dagen van te voren de informatie 2-3 dagen to 3 weken. Derde, informatie geven maar je moet er wel iets mee kunnen en daar dus spelregels voor afspreken tijdinterval afspreken, anders word informatie vergeten en vervolgens gebeurt het en staat alles op stelten. Laaste, het planning system moet advies geven en een planner moet uiteindelijk beslissen. Vaak zie je dat informatie op een bureau blijft liggen in de keten, vaak in het weekend dan komen ze er maandag achter en kan het niet meer worden opgevangen.

B.3 Freight Forwarder 3

This interview was conducted with a planner working at a freight forwarder situated in the NL, which primarily transports consignments via trucks.

S.2 Are you aware of SmT? and S.4 What are your goals w.r.t SmT?

Yes, I am aware of synchromodal transport. I think, it is an approach. Transition to synchromodal transport should be done gradually. First, it should be included in lanes where possibility to switch modalities exists. Routes with more transitional nodes, having greater possibility to changes modes, suit synchromodal transport better. I think we can make some improvement with our services using SmT. It will provide us flexibility to make and execute transportation of our shipments.

SH.2 What are the data fields of a shipment request?

We have our own standards for numbering shipments and specifying its attributes. For communication with different partners EDI standard is maintained.

SH.6. Are different modalities combined for transport of a shipment? Yes, for transporting shipments we combine modalities. The first mile and the last mile is done by trucks and the long haul or the main part is done by barge, mostly. We combine orders also, you can also call it Order consolidation. The most frequent is combining full truck load and less than truck load orders. Additional research is going on for this in a different research project. It is a part of the planning. Order consolidation as a part of re planning (when an disruption has happened) is not done and also there is little scope of it. This is because, the resources have to be booked much in advance, for example, the booking for a train lane is done much in advance, like 1 or 2 months.

P.1 How is transport planning done? Manual or via a planning software?

Currently we do not have a software for automatic planning of shipments and our planners make the plans manually. Integration of data to make plans is done manually, by our planners. Re-planning is done when we want to change the route or carriers for a consignment.

P.4 Which planning applications/software is currently used for planning? What are the optimization parameters?

Planning is done by our planners. We do have a control tower running which you can see on the big screen, outside. It is not actually a tower, it is just a separate office. Control Tower is a buzz word. Control tower is assigned with the work of real time information gathering and providing track and trace facility to the customers.

D.1 Which data sources do you use for real time data?

Right now, there is not much disruption information we use. In road network it is possible to get that

information. But in deep sea vessels, hinterland transport and train transport there is not much information which we are getting. There does exist information but we don't know where to get it, what are the security matters attached to it and when we have the data, we are not sure how can we use it. Till now the disruption information is got only by email or call. There is no way to see what is going to happen in the future at an inland terminal. When the trains are late, we don't get to know it. Even if we get to know about the delay, it is so late that no remedial action can be taken.

M.2 Which factors influence the decisions to use a certain transport modality for a consignment?

The price decides the modality. In some cases where fast delivery is required we use trucks only. Transport bidding is done but using our bidding portal. Almost in all case the cheapest option is chosen by us and also by the carriers.

E.1 Do you monitor real time events in the transport network?

Yes, our control towers monitors and show the location of our containers to the planners. If we get the location of events in the network then we can match it with the location of the source, the pick up location and destination, the drop-off location, or locations along the route. If the location for disruption lies in a 1 or 2 km radius of the source or destination - then it may affect the route and the delivery time. In future, if containers have geo-tags and we know the location of one container, we can determine the location of other containers which are part of the same consignment.

E.2 What do you consider a disruption?

Pick up vehicle is late, temperature low in a container or a customs hold up are all disruptions for us. A truck may raise several messages, but only those messages are shown to the planner which cause a problem with an consignment. Also if any truck is taking more time than normal, it should be noted, since it can be the start of possible disruption.

E.4 What is the current disruption handling policy?

Sometimes we have to change the route or carriers assigned to an consignment. Last minute changes have high costs attached to them. We avoid making such changes to consignments in transit. Sometime our planners can call the client and inform about the new situation, delay or disruption. By conversation, problems can be sorted out. A possibility is that a short delay does not make a difference to the client. In that case there is no need for re-planning.

E.10 What according to you is an optimal disruption handling process?

Order consolidation, handling disruptions for hinterland, trains and deep sea vessels. There exists service level agreements between us and the carriers which causes lock-ins. Lock-Ins prevent flexible bookings and changes to existing plans. We book train tracks for transporting our consignments and these lanes are booked much in advance. It is not possible to change the bookings at the last moment. Any changes incur lot of money loss.

B.4 Freight Forwarder 4

This interview was conducted with a planner working at medium sized freight forwarder situated in the NL.

SH.2 What are the data fields of a shipment request?

Our clients provides shipment data in a fixed format and then we map it manually to the data format we use internally. For communication with partners we use EDI/EDIFACT protocol. It is going to stay that way because it is a standard, until the market changes and a new standard comes along. We have our own standards and our partners have there own. So someone somewhere has to do the translation from one format to another format.

D.2 Which data sources do you use for real time data?

Till now, disruption information is received by email or call. Currently, we don't have a data feed and therefore for the status of consignments we always have to ask for information. We depend on others. This is one of the reasons why we get information so late. Many times, the information is there but our carriers do not share that information. It happens a lot in case of big ports and terminals.

E.1 Do you consider real time events in the transport network?

As I said, carriers provide tracking and location data. Terminal operators provide ETA of vehicles. Now a days, some clients request live status of the consignment, if it is desired by the client, we put sensors on the containers. The customer has to pay for it.

E.4 What is the current disruption handling policy?

No remedial action can be taken, if the trains are late. Because we get the information too late and also proposing to stop at a intermediate location is not a possibility. It is very expensive to change the plan when a leg has already started. The planner has to re-plan the consignment manually and has to consider many factors, cost, service contract, possible routes, availability of vehicles, etc. Disruption information can be got from calling out partners. Advance booking is required for vehicle so even if we want to change the route of the consignment in real time, it could be that our carriers have no available vehicles.

P.1 How is planning done? Manually or via a planning software?

Planning and monitoring is done manually.

B.5 IT Consultant 1

This interview was conducted with a consultant of an IT consultancy company providing IT consultancy services to clients in NL. The services provided by the company includes developing IT applications specific to the application integration challenges faced by its clients (here, freight forwarder). The interview was conducted in Dutch.

P.4 Which planning applications/software is currently used for planning? What are the optimization parameters? and D.1 Which data sources do you use for real time data?

Er zijn genoeg soorten planning software in omloop, dus we integreren data die er is in een app. Bijv. we halen vaarschemas van rederijen op en van marine traffic kunnen we de actuele data ophalen. Dan plotten we dit op een route en kijken we hoe ver het schip is ten opzichte van de planning. Zelfde geldt voor bijv. flightradar. Voor verkeer gebruiken we planning software bijv. PTV. Het neemt actuele verkeerssituatie mee. Ook zijn er scrapers gebouwd die automatisch data van websites halen, omdat anders alle planners dezelfde informatie aan het opzoeken waren, wat niet efficient is.

P6. Does planning application/software provide feedback, for example color coding to see the status of a transport? What kind of feedback?

Ja, dat doen we met kleur of met icoontjes, zit het in een personenvliegtuig of cargo. Zoveel mogelijk visueel weergeven.

SH.1 When a shipment is received, does this shipment always have the same data format?

System kan shipment inlezen, deze zijn alleen niet altijd in hetzelfde formaat, door gebrek aan standardization ze moeten worden toegewezen aan een centraal formaat

SH.3 What data fields are needed for transport planning?

Properties van het shipment, bijv, lengte, hoogte, breedte, gewicht, temperatuur, hoeveelheid en zo.

P7. What are the steps do you take to create a planning for this order?

Shipment Intake — ongestructureerd, via mail, telefoon, edi, fax, papiertjes alles is in oploop. Daarna, grote transportplanning. Het woord afgebroken over de voertuigen heen per dag. Past het niet versleutelaar, charters ingeschakeld. Dan gaat het de operatie in, dus via boardcomputer worden routes naar de chauffeur gestuurd. Voor carrier is de makkelijkst, i.e. eigen middelen, eigen planning, bij 3PL and 4PL word het dus moeilijker. Ook, er zijn 150+ TMS-systemen in nederland, heel gefragmenteerd.

D.1 Which data sources do you use for real time data?

Het weer, verkeersinformatie, werk aan het spoor, wegwerkzaamheden en zo.

M.1 Which transport modalities are being used?

Ligt aan de freight forwarder.

E.9 What factors are considered for re-planning?

Start/End date, Start/End location, Driver, Truck, Modality, Shipment characteristics.

E.2 What do you consider a disruption?

We heeft normtijden aangebracht: (verwachte) vertrektijd, als daar zeg, X tijd overheen is dat genereert hij een alert. Zelfde geldt met ETA, als deze veranderd wordt het aangegeven, en als het buiten de normtijd valt, geeft hij aan dat er naar gekeken moet worden. Bandbrete's kunnen worden ingesteld om in te stellen hoe vaak het systeem moet controleren. Parameters kunnen daarbij zelf worden ingesteld.

E7. What are current disruption handling options?

Bij een vliegmaatschappij boek je vaak capaciteit bij een maatschappij en daardoor wordt er niet vaak reboekt i.v.m de extra kosten. Van te voren word capaciteit ingekocht en daartussen kun je nog wel schuiven. Maar als het al onderweg is ben je heel beperkt. Bij lange afstand transporten kun je soms nog wel wat veranderen, bijv. eerder op een truck plaatsen vanaf een vliegtuig/ship. Op het moment dat de vracht beschikbaar is kun je variëren (stil ligt in een hub). In hinterland je kan het meeste tijd besparen.

E.6 In case of a delay, when do you inform the consignor about the delay?

Het kan worden geautomatiseerd, maar veel freight forwarders kiezen er voor om het zelf te doen om toch het klanten contact te houden. Ook worden ze alleen geïnformeerd op basis van afgesproken regels.

E10. What according to you is an optimal disruption handling process?

Centrale dienst vanuit control tower, iedereen regelt het namelijk suboptimaal voor zichzelf. Pluggable service i.e. abboneeren op data diensten / andere kant providers die de data in een keer ontstluiten. Een community platform waar alle betrokken stakeholders op zijn aangesloten. Om te overleven als bedrijf zullen ze moeten gaan samenwerken.

B.6 IT Consultant 2

This interview was conducted with an IT expert of an IT consultancy company which specializes in the collection and preparation of real time traffic data. It provides this data to freight forwarders and carriers, where it is used for transport planning.

S.3 What is your opinion about SmT practice?

I think success of SmT is based on better track and trace information. In tracking sense, one minute is called real time. In traffic sense its real time. If we have a new data source, say Garmin, one more mapping will be required. Usually, we do the mapping ourselves. Some feeds are easier than others. In NDW its standardized. Some providers feed their data, so that is standardized. In commercial sector standardization is not a big issue for companies. It is not good for their business. When these kinds of real time data is being used for planning then it is good to give the data along with a surety percentage or probability.

P.1 How is transport planning done? Manual or via a planning software?

The planning process we do not perform at the moment, it is the work of our clients, for which we make software. The control tower, used by some clients, focuses on operations and not on planning. The planning software of our clients is quite complicated and also uses traffic profiles, it is not known where do they get their traffic profiles from, but, those profiles are there and also used for planning software. The algorithm is basically an optimization problem.

D.1 What data sources do you use for real time data?

We do not consume the data ourselves. Analytics is not a very big piece of work we do, it is done by other companies, we simply do providing, preparation and curation. In our system, preparation and curation is a very big block. Visualization is something which we also do but that is not our primary job. Visualization is also sometimes provided by the analytics parties, i.e, not us. It is very explicit what we do — data collection, data preparation, data curation and providing access. Preparation and curation especially, in our case, because we deal with different kind of location referring, that is a hard part, so it takes a very large part of our system. In a different project we developed an analytics platform for road events, which was made for one of the highways in NL, where they suffer with a lot of ghost traffic jams. They are jams which do not have a specific cause rather are due to ripple effect. So, it means that we are the data provider and where we get our data is at the road basically, but our main job is taking away the difficulties of data collection and preparation for the other parties, those are companies that analyze data and provide advice to truck drivers and cars based on our data. The advice can be as simple as people installing app in their car. In other project, via a control tower, congestion are related to the routes, on which the trucks are driving, and we know those routes. Well, by doing a lot of location refereeing, we

reference all the data from Tom-Tom to the road network. We related the routes of the client to the road network and then you can relate them to each other. Those calculation are made by an ETA module. It is rather a complex algorithm. It also takes into account the obligatory breaks for the drivers and traffic conditions. Those data parts are combined and shown on the interface of the control tower but, are not connected to the back office system.

E.7 What are the current disruption handling policy?

Well, their trigger is the ETA, whether late or early and that is their, operation triggers. So for all the trucks they can see the ETA for every point. If they have to schedule something now, on a route which is congested, then they make a new plan. Change of plan is formally not a function of a control tower, but it will be in the future. Re-routing based on congestion is an entirely new step. Well, we can give that advice in the future but not at this moment. Plans are fixed and can be made anytime between one month to one week. They are changing to an ad-hoc planning approach.

E.3 Which type of disruptions occur the most?

The information which the operator sees on the screen is for hours ahead. Real time traffic conditions do not have a time horizon of long, they are valid now. ETA based on current conditions can be valid for one hour but not for more than that. For long prediction we use the profile data which is the average of what the road conditions are on a given road, on the given time, on a given day of the week. We buy the data from Tom-Tom, based on months of data. The estimation is also pretty close if it is based on just one month. Ten months is a large data set. Because traffic conditions can change by seasons and in NL traffic jams are a lot, the window should not be too long, though the optimum time period is not known. In my opinion, is it approx. three months.

IT.2 What is the current data storage policy?

There are few things, we are working on a new system for a different project. The control tower, does not use a fancy database framework, it is just a JAVA system, The DB is Postgres DB. It is written in JAVA, uses JPA for the DB interaction, sprain framework as an app framework. A system which we developed for a client is based on AKA actor framework, written for SCALA. AKA provides an event stream, an application event bus, and that we use for streaming data. The new version of the system, has all micro services running in a micro service cluster and all data is streaming on one big distributed message bus, and we use APACHE Kafka for that. And, it will fit in the new big data realm, as it is a distributed, partitioned, message bus basically.

E.9 What factors are considered for re-planning?

NDW is a relevant source of data. It is rather a prominent one, government operated broker for traffic data, And, we use most of the features, NDW provides. Flitsmeister is a company which build apps, and which people can install in their smartphones and can warn other people if there is a traffic jam or

accident. It also warns people if a speed camera is coming up. This app posts the speed, direction and location of the vehicle, every minute or so. It posts the data on the Flitsmeiter server, and we also get that data, so basically, it is a floating car data. Tom Tom is basically a commercial feed based on floating car data, Tom Tom gets the data from the cars of people and processes that data, provides to us and other companies. It is not free, and there are more commercial providers, e.g., an American company, Inrix, we also consume that data, their data is based on floating car data. We also have it from HARE. Then we have data coming from Ministry of Infrastructure and Milieu and also from Rijkswaterstaat. These data are government owned data, semi-public. I would not call them open data. NDW is a part of Rijkswaterstaat. Rijkswaterstaat makes some of their data available via NDW but not all of it. They have different interfaces. Teleatlas, is a commercial map provider. It provides a map of all roads, the properties of those roads and the interconnections among those roads. Teleatlas is a part of Tom Tom. OpenStreetMap, that's open data.

SH.1 When a shipment is received, does the shipment always have the same data format?

I can not tell you about shipment but I can for events. Usually there is a custom job for each feed provider, since all formats and protocols are different, We combine different data and map them on one grid i.e. Teleatlas. For a project, we have an even smaller grid. We like to be as map independent as possible. The actual process of determining, where actually a location on the road is, is quite difficult and is called location referencing (LR). There are different techniques for location referencing. Each feed provider uses a different one, usually some variations of the main ones, we translate all of them to OpenLR, which is also an open standard, we decode that. That's how we do it. How NDW or Tom Tom is collecting data is not our concern. The most common case is an FTP site, where file is posted every minute, we download the file, XML or HTTP or JSON or web sockets with JSON, with Rijkswaterstrat is just a text file, which we have to parse. Our own standard is the OpenLR, all other methods which we have implemented maps to OpenLR. NDW provides locations which are in the profile, and real time data. These locations are basically, translated into OpenLR and then decoded, in Teleatlas, so it can be related to road network, and we end up with decoded locations. Real time data, just has a numeric id to the location, for the combined data set. Lets take an A58 50 m segments as an example, which are already described in OpenLR so they don't need to be translated. Then they are decoded, on Teleatlas map, and given that both this and this one is decoded on the same map, then we can combine them. It seems simple but, it is not. With these coverage and this real time data, we can relate real time data to the road segments. A location basically says that, this little segment from NDW is semi-static, it doesn't change that often. So this location can be translated and decoded and usually stays the same. And this just bears a location ID 1 2 3 4 5 , which is also described here, has speed 110. E.g., given that it can be coded and decoded and you can calculate coverage and this is real time data, we can relate this real time data to the segments. The locations lets just say that well, this little segment from the NDW is on the A1 highway and its semi static, its doesn't

change that often. And this just bears an ID, and let us say that locationID 12345, which is also described here, we get now which segments are actually described by segment 12345 and then we can relate this real time data with the segment, and that's basically just gives us another real time data feed. This is called fusion. Fusion also supports taking in different sources of data like NDW and Tom Tom into one data set.

B.7 IT Consultant 3

The interview was conducted with a consultant of an IT consulting company providing IT solutions to freight forwarders and carriers in NL.

S.2 Are you aware about SmT concept and practice? And S.5 How will an integration platform aid in SmT?

Synchromodal transport is a smart-flexible way for transporting consignments. A major challenge if we look at synchromodal transport, is aggregation of the load. So from the freight forwarder point of view, I ask the question, how can I split my load and combine my load? SmT is based on integration, supply chain integration, and will require more collaboration between freight forwarders and carriers. An integration platform can provide a solution for integration of different applications.

P.4 Which planning application/software is currently used for planning (by freight forwarders)? What are the optimization parameters?

The IT portfolio of freight forwarders is old. In a project, I worked with an international transport freight forwarder company operating from Schiphol airport and they were still using Excel sheets for planning. I mean, this is just an example. Some companies use specific software and applications. As another example, I worked in a project where the freight forwarder used a planning application, and they just migrated from a 2008 version to a 2012 version. Using an old version of the software was limiting the amount of functions that the software has, so they decided to update the software.

IT.1 Which software/applications are currently being used?

This depends on the freight forwarder. There are some applications which are generic, like financial applications and some are transport specific like TMS, WMS, FMS and APS. There are also many documents which planners frequently refer to like customs regulations and requirements. The applications used by a freight forwarders require some kind of integration, otherwise there is a lot of manual integration to be done by the planner. A data integration layer over the applications being used, solves the integration problems. In this way every application can use the functions of every other application. Our company developed a data integration layer for a freight forwarder and provided integration between back office applications, B2B application and employee—employer. The freight forwarder had a total of 16 different systems and had an overlap between their functionalities. The cause of so many systems and low integration between them was, the freight forwarder has been through multiple mergers and during those mergers, they did not integrate their applications. For the freight forwarder we had to achieve a total of 97 integration to make a data integration layer such that all systems used by the freight forwarders are integrated. For another client, a carrier, we had to make a data integration layer. There were 6 systems supporting daily operations of the carrier. One of those systems was developed in-house.

IT.2. What is the current data storage policy?

There is one generic internal data storage where all data is stored. I always say that for a common policy for data, the first step for the freight forwarders or carriers is to create data integration layer.

IT.3 What are security mechanisms for data security and privacy?

There is limited data sharing between transport companies. Everybody attaches a lot of importance to its own data and shares it only with trusted partners, for example, in a consortium. There are some integration challenges which are in the way of data sharing. A data integration layer provides an API with which other companies can connect to the applications being used by a carrier or freight forwarder. But the main question then is, does the freight forwarders/carrier wants to share its data? Proper data governance policy is needed and this again depends on specific needs of the freight forwarder/carrier.

B.8 Research Group

This interview was conducted with a project coordinator of a research institute. The interviewee is responsible for the management of various logistic projects in the institute.

S.2. Are you aware about SmT? and S.3. What is your opinion about SmT practice?

Yes, Synchronomodality is innovative and I have heard about it from different projects. There are no concrete implementations yet.

P.1 How is transport planning done? Manual or via a planning software.

Advanced freight forwarders may use planning software to enable their planners plan consignments. But, I still see many of them using excel sheets and coordinating via emails and calls.

IT.1 Which software/applications are currently being used by freight forwarders?

It is quite a generic question and I would say that it depends on the many factors. The size of the company is a big factor. I see many freight forwarders still use spreadsheet software to make their planning. Though they would like to use specialized applications but it might require additional expenses. They keep in touch with carriers via phone or email to monitor consignments. Yet, some freight forwarders use specialized software for planning and monitoring. Generic names for such applications could be transport management system, fleet management system and financial applications. Depending upon the freight forwarder, some might also use warehouse management system and planning software. So, I would say you have to consider each freight forwarder separately and also consider the transport modes on which a particular freight forwarder operates on.

IT.2 What is the current data policy? and IT.4 What are the current mechanisms for data sharing with carrier?

I think it depends on specific freight forwarders. You have to consider that the different applications used by the freight forwarder are often not integrated with each other. This totally depends on the kind of company and usually there is a lot of manual work for maintaining data. Actually, it is the carriers which provide data about the vehicles and consignment to the freight forwarder. Some freight forwarders and carriers use a kind of marketplace. If a freight forwarder is in need of a carrier it can put a request for transport on that marketplace, so transportation request are made public by the freight forwarders. At the same time capacity information is made public by the carrier. Apart from this, data about consignment in transit might be shared by carriers, as I said before.

B.9 Summary of remaining stakeholder interviews

B.9.1 Theme 1 - SmT stakeholders, goals and requirements

Interviewees' responses to question S.1 suggests that the division of transport companies into freight forwarders & carriers is at times, difficult. In practice, there is an overlap between the two roles as many transport companies perform both roles. E.g., in some geographic regions (or for a cargo category) they function as a freight forwarder, while in other geographic regions (or for a different cargo category) they might function as a carrier.

Transport companies vary considerably in size. While small-to-medium sized freight forwarders do not own trucks, relatively bigger freight forwarders own trucks and use them for short haulage. Even bigger freight forwarders, e.g., those having predominantly international consignors, may build/lease inland terminals and ports. They use inland terminals/ports strategically, to accomplish regional monopoly. Consequently, they also invest in transport infrastructure development (new railway lines, new terminals, better waterway infrastructure) in their region. Via improvements in transport infrastructure their goal is more profits and improved services. Interviewees' responses to question S.3 suggests that their opinion about SmT is influenced by the transport company they represent, and its size. For small-to-medium freight forwarders, data and its properties, e.g., availability, security, reliability, etc. are major challenges for SmT. For big freight forwarders government policies, infrastructure improvement seemed to be the main challenges.

The Government, at the national as well as the European level, is a critical SmT stakeholder. At the national level (in NL), sustainable transportation is one of the main areas for research and innovation. It has considerable research funding, public-private initiatives and governmental support. At the European level, synchromodality, an integrated European transport network is pivotal to the Horizon 2020 vision of the EU.

In the course of my research, I noticed a change in stakeholders' opinion regarding SmT. During interviews in 2014-2015, most freight forwarders' opinion over SmT were driven by curiosity and interest. During 2016-2017, it grew to a better understanding of SmT and its challenges. In rare cases the change of opinion was from, conviction to skepticism to outright disapproval of SmT's applicability in the transport domain. In 2014, an employee working at an inland terminal, was quite keen during the interview and discussed the potential benefits of Synchromodality, at length. Gradually, his views changed, he also changed this employer and started this own consultancy company. Eventually, in 2017, he gave a presentation (attended by me), titled SynchroWhat?, where he questioned the term itself, besides questioning its applicability in the transport sector.

During interviews with representatives from research groups and IT consultants, I discovered that some of them are/have been involved in project(s), where the project goals and results are applicable to SmT.

Although, the project titles or descriptions, may not contain the term SmT, the results of such projects can be reused. Consultants reported that the term SmT is practically unheard of outside the Benelux countries.

Although, transport companies are aware of the benefits from SmT, they do not consider SmT as a lucrative business case or a potential market disruption, yet. They have their reservations over profitability, customer satisfaction and risks associated with SmT. They communicated, handling disruptions better and improved visibility of the transport chain, as their main goals.

Most transport companies in NL, are part of one or more consortium. They also have many business alliances with other transport companies. Therefore, the impetus and subsequent success of SmT seems to depend on other transport companies in any given consortium or alliance. Frequently, there are few leading companies within such consortium. They drive the policies, standards and opinion about new practices, of the whole consortium. For the success of SmT, such companies in transport consortium have to be identified. Their opinion over SmT is useful to understand transport companies' perception of SmT. The same can be said for alliances between transport companies. Mostly, the bigger transport company dictates the processes and policies to be adhered in an alliance. Therefore, small to medium sized transport companies may not start performing SmT processes or invest in technology for SmT until their partners also do the same.

The benefit of SmT in terms of monetary gains are unclear to the transport companies. They are of the opinion, that extra efforts needed for SmT (e.g., new personnel, IT systems, change in route plans, change in business processes), not only disrupt their current business processes but also cause inconvenience to their partners and consignors. Although, handling disruptions better and improved visibility of the transport chain, are freight forwarders' main goals, yet, they are uncertain about how this can be achieved. While responding to question S.6, they discussed generic implementation scenarios, only. Rarely did freight forwarder's have a road-map for using real time data for prediction, forecasting and disruption handling. The risks related to SmT were of concern to all transport companies interviewed by me.

Stakeholder answers to questions S.5 and S.7 were varied. Few stakeholders seemed unsure of, what is meant by an integration platform and what functionalities it should have. However, the requirements for SmTIP could be deduced from stakeholders' responses. For instance, skippers in NL have access to many free and paid information services, e.g., lock opening times, free parking bays, bridge opening times, congested waterways, (AIS) locations of vehicle, etc. To view all relevant information they have to manage multiple screens, hand held devices and their mobile phones. They require a system which can combine relevant information from different sources and present it on a single user screen. Similarly, inland terminals attach high priority to a precise time of arrival, for ships and barges. For them, the availability of data from big ports is limited and at times, unreliable. Their daily operations are frequently affected by events at big ports, e.g., if a deep sea vessel is delayed at a port then their whole planning is affected. Thus, they

require a system which can use multiple data sources and predict events based on historic data.

B.9.2 Theme 2 - Current state of practice in transport sector

Different terms are used by stakeholders to refer to a shipment, e.g., an order, a booking, a load, a consignment, etc. Usage of the term depends upon the stakeholder's role, i.e., a freight forwarder (order), a carrier (consignment), a infrastructure provider (load).

New shipment data is received by transport companies in different formats (.txt file, EDI, XML) and via different media (emails, phone calls, websites). Most transport companies have longstanding consignors, with recurring shipments. In such situations, since previous shipment information is already known to planners, they make a new shipment and fill in the required details, on behalf on the consignor. This saves the consignor from repeatedly sending the same details for each recurring shipment.

There is always a formal contract between a consignor and a transport company. The contract is a terms of agreement document, specifying liability, ownership and service rules. Contracts are demand specific, require origin and destination and have corresponding time windows. Transport companies are aware that flexible/dynamic transport agreements are a prerequisite in a SmT scenario.

All transport companies interviewed for this research, perform transport planning manually. The work of a planner at a freight forwarder is arduous. They have to monitor the transport network round the clock. Employment contract for planners' position specifically mention that they may be required for their work at any time of the day. Interviews with planners indicated that expertise and knowledge of best practices in transport planning, is acquired thorough years of experience. Planners frequently work with multiple computer screens on their desk, each showing a different aspect of the transport network.

Stakeholder responses to question, P.7 reveals that bookings for vehicle capacity and infrastructure use are made by carriers much in advance. For example, to transport a shipment using a freight car, a carrier has to book the railway track for the desired time period, at least 2 weeks in advance. Any subsequent changes in the bookings by the carrier, entail considerable financial cost and may reduce the carrier's business credibility. With the emergence of web portals for transport service bidding and capacity sharing, transport companies are beginning to explore alternative methods of infrastructure use.

For scenarios, wherein the delivery of a shipment is exceptionally delayed due to disruption event(s), transport companies have clear agreements with the consignor. In accordance with the agreement, if the consignor is to be compensated for delays, then transport companies purchase insurance policies to cover such compensation costs.

All transport companies reported that currently they use limited to no contextual data in transport planning. During the interviews they discussed functions they would like to perform if relevant contextual data is available, e.g., analytics, ETA estimation, delayed barge planning, etc. A major concern for them is semantic interoperability, arising from different data sources providing data in different formats. On

being asked question IT.3 and IT.4, data privacy concerns came of transport companies and infrastructure providers came to the forefront.

During interviews, I was informed about ongoing projects which aim to create a shared information space. The aim of such projects is to enable transport companies and infrastructure providers, actively monitor the usage of data shared by them. Transport companies seem ready to share data with partners, if they get compensated, either monetarily or via other means. Besides privacy, the reliability of information is a concern for transport companies and infrastructure providers. At times they receive conflicting information about the same event from different data sources. Such situations make it difficult to use the information for decision making, since it may be unclear, which data source to rely on.

In response to question D.1, transport companies indicated that data in a transport chain is passed from one partner to another. If some partner in this data pipeline, is unwilling to share data then the required data is unavailable for subsequent partners down the pipeline.

Carriers' responses to question M.1, indicates that most carriers specialize in one transport mode. A planner's decision to use a certain transport mode depends on several factors, including, the agreement with the consignor, transport cost and available capacity. Besides transportation costs, the handling costs for a shipment depends on the chosen modality. Frequently, freight forwarders encounter lock-in situations with carriers. A lock-in occurs when a freight forwarder is bound to use the services of a certain carrier or an infrastructure provider. Many factors could lead to a lock-in situation, e.g., alliances, consortium, longstanding business relations, regional monopolies, service quality, etc.

IT applications used by transport companies are, planning/TMS application (helps the planner to plan, no automatic planning) and financial applications for sales and accounting. The data used by a freight forwarders for daily operation is transport data and track and trace data.

Appendix C

Detailed stakeholder requirements for SmTIP

R1 Supports the planner to play the role of a central logistics provider

R1.1 Add/Edit/Delete Orders

R1.1.1 Add orders manually using an add order page

R1.1.2 Export orders from different file systems

R1.1.3 View all orders (complete, in-transit, waiting, disrupted)

R1.1.4 Edit the fields of an order

R1.1.5 Delete an order

R1.2 Add/Edit/Delete LSPs in an order job

R1.2.1 Assign an LSP to an order part

R1.2.2 Edit/Change an LSP to an order part

R1.2.3 Delete an assigned LSP

R1.3 Can contact every party involved

R1.3.1 Contact customer for his order, email directly from the artifact

R1.3.2 Contact LSP for his order(s), email directly from the artifact

R2 Shows the entire transport chain to the planner

R2.1 Show the supply chain from start to end to the planner

R2.1.1 The planner can select an order can see all stoppages, all LSP assigned, all disruptions

R2.2 Show the current location of the shipment

R2.2.1 The planner can select an order can see its current location

R2.3 Show the ETA at destination

R2.3.1 The planner can select an order and see its ETA for it destination stoppage

R2.4 Show major events along the route

R2.4.1 When an order is selected all know disruptions along the route are shown to the planner

R3 Should allow the planner to use smart planning applications

R3.1 The planning algorithm should consider expected demands

R3.2 The planning algorithm should provide best route based parameters given by planner

R3.3 It should be possible to change the parameters for route planning

R4 Support the planner to change the already made planning in real time

R5 Support the planner to switch consignment between transport modes

R5.1 Show modality changing options for an order along a route

R5.1.1 Order route can be divided into parts, called legs

R5.1.2 For each leg an LSP can be chosen, while order is not completed yet

R5.1.3 For each leg a modality can be chosen, while order is not completed yet

R5.2 Show modality changing resources required

R5.3 Show modality changing capacity required

R5.4 Get status of modality change

R6 Support the planner to aggregate demand in order to get the best transport offer

R6.1 Bundling of orders should be included in the planning algorithm

R7 Be able to give the planner, carrier and consignor an integrated transport system

R7.1 All possible routes should be shown

R7.2 All intermodal hubs should be shown with facilities

R7.2.1 On a map all order stopped/moving must be shown

R7.2.2 On a map all hubs/stoppages must be shown

R8 Be able to make a synchronized combination of transport modes and services to the planner, carrier and consignor

R8.1 Allows orders to be booked mode free

R8.1.1 Customer can book order mode free

R8.1.2 Customer can specify the mode with which it wants the transport

R8.2 Allows to compose an order route with different modalities and partners

R8.2.1 See from order-list which orders are mode-free booking

R8.2.2 Select a mode free order

R8.2.3 Choose the next stoppage for a mode free order

R8.2.4 Choose the modality for next stoppage

R8.2.5 Choose a date for the transport

R8.2.6 Check whether specified modality exists between current and next stoppage

R8.2.7 If modality exists update order plan and order status (to open)

R9 Should enable the planner to cope with disruptions regarding every transport mode

R9.1 Get Live Updates of Disruptions

R9.1.1 Identifies the sources causing disruption

R9.1.2 Validates (or dis validates) the source of disruption

R9.1.3 Marks that hub/stoppage unavailable

R9.2 Danger Alert

R9.2.1 Is it a disruption ? Verifies if a disruption qualifies as one, according to the company policy or business rule

R9.2.2 Can record a disruption

R9.2.3 Get (and save) details about a disruption, like, location, mode, severity etc

R9.2.4 Alerts the planners about a disruption

R9.3 Effected orders must be shown

R9.3.1 Matches a disruption with order list

R9.3.2 Make a list of orders which are effected by a certain disruption

R9.3.3 Retrieves the order details of all orders which are effected

R9.4 Provides options to address a disruption

R9.4.1 Lets the user choose a disrupted order

R9.4.2 Lets the user re-plan the order

R9.4.3 Allows sending email to the customer

R9.4.4 Allows sending email to all successive parties

R10 Should enable the planner to distinguish user roles and their rights to view, add, edit and delete data

R10.1 Admin work

R10.1.1 An user-account for planner

R10.1.2 The planner can add, edit and delete all orders

R10.1.3 An user-account for customer

R10.1.4 The customer can see only his current and past orders

R10.1.5 An user-account for LSP (or partners)

R10.1.6 The LSP/partner can see only his current and past orders

R10.1.7 An user-account for Admin (or Super User)

R10.1.8 The Admin has access and privilege to edit any information

R11 Analytics

R11.1 ETA prediction

R11.2 Demand forecasting

R11.3 Event prediction

R11.4 The system can inform the planner about congested routes

R12 Should use contextual data for planning

R12.1 The planner can choose which data to use for planning

R12.2 Historical data can be viewed by the planner

R13 The planner should be notified of contextual events

R13.1 Events should be divided into urgent and non-urgent

R13.2 There should be an option for the planner to specify which events he wants to be notified about.

R13.3 Disruptive events should be saved in the database.

R13.4 It should be possible to share event data with partners.

Appendix D

SmTIP Disruption Rules

Situation 1 : A Container Event

```
1: rule SITUATION DETECTION RULE TO DETECT SITUATION 1
2:   define ContainerEvent1 as type (OntoSmT:Container_Event)
3:   define Container1 as type (OntoSmT:Container)
4:   ContainerEvent1  $\leftarrow$  OntoSmT : ContainerEvent
5:   Container1  $\leftarrow$  OntoSmT : ContainerEvent : isAbout
6:   if
7:     exists (OntoSmT : Container) such that
8:        $\$OntoSmT : Container : hasContainerID == \$Container1 : hasContainerID$  then
9:         OntoSmT : Container :: hasEvent = add(ContainerEvent1)
10:        SituationDetected (situation = ContainerEvent, event = ContainerEvent1, container =
        OntoSmT : Container)
11:    else
12:      do nothing
13:    end rule
```

Situation 2 : A Vehicle Event

```
1: rule SITUATION DETECTION RULE TO DETECT SITUATION 2
2:   define VehicleEvent1 as type (OntoSmT:Vehicle_Event)
3:   define Vehicle1 as type (OntoSmT:Vehicle)
4:   VehicleEvent1  $\leftarrow$  OntoSmT : VehicleEvent
5:   Vehicle1  $\leftarrow$  OntoSmT : VehicleEvent : isAbout
6:   if
7:     exists (OntoSmT : Vehicle) such that
8:        $\$OntoSmT : Vehicle : hasVehicleID == \$Vehicle1 : hasVehicleID$  then
9:         OntoSmT : Vehicle :: hasEvent = add(Vehicle_Event1)
10:        SituationDetected (situation = VehicleEvent, event = Vehicle_Event1, vehicle = OntoSmT :
        Vehicle)
11:    else
12:      do nothing
13:    end rule
```

Situation 3 : A Route Event

```

1: rule SITUATION DETECTION RULE TO DETECT SITUATION 3
2:   define RouteEvent1 as type (OntoSmT:Route_Event)
3:   define Route1 as type (OntoSmT:Route)
4:   RouteEvent1 ← OntoSmT : RouteEvent
5:   Route1 ← OntoSmT : RouteEvent :: isAbout : Route
6:   while
7:     exists (OntoSmT : Route) such that
8:       (Route1 overlaps OntoSmT : Route) or (RouteEvent1 : hasGeoLocation liesOn OntoSmT : Route)
9:   do
10:    OntoSmT : Route :: hasEvent = add(RouteEvent1)
11:    SituationDetected (situation = RouteEvent, event = Route_Event1, Route = OntoSmT : Route)
12: endrule

```

Situation 4 : The temperature of the cargo is more than the required temperature

```

1: rule SITUATION DETECTION RULE TO DETECT SITUATION 4
2:   Situation Exists ContainerEvent // Situation 1 exists
3:   define Container1 as type OntoSmT:Container
4:   Container1 ← $ContainerEvent : isAbout
5:   if diff $Container1 : hasRequiredTemperature and $ContainerEvent : hasValue greater than 5 then
6:     exists (OntoSmT : Consignment) such that
7:       Container1 : isPartofConsignment == OntoSmT : Consignment
8:       SituationDetected (situation = ContainerDisruption, event = ContainerEvent, Container =
9:         Container1, Consignment = OntoSmT : Consignment)
10:    else
11:      $Container1 : hasTemperature == $ContainerEvent : hasValue
12:    end rule

```

Situation 5 : Situation when a vehicle is carrying a consignment

```

1: rule SITUATION DETECTION RULE TO DETECT SITUATION 5
2:   define Vehicle1 as type OntoSmT:Vehicle
3:   Vehicle1 ← OntoSmT : Vehicle
4:   if
5:     exists (OntoSmT : Consignment) such that
6:       $Vehicle1 : isCarrying :: OntoSmT : Consignment == $OntoSmT : Consignment then
7:         OntoSmT : Consignment :: isOn ← $Vehicle1
8:         SituationDetected (situation = ConsignmentOnVehicle, Vehicle = Vehicle1, consignment =
9:           OntoSmT : Consignment)
10:    else
11:      do nothing
12:    end rule

```

Situation 6 : Situation when a consignment has a pick up vehicle

```

1: rule SITUATION DETECTION RULE TO DETECT SITUATION 6
2:   exists Consignment // There exists a consignment
3:   define Plan1 as type (OntoSmT:Plan)
4:   define TransportActivity1 as type (OntoSmT:Transport_Activity)
5:   Consignment1  $\leftarrow$  Consignment
6:   Plan1  $\leftarrow$  Consignment1 : hasPlan
7:   if
8:     exists (OntoSmT : TransportActivity) such that
9:       Plan1 : hasTransportActivities consists of OntoSmT : TransportActivity and
10:      OntoSmT : TransportActivity : hasPlannedStartTime is greater than CurrentTime then
11:      Vehicle1 = OntoSmT : TransportActivity :: hasVehicle
12:      SituationDetected (situation=ConsignmentPickUpVehicle,Vehicle= Vehicle1, consignment= Consign-
    ment1)
13:   else
14:     do nothing
15:   end rule

```

Situation 7 : Consignment disrupted, due a vehicle event, about the vehicle carrying the consignment

```

1: rule SITUATION DETECTION RULE FOR DETECTING SITUATION 7
2:   Situation Exists ConsignmentOnVehicle // Situation 5 exists
3:   Situation Exists VehicleEvent // Situation 2 exists
4:   define Vehicle1 as type (OntoSmT:Vehicle)
5:   define Vehicle2 as type (OntoSmT:Vehicle)
6:   define Event1 as type (OntoSmT:Event)
7:   define Consignment1 as type (OntoSmT:Consignment)
8:   Vehicle1  $\leftarrow$  ConsignmentOnVehicle :: Vehicle // Related vehicle for ConsignmentOnVehicle situation
9:   Consignment1  $\leftarrow$  ConsignmentOnVehicle : Consignment // Related consignment for ConsignmentOnVehicle situation
10:  Vehicle2  $\leftarrow$  VehicleEvent : Vehicle // Related vehicle for VehicleEvent situation
11:  Event1  $\leftarrow$  VehicleEvent : Event // Related event for VehicleEvent situation
12:  if
13:    (VehicleEvent) during (ConsignmentOnVehicle)
14:    and $Vehicle1 : hasVehicleID == $Vehicle2 : hasVehicleID
15:    and Event1 : hasDelay > Consignment1 : allowedDelay then
16:    SituationDetected (situation = Disruption_VehicleEvent, vehicle = Vehicle1, consignment =
    Consignment1, event = Event1)
17:  else
18:    do nothing
19:  end rule

```

Situation 8 : Consignment disrupted, due to a vehicle event, due to a Pickup Vehicle

```

1: rule SITUATION DETECTION RULE FOR DETECTIONG SITUATION 8
2:   Situation Exists Consignment_PickUpVehicle // Situation 6 exists
3:   Situation Exists VehicleEvent // Situation 2 exists
4:   define Vehicle1 as type (OntoSmT:Vehicle)
5:   define Vehicle2 as type (OntoSmT:Vehicle)
6:   define Event1 as type (OntoSmT:Event)
7:   define Consignment1 as type (OntoSmT:Consignment)
8:   define TransportActivity1 as type OntoSmT:TransportActivity
9:   Vehicle1 ← Consignment_PickUpVehicle :: Vehicle // Related vehicle for Consignment.PickUpVehicle situation
10:  Consignment1 ← Consignment_PickUpVehicle : Consignment // Related consignment
11:  Vehicle2 ← VehicleEvent : Vehicle // Related vehicle for VehicleEvent situation
12:  Event1 ← VehicleEvent : Event // Related event for VehicleEvent situation
13:  if
14:    and $Vehicle1 : hasVehicleID == $Vehicle2 : hasVehicleID
15:    and Event1 : hasValue > Consignment1 : allowedDelay then
16:      SituationDetected (situation=Disruption_PickUpVehicleEvent,vehicle=Vehicle1, consign-
ment=Consignment1, event=Event1)
17:    else
18:      do nothing
19:    end rule

```

Situation 9 : Situation when a vehicle is on a route

```

1: rule SITUATION DETECTION RULE FOR SITUATION 9
2:   exists Route // A route exists
3:   define Vehicle1 as type OntoSmT:Vehicle
4:   if
5:     exists (OntoSmT : Vehicle) such that
6:       Route : hasVehicle consists of OntoSmT : Vehicle then
7:         Vehicle1 ← OntoSmT : Vehicle
8:         Vehicle1 :: hasRoute = Route
9:         SituationDetected (VehicleOnRoute, vehicle=Vehicle1, route=Route)
10:    else
11:      do nothing
12:    end rule

```

Situation 10 : Consignment disrupted due to Route event

```

1: rule SITUATION DETECTION RULE FOR SITUATION 10
2:   exists RouteEvent // Situation 3 exists
3:   exists VehicleOnRoute // Situation 9 exists
4:   exists ConsignmentOnVehicle // Situation 5 exists
5:   define Route1 as type (OntoSmT:Route)
6:   define Route2 as type (OntoSmT:Route)
7:   define Vehicle1 as type (OntoSmT:Vehicle)
8:   define Vehicle2 as type (OntoSmT:Vehicle)
9:   define Event1 as type (OntoSmT:Event)
10:  define Consignment1 as type (OntoSmT:Consignment)
11:  Event1  $\leftarrow$  RouteEvent : Event // Related Event for RouteEvent situation
12:  Route1  $\leftarrow$  RouteEvent :: Route // Related Route for RouteEvent situation
13:  Vehicle1  $\leftarrow$  VehicleOnRoute : Vehicle // Related vehicle for VehicleOnRoute situation
14:  Route2  $\leftarrow$  VehicleOnRoute : Route // Related route for vehicleOnRoute situation
15:  Vehicle2  $\leftarrow$  ConsignmentOnVehicle : Vehicle // Related vehicle for ConsignmentOnVehicle Situation
16:  Consignment  $\leftarrow$  ConsignmentOnVehicle : Consignment // Related consignment for ConsignmentOnVehicle situation
17:  if
18:    RouteEvent during VehicleOnRoute // Event occurs while vehicle is on that route
19:    and VehicleOnRoute overlaps ConsignmentOnRoute // Vehicle on route while it carries consignment
20:    and (Route1) == (Route2)
21:    and $Vehicle1 : hasVehicleID == $Vehicle2 : hasVehicleID
22:    and $Event1 : hasDelay > Consignment1 : allowedDelay then
23:      SituationDetected (situation = Disruption_RouteEvent, vehicle = Vehicle1, consignment =
        Consignment1, event = Event1, route = Route1)
24:    else
25:      do nothing
26:  end rule

```

Situation 11 : Consignment disrupted due to Route event on a planned/future route

```

1: rule SITUATION DETECTION RULE FOR SITUATION 11
2:   exists RouteEvent // Situation 3 exists
3:   exists VehicleOnRoute // Situation 9 exists
4:   exists ConsignmentOnVehicle // Situation 5 exists
5:   define Route1 as type OntoSmT:Route
6:   define Route2 as type OntoSmT:Route
7:   define Vehicle1 as type OntoSmT:Vehicle
8:   define Vehicle2 as type OntoSmT:Vehicle
9:   define Event1 as type OntoSmT:Event
10:  define Consignment1 as type OntoSmT:Consignment
11:  Event1  $\leftarrow$  RouteEvent : Event // Related Event for RouteEvent situation
12:  Route1  $\leftarrow$  RouteEvent :: Route // Route for RouteEvent situation
13:  Vehicle1  $\leftarrow$  VehicleOnRoute : Vehicle // Related vehicle for VehicleOnRoute situation
14:  Route2  $\leftarrow$  VehicleOnRoute : Route // Related route for vehicleOnRoute situation
15:  Vehicle2  $\leftarrow$  ConsignmentOnVehicle : Vehicle // Related vehicle for ConsignmentOnVehicle Situation
16:  Consignment  $\leftarrow$  ConsignmentOnVehicle : Consignment // Related consignment for ConsignmentOnVehicle situation
17:  if
18:    RouteEvent before VehicleOnRoute // Event occurs before vehicle is on that route
19:    and VehicleOnRoute overlaps ConsignmentOnVehicle // Vehicle on route will carry consignment
20:    and (Route1) == (Route2)
21:    and $Vehicle1 : hasVehicleID == $Vehicle2 : hasVehicleID
22:    and $Event1 : hasDelay > Consignment1 : allowedDelay then
23:      SituationDetected (situation = Disruption_RouteEvent, vehicle = Vehicle1, consignment =
        Consignment1, event = Event1, route = Route1)
24:    else
25:      do nothing
26:  end rule

```

Situation 12 : Situation where a route event affects terminals

```

1: rule SITUATION DETECTION RULE FOR SITUATION 12
2:   exists RouteEvent // Situation 3 exists
3:   define RouteEvent1 as type (OntoSmT:RouteEvent)
4:   RouteEvent1  $\leftarrow$  RouteEvent
5:   if
6:     exists (OntoSmT : Terminal) such that
7:       (RouteEvent1 : hasStartLocation == OntoSmT : Terminal : hasAddress) or (RouteEvent :
hasEndLocation == OntoSmT : Terminal : hasAddress) then
8:       SituationDetected(situation = TerminalEvent, Terminal = RouteEvent1, delay = RouteEvent1 :
hasDelay)
9:   end rule

```

Appendix E

Test subject responses - SmTIP Empirical Cycle 1

Test subject responses to Q(a); Does SmTIPv1 facilitate SmT processes/activities?

S1Q(a) - "To show that the tool supports the philosophy of Synchromodality it should be possible to change the mode, time and location of orders dynamically. Just deciding upon disruptions doesn't contribute much to a synchromodal supply chain, which is a complex interaction of actors".

S4Q(a) - "I didn't understand what is the smallest unit of analysis, is it one order or 1 container. Orders are split into smaller shipments, can SmTIPv1 achieve that? How does the SmTIP behave when there are multiple clients. Bundling of freight has to be done in real time which we did not see."

S8Q(a) - "Is the tool proactive, i.e. can it anticipate disruptions happening in future or possible events which could be disruptions".

S10Q(a) - "Synchromodality is a multi-actor concept. Does SmTIP support model the supply chain from more than perspective. SmT can only be achieved when actors collaborate "

S11Q(a) - "Whose perspective does the tool uses, that of the 3PL, 4PL or Shipper. Disruptions can't be handled in a *yes* or *no* way. The correct way to handle disruptions is based on probability. There is also a probability that a disruption/event does not effect an eTA at all. The customer is interested in the probability that a time window of delivery is going to change. There was no way for the planner or the 4PL to evaluate, if by using the SmTIP the company is performing better than without it."

S14Q(a) - "It was not clear who the target user is. What is his role in the company? What is the works that he performs?"

Test subject responses to Q(b); Does SmTIPv1 functionalities satisfy stakeholder requirements?

S2Q(b) - "The application should provide more functionalities, like analytics to the planner or customer than just placing orders and viewing them via the application. Prediction of disruption is an important functional requirement of such a software, but we did not use it today. Is it already or planned to be implemented."

S8Q(b) - "The route should show intermediate stoppages of a shipment and not just the starting and ending locations. The planner should have an overview of intermediate stops so that, he knows at which terminals the transport modality can be changed."

S9Q(b) - "Some shippers have fixed delivery slots and it must be taken into account. Therefore, the functionality of disruption handling is not complete until the shipper agreement is considered. The disruption handling cannot be constraint free "

S14Q(b) - "I am not sure whether the the functionalities in SmTIP. v1.0 would be useful to the planner in a logistic company. The functionalities we saw can be provided by many software. How is SmTIP making the task easier than, opening the web browser to search for this information and manually changing the order ?"

Test subject responses to Q(c); Do the stakeholders find SmTIPv1 useful?

S1Q(c) - "I think SmTIPv1 complicates the work flow of the planner, because only some parts of his usual work flow are automated and the rest he has to do manually, as he does now. Therefore, as a start, SmTIPv1 is on the right track, but a holistic goal based approach is needed. If we go to a planner and he performs the same tasks as we did, he might be happy to do that on a computer but in the long run, he wont be satisfied with the time spent versus the benefit of using SmTIPv1."

S7Q(c) - "What is the added value by SmTIP. In what processes this tool will be useful. What are the things which are not possible by current tools in companies which SmTIPv1 offers?"

S11Q(c) - "There are many sources of disruptions than only weather and road works. Weather is not an important cause of disruptions on routes, but could have consequences at terminals. Further, road works, traffic jams and weather information can be easily received by drivers and skippers on their while they are on their respective vehicles. Are we not complicating the flow of information. Like, trying to make it more complicated than it really is. It is not clear to me, what is the focus and main goal of SmTIPv1. The tool has a bit of everything and therefore there is not special feature to look into. It is very generic."

Test subject responses to Q(d); What additional functionalities should SmTIPv1 have?

S2Q(d) - "SmTIP should generate orders randomly for a good simulation requirement. It is not a good practice that the user should add orders manually or import them via XML files. It is good to have an option, but the generation of orders must be automatically."

S4Q(d) - "In the next version, real time location of the shipment should be shown on the map"

S5Q(d) - "In the next version of SmTIP, orders which en-route on a disrupted route, should be displayed as disrupted. "

S9Q(d) "Each shipment should consists of separate legs, just like it is in real life. Each plan can have n number of legs"

S12Q(d) - "There should be a list of all (historic) events and disruptions on the network disruptions. Also, it should be possible for the planner to mine this list and get insights over future events. Can some services be exported, like data services? So that they can be used by other applications in the company or other external logistics companies. It would create an additional income stream for the host 4PL and a trigger to use SmTIP prototype"

S14Q(d) "Three things should be accomplished by SmTIPv2: (a) creating insights, (b) mechanisms to anticipate future events and disruption, (c) synchronization of resources."

Test subject responses to Q(e); What improvements can be made in the experiment setup?

S3Q(e) - "Instead of a showing the functionalities (solely) via a ppt., may be its better show them by using an example case. Currently the tool is so generic, that is requires a lot of explanations before which the users can understand the actual use of the platform."

S6Q(e) - "Costs in SmTIP should be included as a property for routes and per container. That would make the experiment case example more realistic. Currently, you consider all routes as equal which is not the case in reality."

S8Q(e) -"Since no case scenario was given, different stakeholder would think of different SmT scenarios, based on their understanding. This influences experiment results, therefore try to maintain a common understanding of SmT among your interviewees. More time should be allowed for performing the functions on SmTIP; 30 minutes is not ample time for performing all tasks."

S11Q(e) - "Ask a research assistant to help you in taking notes. Conducting the experiment and taking notes requires too much attention leading to neither of the works being done optimally."

Appendix F

Questionnaire - SmTIP Empirical Cycle 2

Question 1.1. *Demand Aggregation task using SmTIPv2 is easy and simple*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 1.2. *By using SmTIPv2, demand aggregation can be done in a better way*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 1.3. *Errors I encountered while performing demand aggregation task using SmTIPv2*

0-2 _____

3-5 _____

6-8 _____

8+ _____

Question 1.4. *Demand Aggregation task was same as performed in SmT scenario*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 1.5 *Disruption Handling task using SmTIPv2 is easy and simple.*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 1.6 *By using SmTIP, disruption handling can be done in a better way.*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 1.7 *Errors I encountered while performing disruption handling task using SmTIPv2*

0-2 _____

3-5 _____

6-8 _____

8+ _____

Question 1.8 *Disruption Handling task was same as performed in a SmT scenario.*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 2.1 *I had knowledge of Synchromodal Transport before starting this experiment.*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

Question 2.2 *SmT is a promising concept with high applicability in transportation*

Strongly Agree _____

Agree _____

Disagree _____

Strongly Disagree ____

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 - 26 Prince Singh (UT), An Integration Platform for Synchronodal Transport
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Prince Singh was born on 20th November 1987 in Prayagraj, India.

He received his B.Tech. degree in Computer Science & Engineering in 2009 at National Institute of Technology (NIT), Calicut, India.

In his bachelor thesis, he devised a method for model based verification of messaging protocols.

From 2009 to 2011, he was a Research Engineer at the Centre for Development of Telematics (C-DoT), New Delhi, India.

In 2013, he obtained his MSc. degree in Business Information Technology at University of Twente in Enschede, The Netherlands. His master thesis was on Integrating Business Value in Enterprise Architecture Modeling and Analysis.

Thereafter, in 2014, he started his Ph.D. research on Synchromodal Transport under the supervision of prof. dr. Roel Wieringa and dr. Marten van Sinderen.

On 18th September 2019, Prince defends his PhD thesis at University of Twente.

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