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ORIGINAL ARTICLE

Designing a shared freight service intelligence platform for transport stakeholders using mobile telematics

Christoph Heinbach[1] · **Pascal Meier**[1] · **Oliver Thomas**[1,2]

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Abstract

Internet of Things (IoT) technology transforms freight transport operations by adopting novel data-driven services and enables information sharing among actors involved in global transport chains. Mobile telematics represents emerging IoT technologies for global forwarding increasingly applied to full loads conveyed by freight transport assets (FTAs) (e.g., ISO containers) facilitating intelligent services. In this light, telematics-enabled FTAs support freight transport operations utilized by individual stakeholders in three overarching service dimensions: transport management, fleet management, and risk management. This topic is, however, understudied by information systems (IS) research and service science. For this reason, we establish a design science research project, conceptualize a shared Freight Service Intelligence Platform (FSIP), and introduce freight service intelligence as an interdisciplinary research field. To this aim, we first review related literature, interview 14 transport stakeholders, and theorize six meta-requirements. Second, we propose five design principles that indicate how the meta-requirements may be associated. Third, we develop a web-based prototype application to instantiate the proposed design principles comprising performance analytics, anomaly detection, risk assessment including prediction, data exchange, communication, and IS integration. Subsequently, we evaluate the application with six transport stakeholders and logistics software vendors. Finally, we conclude with a discussion on the implications of an emerging topic addressed by this paper.

Keywords Freight service intelligence · Mobile telematics · Data-driven forwarding · IoT service · Shared platform · Design science research

✉ Christoph Heinbach
christoph.heinbach@dfki.de

Extended author information available on the last page of the article

1 Introduction

Freight transportation is a key process for logistics services and represents a vital element in the intertwined economic growth of societies around the globe. Today, environmental awareness, transport risks, shortage of truck drivers, high operating costs, and evolving legal requirements for the compliant movement of materials and finished goods constitute significant challenges for global supply chains. For this reason, freight transport operations require new technological approaches to achieve efficient management of intermodal transport processes (Harris et al. 2015; Giuffrida et al. 2021; Heinbach et al. 2021a). Information flows in supply and transport chains have consequently been a central aspect of data-driven transport operations in recent years (Sanders et al. 2019). Likewise, the field of collaborative electronic business in logistics has increasingly leveraged "*business-to-business interactions facilitated by the internet*" (Johnson and Whang 2002). This has led to the emergence of cloud computing and the Internet of Things (IoT) revealing new approaches for secure information sharing among the actors involved in logistics flows, interoperable logistics systems, and smart logistics based on the use of multi-agents and blockchain technologies (Gnimpieba et al. 2015; Jabeur et al. 2017; Humayun et al. 2020).

Against this backdrop, Giannopoulos (2009) has advocated to "*increase the intelligence of freight transport operations and make it available to all players*" based on integrated technologies associated with information systems (IS). Although IoT technologies are widely used in logistics systems to enable real-time tracking, quality management, and control of supply chain operations (Chamekh et al. 2018), the application of mobile telematics and their service capabilities in the forwarding domain represents yet a nascent field. To be more precise, loading units (e.g., cargo or products on pallets) require physical and standardized freight transport assets (FTAs) (e.g., ISO containers, swap bodies, intermodal trailers) over the road, rail, and sea transport mode to facilitate freight services. Herein, freight service intelligence is positioned within the concept of smart cargo (McFarlane et al. 2003), autonomous freight transportation (Sternberg and Andersson 2014), and intelligent goods services (Jevinger and Olsson 2021) at the edge of an integrated platform for shared information from freight operations among transport stakeholders. Thus, for the purpose of this paper, we understand freight service intelligence as the capabilities of mobile telematics applied as an IoT enabler to FTAs based on the concept of smart connected products (Porter and Heppelmann 2014). In this context, telematics-enabled FTAs represent a boundary object in intelligent freight service systems and facilitate information processing and autonomous decision-making associated with intelligent resources (e.g., tagged goods) (Beverungen et al. 2019).

Looking at freight operations more closely, however, reveals the need to integrate information into collaborative transport management yielding improved visibility and accuracy of decision-making for operations as suggested by Okdinawati et al. (2015). Even though IoT technologies used in freight transportation are promising, their application is rather limited to end-to-end monitoring, particularly of drivers on the road, and decision-making, investigations from a stakeholder perspective are scarce (Farquharson et al. 2021). This is surprising since related IoT services that build on the data obtained from FTAs are used to describe the current conditional state of the cargo loaded, enabling advancements for the collaboration among multiple transport stakeholders by a cloud-based platform investigated by Gnimpieba et al. (2015). This fundamental approach is likewise supported by actual European legal initiatives that strive for the establishment of a cloud-based platform among the stakeholders to exchange electronic freight transport information (eFTI[1]) in the digital transport ecosystem.

Following this train of thought, IoT combined with cloud computing contributes to freight transport operations through value co-creation examined in the shipping industry (e.g., Agrifoglio et al. 2017). In essence, interactions of transport stakeholders via product-service platforms based on IoT technology result in value co-creation that draws on the service-dominant logic (Balaji and Roy 2017), providing a new research ground for telematics-enabled FTAs. This idea builds on emerging concepts discussed as “smart service platform” that requires design knowledge to support interactions among different stakeholder groups for mutual benefit (Beverungen et al. 2020). Considering the different stakeholders and tasks for freight transport operations in a fragmented transport market that makes data sharing and its exchange difficult, the concept of a shared Freight Service Intelligence Platform (FSIP) represents a foundation of IoT services in three operational dimensions: (1) transport management (e.g., handling of transport orders), (2) fleet management (e.g., use of the physical freight equipment), and (3) risk management (e.g., probability of service issues such as delays). This situation addresses a problem space from the real-world requiring design knowledge to explore innovative solutions that contribute to design science (Maedche et al. 2019).

To cater for these issues, we think a stakeholder-oriented approach to exploring the design of a FSIP based on telematics-enabled FTAs is appropriate to lead us to a novel solution grounded on the underlying need to share information among the actors participating in freight operations. Furthermore, this idea sheds light on an emerging topic in the sphere of smart and connected logistics providing benefits to (a) explore freight service intelligence capabilities, (b) uncover transport stakeholder requirements to manage shared information associated with freight transport operations, and (c) specify the interactions of stakeholders yielding new forms of value co-creation. Currently, there is no guidance for designing a software platform that would address the multifaceted requirements and aspects of shared information for transport users based on freight service intelligence (Saoud and Bellabdaoui 2021). For instance, a shared (smart) platform connected with telematics-enabled FTAs could assist joint performance monitoring, identify critical situations for further investigation, derive operational measures for improvements in the form of a business intelligence dashboard (Silva et al. 2020), and support automated decision-making for individual stakeholders. For this purpose, we investigate the following

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32020R1056&fr (Retrieved 31 March 2022).

research questions (RQs) in this study to bridge the existing gap of knowledge between data science and practice:

RQ1 What are the requirements of transport stakeholders (specifically shippers, consignees, transport operators, and insurance companies) for a software platform enabling collaborative freight service intelligence?

RQ2 How can a shared "Freight Service Intelligence Platform" be designed that addresses these requirements?

To answer the research questions, we establish a design science research (DSR) project and follow the theoretical Build-Evaluate-Pattern to design an IT artifact in the ex-ante evaluation block. We, thus, organize the remainder of the paper as follows. The next Chapter 2 describes a theoretical foundation of freight service intelligence in the freight transport industry based on telematics. In Chapter 3, we introduce the research design of the DSR project. Afterward, we present our findings of the proposed design specifications (Chapter 4), the platform prototype (Chapter 5), and the first cycle for design evaluation based on a proposed application (Chapter 6). Finally, in Chapter 7, we discuss our findings regarding their novelty, theoretical contribution, limitations, and future research. In Chapter 8, we give conclusions of our work.

2 Theoretical background

2.1 Mobile telematics for freight operations

Transport objects (e.g., loading units, ocean containers, and road trucks) are presently equipped with radio frequency identification (RFID), sensor-tracking devices, and telematics units enabling IoT services to optimize transport operations (Farquharson et al. 2021). As a result, the objects gain intelligent characteristics encompassing identification, localization, communication, sensing, or logical functions and enable innovative IoT services in supply chain management (Atzori et al. 2010). In the context of freight forwarding, IoT technologies are growingly applied in the form of telematics technologies and operate as a gateway to process information from transport assets (e.g., containers providing GPS-based position for localization) and the conditional state of goods loaded (e.g., temperature) enabling decentralized control of transport operations (Becker et al. 2010; Salah et al. 2020). Telematics concerns particularly the use of driver monitoring and vehicle efficiency by trucks using integrated systems (Heinbach et al. 2022b). Notwithstanding road trucks, based on the application of mobile telematics, processing information capabilities contribute to an intelligent system and allow FTAs to make decisions that often refer to "tagged goods" discussed in the context of decentralized freight intelligence (Sternberg and Andersson 2014). However, in this paper, we focus on telematics-enabled intelligence of freight services understood as moving full freight loads (e.g., full container load) comprising loading units (e.g., pallet) associated with standardized FTAs in conditions appropriate to their sensitivity and provided by transport operators (e.g., carrier, forwarder). Accordingly, full loads forwarded by transport assets do not require goods tagged (e.g., RFID) to facilitate freight intelligence since telematics technologies represent intelligent resources enabling processing information and making decisions.

Telematics comprises telecommunications and information technology and facilitates to collect, progress, and supply of real-time actionable sensor information and function as an integrated IoT enabler with capabilities to automate freight operations of FTAs in remote positions without power supply (e.g., Kückelhaus et al. 2013; Schulte 2013; Sternberg and Andersson 2014). To this extent, scholars have investigated telematics applied in the transport industry that supports fleet operations through data insights of trucks addressing cost optimizations (e.g., monitor fuel consumption), driver workflows (e.g., communicate driver instructions), and compliance aspects (e.g., identify risky driver behavior) (Mikulski 2010; Winlaw et al. 2019; Heinbach et al. 2022b). Likewise, the application of telematics for FTAs reveals IoT service capabilities based on transport monitoring, tracking, and automated notifications in case of deviations in conditions (e.g., temperature), particularly for the food industry (Verdouw et al. 2016; Li et al. 2017; Salah et al. 2020). The real-time information and automatization of telematics-enabled FTAs allow transport stakeholders to achieve visibility and optimizations over freight operations based on the gained data yielding data-driven business models in logistics (Möller et al., 2020; Heinbach et al. 2022a). That is, for instance, an automated billing service offered to customers once the FTA equipped with telematics has arrived in a geofenced area. At the same time, telematics technologies have shown capabilities to detect freight integrity and damages of shipments that support the management of risks for shippers, consignees, transport operators, and insurance companies involved in freight operations (Salant and Gershinsky 2019; Chaba 2021).

Having said this, capturing and understanding the same information along the transport chain is pivotal to identifying the root causes and taking proper measures for optimizing processes. Although telematics is predominantly applied to achieve greater visibility of FTAs in freight transport systems, the emerging capabilities of telematics in the transport market indicate new applications that arise for advanced fleet management and go beyond vehicle-integrated telematics systems (e.g., trucks) (Huk and Kurowski 2021). For instance, the telematics technology provider Mecomo[2] offers solar-based telematics hardware for intermodal fleet operations to be mounted on FTAs that interact with cloud-based software to integrate the data for connecting and automating freight processes. Integrated data is therefore collected and shared for the purpose of monitoring, controlling, and tracking yielding more efficient decision-making and transport logistics performance managed by platform users (Ben-Daya et al. 2019). As a consequence, telematics-enabled FTAs that communicate with their environment and make partially autonomous decisions indicate data-driven intelligence of transport assets to facilitate shared freight services at the

[2] https://www.mecomo.com/ (Retrieved 6 January 2022).

intersection of smart products, IoT, and cloud computing as demonstrated in academia (e.g., Chamekh et al. 2018; Farquharson et al. 2021).

2.2 Stakeholder-oriented and shared freight service intelligence

"*Telematics is the tool that visualize the actual course of transportation units*" (Huk and Kurowski 2021). Looking at the freight forwarding industry, this technology provides a variety of functions primarily with increasing value applied to road freight operations for advanced fleet management (Heinbach et al. 2022b). For instance, commercial manufacturers offer vehicle-integrated telematics systems delivering services to make truck and vehicle status visible (e.g., speed), support fleet operations (e.g., predictive maintenance), enable transport order execution, and optimize consumption to reduce emissions (Mikulski 2010; Osinska and Zalewski 2020). Furthermore, the emergence of telematics capabilities for road freight has led to fleet management systems that "*(…) consists in data collecting, processing, transmitting, and analyzing within three subsystems: a data acquisition subsystem, a data processing subsystem, and a subsystem for displaying contents to users*" (Iwan et al. 2018, p. 60).

Considering the sensitivity of freight or goods being delivered, intermodal transportation units that operate remotely without power supply such as trailers, swap bodies, and containers are increasingly equipped with telematics technologies to achieve augmented visibility and optimized operations of the freight equipment in use (Hajdul and Kawa 2015; Farquharson et al. 2021). Telematics-enabled FTAs, therefore, represent boundary objects and can be tracked, traced, and monitored via the internet following the concept of IoT (Schoenberger 2002) with capabilities to sense, analyze data, and execute specific tasks through information sharing and synchronizing decisions (Haddud et al. 2017) and, thus, follows the concept of 'smart service systems' (Beverungen et al. 2019). Since telematics hardware remains permanently installed in transport units, the advantage is the continuous availability of information and communication technology (ICT) acting as a gateway that collects and transmits data in association with wireless sensor network nodes (e.g., RFID tags attached to loading units such as pallets) (Becker et al. 2010; Gnimpieba et al. 2015). Based on the "mobile" characteristic, the application of telematics and their sensor capabilities are investigated for intermodal freight processes of containers in the maritime and rail industry (e.g., Mahlknecht and Madani 2007; Becker et al. 2010; Ußler et al. 2019). That is, a battery or solar-powered telematics device with built-in sensors gathers data grouped according to their monitoring purpose in their direct environment into position, temperature, humidity, accelerometer, light, acceleration, shock, and tamper-proof (e.g., door status) respectively (Kückelhaus et al. 2013). Given the emerging data-driven service opportunities of FTAs, telematics represents a promising technology for physical transport assets in combination with IoT resources and Big Data since the data collected by the sensors and communicated in real-time helps to increase transparency (e.g., location of the transport asset), ensure freight integrity (e.g., real-time event notifications in case of security issues or temperature deviations), and optimize fleet equipment management for transport operators (e.g., prediction of maintenance services). The spectrum of digital service capabilities facilitated by telematics, thus, contributes to collaborative freight operations by sharing information using cloud infrastructure (Okdinawati et al. 2015; Jabeur et al. 2017; Saoud and Bellabdaoui 2021) and fosters the development of multimodal intelligent transport systems (Torre-Bastida et al. 2018).

Typically, freight services are provided by forwarders, carriers, and logistics service providers to customers. This group of transport operators offers transport services focusing on the economic use of transport equipment (e.g., transport costs, high load utilization) to sustain in a heterogeneous and competitive transport market. Speaking about IoT-enabled services in freight ecosystems, a variety of services from telematics-enabled FTAs can be offered to additional stakeholders participating in transport operations, namely: shippers, consignees, and insurance companies. Naturally, shippers have an interest in understanding the tradelane performance of FTAs to maintain service quality based on the full-load transport orders transmitted to transport operators. Likewise, consignees benefit from services to estimate time of arrival (ETA) and support communication in case of issues that may arise. Addressing the sensitivity of loaded freight in vulnerable transport chains, insurance companies seek to understand freight transport risks affecting transport service quality and costs of goods consequently. Since all stakeholders operate along the same line of freight transport activities, we infer that telematics-enabled FTAs intermediate data-driven freight services in three overarching dimensions for the actors involved: (1) transport management addressing the handling of full-load orders, (2) fleet management to achieve equipment efficiency, and (3) risk management encompassing the prevention of critical impacts to the freight including order performance, tamper-proof deployment of FTAs, and the handlings of claims among the stakeholders.

For this reason, freight service intelligence reveals a spark toward further exploration of shared information services that encompasses different definitions and concepts addressed by scholars including intelligent cargo, smart goods, smart freight, intelligent goods, and intelligent packaging. The definitions have emerged over the years from an IoT perspective yielding varying concepts. For instance, the European Commission describes intelligent cargo as implying that "*(…) goods become self, context- and location-aware as well as connected to a wide range of information services*" (European Commission 2008, p. 8). Thus, FTAs connected via the internet support freight intelligence that builds on the features of intelligent products proposed by McFarlane et al. (2003). Based on the characteristics of McFarlane et al. (2003), Lumsden and Stefansson (2007, p. 7) and Meyer et al. (2009) further describe the capabilities of intelligent products as possessing a unique identity, communicating with the environment, storing data about itself, deploying a language to display its features, production requirement, etc., and participating in or making decisions relevant to its own routing.

Sternberg and Andersson (2014) explain that goods processing information and making decisions are per se viewed as intelligent if tagged with RFID or Barcode facilitating storing and identification but not on an item level (e.g., box, parcel). This approach likewise applies to physical FTAs with information processing capabilities enabled by ICT systems (e.g., sensor tracking technologies) (Landers et al. 2000; Holmström et al. 2010) and associated with "tagged goods" for decentralized freight

Table 1 Examples of freight service intelligence capabilities based on Jevinger and Olsson (2021)

Freight service intelligence capabilities	Exemplary service of telematics-enabled FTA	Overarching service category	Stakeholders applying the service
Metadata information	Provision of identification of transport assets operating in fleets	Fleet Management	Transport Operator
Condition monitoring	Monitoring of temperature during transportation (motion and stationary)	Transport and Risk Management	Shipper, Transport Operator, Insurance Provider
Position monitoring	Identify geo-positions of the transport assets to calculate an estimated time of arrival (ETA)	Transport Management	Shipper, Consignee, Transport Operator
Shipment integrity	Detection of door status (open/closed) in remote positions, such as parking areas	Risk Management	Transport Operator, Insurance Provider
System autonomy	Automate the billing process once the transport asset has arrived at its (geofenced) destination	Transport Management	Shipper, Transport Operator

intelligence systems (Sternberg and Andersson 2014). From that perspective, Jevinger and Olsson (2021) suggest five types of service capabilities enabling intelligence that can correspondingly be applied to transport assets equipped with telematics to realize freight service intelligence: (1) metadata information, (2) condition monitoring, (3) position monitoring, (4) shipment integrity, and (5) system autonomy. In Table 1, we present freight service intelligence capabilities derived from intelligent goods services, provide corresponding exemplary services of telematics-enabled FTAs, assign the overarching service category for freight transport operation, and state the group of transport stakeholders applying the services.

From the overlapping of service intelligence assigned to different stakeholder groups, a shared value from the data insights gained from virtualized FTAs equipped with IoT is indicated. More precisely, telematics-enabled FTAs become context-aware as they can sense, communicate, act, interact, and exchange data, information, and knowledge (Sundmaeker et al. 2010). Therefore, cloud computing is applied to support the virtualization of transport chains, which has been demonstrated especially for food supply chains due to the natural sensitivity of goods based on smart connected objects operating in a dynamic environment (Verdouw et al. 2015). In essence, transport stakeholders involved in freight transportation benefit from shared information for collaborative decision-making yielding advanced operations enabled by IoT services. Focusing on the different activities and responsibilities of freight transport tasks in a complex environment, we suggest a stakeholder-oriented approach that allows us to understand their requirements and information needs. This helps to identify uniform design knowledge for a shared platform based on virtual telematics-enabled FTAs supporting freight operations collaboratively as intended by this paper.

3 Research design

3.1 Design science research approach

To address our research goal and enable the development of a novel software platform supporting transport stakeholders by shared freight service intelligence, we apply a Design Science Research (DSR) method. DSR provides a structured method for the development of artifacts from the identification of a problem to the implementation and application (Baskerville et al. 2018). For this reason, we use the approach of Sonnenberg and vom Brocke (2012) who frame the phases *Identify Problems*, *Design*, *Construct* and *Use* and suggest an evaluation between each phase. Following this approach, we completed the steps to justify our research problem, derive meta-requirements and design principles, and arrive at the ex-ante evaluation (e.g., first cycle) of a developed FSIP based on the use of mobile telematics in the freight forwarding domain (Fig. 1, colored gray). From the application of the method, we aim at (1) providing a relevant solution for the identified problem as described in the introduction section by applying a scientific approach, and (2) deriving generalized design implications for the IS research discipline according to

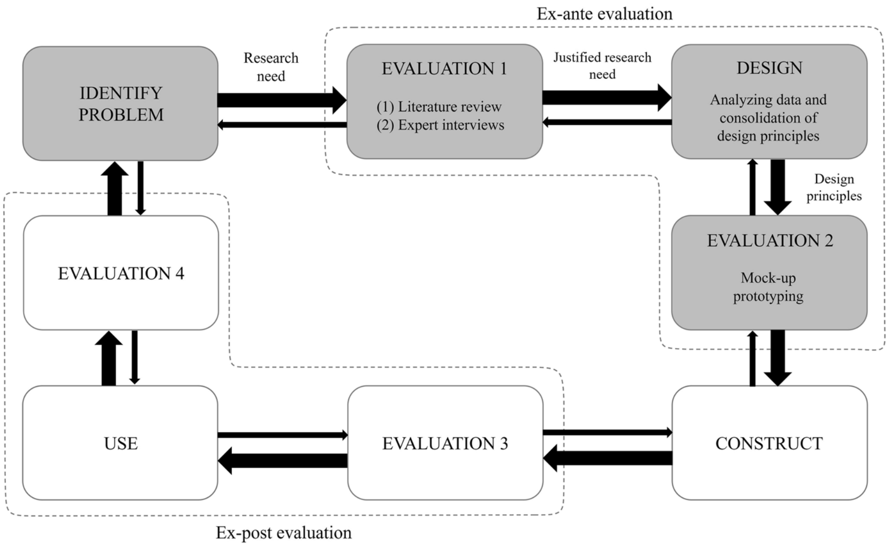

Fig. 1 Research design of the study based on Sonnenberg and vom Brocke (2012)

Gregor and Jones (2007), and (3) presenting a design foundation for construction in subsequent iterations. Implementation in the real world consequently facilitates ex-post evaluations.

3.2 Data collection

Based on the problem definition that we have already presented in the introduction section, we collected data from scientific literature and interviews with professionals from forwarding practice in Germany. Since the design search process requires flexibility for uncovering the needs and preferences of users that work in the freight transportation industry related to the topic, we decided to conduct a semi-structured interview study (Eisenhardt 1989). To this end, we selected four different freight service stakeholder groups from the side of shippers, consignees, transport operators, and insurance companies based on theoretical relevance and due to our scientific network and direct access to potential practitioners. We decided to interview at least two professionals from each stakeholder group to ensure that our results will represent generalizable insights. From the identified requirements, we theorized meta-requirements, derived design principles for meeting those meta-requirements, and developed a web application that implements the proposed design principles by an instantiated artifact. Subsequently, we evaluated the developed web application by conducting additional interviews and the course of an additional interview study. Since the prototype is evaluated ex-ante and does not allow experimental evaluation yet (evaluation 2), the interviews conducted with professionals from multiple organizations represent general stakeholders involved in the freight transportation process related to our identified problem presented in the introduction section.

For the literature review, we queried the term *freight* AND *digital* AND (*transport** OR *supply*) AND *data* AND (*middleware* OR *cloud* OR *platform*) in seven bibliographic databases: SpringerLink, ScienceDirect, Wiley, Emerald Insight, AIS, Web of Science, and EBSCOhost. We carefully sorted out the results of our literature search by their relevance to our topic and initially identified seven relevant articles. We employed forward and backward searches, leading to the inclusion of further articles that focused on freight transportation in international trade. Finally, we analyzed 10 papers using a concept matrix (Webster and Watson 2002) to identify requirements for the FSIP from the scientific literature with relevance to our research study.

In addition, we conducted 14 interviews (interview evaluation 1) to gather data from practice and six additional interviews (interview evaluation 2) for evaluating and refining the proposed design principles and their implementation. Therefore, we recruited freight transport professionals engaged in the full load freight transport industry (e.g., freight conveyed in a full truck or full container loads) with a focalized interest in IoT, tracking, and sensor technologies of trucks, trailers, swap bodies, ocean containers or similar freight transport units. Moreover, we interviewed experienced logistics software vendors consisting of software developers and designers due to our access to receive their opinion on the technical feasibility of the designed FSIP. The interviewees are from the German transport market to ensure consistent data collection subject to the same legal frameworks of operations (e.g., freight loading). All interviews were semi-structured and conducted by at least one author of this paper with sensitivity in the field of digital logistics and freight forwarding following pre-defined questionnaire guidelines. The questionnaire guideline for the interviews during the first evaluation was divided into four sections: interviewee's background, IoT technologies and services for freight transportation, usage of telematics enabling freight service intelligence, and prototype of a FSIP. Appendix 1 illustrates the questions we developed per section for the interview guideline.

During the second evaluation of the ex-ante phase, the questionnaire guideline focused on receiving feedback on the proposed design principles and the implemented prototype. Additionally, we asked further questions in all interviews and left room for the interviewee's thoughts if needed. All interviews were conducted one-on-one, transcribed in German, and translated into English. The average work experience of the professionals is 14 years and the interviews lasted for 43 min (evaluation 1) and 44 min (evaluation 2) on average. Table 2 provides an overview of the interview professionals including the organization's stakeholder role, size, expert position, their respective work experience, and interview duration during the evaluations of the DSR process (cf. Fig. 1). Further details cannot be presented due to confidentiality agreed with professionals upon the interviews.

Table 2 Descriptive information about semi-structured interviews

Organization stakeholder role	Organization size[a]	Expert position	Work experience (years)	Interview duration evaluation 1 (min)	Interview duration evaluation 2 (min)
Consignee A	Large	Head of Logistics	10	30	
Consignee A	Medium	Logistics Operations Manager	28	35	39
Consignee B	Medium	Head of Customs Management	10	36	
Insurance provider A	Large	Field Service Account Manager	5	33	
Insurance provider B	Medium	Managing Director	18	36	
Insurance provider C	Small	Head of Transport Liability	22	57	44
Shipper A	Large	Logistics Planner International Distribution	7	62	59
Shipper B	Large	Logistics Controlling Group Leader	32	64	
Shipper C	Large	Logistics Manager	9	39	
Shipper D	Large	Logistics Service Seafreight Manager	31	50	
Transport operator A	Small	Head of IT and Logistics	5	47	
Transport operator B	Medium	Head of Resources and Analytics	6	40	
Transport operator C	Medium	Head of Project Management Office	9	30	37
Transport operator D	Small	Global Visibility and Tracking Manager	8	40	
Logistics software vendor A	Large	Head of Digital Supply Chain Management	25		42
Logistics software vendor B	Medium	Director Telematics	6		45

[a]Size according to EU definition, see: https://ec.europa.eu/growth/smes/sme-definition_de (Retrieved 18 March 2022)

3.3 Data analysis

To analyze the data from transcribed audio records, we performed a qualitative content analysis (Mayring 2014) using the software MAXQDA (Release 2020.0.0) and elicited requirements. The software is offered by the company VERBI[3] and applied for computer-aided qualitative data and text analysis of interviews. It allows assigning codes systematically to segments of texts based on unstructured data. The software-assisted analysis consisted of reviewing, coding, categorizing, and interpreting the data. For the reviewing and coding process, at least one author and one scientific assistant analyzed every sentence in the transcripts line-by-line independently to identify key requirements comprising platform and freight service characteristics (open coding). Relevant content related to freight service intelligence was identified and we labeled common themes in the data (text segments) that correspond with the topic of our study (Bhattacherjee 2012). Afterward, we identified (coded) relevant themes, or ideas in the data with relevance to our research interest and grouped them into categories. Subsequently, we divided the analyzed content into smaller fragments and aggregated these into more abstract, conceptual categories using descriptive codes to label platform aspects for freight service intelligence.

To this end, our focus lies on the transport stakeholder description of the shared platform and IoT-enabled freight service intelligence based on freight units equipped with mobile telematics. We consequently consolidated our findings into a matrix table according to the identified coding dimensions by comparing the results and ensuring inter-coder reliability. When interpreting the results, the authors and assistants operated independently to derive the concepts and categories without coherence that were reviewed and discussed until a consensus was reached. Finally, codes are devised to concepts pursuant to the evaluation of design principles and to enhance the prototype. This process likewise includes grouping basic sets of concepts (sub-categories of codes) together.

4 Exploring the design of a shared freight service intelligence platform

4.1 Deriving requirements from scientific literature and transport experts

Due to the identified problem in the introduction section, we deduce requirements and discuss how we derived meta-requirements and design principles with relevance for the development of a shared FSIP applied by transport stakeholders. To explore the requirements for a FSIP, we analyzed data collected from scientific literature (L) and expert interviews (E) with practitioners. Overall, we specified 17 requirements and further aggregated them into six meta-requirements that aim of supporting shared freight transport operations of telematics-enabled FTAs (see Fig. 2 below).

[3] https://www.maxqda.de/ (Retrieved 10 June 2022).

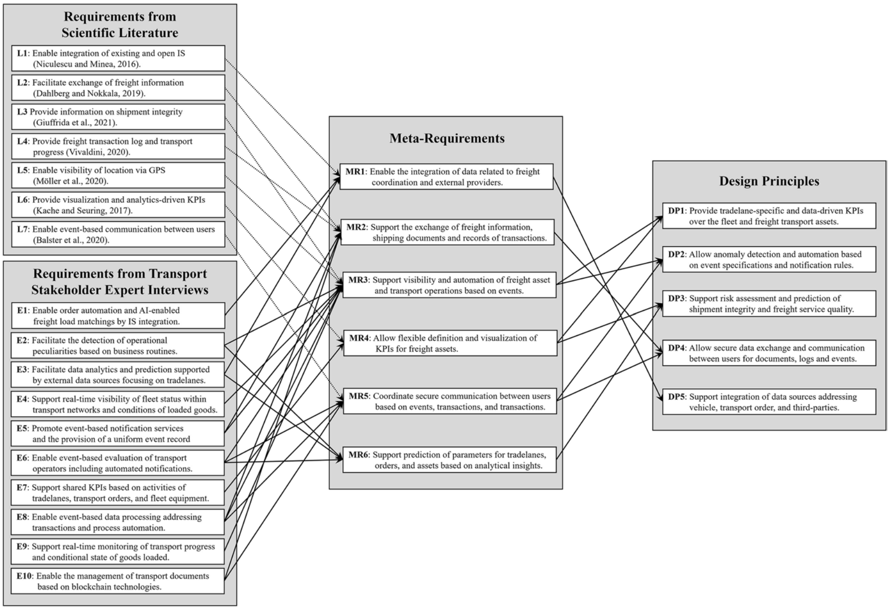

Fig. 2 Derived meta-requirements and design principles for a FSIP

Based on a concept matrix, we mapped the analyzed articles to the derived requirements for a FSIP. The literature reveals that a FSIP must enable the integration of data from various IS (**L1**) to facilitate automation and exchange of synchronized transport data (e.g., transport order details obtained from transport management system—TMS). This refers likewise to electronic and shared document management (**L2**) due to the vast amount of transport-related and physical paperwork handled during operations among the stakeholders. Transport assets equipped with mobile telematics are required to provide information on shipment integrity (**L3**) for transport stakeholders to ensure compliant conditional states (e.g., temperature control of goods moved with cold chains). To achieve transparency about transport operations, a FSIP must provide a record of transport process transactions (e.g., a digital log of incidents) and present the transport progress (**L4**), which is important to provide a comprehensive information basis for the participating transport users to gain shared insights into actual freight operations. This feature is supported by real-time visibility of geo-positions based on GPS for the objects (**L5**). The desired platform must further support visualization and data analytics by key performance indicators (KPIs) (**L6**) to determine the performance analysis of FTAs. Since telematics-enabled FTAs allow the generation of event notifications, i.e., any deviation from a predefined value detected by the integrated sensors does trigger a server message communicated to transport stakeholders that benefit from event-based communication among the users (**L7**).

From the interviews, we derived that intelligent transport management is assisted by integrated freight load matching opportunities, specifically on the road, enabled by artificial intelligence (AI) (e.g., automated assignment of shipments received from freight exchanges) (**E1**), to increase transport asset utilization and achieve competitive freight rates with transport operators for shippers:

> "*If the mobile telematics unit detects that the trailer has been waiting at a ramp for at least 20 min, a trained system should set the asset status to 'unloaded'. Based on the status, the trailer should automatically be assigned to another transport order available from our planning system.*" (Shipper A)

Moreover, both shippers and transport operators show a strong interest in the detection of operational peculiarities based on business routines and individual transport parameters (**E2**). This allows the recognition of critical impacts based on irregular activities (e.g., stationary time and route deviations of FTAs) in combination with process automation (e.g., booking of orders in the order planning system):

> "*(…) I think that based on the configured transport settings including time windows, transshipment points, and freight monitoring parameters, transport assets must monitor activities themselves and provide suggestions for improvements automatically according to the data retrieved.*" (Transport operator C)

In this way, a FSIP utilizes data integrated from external data sources (e.g., weather information system) to analyze the actual situation and facilitate predictive operations of FTA activities for tradelanes (**E3**):

> "*I suggest including weather forecasts. (…) If I am traveling from Poland to Spain by train for 5 days, strong snowfalls may lead to interruptions since freight wagons are completely frozen and freight operation is not possible. Indeed, it is important to obtain predicted information of tradelanes in the platform that affects my end customer business.*" (Consignee B)

More specifically, tradelanes represent a shipper-specific and contracted agreement with transport operators for recurring shipments to be forwarded within the same transport boundaries, i.e., same shipper and consignee. Furthermore, the freight equipment in use within transport networks is supported by real-time visibility (**E4**) that facilitates the presentation of the fleet status of assets and conditions of the goods loaded according to customer requirements:

> "*From a service perspective, I would equip all swap bodies used in the freight networks with solar-based telematics units to capture asset data for managing our fleet equipment efficiently and provide our customers advanced real-time visibility services after booking a transport.*" (Transport operator A)

In addition, transport stakeholders require event-based notification services (e.g., automatic notification if the FTA has arrived at its destination) and the provision of a uniform event record (**E5**) to analyze transport and fleet activities collaboratively:

> "*The gained data from assets should be provided in a modularized output format allowing users to navigate throughout their individual reports using the same data. Thereby, every stakeholder is supposed to read and understand the events generated from the transport assets in the same way.*" (Insurance provider A)

Table 3 Types of required key performance indicators (KPIs) for a FSIP

Types of KPIs	Exemplary quote
Availability	"*What would interest me is the availability of the telematics system or the platform in percent, in terms of downtime due to maintenance and errors.*" (Shipper C)
Utilization	"*In fact, the utilization rate is of high importance for our performance measurement of both our own fleet and the carrier's fleet, i.e., the outbound utilization rate indicating the percentage the available loading unit is used.*" (Transport operator D)
Events	"*Every transport asset equipped with an IoT device is capable to detect the activities in real-time that is of interest for me to determine whether freight operations require my attention for improvements.*" (Transport operator B)
Conditions	"*Monitoring the conditional states of freight are always a concern especially if the transport underlies different parameters for protecting the goods as is the case in the food supply chain in terms of temperature control.*" (Transport operator C)
Shipment integrity	"*Risks can be linked to the handling of transport assets, and I suggest introducing an indicator that represents the sensitivity of the loaded freight to care about their quality and damages.*" (Insurance provider A)
Distance	"*Any kilometer we are traveling with our transport assets results in costs and my interests are to measure the kilometers over all transport units in use to achieve my economic targets.*" (Transport operator A)
Time	"*Lead time, as well as on-time deliveries, are extremely helpful indicators for freight operations to monitor whether the "behavior" of transport assets is normal and not indicating any suspicious situation requiring my or the forwarders intervention.*" (Shipper D)
Emissions	"*To achieve greener shipping and more sustainable freight operations, we'd like to receive the amount of CO2 in gram per kilometer produced for the full load.*" (Consignee B)

From the events detected through the applied telematics units attached to FTAs, the desired platform must enable an event-based evaluation of transport operators including automated notifications. The platform consequently supports subsequent processes (e.g., inbound) to achieve interconnected freight operations (e.g., frequent deviations detected at a specific location are being automatically communicated to stakeholders) (**E6**):

> "*If I have a shock sensor, acceleration is frequently measured with excess at a specific location, I might even want to get an email automatically. Indeed, this service goes with rules: If the temperature is above 20 degrees and there is a shock that is greater than X, then it informs our planning system directly or the inbound operation team is informed that goods inspection must be carried out 100% as soon as the freight arrives.*" (Shipper B)

These initiatives are accompanied by shared KPIs that are especially important for all interviewees to measure specific performances based on activities of tradelanes, transport orders, and fleet equipment (**E7**). Overall, our 14 interviewees described 54 different KPIs that are of interest to them, and it is likely that this number would grow further with additional interviews. Thus, we aggregated the KPIs to specify eight overarching KPI types for transport stakeholders: availability, utilization, events, conditions, shipment integrity, distance, time, and emissions. The types are neither collectively exhaustive nor mutually exclusive. In Table 3, we list the types of KPIs with an exemplary quote that illustrates the need for this KPI.

Since transport management follows standardized processes using multiple IS, generated events (e.g., entry of FTAs into geofenced areas) and data processing (e.g., calculations of ETA) can be utilized to compile values for transaction records. Furthermore, the data triggers subsequent processes toward freight process automation (e.g., generation of carrier invoices after entering the geofence) (**E8**):

> "*The benefit of using mobile telematics for freight operations is definitely its real-time capabilities and the connected services, such as the automated invoice generation for carriers once the assets have entered our pre-defined geofence.*" (Shipper C)

The interviewed experts confirmed that a FSIP must support real-time monitoring of transport progress and conditional state (**E9**) to ensure the quality of transport services and nature of goods loaded:

> "*I would like to be informed promptly once the transport status has changed or is foreseen to change in a way that negatively affects my operations or customers satisfaction.*" (Shipper D)

Since freight documents are broadly exchanged in physical format among transport stakeholders based on operational and customer needs (e.g., delivery note, proof of delivery, waybill), we identified that the aspired platform solution requires managing transport documents based on blockchain technologies (**E10**). Since transport operators have argued that data exchange based on the documents in electronic format requires a trustworthy environment, blockchain is considered an enabler technology to provide secure data flow:

> "*Sharing documents such as a waybill in a digital and secured manner is a prime feature for our operations. (…) I suggest incorporating blockchain technology to achieve secure data exchange.*" (Transport operator D)

Based on our analysis, we further consolidated the identified requirements and derived six meta-requirements (MRs). A FSIP should enable the integration of data related to freight coordination and external providers (**MR1**, based on L1, E1, and E3). Since sharing freight-related information by a platform to leverage collaborative transport management is key to facilitating transport-specific decision-making (Saoud and Bellabdaoui 2021), the platform should support a uniform user view to read and interpret the aggregated data. This encompasses the exchange of freight information, shipping documents, and records of transactions for freight transport operations (**MR2**, based on L2, L4, E5, E8, and E10). Due to the automated capabilities facilitated by emerging IoT (tracking) technologies, transport stakeholder processes are assisted by event-based real-time visibility and automation services addressing FTAs and transport operations (**MR3**, based on L3, L5, E2, E4, E5, E6, E8, and E9). Freight service intelligence consequently appears to be explicit for automation in two ways: (1) driven by events to trigger automated actions (e.g., an FTA entering a geofenced area does make a booking for inbound freight in shippers' logistics IS to optimize gate in processes), and (2) following pre-set routines to provide telematics-enabled FTAs gradual autonomy toward self-optimization (e.g., a detected idling time of FTAs suggests using the equipment to transport freight dispatchers; overdue maintenance services, such as preventive accident check may set the FTA status "on hold"). Meanwhile, performance and analytical insights into transport assets are particularly relevant for advanced management of fleet objects and transport orders. The FSIP should allow individual definition and visualization of KPIs for FTAs equipped with telematics (**MR4**, based on L6 and E7). Following the dynamic transport situations in a complex global forwarding environment, the FSIP should facilitate immediate and secure communication among transport users for transport operations based on events generated by transport assets and shipment status related to freight documents (**MR5**, based on L7, E6, E8, and E10). To achieve optimized transport operations and support individual decision-making, the platform should support the prediction of parameters for tradelanes, transport orders, and FTAs based on analytical insights attained from the aggregated data using telematics and integrated IS (e.g., TMS) (**MR6**, based on E2, E3, and E6).

In Fig. 2, we illustrate a detailed overview of the relationships between requirements from the scientific literature (L1–L7), the transport stakeholder expert interview (E1–E10), and the derived meta-requirements (MR1–MR6). Furthermore, it likewise visualizes the connections between the meta-requirements and the short form of design principles that are derived in the next section.

4.2 Deriving design principles for a freight service intelligence platform

After the identification of meta-requirements, we propose five design principles (DPs) and contribute to the specification of design theory (Gregor and Jones 2007). To derive the connections between meta-requirements and design principles, each meta-requirement may address multiple design principles and each design principle may be addressed by multiple meta-requirements indicating a many-to-many (m:n) relationship. In addition, we follow the proposed scheme by Gregor et al. (2020) and distinctively specify design principles that support us to arrive at design knowledge for further development and implementation.

4.2.1 Shared tradelane-specific and data-driven KPIs over the fleet and freight transport assets

Data processed using mobile telematics reflect the performance of FTAs for the overall objective assigned to customer-specific tradelanes and transport orders. The insights gained from the assets and based on the data support an advanced dashboard approach providing a set of KPIs to support data-driven decisions to be made by transportation managers, particularly for logistics services and the management of related transport processes in conjunction with business intelligence (cf. Silva et al. 2020). Therefore, KPIs are provided by quantifiable metrics for assets utilized within fleet organizations that allow users to measure the quality of processes and freight services based on flexible definition and visualization (MR4). Since shippers may have a business relationship on a contractual basis with transport operators, tradelane-specific KPIs allow close monitoring of carrier performance based on existing agreements for individual FTAs. In return, shippers, consignees, transport operators, and insurance companies benefit from a unified presentation of real-time performance metrics to obtain insights into activities with an impact on transport management (e.g., on-time delivered orders), fleet management (e.g., distance traveled compared to all FTAs), and risk management (e.g., shipment damages or loss) during transportation (MR3). Thus, we define our first design principle as follows:

Design Principle 1. *To allow transport business managers in an organization (users) to support analysis of freight transport asset performance (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should provide shared tradelane-specific KPIs, i.e., deviations from contractually agreed transport routines, over the fleet and individual freight transport assets.*

4.2.2 Anomaly detection and automation based on event specifications and notification rules

Given the increasing digital competition in the transport market due to emerging IoT technologies and digital platforms yielding digital business models by start-ups (Möller et al. 2020; Heinbach et al. 2022a), visibility in transport chains has emerged as a commodity service for shippers and consignees. Against this issue, our analysis revealed that transport operators have a strong interest in the detection of irregularities in the equipment used to observe the performance of their fleet with a focus on operational efficiency and customer satisfaction. The automated detection of anomalies from business routines is therefore of paramount importance on the tactical management level for all stakeholders to understand the status of real-world operations indicating critical tendencies. Furthermore, we found that this feature enables the automation of freight operations identified in our analysis (e.g., an email sent to pre-defined users once the geofenced area has been entered). Hence, flexible events (e.g., setting a max. temperature for the goods loaded) are associated with notifications that allow automation of (subsequent) processes (MR3). Accordingly, transport users that participate in freight operations receive the opportunity to take preventive actions before deterioration. In addition, a shared user interface facilitates communication among all transport users (MR5) and fosters collaborative management of freight handling operations by interpreting the same values. Therefore, we define our second design principles as follows:

Design Principle 2. *To allow freight transport users in an organization (users) to support efficient freight operation (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should enable anomaly detection and automation of freight operations based on event specifications and notification rules that be defined in a shared and flexible manner.*

4.2.3 Risk assessment and prediction of shipment integrity and freight service quality

Performance analysis for telematics-enabled FTAs based on KPIs was identified as a business need for managers involved in transport and fleet management (MR4). The data compiled by telematics is based on the individual parameters set by shippers and the scope of shipment integrity monitored using various sensors. This is subject to the nature of goods loaded (e.g., high valuables, cold chain) and results in a vast amount of data retrieved, stored, and analyzed. In essence, business intelligence provides highly accurate information and the appropriate tools for data analysis, and decision-making processes (Wauyo et al. 2017) leading to a competitive advantage in the sector at the nexus of Big Data Analytics and Supply Chain Management (Kache and Seuring 2017). The data source for risk assessment includes telematics sensors, TMS, enterprise resource planning systems, and external databases (e.g., weather information systems, social media, or news channels). Based on these sources, we identified that analytical insights support the risk assessment and prediction of shipments integrity (e.g., compliance with freight transport conditions, unauthorized door opening) and freight service quality (e.g., transport lead time, ETA accuracy anticipated, deliveries made in full, delivery rate forecasted) (MR6). The essence of a secure FTA during transportation from our analysis grounds on industrial road freight security standards from associations such as the TAPA EMEA[4] based on security levels that support a risk scoring concept for FTAs. Therefore, a FSIP should highlight indicators that represent the risk for shipments and freight service performance. For this reason, we propose our third design principle as follows:

Design Principle 3. *To allow decision-makers focusing on risk management in an organization (users) to achieve secure freight transport operations (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should facilitate the assessment of risks and prediction of shipment integrity and freight service quality.*

4.2.4 Secure data exchange and communication among participating transport stakeholders

We identified that a seamless freight service over different modes of transport used entails a substantial commitment and willingness to cooperate with the engaged transport stakeholders (Flodén and Williamsson 2016). To coordinate an efficient operational freight service process, communication was emphasized by the transport stakeholders to enable unobstructed logistics workflows using ICTs (Ross 2010). Considering the FSIP as a shared front-end for transport stakeholders, operational issues that may arise can be immediately addressed and solved through direct interaction facilitated by an integrated communication module. This feature reflects the significant amount of transport activities and different logistics actors involved in the

[4] https://tapaemea.org/ (Retrieved 12 April 2022).

transport processes and goes along with the exchange of operational information and documents enabled by a platform solution to achieve more efficient transport operation (Dahlberg and Nokkala 2019). We analyzed that the forwarding domain extensively processes information related to transport orders, fleet assets, and risks in a paper-based format. Therefore, the electronic exchange of freight handling information, shipping documents, and recorded events including transactions in the platform solution does support a consistent freight service workflow (MR2). Furthermore, more efficient decision-making is enabled according to our analysis by the coordination of shared communication in a secure manner among transport users related to transport operations (MR5). To this end, blockchain technologies are suggested for application to secure freight processes and communication in a trusted environment, particularly among shippers and transport operators (cf. Lacity and Hoek 2021). We consequently define the following design principle:

Design Principle 4. *To allow freight transport users in an organization (users) to support collaborative freight service decisions (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should allow secure data exchange and communication of participating transport stakeholders for freight documents, transaction logs and events from freight transport assets.*

4.2.5 Integration of additional data sources based on a high-level architecture

Based on our analysis, we identified the need to integrate additional data from various sources to achieve more efficient freight transport services addressing freight coordination, environment, and third parties (MR1). To address this meta-requirement, we propose aggregating data by centering a database within the cloud infrastructure. This facilitates more accurate and precise KPI measurement, risk assessment, and prediction of performance for the use of FTAs and the orders being handled among the stakeholders. Likewise, enhanced multimodal freight operations have been demonstrated by integrating real-time IoT data in decentralized ecosystems based on peer-to-peer to securely share data using blockchain technologies among the participants (Gallay et al. 2017). Moreover, transport orders from digital platforms have shown capabilities by integrated and connected transport operations that emerge especially in the road forwarding sector (e.g., Sucky and Asdecker 2019; Heinbach et al. 2022a). For this reason, we suggest a high-level architecture and present related information flows that build on the Industrial Data Spaces (IDS) architecture promoting the concept of decentralized intelligence in logistics and requiring adopters for operation (Sternberg and Andersson 2014). IDS suggests the application of connectors with embedded algorithms to connect the data sources with the cloud infrastructure for trusted data exchange in a decentralized manner among the platform participants (Otto et al. 2021). Following the work of Gallay et al. (2017), we suggest additional connectors to merge data from sources based on their data specification and manage aggregated data (e.g., meta-connector) to optimize processes by providing information to stakeholders via a user interface. Our analysis, thus, suggests data integration from various sources addressing transport

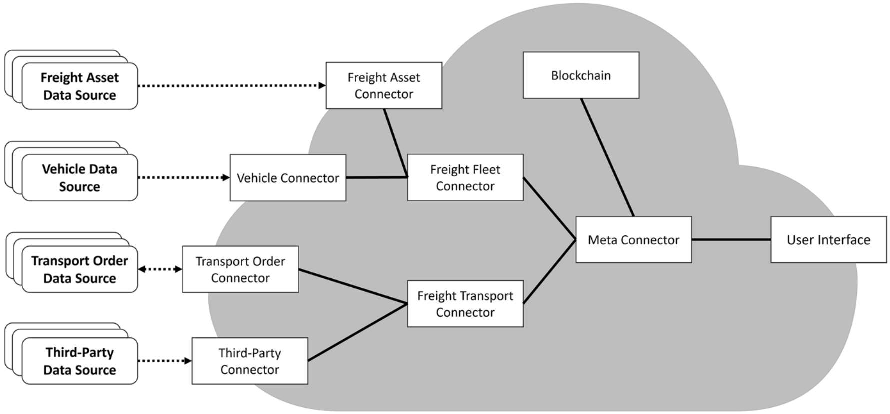

Fig. 3 Proposed high-level architecture and data flows for integration of additional data in a FSIP adopted from Gallay et al. (2017)

assets (e.g., telematics-enabled FTAs), vehicles (e.g., trucks equipped with telematics), transport orders (e.g., freight exchanges, TMS), and third parties (e.g., weather information, news channels). Figure 3 presents the proposed high-level architecture including data flows for integrating the data from FTAs, vehicles, transport orders, and third parties.

Our suggestion to use real-time IoT sensor data from FTA for merging with other data sources to achieve a uniform and enriched data space for freight operations consequently leads us to the definition of our fifth design principle:

Design Principle 5. *To allow freight transport users in an organization (users) to support optimization of data connection with data sources (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should allow data integration* via *connectors embedded with algorithms to merge data sources and manage aggregated data from transport assets, vehicles, transport orders, and third parties.*

4.2.6 Summary of design principles

Overall, we propose five DPs to address the identified meta-requirements. In Table 4, we summarize the DPs and provide the associated meta-requirements derived from literature and expert interviews.

5 Development of a freight service intelligence platform

5.1 Information architecture of freight service intelligence platform

To virtualize transport operations and freight services intelligence at the boundary of cloud computing and IoT according to the derived design principles, we follow Verdouw et al. (2016) and propose different elements for the IS architecture of a

Table 4 Design principles and associated meta-requirements

DP	DP description	MRs addressed by DP
1	To allow transport business managers in an organization (users) to support analysis of freight transport asset performance (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should provide shared tradelane-specific KPIs, i.e., deviations from contractually agreed transport routines, over the fleet and individual freight transport assets.	MR3, MR4
2	To allow freight transport users in an organization (users) to support efficient freight operation (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should enable anomaly detection and automation of freight operations based on event specifications and notification rules that be defined in a shared and flexible manner.	MR3, MR5
3	To allow decision-makers focusing on risk management in an organization (users) to achieve secure freight transport operations (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should facilitate the assessment of risks and prediction of shipment integrity and freight service quality.	MR4, MR6
4	To allow freight transport users in an organization (users) to support collaborative freight service decisions (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should allow secure data exchange and communication of participating transport stakeholders for freight documents, transaction logs and events from freight transport assets.	MR2, MR5
5	To allow freight transport users in an organization (users) to support optimization of data connection with data sources (aim) when mobile telematics is applied to full loads in the freight forwarding industry, a Freight Service Intelligence Platform should allow data integration via connectors embedded with algorithms to merge data sources and manage aggregated data from transport assets, vehicles, transport orders, and third-parties.	MR1

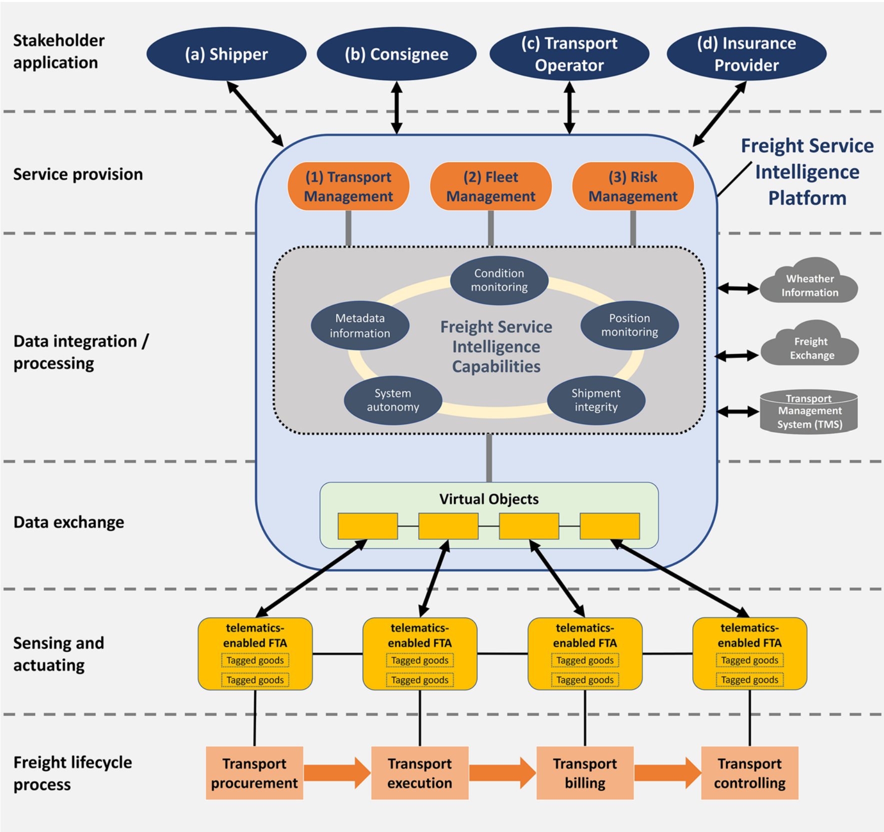

Fig. 4 Stakeholder-oriented freight service intelligence architecture adopted from Verdouw et al. (2016)

platform-centered freight transport chain: (1) identification, sensing, and actuation, (2) data exchange, (3) information integration and (4) application services. This concept provides a valuable approach to investigating our research topic since telematics-enabled FTAs constitute IoT devices with capabilities to convert transport assets into smart connected FTAs that follow the paradigm of a smart service platform (Porter and Heppelmann 2014; Beverungen et al. 2020) to enable smart services along with the end-to-end freight lifecycle processes (Issaoui et al. 2020; Heinbach et al. 2022a). Therefore, we combine the theoretical concepts of virtual food supply chains (Verdouw et al. 2016) and intelligent good services (Jevinger and Olsson 2021) and establish an adopted architecture for a novel FSIP as the research ground for the study presented in this paper. To this extent, we follow the definition of intelligent goods proposed by Jevinger et al. (2014) who characterize the intelligence of goods as different capability dimensions delivering support to different degrees. That is, for instance, the memory storage capability dimension of goods that facilitate the storage of an identity, additional types of data, or algorithms/decision rules. Herein, Jevinger and Olsson (2021) emphasize that intelligence requires more than being able to communicate the identity of tagged goods allowing intermodal transport assets equipped with an ICT to function as an enabler to realize freight service intelligence. In essence, freight service intelligence comprises information processing and autonomous decision-making capabilities based on ICT-enabled physical assets (e.g., FTAs equipped with permanently installed telematics units) and loaded with intelligent resources (e.g., RFID tagged goods) to invoke services and start processes autonomously applied by different stakeholders. In Fig. 4, we propose the theoretical concept of a stakeholder-oriented FSIP. The presented concept is based on six layers that describe the derived information system architecture for virtualized freight transport chains facilitated by telematics-enabled FTAs to be elaborated in more detail in the following.

For the first layer, the underlying freight lifecycle processes aligned to the phases of TMS applications form the basis for information services to support the different activities and tasks. In the next layer, FTAs using telematics facilitate automatic identification by unique identifiers (e.g., asset identification number of swap bodies, license plate of trailers). In addition, sensors are applied to measure different dynamic parameters according to the environmental conditions in which FTAs operate (e.g., temperature, humidity). Thus, in the layer sensing and actuating, RFID transponders and tags are used to track and trace objects on a freight item level (Chamekh et al. 2018; Anandhi et al. 2019) to communicate sensor data from telematics through wireless (sensor) networks (e.g., GPRS, and Wi-Fi) to an intermediary back-end system using cloud storage. Physical FTAs, therefore, exchange data with virtual objects in the next layer that are constantly updated (Verdouw et al. 2016). The cloud-based middleware acts as a data hub and the exchanged data can be further enriched through the data integration/processing of other IS (e.g., weather information systems, cloud-based freight exchanges, TMS) by the existing freight service intelligence capabilities derived from intelligent good services (Jevinger and Olsson 2021). Subsequently, service provisions are determined in the next layer and *"(…) differ from basic virtualizations that only show the whereabouts of physical objects to smart virtual objects that proactively take actions"* (Verdouw et al. 2016). The provided services reflect the tasks and responsibilities of stakeholders bound in three overarching dimensions: (1) transport management, (2) fleet management, and (3) risk management. These dimensions follow a user-oriented approach and correspond with the generic types of application services proposed by Meyer et al. (2009): information handling (e.g., position details among different transport management systems), problem notification (e.g., position out of a geofenced area, temperature too low), and decision-making services (e.g., billing upon arrival according to the estimated time of arrival). Shared information from freight service intelligence is offered in the front-end to users that build on the telematics-based service offerings in the layer stakeholder application for four different groups: (a) shipper, (b) consignee, (c) transport operators, and (d) insurance companies.

In summary, the illustrated information architecture provides a novel concept for telematics-enabled FTAs in global forwarding operations. Furthermore, the theoretical concept provides the conceptual ground for designing an innovative FSIP focusing on IoT-enabled services and shared information used by different stakeholders to support freight operations.

5.2 Prototype demonstration

After we derived the design principles and presented the information architecture, we developed a web application artifact called Freight Service Intelligence Platform (FSIP) that serves as a prototype demonstration for the first evaluation cycle with potential users (cf. Fig. 1). With that objective in mind, we subsequently demonstrate the prototype and show the front-end of the platform to potential users from the field of freight forwarding operations and transport software development that will be elaborated in the next Chapter. We developed a web-based application accessible via a web browser and implement DP1–DP5 with the development tool Figma,[5] which uses the latest web technologies. The web application is not connected to other components of the architecture (cf. Fig. 4) and has no access to a real database and, thus, uses dummy data intertwining the layers "service provision" and "stakeholder application". However, the artifact represents a user interface (UI) illustrating the implementation of the design principles. Moreover, the development of hypotheses, statistics-based confirmation, or rejection is not part of this study and requires further evaluation studies to be conducted in the future. This approach is recommended for DSR projects (Kuechler and Vaishnavi 2012) as demonstrated, for instance, by Sein et al. (2011) who conduct multiple studies based on different prototypes. Pursuant to the developed UIs, we discussed the usefulness of the prototype with potential users.[6]

The web application presents a landing page, i.e., the first screen the users would see, and provides an overview of all apps installed on the platform. An app is a software module that provides specific functionality to the user divided into three types: *Administration Apps*, *Freight Performance Apps*, and *Transport Operations and Management Apps*. *Administration Apps* are necessary, for instance, to maintain master data about users, transport assets, and tradelanes. *Freight Performance Apps* provide the users with basic KPIs and analytical information about tradelanes and FTAs, i.e., transport asset utilization, event performance, probabilities of ETA accuracy, and anticipated status of freight integrity including freight risks. *Transport Operations and Management Apps* encompass the monitoring of FTAs, the definition of events, notification rules, information on the freight risk, handling of freight documents, records of logs based on transactions, and the management of data connections. When the user selects an app, a corresponding UI is loaded.

In Fig. 4, we illustrate the UIs in a web-based front-end for the FSIP. Moreover, we show the elements addressing DP1–DP5 that we have implemented in the web application and describe them in more detail in the following. The first DP refers to the freight performance based on tradelane-specific KPIs in addition to individual transport asset KPIs (DP1). Thus, the UI provides users with metrics according to the actual performance related to freight equipment, events, asset utilization, weight per asset, emissions generated, and service quality, i.e., delivery performance, customer claim rate, and time per transport. In addition, based on the collected data

[5] https://www.figma.com/ (Retrieved 13 October 2021).

[6] The developed prototype may be accessed online: https://bit.ly/3GQvgLm.

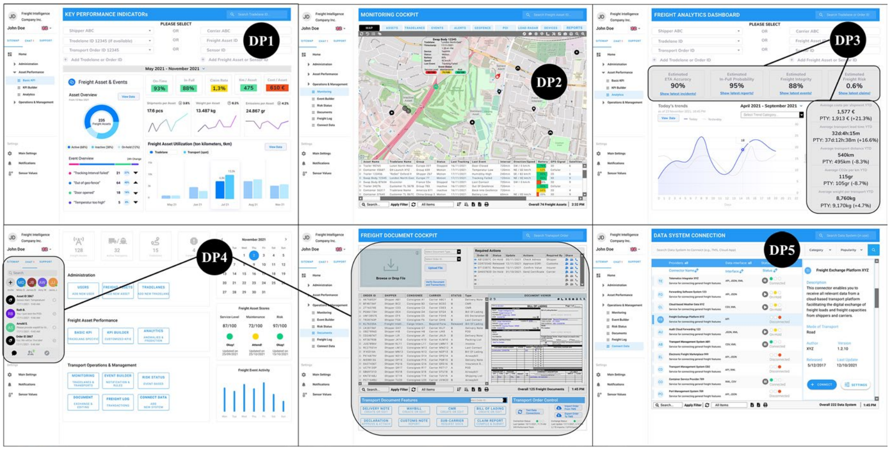

Fig. 5 User views of UIs for the developed FSIP

from telematics-enabled FTAs, analytical insights enabling prediction are presented by the ETA, the projected in-full deliveries, the freight integrity status, and the freight risks associated with integrated environmental information and performance prediction (DP3).

To support operational transport decisions aligned to DP2, users benefit from a shared *Monitoring Cockpit* to achieve real-time visibility of FTA status and the goods loaded. The platform allows users to communicate the transport status, events, transactions (logs), and exchange data based on freight documents (DP4). Thus, we incorporated a *Document Cockpit* module in the FSIP that enables the upload of various transport and shipping documents with an assignment to transport orders. Additionally, the platform summarizes the actual status of pending tasks for users to be addressed during operations to achieve transport efficiency. Moreover, users can administer freight documents assigned to transport orders by controlling a list that allows them to preview a selected document and leave comments for other users in case of required document revisions. To this end, this feature provides a set of functions to users to create, edit, approve, attach, report, request, compile and submit documents. If a transport document was created or revised according to the transport order, a *Transport Order Control* area offers features enabling the import of transport orders according to the data retrieved from integrated transport order data systems (e.g., TMS) or to update the order information vice versa, if revised. This feature is assisted by testing data connections to ensure data exchange between the FSIP and, for instance, integrated transport order data systems.

To facilitate freight communication based on the documents in case of issues or questions that may arise among users, a link to the *Chat* software module is integrated providing an overview of pending tasks. Since a *Chat* represents an implemented feature that is permanently available for users, it consolidates communication addressing documents and events from mobile telematics applied to transport assets. Ultimately, specific data from various data sources can be integrated by a *Connect Data* module (DP5) in the platform core, offering value-adding information to the freight transport operations. This yields the integration of specific vehicle data (i.e., integrated truck telematics), transport order data components (i.e., TMS, forwarding software, cloud-based freight exchange platforms), and third-party data (i.e., weather information, social media systems, customs systems), to support the freight-related services based on data exchange, transport load coordination, and prediction. In essence, we have implemented DP1–DP5 addressing the derived meta-requirements and provided the respective UIs in our web-based prototype application illustrated in Fig. 5.

6 Prototype evaluation

After completing the design and prototype, we aimed at the iterative evaluation. For this reason, we conducted an ex-ante evaluation that is the first evaluation cycle. The purpose of this evaluation was to obtain formative feedback on the prototype and measure the completeness of the DPs. To reach this goal, we demonstrated the prototype to potential users from the field of global forwarding operations and transport software development. Following this way, the participants were then asked if the design has possibilities for improvements. Correspondingly, our first evaluation cycle focuses on receiving support, criticism, and ideas about our proposed DPs and the web-based prototype.

Shared tradelane-specific and data-driven KPIs over the fleet and freight transport assets (DP1). From the feedback of the participants in our evaluation study, we received confirmation on the appropriateness and usefulness of the demonstrated KPIs shared among the users. Shippers and consignees have emphasized that a tradelane-specific KPI does support the performance analysis of distribution networks and assists the measurement of service quality received from contracted transport operators according to the assigned tradelanes.

> "*It makes much sense in my opinion to measure KPIs related to the agreement with freight forwarders for specific transport destinations since we will be able to understand the performance together with the shipper by reading the same indicators.*" (Consignee A)

Likewise, transport operators explained that KPIs are most relevant to monitoring and controlling their fleet equipment enabling the measurement of fleet performance based on the assets and events that occur. Specifically, the provided utilization of freight transport assets supports an indication for fleet operators on the use of assets and the corresponding economic impact. Overall, asset-based metrics relate to shipments, weight, and emissions generated:

> "*I need my performance metrics to manage our fleet equipment efficiently and decide if I need to change anything. In this way, shared KPIs with customers can be helpful to compete in the market.*" (Transport Operator)

Anomaly detection and automation based on event specifications and notification rules (DP2). The participants confirmed the importance of anomaly detection of FTAs based on events and automated notifications. Therefore, a metrics system to measure the performance of transport orders carried out (e.g., lead time, on-time deliveries), FTA activities (e.g., in motion, stationary), sensor values (e.g., an opened/closed FTA door), and scorings addressing service level, maintenance, and risks is useful for the stakeholders to obtain the real-time status and facilitate immediate actions based on detected irregularities compared to historical data recorded. Herein, we found that our presented scoring approach to provide a metric for measuring event-based performance is a properly addressed area for all participants to make freight operations status visible to the users provided by the *Monitoring Cockpit*. Data-based insights consequently address issues in advance to prioritize transport and fleet management decisions. Moreover, we identified that the collaborative specification of events and notification rules, i.e., email messages upon entering geofences, in a flexible manner is a significant feature for the users:

> "*In my opinion, event management is the most significant proposition of the platform since I am able to determine deviations of transport operations collaboratively based on individual event configurations.*" (Shipper A)

Risk assessment and prediction of shipment integrity and freight service quality (DP3). In the first evaluation cycle, the participants supported the detection of risks and prediction of transport performance based on business intelligence tools enabling data analytics. We identified that freight analytics presents an opportunity for economical and qualitative decisions on tradelane services, shipment integrity, and fleet operations with high relevance for managers. For instance, one shipper explained the benefit of ETA for customer service due to the accuracy in combination with political incidents of the real world offered by an integrated link (e.g., a news ticker indicating a strike at the port of unloading):

> "*If a container on an ocean vessel is of high interest, I need to know if the port of arrival will be closed due to strikes that may arise, which has an impact on the ETA accuracy. Therefore, the linked information presented in this system is particularly important to inform my customers in advance.*" (Shipper A)

Interestingly, an insurance provider explained that the estimated freight risk presented does not support their claim processing solely. Rather, historical data of the entire freight lifecycle including the sensor values and a log record encompassing all transactions provide a greater benefit to deciding on an insurance case:

> "*When a consignee declines acceptance of a container because the cold chain was interrupted due to high temperatures, it is of interest for us to identify the time and place of occurrence (…) based on a temperature profile. (…) The presented system allows me to individually compile data reports and obtain the information I need to manage the insurance case efficiently.*" (Insurance provider C)

Secure data exchange and communication among participating transport stakeholders (DP4). The *Chat* feature and the integration in the *Document Cockpit* module were confirmed by all participants to support efficient handling of freight documents along with the progress of freight transport activities. The usefulness of this DP is found in the direct coordination of issues addressed by the summary of pending tasks and the integrated app messenger that facilitates instant communication with personal contacts comparable with existing smartphone app services as emphasized by a transport operator:

> "*The document cockpit will in my opinion lead to synergies since the shared and secured form of electronic document handling combined with embedded communication does support an efficient document management process.*" (Transport operator C)

However, we identified that insurance providers exchange an extensive number of paper-based documents, especially with logistics service providers in a sparsely digitalized transport environment. Thus, our *Document Cockpit* module has been confirmed especially as an interactive application for shared electronic freight transportation information accompanying freight movement:

> "*Your document cockpit for us as an insurer currently represents a 'clockwork' we have never taken a careful look at yet. (…) Since you have the order ID, shipper, and consignee details in the platform it will help the carrier to manage his work and consequently us.*" (Insurance provider C)

Integration of additional data sources based on a high-level architecture (DP5) During our evaluation study, it became apparent that data integration is necessary to facilitate shared KPIs, anomaly detection, risk assessment, and prediction. Likewise, data exchange must address transport orders to synchronize the information on a shipment level. We found that the participants support data connection with IS components through the integration of transport data, particularly from transport order data sources and third-party data sources that impact FTA operations based on uniform data interfaces (e.g., API, JSON). Furthermore, freight service users and software vendors support data aggregation from various data sources aiming to achieve digital forwarding toward process automation (e.g., an invoice is created in the TMS once real-time data from FTA communicate that a geofence area has been entered at the customer site). However, it is important to note that merging IoT tracking technologies with transport assets (e.g., telematics-enabled FTAs) is a prerequisite in our research study addressed by the *Freight Assets* software module in the *Administration App* of our prototype:

> "*The integration of data from other information systems is mandatory to support our transport management solutions. Customers rely on updated information in the TMS that is equipped with Power BI and the presented interface module is in my eyes an advantage to connect systems on demand.*" (Logistics software vendor A)

Evaluation Summary. Overall, our evaluation study indicates that all participants promote the design principles and approve our developed prototype. The potential users have rated the UIs of our implemented DPs as a suitable support for transport stakeholders to enhance freight service operations based on telematics-enabled FTAs. Nevertheless, we have identified specific areas for improvement that do not cause major design issues. This comprises a refined consideration of KPIs from the shippers' side and a more condensed view for users based on individual workflow management over the different modes of transport and order transactions as proposed by the *Freight Log* software module.

7 Discussion

7.1 Novelty and practical contribution

In our DSR project, we designed a digital platform that aims at supporting transport stakeholders, i.e., shippers, consignees, transport operators, and insurance providers, to foster shared freight service operations in the global forwarding industry. In particular, the objective was to explore the design of the desired platform that addresses shared freight service intelligence based on generated data using IoT-enabled freight transport assets (e.g., ISO containers, intermodal trailers, swap bodies equipped with mobile telematics units). To accomplish this, we derived requirements from scientific literature and interviews with practitioners from the transport logistics industry. Subsequently, we consolidated these requirements into meta-requirements. Based on the input from the knowledge base (rigor) and the application of such a platform in practice (relevance), we derived design principles and thereby answer our RQ1. Afterward, we proposed an information architecture and implemented the design principles in a web-based platform application that addresses RQ2 and conducted an evaluation study of the prototype in the first evaluation cycle of our DSR project.

During the evaluation phase, the developed platform is presented in the form of instantiated front-end user interfaces to potential users. The developed prototype allows users to obtain uniform information based on performance metrics and analytical insights into the trend for conditional state for loaded freight items, transport assets (e.g., events), and the associated risk (e.g., freight damages). Transport operators are particularly provided with fleet management capabilities to operationalize flexible and customized KPIs related to the transport assets in use. It likewise provides KPIs to shippers and consignees that depend on tradelane configurations based on formal agreements among shippers and logistics service providers. Thus, the *Freight Performance Apps* are to be considered useful, since the transport stakeholders control the KPIs focusing either on tradelanes, transport orders, or FTAs. Tradelane-specific KPIs reveal performance understanding of FTAs associated with contractual agreements, and the platform, therefore, assists the alignment of actual freight operations with existing customer service levels. To this end, the shared metrics allow shippers, consignees, transport operators, and insurance providers to make joint decisions according to the performance of freight operations addressing transport orders, FTA activities, state of goods, and risks assessed. Our findings fill in existing knowledge specifically toward freight integrity that results from events detected by the platform based on pre-defined values, which offers new data opportunities for freight transport efficiency beyond economic indicators (cf. Silva et al. 2020). For this reason, our study reveals that the involvement of insurance providers in freight operations to judge risks or issues on established business routines (e.g., tradelanes composed of recurring shipments) and freight service quality (e.g., quote of shipment damages or delays) is useful for shippers and transport operators similarly to support tactical decisions on transport configurations (e.g., high stationary time indicating room for improvements) yielding advanced freight service operations. Moreover, risk assessment can be associated with additional dimensions such as political incidents mentioned by shipper A to provide improved indicators for advanced freight handling (e.g., addressing transport delays that arise due to strikes).

Even though telematics-enabled FTAs support autonomous decision-making associated with intelligent resources (e.g., tagged goods), freight service intelligence focuses on the provision of relevant information fostering individual processes for stakeholders. Since data exchange and communication remain substantial challenges for transport stakeholders in practice, a shared platform solution does ultimately require mechanisms to provide information in the same data format, understand the status of freight operations, and indicate ways for improving the entire end-to-end workflow. In this way, the *Monitoring Cockpit* combines tracking and tracing information and connects real-time visibility of FTAs and related transport orders with additional features to control freight equipment, geofences, points of interest, sensor devices, and manage reports. Shippers have argued that tradelane agreements with transport operators affect the way of collaborative transport management with transport operators. For instance, an agreement of "round-trips" for specific tradelanes enables shippers to turn their position into self-freight dispatchers focusing on optimized asset utilization to achieve economic advantages. Thus, the implementation of assisting features, i.e., a "load radar" that proposes available full load offers obtained from integrated freight exchanges, is of benefit to assist collaborative freight transportation together with freight dispatchers from the side of transport operators. Regarding the sensor values, insurance providers have explained in the study to require primarily historical data combined with details of secure transactions based on blockchain-assisted "Smart Contracts" (Vivaldini 2020). The obtainment of relevant data for decision-making does therefore require precise user management to ensure a diligent use of the platform among all transport stakeholders.

We identified the *Document Cockpit* as a crucial and innovative feature to reduce the time for data exchange and communication within the group of stakeholders. Shippers, consignees, and logistics services providers benefit from the instantiated "single window" concept (Niculescu and Minea 2016) for freight documents that address the collection of all documents required to proceed with a transport order, the assignment of tasks for stakeholders in case of arising issues, and the immediate communication by the integrated link to the *Chat* module. In addition, insurance providers elucidated their participation in the platform to obtain electronic documents for completing their tasks. It was identified in the study, that the platform allows the integration of technologies to further protect data exchange of freight documents such as blockchain. This aspect might attract other stakeholders (e.g., financial institutions, public authorities) and support current developments toward data exchange standards. Likewise, our developed prototype features the emergence of interconnecting data exchange for transport operations, for instance, as represented by the European initiative to establish a standard for electronic Freight Transport Information (eFTI).

Finally, the *Chat* module reveals further interesting and feasible aspects that support transport operations and management by addressing issues immediately and combining detected events from FTAs while navigating in an individualized environment. Since all transport stakeholders argue that freight forwarding is yet facing communication and transparency problems, the incorporation of shared and interactive messaging services may enhance freight transport service decisions and quality.

7.2 Theoretical contribution

In the presented research, we designed a specific solution to solve a relevant problem from the day-to-day business of the logistics industry and thereby contribute to theory in the form of prescription. Prescriptive recommendations are typically characterized by design principles (Kuechler and Vaishnavi 2012) and support the guidance of instantiations. Based on the description of our problem, the meta-requirements are addressed by the design principles, which prescribe how the problem can be solved (Day et al. 2009) and thereby represent a theoretical contribution. A theoretical contribution is consequently given by the theoretical relationship presented by each combination of the meta-requirements, design principles, and the proposed information architecture. While our generated knowledge is described as prescriptive knowledge (Gregor and Hevner 2013), the formulated design principles describe an IT artifact (Gregor et al. 2020) and we suggest further investigations of the findings by empirical testing or by action research to achieve generalization of the theory (Lee and Baskerville 2003; Day et al. 2009).

To the best of our knowledge, no other study investigated the design of a shared software platform for telematics-enabled FTAs facilitating freight service intelligence. Given the complexity of business relationships, legal frameworks, and technological impediments in the freight transport market, this development is highly relevant since transport stakeholders are not using a single platform to manage freight transport management collaboratively. Notwithstanding this issue, the existing capabilities of freight service intelligence toward automated process and autonomous decision-making explored in this paper are predominantly grounded on the collection, aggregation, and processing of data from various data sources, yielding the provision of information in a uniform cloud environment that facilitates operational interactions among the users.

Our investigation of a domain-specific problem yields six meta-requirements that reveal the aspects to be met by a solution that supports the collaborative analysis and anomaly detection of transport assets, tradelane, and transport orders and collaborative decision-making to achieve efficient transport operations and management. We call the solution Freight Service Intelligence Platform (FSIP). Even though the proposed novel system for advanced freight transport operations is proposed as a new solution, existing technologies (e.g., digital platforms for transport management) and analytical data capabilities (e.g., Big Data Analytics, Business Intelligence) serve as a basis for our platform solution. Therefore, we generate prescriptive knowledge by adopting known solutions to solve new problems (Gregor and Hevner 2013) and herein position our work. For this reason, prescriptive knowledge is contributed in the form of design principles that address meta-requirements and a developed artifact instantiation (Gregor et al. 2020). After the adoption of the platform by transport stakeholders, we expect descriptive knowledge, for instance, by conduction of an empirical evaluation.

In summary, we provide valuable insights into the emerging topic of uniform interfaces to facilitate electronic data exchange in a dynamic freight forwarding business domain. We establish the theoretical concept of a stakeholder-oriented FSIP and propose an information system architecture for virtualized freight transport chains facilitated by telematics-enabled FTAs. This leads us to a shared digital platform instantiation that addresses the concept of value co-creation through the engagement of the transport stakeholders. Value co-creation applies in the form of shared KPI measurement, anomaly detection, risk assessment including prediction, data exchange including communication, and the integration of additional data sources. The FSIP solution consequently contributes to service science knowledge and proposes a smart service platform "*that builds on a smart product to enable direct interactions between two or more distinct but interdependent groups of users to create mutual value*" (Beverungen et al. 2020).

Both the *Chat* module and the *Document Cockpit* provide input for future directions of enhanced freight service operations. In essence, our study has shown that IoT services enabled by FTAs equipped with mobile telematics support transport management, fleet management, and risk management using a shared platform front-end by transport stakeholders. However, decentralized intelligence does yet support the autonomous behavior of telematics-enabled FTAs (Sternberg and Andersson 2014) that are not mature from a service perspective applied by transport stakeholders in a shared manner. Other than focusing on service applications by users, the capabilities of freight service intelligence are to be illuminated by focusing on individual activities along the freight lifecycle in the context of smart service systems (cf. Beverungen et al. 2019) based on the operational use of telematics-enabled FTAs as a boundary object following the characteristics of smart connected products (Porter and Heppelmann 2014). From that perspective, it is yet to be explored whether the proposed system allows a transferability to other domains such as the health industry and smart living using similar and interoperable IoT technologies leveraging data-driven service systems engineering in a collaborative manner within decentral data ecosystems (e.g., Kortum et al. 2020).

7.3 Limitations and future work

Due to the complexity of freight service intelligence and the different transport stakeholders involved in this study, our findings are subject to some limitations. First, while this study provides an adopted solution in an under-research business domain, our proposed design and prototype are evaluated qualitatively. Since the development of a more advanced prototype allowing a more comprehensive evaluation would yield excessive costs, it was not possible to develop during the first evaluation cycle. Second, a limitation is the small number of study participants for the evaluation that was given due to the limited access to transport stakeholders. Third, although we formulated meta-requirements and design principles on an abstract level that allows the application of our insights gained from all modes of transport, a more granular focus on dedicated intermodal freight transports (e.g., container transports performed by road trucks, rail, or ocean vessels) would have revealed additional insights into specific transport areas. This applies especially to ocean-based container transports that present the largest share of the global freight market with a tradition to develop sensor and network technologies for tracking and monitoring service offerings enabling digital business (Gruchmann et al. 2020; Heilig et al. 2020). However, the market entries of providers such as Mecomo give rise to a focal point on technologies for intermodal freight transportation. The fourth limitation in our DSR project is the collected data of four stakeholder groups from the regional market in Germany that cannot guarantee an entire representation of the global freight forwarding market. The involvement of other stakeholders (e.g., customs authorities) from other regional markets (e.g., Asia, North America) may have revealed other requirements. These limitations should be addressed in future research.

As a spark toward further exploration, the proposed design should be implemented and evaluated through the usage of a prototype with data from the day-to-day business. This allows scholars to explore new features supporting collaborative transport management beyond the existing relationships in traditional business. That is, for instance, the integration of external data sources with an impact on transport operations (e.g., social media) providing analytical insights indicating delays. From the stakeholder perspective, it remains to be explored how the platform ownership can be organized among the participants to capture the value of (multi-sided) platforms based on the service-dominant logic. Thus, we suggest conducting further research focusing on the governance mechanism and value co-creation within the boundaries of transport chains that is pivotal to establishing digital platform ecosystems, for instance, as a "consortium" (Hein et al. 2020). Furthermore, the prescriptive theoretical findings may guide future research in designing freight technologies toward smart services supporting logistics platform strategies for organizations (Heinbach et al. 2021b). To give an example, manufacturers and insurance companies can assess the tradelane-specific performance of transport carriers and identify the number of sub-contracted carriers. Therefore, it could be interesting to establish indicators about the number of sub-contracted carriers used for a tradelane and provide their compliance status based on events. The service offerings enabled by the FSIP utilize data generated during freight lifecycle processes and open new opportunities for research on emerging digital shadows as an informational representation of transport operations. In this context, future work is likewise necessary to understand how the presented platform can support value creation by interactions among the stakeholders associated with production system networks and their stakeholders, for instance, toward innovative business models (Stecken et al. 2019).

8 Conclusion

In this research paper, we constitute freight service intelligence as an emerging interdisciplinary research field that builds a bridge between IS researchers and researchers from other disciplines, i.e., operations research, data science, and service engineering. In our belief, freight service intelligence provides new application domains for IS scholars by combining function-oriented IoT technologies and collaborative freight transportation in an overarching stakeholder approach that relies on data to attain efficient processes embedded in organizations.

Moreover, we designed a Freight Service Intelligence Platform (FSIP) for transport stakeholders by establishing a DSR project. By investigating the two research questions, our research aimed to a) examine what requirements should be considered when designing a software platform for freight service intelligence, and b) how these requirements can be addressed to conceptualize a software platform. To this aim, we propose an information architecture for a stakeholder-oriented FSIP and five design principles from the derived meta-requirements of scientific literature and expert interviews of transport stakeholders. Subsequently, we conducted an evaluation study to verify our results based on a developed platform prototype. By means of our developed prototype, we make a first step in contributing to design theory for FSIPs due to the design principles associated with meta-requirements indicating specific goals for users. Moreover, our contribution is likewise relevant for logistics software vendors, software enterprises, and technological service providers committed to IoT services in logistics and supply chain management in practice since no platform exists to our knowledge that addresses our identified requirements.

It is hoped that the insights from this paper span the gap between industry practice and academic theory for testing freight service intelligence theories within a logistics and supply chain context. This will further contribute to novel design knowledge on a contemporary issue and, in doing so, augment multidisciplinary discussions on the topic.

Appendix

Sections and questions of the interview guideline during the first evaluation

A. Interviewee's background	
1	In which position are you currently working in your organization?
2	How many years have you been working in this position?
3	In which industry does your organization operate?
B. IoT technologies and services for freight transportation	
4	How many years of experience do you have with IoT technologies (e.g., sensor devices, telematics) applied to full load transportation (e.g., full truck load, full container load) in the forwarding industry?
5	Can you imagine a situation in which IoT technologies are used to enable data-driven freight services?
6	Did you experience IoT technologies and digital platforms focusing on the support or enhancements of freight services based on the generated data during transportation?
C. Usage of telematics enabling freight service intelligence	
7	In your opinion, what real-time information about an "intelligent" logistics object (e.g., freight unit equipped with mobile telematics) is of interest in global transport chains to generate concrete benefits?
8	What aspects are of importance to support freight operations using mobile telematics from your stakeholder view?
9	Which decisions and processes could be supported by data-driven freight services from telematics-equipped freight units?
D. Prototyping a freight service intelligence platform	
10	Do you see potential for the use of a digital platform providing freight service intelligence enabled by telematics-equipped freight units?
11	In your opinion, what are the limits or restrictions for implementing a freight service intelligence platform?
12	Are there any other aspects that are important we did not mention yet?

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Authors and Affiliations

Christoph Heinbach[1] · **Pascal Meier**[1] · **Oliver Thomas**[1,2]

Pascal Meier
pascal.meier@dfki.de

Oliver Thomas
oliver.thomas@dfki.de; oliver.thomas@uni-osnabrueck.de

1 Smart Enterprise Engineering, German Research Center for Artificial Intelligence, Parkstraße 40, 49080 Osnabrück, Germany

2 Department of Information Management and Information Systems, University Osnabrück, Parkstraße 40, 49080 Osnabrück, Germany