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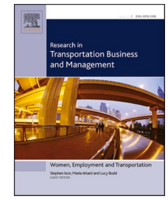

A data-to-value framework for freight ITS: Insights from a living lab

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ABSTRACT

The emergence of Intelligent Transportation Systems (ITS) for freight transport in recent times has created interest among practitioners and researchers to extend freight ITS to support broader logistics processes, including dynamic tour scheduling, loading and unloading, warehousing, and even production. However, connecting transport data, ITS and logistics information systems require collaboration between different organizations and new business models to create business value for logistics actors. It is critical for these stakeholders to consider how their business models connect to create meaningful new data-to-information value chains. This study develops a conceptual framework to identify opportunities for logistics value creation with freight transport data. Building on the literature we construct a framework that reconciles multi-firm and firm-level business modelling. The main component is a generalized framework for Data-to-Value (DtV) chains for applications in information and communications technology. In order to support its business validity, we extend this framework with Business Model Canvases (BMCs) of the actors in the value chain. Three real-life use cases from a freight ITS community in the Netherlands are used to evaluate and illustrate the framework.

1. Introduction

In modern data-rich organizations, the ability to use and extract value from data is seen as a core capability (Pesce et al., 2019). Advancements in ICT technologies have enabled the sharing of real-time data and information between actors. Real-time data based decision support systems have been widely adopted in several sectors such as education (Nikolić et al., 2019), health care (Chatterjee & Chakraborty, 2021), sports (Loia & Orciuoli, 2019), and transportation (Gössling, 2018). Freight transportation plays a crucial role in the world economy. According to the US bureau of transportation statistics, freight transportation contributed to $1.6 trillion (7.7 % of GDP) to US economy in 2020. It is responsible for 25 %- 50 % of total logistics cost (Perego et al., 2011). As global freight demand increases and traffic congestion worsens in built-up areas, subsequent delays in transportation processes lead to increased supply chain costs (Hoef et al. (2019)). Our interest in the context of freight ITS is the creation of logistics added value from ITS (transport) data. Improving the deployment of transport resources through ITS applications is seen as a potential solution. The application of ICT in transport has lead to the development of Intelligent Transportation Systems (ITS) which facilitate the visibility of vehicles and their cargo, enabling managers to make better informed decisions and to improve supply chain performance (Mirzabeiki, 2013). ITS applications for smart urban mobility initiatives (Ferreira et al., 2017; Prendinger et al., 2013), urban freight transport (Gatta et al., 2017), and smart buildings (Delinchant et al., 2016) are examples in the literature. The promise of these systems is that they deliver new value to the supply chain in terms of reduced delays (Vanga et al., 2022), lower inventories, lower personnel costs and general resource savings (Nadi et al., 2022; Su et al., 2023). While the benefits of leveraging freight transport data in logistics processes can be significant, research is absent on how this should be organized. While clearly of interest for practice, we also argue that knowledge development is needed on this subject, to understand how such value chains conform to existing models of business development and inter-organizational collaboration. The focus of this paper, therefore, is on the configuration of business models needed to capture the value of freight transport data in logistics processes.

While some freight ITS innovations may involve only internal stakeholders of an organization, especially when supporting broader logistics processes than concerning transport alone, chaining of

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organizations will often be needed (collaborative innovation or co-innovation). Such innovations will often be developed in living labs or, according to the European Network of Living Labs (ENoLL), "user-centred open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real-life communities and settings". Interestingly however, the literature on ITS innovations either focuses on a focal stakeholder's business model perspective, or a value chain perspective, where stakeholders are assumed to work together. We have not identified any work on freight ITS presenting a conceptual framework that integrates these two perspectives. Our ambition is to help fill this void. Below, therefore, we develop a conceptual framework applied to freight ITS, which reflects the value creation process from transport data to information for logistics decision support. This framework should be comprehensive in the sense that it captures business requirements of relevant actors within an underlying DtV chain concept. This chain concept reflects the business interactions between suppliers and clients of data, software and information. In the paper we design this framework as a business artefact, aiming to support vertical collaboration between stakeholders for the formation of business ecosystems around logistics decision information. As an empirical context for framework development, we use three pilot studies of a recent living lab from the freight logistics sector. The studies are used to validate and demonstrate the framework by implementing it inside the three pilots.

In summary, the study contributes to the literature with a novel framework for data-to-value transformation in the field of freight ITS. The framework connects the value chain level with the individual company level, building on well-established concepts from both levels. It allows practitioners to choose their position in this value chain and define their business model in a way that it connects to upstream and downstream parties in the chain. This should support the creation of information systems that deliver value to users of the freight transport system.

Section 2 presents the literature review about ITS innovations in freight transportation, in particular including recent developments on conceptual DtV frameworks. Section 3 describes the research and design methodology applied in this study. Further, it introduces the practical context of the living lab in the Netherlands that provided the inspiration and data utilized in this study. Section 4 explains the development of the integrated framework and Section 5 discusses the findings and concludes the paper.

2. Literature review

This section first provides a review of ICT/ITS applications in transportation followed by an overview of collaborative innovation approaches and existing conceptual frameworks related to DtV chains. This positions our research at the crossroads of these 3 subjects and also helps to identify existing partial frameworks that apply to the data-based innovation processes of our interest.

2.1. ICT and ITS applications in transportation

In the literature, several articles (Chatti, 2021; Feng & Ye, 2021; Perego et al., 2011; Samir & Mefteh, 2020; Song et al., 2021; Suresh & Shanmugam, 2018) present an overview of ICT applications in the transportation domain. The number of research articles on urban logistics is relatively high, which may reflect the ICT adoption rates in this domain (Marchet et al., 2013). Further, when compared to public transportation, freight transportation by private organizations has received very limited attention in the context of ICT adaptation (Perego et al., 2011). Unsurprisingly, road transport plays an important role in the literature, as it contributes around 70–72 % to global land-based transportation. Rafiq et al. (2013) presented an early overview of European projects focused on ITS initiatives in the transportation sector. Several works focus on disruption management due to bad weather (Dey et al., 2015), road works (Lu et al., 2018), accidents (Tomasoni et al., 2022), congestion (Nwankwo et al., 2019), which can effect planned operations. Researchers proposed development of ITS applications as the solution to bring visibility to mitigate the negative effects of disruptions. Marchet et al. (2009) present an exploratory study on the adoption of ICT technology in the Italian freight transportation network. Jin et al. (2021) deals with solving routing problems in China using GPS data by modifying the VRPTW model. Chen et al. (2021) and Fourie et al. (2018) use transport status information from GPS and GIS data for service optimization by employing the real-time position of freight transport modes. Park et al. (2021) use estimated time of arrival (ETA) predictions for planning of intelligent port facilities. Prasanna and Hemalatha (2012) study the integration of RFID technology to understand the transport of products through the supply chain. (Perboli et al., 2017) study the use of ship position data on port hinterland operations. Melo et al. (2017) studied the effect of providing guidance information based on real-time events to the city drivers and estimated the emissions and travel costs. Lu et al. (2018) focused on developing a cooperative ITS platform to provide multiple services to urban road users. Prakoso et al. (2022) developed an approach using inbound truck ETA predictions to optimally manage loading slots against uncertain road congestion. A widely supported insight is that combined data sources (e.g. cargo data and vehicle position data) can enable tracking and prediction for cost reduction and/or service level improvement in the supply chain. The above articles mostly deal with the contents of data exchange and do not shed any light on the business configuration that would make data exchange and production of information feasible at firm-level.

2.2. Collaborative innovation

In order to produce logistics decision information from transport data, collaboration is needed between data owners (usually carriers and shippers), those who process data and produce information (e.g. software providers and information brokers), and the users of information who wish to improve the effectiveness of logistics decisions (shippers and logistics service providers). Therefore, the realization of new logistics information systems constitute important inter-organizational innovations, beside the obvious technological challenges. Bertassini et al. (2021a) define this need for firms as to"collaborate internally and externally through formal and/or informal arrangements to create mutual value". Collaboration allows dynamic interactions among multiple stakeholders with often complementary capabilities to work towards creating new business value together, within their business ecosystems (Fuller et al., 2019). Fig. 1 presents our view of the innovation process based on the discussed literature.

The first step in innovation process is the idea inception. This step involves requirement analysis, generation, and evaluation of innovative ideas followed by project planning. The implementation phase involves the prototype development and testing by stakeholders. A successful ecosystem allows the stakeholders to co-evolve and form semi-permanent relations in the form of data, service, and money flows (Fuller et al., 2019). Each member of an ecosystem will have a specific role with a complementary skill to realize the intended value, based on their own enterprise business model. Several studies (Battistella et al., 2013; Popov et al., 2021; Rong et al., 2017; Talmar et al., 2020) in the literature emphasize the importance of this stakeholder alignment in the success of business ecosystems, where business models of individual firms are linked into ecosystem-level value chains. Several researchers in the literature focused on the creation of the value chains. Chatterjee et al. (2022) focused on the factors that enable the value creation in a co-production and consumers' participation scenario. Lim et al. (2018a) provide a nine-factor framework for information-intensive services which displays activities and resources required in DtV chains. According to these authors, it is critical for all the stakeholders to understand the mechanisms and related factors of data creation in improving

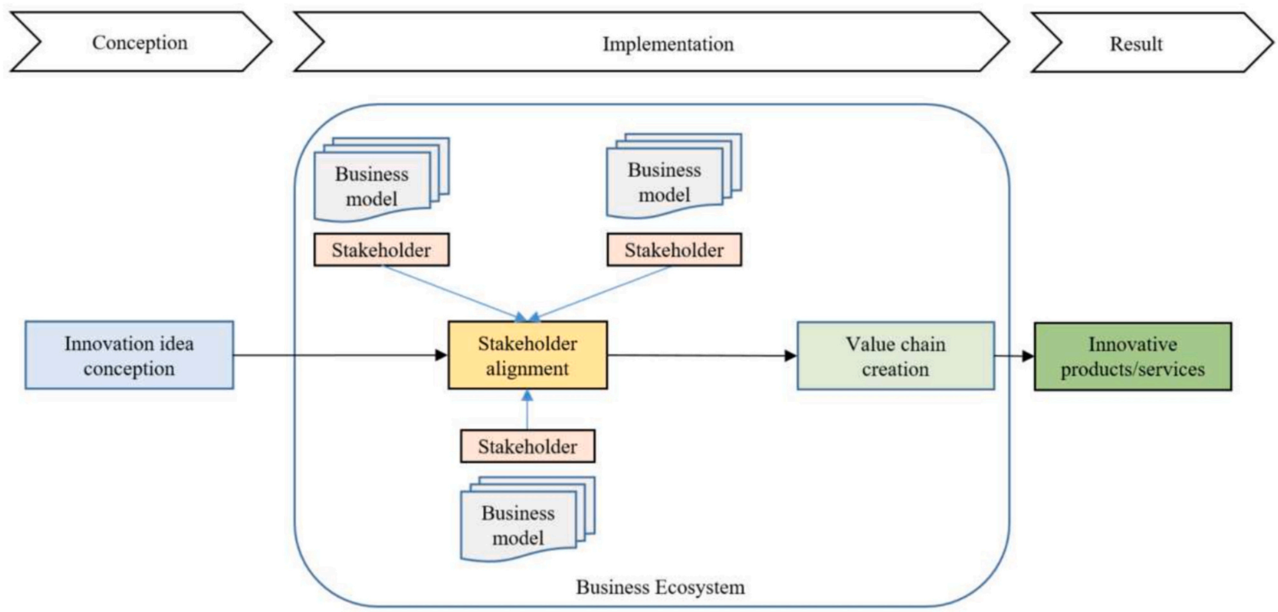

Fig. 1. Overview of innovation process in business ecosystems.

the services using information technology. According to Nischak et al. (2017), digital business ecosystems are comprised of three components: value exchange (innovation, information, products/services), resources (digital and non-digital) and actors (organizations, individuals, societies). Business challenges or even minor misalignment between stakeholders can lead to the failure of entire ecosystems (Kalinauskaite et al., 2021). From this literature it emerges that business models as main tool for value creation in organizations (Richardson, 2008) and are an indispensable element of our DtV framework. A business model identifies the value proposition of a firm, and provides evidence of the feasibility of this proposition through value creation and delivery. It also outlines the architecture of revenues, costs, and profits associated with the business enterprise delivering that value (Teece, 2010). Partner/stakeholder alignment is crucial for value creation and capture in any innovation system but many innovation initiatives fail to identify the business-level prerequisites concerning value creation and capture (Oomens & Sadowski, 2019). The extent to which firms align through different arrangements will affect their capacity to create value for the end customer (Adner, 2017). Thus it is imperative for the stakeholders to understand the intricacies of value creation and value capture through the integrated view of value chains and business models.

2.3. *DtV frameworks*

Several authors present conceptual frameworks to describe the process of value creation from data. For example, Allen et al. (2021), Kaschesky and Selmi (2014) and Elia et al. (2020) discuss the importance of real-time data and information for business value creation in healthcare, public agencies, and various firms through their respective frameworks. Lim et al. (2018a) identified nine factors of value creation from data in information intensive services and presented a conceptual DtV framework. Lim, Kim, Kim, Kim, & Maglio (2018b) extend this framework for value creation with customer related data. No application was done for the freight logistics sector.

In freight logistics, opportunities may arise from data from both traffic and logistic activities. Guido et al. (2020) and Latino et al. (2022) create data-value chains for food supply chains by incorporating RFID with onboard sensors in truck carriers, to improve process transparency in food value chains. Cedillo-Campos et al. (2022) present a conceptual model to measure logistic value based on several indicators of transport infrastructure. Lumsden & Mirzabeiki (2008) and Flamini et al. (2011) stress the importance of product and vehicle location information for logistics value creation via a theoretical explanation. The urban logistics framework by Hauge et al. (2021) relies on performance metrics from traffic data, spatial characteristics and supply chain structure. Zambetti et al. (2021) delivers a related framework to serve as an effective decision-making tool. None of the above frameworks takes into account explicitly or systematically how data and information exchanges fit into the business models of the individual actors. Hence, the feasibility of overall DtV chains remains uncertain. According to Perboli et al. (2017), one of the main reason for the failure of innovation projects is ignoring the business development side of the innovations. In order to increase stakeholder awareness on changing business models, they develop a business model at the DtV chain level, which could be regarded as a DtV framework. However, it does not specify the function of individual stakeholders inside the value chain. In the backdrop of innovation in business ecosystems, there have also been recent research efforts to explain and analyze the roles of different stakeholders. Zenezini et al. (2018) presented a conceptual model for city logistics initiatives from a role-based business ecosystem perspective to identify and explore the stakeholder business dynamics. Boschian and Paganelli (2016) also presented a method to use BMC to track the changes of ICT implementation in each stakeholder's business in logistics sector. Schuurman et al. (2019) developed a innovation management framework called Innovatrix (based on the business model canvas) with eight elements for applying in living labs. More recently, Timeus et al. (2020) extended the BMC for smart city initiatives by adding the environmental and social aspects. In order to analyze and understand the critical player to coordinate ecosystem activities, Kramarz et al. (2021) presented a conceptual model for representing a cross-country multi-modal freight transport ecosystem based on strength of influence, and level of interest, level of predictability.

Even though some of the research articles focused on the co-creation by different stakeholders, there is no literature that provides a comprehensive framework to describe or inform the value creation from both perspectives of the individual business and the value chain. Our paper integrates these two perspectives into one conceptual model, building on the work of Lim et al. (2018a) to represent the DtV chain, while positioning it in the context of freight logistics innovations, and operationalizing the individual businesses' role using business models.

In summary, we find that while many ingredients exist, there is a gap in the literature concerning integrative DtV frameworks for ITS applications for logistics systems, which also recognize the business models of individual stakeholders. In the following, we introduce the approach towards the design of such a framework.

3. Methodology and data

The main method employed in this study is conceptual modelling. We use data from 3 real-life cases and elaborate a basic conceptual model by analogy with theory-building research. Our aim is to arrive at a comprehensive framework, which combines the business modelling and value chain concepts, in the context of business ecosystem formation. According to Crawford (2019), the development of conceptual and theoretical frameworks utilizes three sources - experience, literature, and theoretical frameworks, and follows three activities guided by the purpose of the framework - generation, explanation and argumentation, as shown in Fig. 2. Experience of the researchers usually provides continuous guidance of the main research idea but literature is needed to provide argumentation for generation, testing, and elaboration of appropriate and relevant new frameworks. From the empirical context, the generation phase defines the problem statement and the research question. Explanation entails the visibility and communication of joint framework development, and argumentation provides qualitative analysis and logical rigour. As discussed, to develop a conceptual framework using consistent empirical cases, there is a need for a empirical study in a relevant context. The context in this research arose from the FTMaaS (Freight Traffic Management as a Service) project funded by The Dutch Research Council (NWO). The FTMaaS project is a living lab comprised of a large consortium of public authorities, private organizations, and research institutions active in the logistics sector. They worked together on three different pilot studies to create logistical benefits from freight transportation data. The main objective is to integrate the inter-dependent logistics and transportation domains and study the value creation in the first sector based on the data from the second. The use cases focus on problems such as uncertain travel times due to road works (Use Case 1), incoming truck visibility for dock allocation at warehouses (Use Case 2) and inefficient slot management due to road congestion (Use Case 3). In order to develop the envisioned framework, it is necessary to collect some critical data from each stakeholder. The details of the data collection are presented in Section 4.

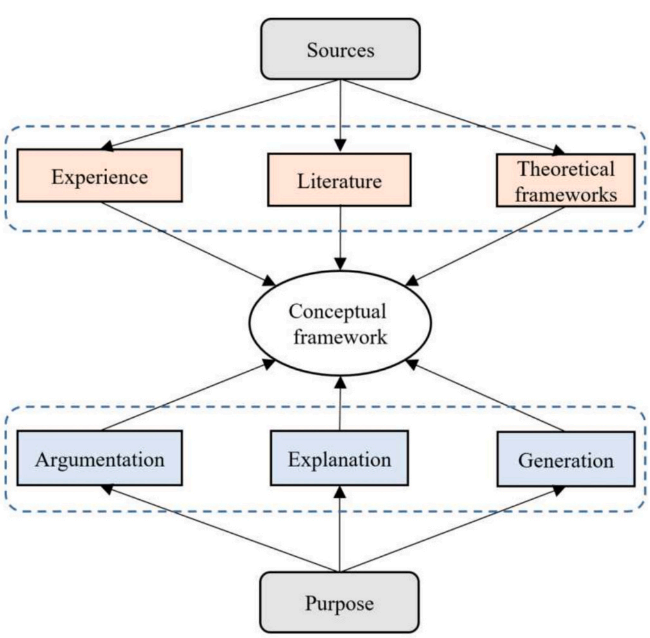

Fig. 2. Conceptual framework building procedure (adopted from Crawford (2019) and Ketokivi and Choi (2014)).

In this study, three freight ITS use cases functioned as an empirical basis for inductive reasoning. The pilots were developed to explore the logistic value of traffic information availability in three different logistics decision-making contexts. The first related to trip re-planning and re-scheduling. The second use case was defined in the context of warehousing, with decisions related to loading and unloading, quality checks, inventory management and shipment handling. The third was defined in a production environment, to support decisions about the planning of loading operations and buffering or storage of ready products. Table 1 provides an overview of these pilots, describing the different business stakeholders and their roles.

The first use case is focused on the truck routing and scheduling problem of 3PL service providers (Stakeholder3) and proposes to integrate the predicted traffic congestion information (Stakeholder1 and Stakeholder4) due to planned roadworks into a transport management system software (Stakeholder2). The second use case is focused on the pick-up and delivery planning problem at a warehouse (Stakeholder8) with uncertain truck arrivals and proposes to utilize the truck Estimated Time of Arrival (ETA) predictions (Stakeholder9) along with e-CMR data (Stakeholder10) to optimize the warehouse operations. The third use case is focused on the slot management problem at a loading facility (Stakeholder12) with uncertain truck arrivals and proposes to improve the slot resilience by utilizing the incoming truck ETA predictions (Stakeholder9) in slot rescheduling decisions.

Table 1
Overview of the FTMaaS usecases.

	Description	Stakeholders	Role
Use case 1	Objective: to understand benefits of providing road works information to carriers. Expectation: increases efficiency of routing and scheduling of shipments under disruptions. Mechanisms: drivers and/or logistics planners could opt to change the route, stop sequence or delivery date. If not, it would allow them to inform the customer in advance that a delay can be expected so they can take appropriate measures.	Stakeholder1	Mobility Program of a province
		Stakeholder2	Open TMS Provider
		Stakeholder3	Hauliers
		Stakeholder4	Technology provider
		Stakeholder5	Road authority
		Stakeholder6	Road authority
		Stakeholder7	Research institution
Use case 2	Objective: to investigate the expected benefits of informed decisions such as dock and resource planning at a warehouse, when providing both arrival time and waybill (e-CMR) information at truck level. Expectation: reduced stress of intake of goods including lower crew costs and higher quality of inventory. Mechanisms: By being informed in time, crew planners and quality control can prepare for actual arrivals.	Stakeholder8	Problem owner
		Stakeholder9	Technology provider
		Stakeholder10	Technology provider
		Stakeholder3	Hauliers
		Stakeholder11	Research institution
Use case 3	Objective: to investigate the effects of a digital solution for dynamic slot rescheduling for inbound trucks based on continuous arrival time predictions. Expectation: reduced waiting times at the gate; increase the resilience and flexibility of the loading process under high congestion levels. Mechanisms: slot planning can change the order of trucks served depending on their arrival time.	Stakeholder12	Problem owner
		Stakeholder9	Technology provider
		Stakeholder13	Technology provider
		Stakeholder3	Hauliers
		Stakeholder14	Research institution

4. Results

This section presents the results of the development of the conceptual framework. It provides the contextual DtV framework for the three pilots by interpreting and combining frameworks available from the literature. The next subsection presents the operationalization of the contextual DtV framework to include business models, completing them for the three freight ITS applications at hand. Thirdly, we provide the integrated framework followed by validation procedure of the developed framework.

4.1. Contextual DtV framework

An overarching DtV framework provides the necessary understanding of how different resources and activities come together to create value from data (Miller & Mork, 2013). Several studies focus on DtV frameworks (e.g. Lim et al. (2018a), Miller and Mork (2013), Kaschesky and Selmi (2014)). Based on the literature survey, the framework based on the nine factors by Lim et al. (2018a) was selected for the adaption and enrichment in the context of the FTMaaS project, because of its detail and fit to the problem at hand. The new contextual DtV framework (as presented in Fig. 3), as adapted from Lim et al. (2018a), is meant to support the translation of transport data to logistics value. A specific construct specification is necessary by formally labelling the application context in relation to the general framework, to support the generalizability of our result in line with this broader framework (Flick, 2017; Nilsen & Bernhardsson, 2019). The broader context for the adaptation of the DtV framework was therefore labeled as follows:

"Value for Freight Logistics using Real-time Traffic Data".

This contextual labeling allows the addition of this problem to the generic DtV framework, and allows it to serve as the basis for the coding of the three use cases as presented in Fig. 3. We describe the uses cases along the lines of this framework below.

Use Case 1 provides value in terms of reliability of routing for a carrier. The data concerning originates from the road management authorities (Data Source), who provide the relevant information regarding planned road works for each specific route. In addition, public data utilization from Stakeholder5 and Stakeholder1's platform aids for the analysis in the use case. Accumulating data of real-time information involving public infrastructures occurs with the help of web crawlers (Data Collection System). Real-time road works information denotes the planned disruptions happening in roadways infrastructure and the real-time transport information regarding the truck's status. In combination, these two are crucial (Data) for understanding and assessing the road environment for trucks to travel seamlessly under an optimal travel time. The gathered information is utilized by Stakeholder1, Stakeholder2 and Stakeholder4 for forecasting congestions, optimizing the existing routes and calculating the expected travel times and delays for the truck to reach its destination (Data Analysis). Stakeholder2 plots the maps from the data provided by the road management, thereby adjusting and amending travel times and routes in the pursuit of decreasing the delays. The information residing in the data translates to the travel characteristics - the optimal route and the expected travel time of truck, due to the planned road works. The information is provided (Information Delivery) through the open TMS by Stakeholder2, enabling process visibility for the users (Stakeholder3). The transport companies/3PLs are the final users of the processed information and facilitate flow in the supply chain, who face a consequential impact through route reliability, resulting from optimization techniques performed by Stakeholder2, along with insights from Stakeholder7 (Research Institute).

Use case 2 focuses on creating more efficient warehouse operations. Truck drivers, traffic sensors and e-consignement notes act as crucial data sources of this use case. The former provides details regarding the truck positions by sharing GPS data of the respective trucks. The traffic sensors deliver real-time stats concerning the road traffic status and updates on the information necessary for analysis. The truck telematics systems collect data using sensors, GPS technology, and onboard cloud devices. The e-CMR data, real-time data from traffic sensors, and truck

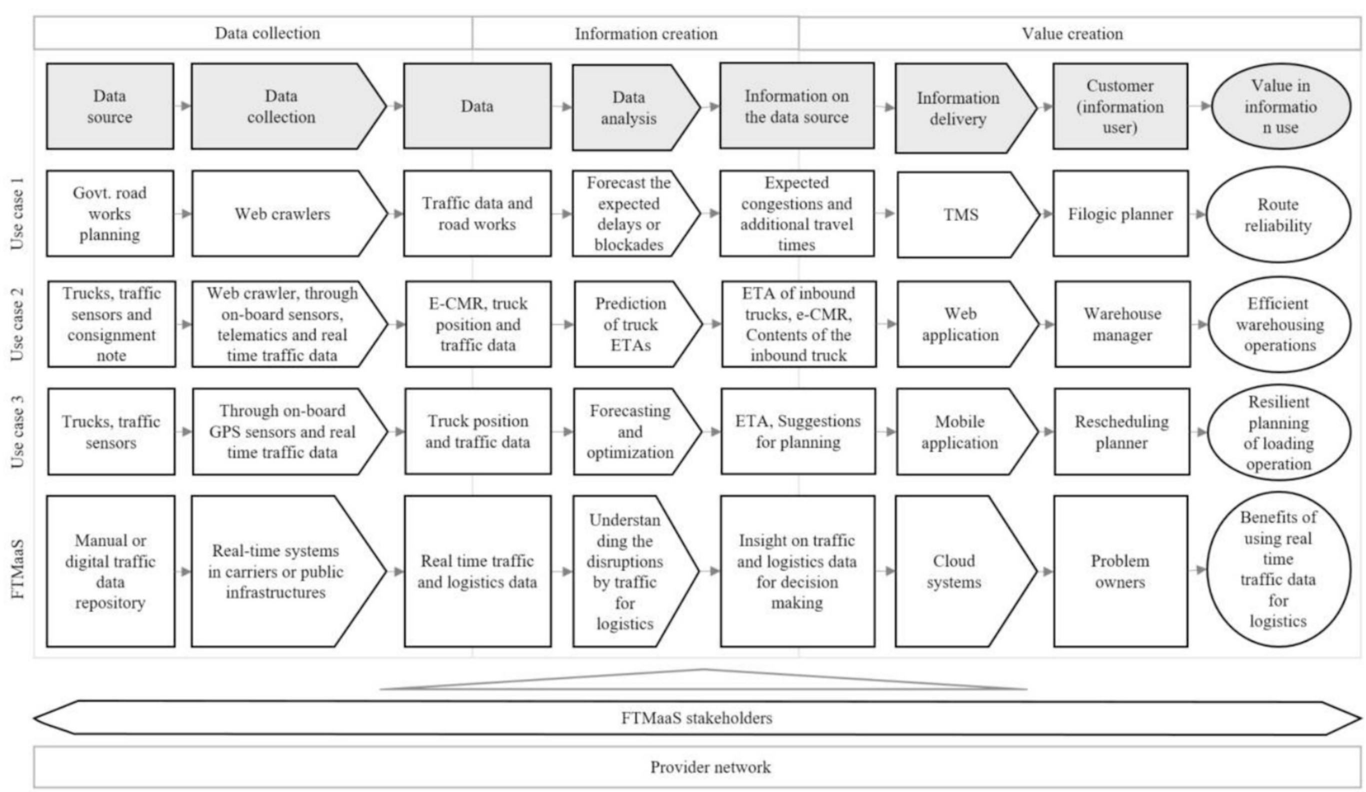

Fig. 3. The Contextual DtV framework for FTMaaS (adapted from Lim et al. (2018a)).

location information are the three data types used in this case.

Input data is used to perform data analysis by Stakeholder11 to determine important factors such as Predetermined Time Factor and Predetermined Place Factor of the incoming trucks. These factors along with real-time truck ETA information is utilized in dock management at Stakeholder8. The information delivery happens with the help of websites to the warehouse manager at the Stakeholder8 Facility. This approach is proposed to help in efficient dock planning at Stakeholder8, which helps streamline processes and provides end-to-end visibility for the supply chain, thereby improving resilience.

Use Case 3 aims at more resilient loading operations at a factory for its outbound flows. This use case uses truck location information and traffic sensors data to predict truck ETA information at a loading facility and adapt the loading plan. The real-time stats for each truck is collected (Data Collection System) through onboard sensors fastened to every truck. In addition, real-time traffic data about the truck's position plays a significant role in insights into the road environment. The combination of these two data sets helps in performing the data analysis (predicting truck arrivals). With research assistance from Stakeholder14, the data analysis also deals with determining the optimal rescheduling of loading slots of the inbound trucks (Information) at the Stakeholder12 Facility located in the port area of one of the important European port. The information delivery takes place with the help of a mobile application to the rescheduling planner at the Stakeholder12 Facility. This approach results in efficient slot planning at Stakeholder12's loading facility leading to a resilient loading operation.

Across the 3 use cases, the DtV framework shows in the bottom row of the framework how an aggregate DtV entry could look for freight ITS. Partners and service providers represent (1) public authorities, who govern the infrastructure and public data and (2) private organizations like logistics and information solution providers. The source of traffic data can be either manual and digital such as truck drivers (manual) or traffic sensors in public infrastructures (digital). The collection of real-time stats occurs using sensors in the truck to record the flow characteristics or using public infrastructures for real-time traffic flow data. Data analysis deals with computing coded observations to extract useful information providing insights in locations, speeds and surrounding traffic patterns. Information concerns refined results, prepared for use in decision-making by the respective actors, including logistics planners and managers. Cloud services like mobile applications, websites or specific digital platforms deliver information to establish end-to-end visibility for communication and information flow across the supply chain. The problem owners constitute the logistics decision makers as final users of the information, and the value emanates from increase effectiveness of these decisions with practical benefits concerning service quality and resources used. Note that this overarching framework does not yet specify actors and their roles. This step in the framework is added in the following.

4.2. Operationalizing the DtV chain

Next, the general DtV framework needs to be developed to become valid in terms of business feasibility, from the perspective of cooperative ventures between stakeholders. For the consortium of stakeholders, the specific business ecosystem defines the structure and the relationships between them. The design of the complete framework depends on how every stakeholder is positioned (Weiller & Neely, 2013) in the underlying DtV chain. To build on this notion, we use the perspective of *ecosystems as a structure* by Adner (2017): *"The ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact for a focal value proposition to materialize."* Their shared goal is to create value for logistics from transport information derived from traffic data. As described in Fig. 4, we now enforce stakeholder alignment in the DtV chain by formulating the operational business models (Nathanail et al., 2016) that together allow value creation and can be assessed by the stakeholders for their individual and collective business validity.

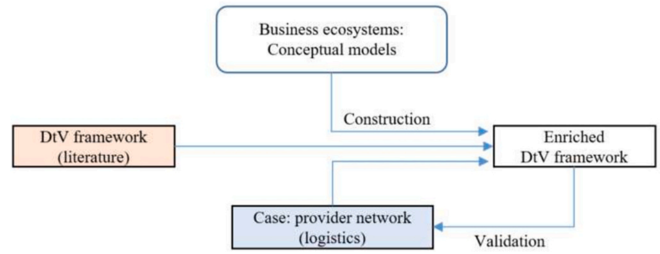

Fig. 4. Overview of creating the integrated framework for logistics.

4.3. Operationalizing the Business Ecosystem

Positioning the different parties in the ecosystem identifies their business context, business partners to interact with, the overall business network, the revenue flows, and the value proposition per actor (Bahari et al., 2015). Different actors may have distinct roles and goals, thus illustrating the difference in placing between them. This difference in placing also shows every partner's contribution to the final value for logistics. The fit between business models and the broader DtV chain depends on the position of all actors and the flows between them (Bertassini et al., 2021b). In our context, positions concern their presence in one or more stages in the DtV framework: Data Collection, Information Creation or Value Creation, and the chosen linkages with other actors. Flows deal with information and finances that contribute towards value creation for logistics from transport information derived from traffic data. We have chosen the BMC (Osterwalder & Pigneur, 2010) as tool to operationalize and validate the business ecosystem. The BMC addresses the independent organization's business structure and is an important building block for a valid business ecosystem as it explicitly shows interconnectedness of different organizations in an ecosystem. The BMC is a graphical template that allows to systematically describe the defining properties of a business: around its core value proposition, it addresses how this value is created and how the product or service is delivered to client segments. It includes the financial flows, both concerning revenues and expenditures. The DtV framework described above provides the context (Moore, 1993) of sytem goals in which the individual actors operate and connect, as well as the ground for a common objective (Demil et al., 2018). In the following we present the configuration of BMCs within the DtV framework.

4.4. BMC data acquisition

Probing the roles, responsibilities, positioning and value propositions of every stakeholder was vital for understanding the FTMaaS ecosystem. Through a business model workshop, we collected details of each stakeholder within the D2V context. The workshop was divided into 2 phases. In the first phase, a presentation was given by the research team describing the agenda, context and expectations from the workshop. The DtV and BMC frameworks were explained to help the stakeholders' understanding. In the second phase, each stakeholder was provided with empty BMC templates and were asked to fill them out. The Research team helped each stakeholder in completing the task. In conclusion, we were able to gather information about: (1) the drafts of BMCs of each stakeholder, (2) perspectives of different Stakeholders about the different factors of BMC and (3) reflections on the contextual DtV framework. As a follow-up, we conducted semi-structured interviews with stakeholders where necessary, to support the correct interpretation of the BMC and complete missing pieces. An interview was held with Stakeholder1 was to clarify the stakeholder's relation with fellow stakeholders, the composition of their mobility program, and its intended revenue structures, resulting in the right interpretation of the framework. Another interview with Stakeholder10 was focused on completing their BMC in the context of the complex customer segments, subscription-based charging structure and the role as an e-CMR provider. Detailed information on the interviews is provided in the Appendix. Both interviews were recorded, transcribed and analyzed further to enhance the BMCs.

4.5. Business Models

As shown in Fig. 3, the data-value chain consists of four main stages in the value chain (i) data collection, (ii) information creation, (iii) value creation, and (iv) Provider network. The stakeholders under the **Data Collection phase** create the fundament for value creation. These actors predominantly fall under the category of municipalities/governments (Stakeholder6), data websites owned/operated by the government (Stakeholder5), and carriers (Stakeholder3), facilitating both manual and digital forms of data.The DtV framework covers the numerous facets of the generalized BMC. 3PLs with GPS systems (Key Resources) provide the real-time location (Key Activities) to the platform services like Stakeholder9 and serve as the prime *Data Source* for the prediction of ETA at the facilities of Stakeholder12 and Stakeholder8 (*Data Analysis*). Stakeholder6 builds direct and reliable relationships with organizations such as Stakeholder5 (*Data Source*), for road works info (*Data*) to the organizations for *Data Analysis* on expected congestion and delays. The value proposition of delivering reliable data by Stakeholder5 reflects on the *Value in Information Use* on automation and improving service levels.

The stakeholders under the **Information Creation phase** process the raw data and deploy analytics methods to create relevant and valuable information. Analyzing traffic data based on the problem under the scope aids in benefiting different parts of the supply chain. Therefore, the actors predominantly fall under logistical solutions and IT are - Stakeholder9, Stakeholder2, Stakeholder4 and Stakeholder10. The refined real-time information (road works info from *Data*) reaches the carriers through TMS (*Information Delivery*), complementing the value proposition of Stakeholder2. The *Information* on expected delays by Stakeholder4 helps optimize logistical processes. The provision of e-CMR (*Data*) by Stakeholder10 helps in a digitized and sustainable solution for Stakeholder8 (*Customer*). Stakeholder9 work with map providers (Key Partners and Resources) for ETA calculations of the truck and with slot-booking platforms for efficient planning at the facility (Stakeholder12, Stakeholder8 - *Value in Information Use*).

The **Value Creation stage** depends on the actors whose logistics operations benefit from improved decision making with real-time information, and contribute principally to logistical value creation. The actors under this phase are the problem owners - Stakeholder12, Stakeholder8, and Stakeholder1. The ETA from Stakeholder9 and e-CMR from Stakeholder10 (*Information*) through Websites (*Information Delivery*) help in effective dock management at Stakeholder8, resulting in a streamlined unloading process and resilient system (*Value in Information Use*). The efficient slot planning at the Stakeholder12 facility (resulting in a reliable system, Value Proposition), from ETA of inbound trucks (*Information*), makes them the end-users (*Customer*). Stakeholder1 creates awareness of traffic data usage for logistics, reflecting on the increasing reliability of the system as a whole.

4.6. The integrated framework

The individual BMCs identified in the context of the DtV framework lead to the development of an integrated framework. Below we present the generalized framework and the specific framework for the project, for the context of freight ITS and logistics.

4.6.1. Elements of the Business Ecosystem

The strategic linking of business models gives rise to the business ecosystem of FTMaaS. Any BMC consists of 9 factors, that are transformed into three factors - Input, Value Proposition and Output as represented in Fig. 5 along with other different connectors.

The arrow links represent the financial flows (dashed arrow links in blue color). In the integrated framework, the output of one stakeholder serves as the input of the other stakeholder in terms of information sharing or business interactions (represented by black arrows). The explanation of the three factors is as follows. **Input** contains the creation process that needs to be followed by the stakeholder for the productive contribution to the ecosystem. The inputs stem from the outputs of the key partners (stakeholders). For instance, at the Stakeholder12 facility, Stakeholder9 conveys the information about the ETA of the inbound trucks through the means of a mobile application. **Value Proposition** shows the benefit that the core product or service promises to the client. For instance, Stakeholder4 strives to provide reliable travel times to Stakeholder2, which helps the latter provide optimal truck routing. The value proposition requires Input to be produced and Output to be delivered. **Output** indicates the delivery of the service or product to realize the Value Proposition. The Output connects to an Input of a stakeholder downstream to facilitate systemwide value creation. For instance, the e-CMR information is delivered through Stakeholder10 to Stakeholder8 via a website, which allows the latter to use the information directly.

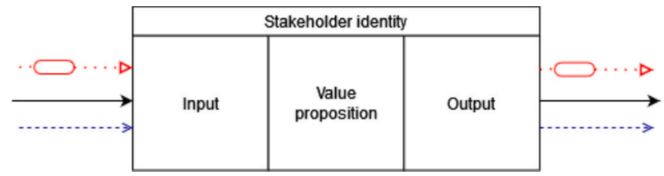

Fig. 5. Simplified Business Model representation.

4.7. Framework Consolidation

The contextual DtV framework (Fig. 3) serves as the frame for connecting the business models (simplified BMCs); together they form the integrated general framework and specific framework for our case (Figs. 6, 7).

Consolidation of the nine factors present in the Contextual DtV framework helps in structuring and positioning the business models and, therefore, summarizing the ecosystem description in terms of three facets, as follows.

Data Collection constitutes the stakeholders who deal with the view on how to produce data for extracting useful information. The Stakeholder3, Stakeholder6, and Stakeholder5 act as three bedrocks, which comprise the type and source of data and the medium with which the data collection takes place /storage occurs/transferred to the fellow partners in the framework. For instance, the centralized database - Stakeholder5 (*stakeholder*) provides road works data (*type of data*) through Stakeholder1's platform (*medium of transfer*) to Stakeholder1, Stakeholder2, and Stakeholder4. Another instance can be the case of Stakeholder3, whose GPS data from their trucks serves appropriate for the traffic data analysis of Stakeholder9. These stakeholders prove beneficial on the grounds of providing real-time traffic data through different means - truck position, data websites, forming as the fundamental for value creation and therefore take the top segment in the chain.

Information Creation follows data acquisition with processing, refinement, modelling, and presentation, extracting useful information, and delivering it to the customers. Stakeholders under the information creation facet include Stakeholder9, Stakeholder4, Stakeholder10 and Stakeholder2. Their role is as follows: Stakeholder2 processes the road works data (*relevant data*) provided by Stakeholder5 to create optimal routes for freight trucks (Stakeholder3), whose operation gets hindered. The information about congestion, expected delays and updated routes (*useful information*) are conveyed to the Stakeholder3 (*end-users*) with the help of an agreed information (*delivery channel*). Stakeholder9 carries out a similar operation, where the traffic data analysis takes

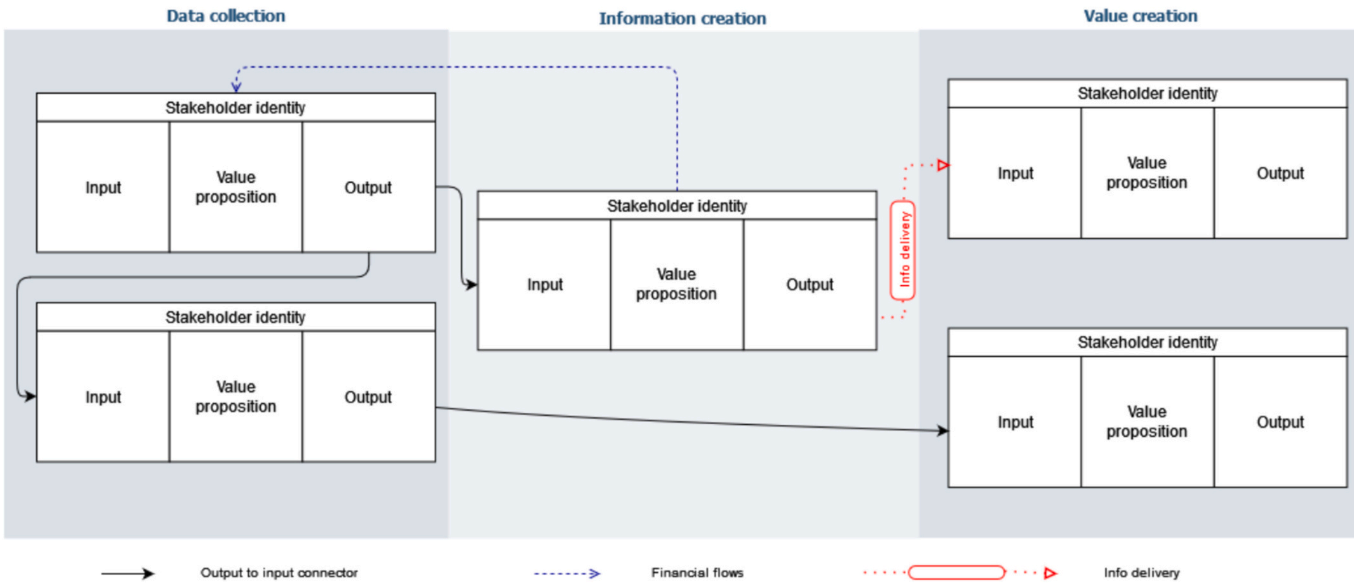

Fig. 6. Integrated Framework.

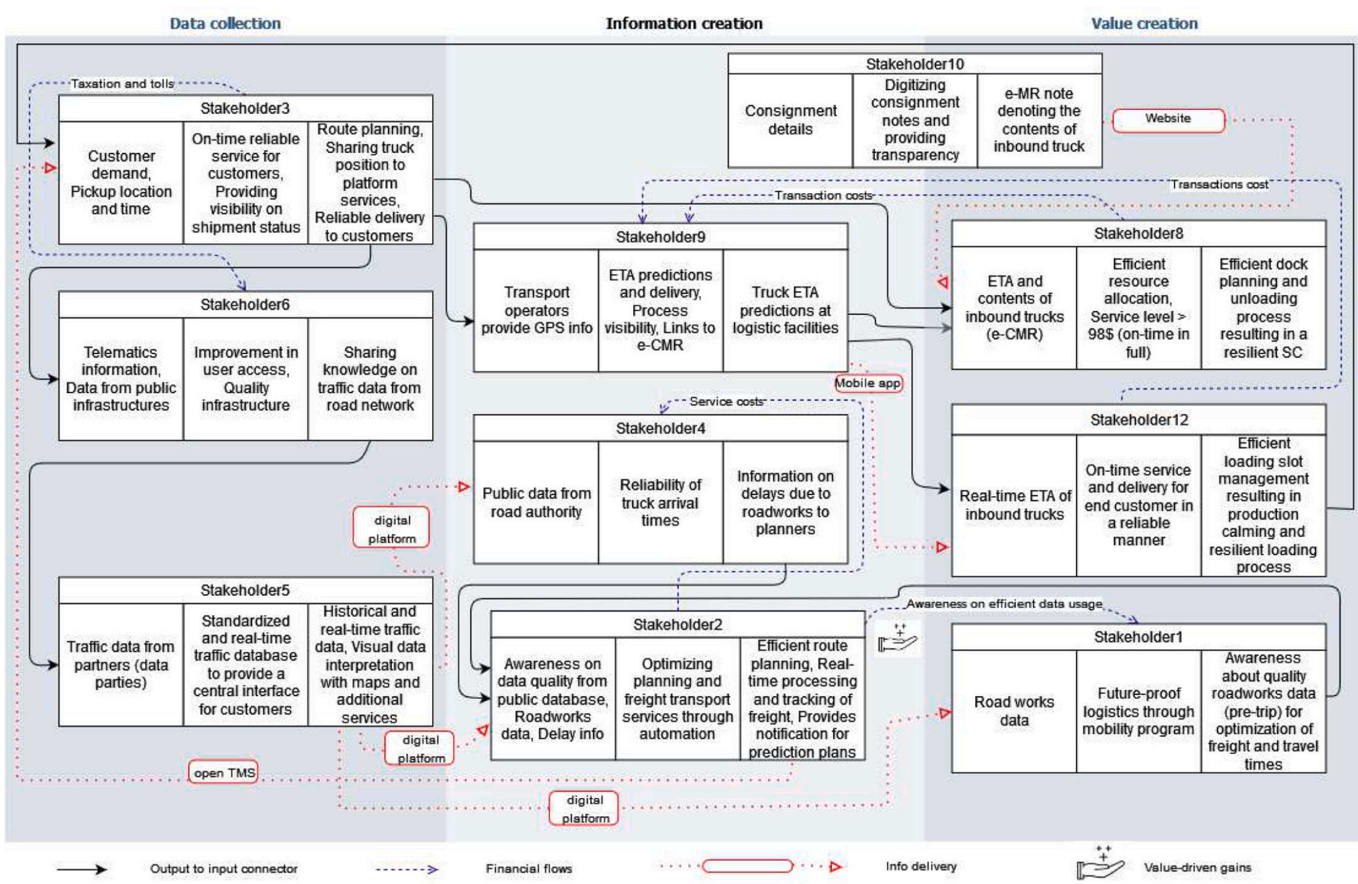

Fig. 7. Integrated Framework for the case of FTMaaS living lab.

place with the help of truck position data (*relevant data*) from Stakeholder3. The ETA information (*useful information*) transfers (represented in the framework) through mobile applications to Stakeholder12 (*end-users*). The stakeholder's functionality as part of information creation drives the framework towards value creation for logistics.

The component of **Value creation** reflects how the stakeholders benefit from the information. Value generation happens only when the information acquisition from the stakeholders suits a specific decision purpose (Lim et al., 2018a). Four stakeholders reside under this facet - Stakeholder10, Stakeholder8, Stakeholder12 and Stakeholder1. Stakeholder10, as an organization, owes to creating value through digitized consignment notes. This practicality leads to two directions - Firstly, the creation of consignment notes that help document the truck's contents (*information creation*). And Secondly, the digitization of the consignment notes with the e-CMR platform helps gain end-to-end visibility for the supply chain, contributing to the value of creating transparent logistics in real-time (*value creation*). One stakeholder that benefits from Stakeholder10, as shown in Fig. 1 is Stakeholder8. Thus, Stakeholder8 as a final user of the information, utilizes e-CMR notes that deliver through the website in effective allocation of docks (*value*). Stakeholder1 acts as a data subsidizing program that facilitates the awareness of using quality data for logistical operations. They deliver this value to Stakeholder2 for the scope of the research and receive value-added gains. On the other hand, Stakeholder12 gains value for slot allocation with the ETA Information provided by Stakeholder9. Due to the congestion in the en-route their plant location, they facilitate the communication of the slot availability to the Stakeholder3 to ensure a smooth planning process and visibility of truck arrivals. The cases of Stakeholder1 and Stakeholder12 resemble a loop of information flow, where the end benefits reflect on the logistical operations.

4.8. Final evaluation

The main purpose of validating the integrated framework (Figs. 6, 7) is to identify to what extent it fulfils its primary research objective. Also it helps to reflect on the critical attributes of the framework - positioning and interlinking of stakeholders, modelling information and financial flows, emphasizing value creation and complementing both underlying conceptual frameworks. As presented in Fig. 8, we consider qualitative deduction Johnston et al. (1999) for the validation case through a feedback loop, with a focus on the credibility of the information in the eyes of the stakeholders of the case.

The representative actors of FTMaaS from each use case shared a similar view on the rationale of the problem statement. They agreed that the visibility of the information flow between the stakeholders was important for ecosystem-level value creation. None of the actors had been part of such a collaborative effort before in which a DtV chain was presented and exercised through with business models. They confirmed that as a tool, the DtV framework was appropriate and easy to interpret for value creation from the use of information. Furthermore, using simplified BMCs as a tool for data collection and integration with the final framework was easy to interpret for people from practitioner backgrounds. The actors provided these comments before the presentation of the final conceptual framework.

A crucial constructive feedback was that, at first glance, the whole framework (initial version of integrated framework) needed an enlarged view. The actors understood the technical difficulties while representing the framework, owing to nine stakeholders with varied interlinks. An explanation followed to stress the scoping for three use cases dealing with FTMaaS for the three actors. This feedback lead to the creation of the present framework in Fig. 8 with improved readability. Another thoughtful suggestion about the work was the representation of financial flows. All three stakeholders agreed on the model but also highlighted that there might be hidden costs. In addition, all stakeholders expressed their views on the willingness of parties to share information for visibility, complementing the idea of business ecosystems. Regarding the proposed questions on the lines of achieving the objective and covering the critical attributes consistently, it was concluded that the integrated framework convincingly clarifies the concept of value creation. After a second iteration, the framework was adapted and accepted as final framework.

5. Conclusions

Our literature review confirmed the lack of an integrated framework for freight ITS-based information provision to logistics decision makers, which also holds validity in terms of business feasibility. We present a conceptual DtV framework to depict new freight logistics value creation from freight transportation data, in a living lab ecosystem involving multiple stakeholders. The developed framework models stakeholder alignment by capturing key business positions in the data-to-logistics value chain, together with the information flows and financial flows between stakeholders. We applied case-based reasoning and framework development by analogy with theory elaboration, to integrate two underlying frameworks for this purpose: a conceptual model for information-based DtV chains, and the enterprise-level BMC. The empirical context for framework elaboration was provided by the FTMaaS project. The cases have confirmed the applicability of the framework.

The main contribution to the literature is a new conceptualization of DtV chains for freight ITS, which connects the micro level framework of company business models to a higher level framework of creating logistics value from transport data. The business model canvas ensures company-level feasibility while the value chain framework ensures consistency between business models upstream and downstream. While the two main components of this framework have their own streams of work in the literature, their combined implementation and application from the broad perspective of freight ITS is new. We find that existing research on DtV chains in freight logistics has so far been narrowly framed for specific use cases, and its positioning with respect to generic frameworks such as (Lim et al., 2018a)'s has remained unclear. In our study, this connection is made explicitly. Vice versa, we have applied the general framework from (Lim et al., 2018a) for the sector of freight transport and logistics, which had not yet been done. The acceptance of the framework by the experts suggests that it is also valid for applications in this sector. Concerning its use by practitioners, the integrative framework can support the industry and public institutions to invest in complementary data sources and software which together fulfill needs of the logistics sector. It allows to evaluate the presence of the necessary constituent links of the DtV chain. This can help entrepreneurs in the world of intelligent transport systems to focus on real opportunities where data and information needs exist, and where these can be profitably linked, helping to overcome the problems signalled in Perboli et al. (2017).

Our prime reflection on these results is its ability to provide an overall picture of value creation in a freight logistics system by involving the stakeholders and respective roles in terms of their activities, information and financial interlinkages. The work embodies an initial step towards involving multiple actors in a data-value chain. Provided that the appropriate business-level information could be acquired, earlier

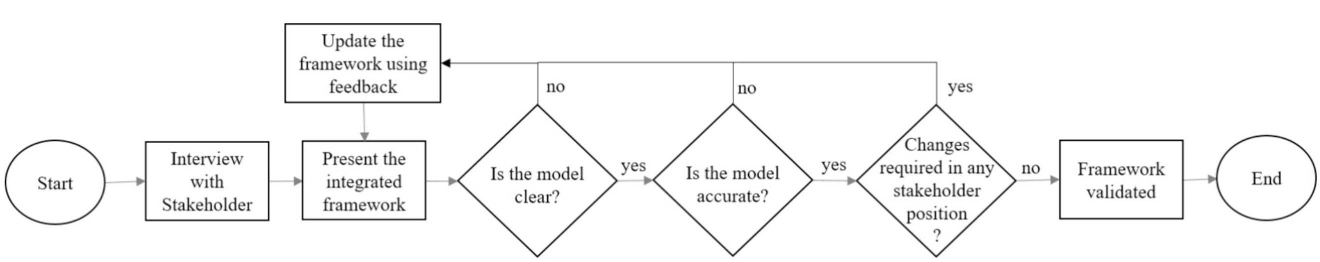

Fig. 8. Validation procedure.

studies on DtV chains in the area of logistics could be incorporated in this framework, adding to the cases presented here. This would not only help to assess the business validity of these earlier studies, but also provide opportunities for further generalization, allowing for different scenarios and a broader set of cases, actors and modes of transport. A possible next step is to further adapt the developed framework to ecosystems, where the roles in of stakeholders change dynamically in different phases of system growth. Another interesting research direction is to develop an approach to analyze and determine the critical factors for the success of such information-focused business ecosystems, where actors involved in physical logistics services take on roles of digital service providers.

CRediT authorship contribution statement

Ratnaji Vanga: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation. **Nagasubramanian Thiyagarajan:** Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Sarah Gelper:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Yousef Maknoon:** Writing – review & editing, Supervision, Formal analysis. **Mark B. Duinkerken:** Writing – review & editing, Supervision, Methodology. **Lóránt A. Tavasszy:** Conceptualization, Methodology, Validation, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

We confirm that this work is original and has not been published or is under consideration to be published elsewhere. We have no conflicts of interest to disclose.

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Appendix A. Interview details

The personal interviews with the two of the stakeholders (stakeholder 1 and stakeholder 10) were conducted in virtual meeting and the meeting proceedings were recorded and transcribed. The main objective of these interviews was as follows.

- How do we include different stakeholders in the transport information and logistics services market in these chains?

Before each interview, the following steps were taken and relevant information was discussed with the interviewees.

- Title of master thesis of the second author: To explain the topic and scope of the research briefly
- Purpose: In relation to the sub-research question, explain the purpose of drafting the BMC to the stakeholder. In the case of Stakeholder1, the interview was the needed to make sure we have a complete and interpretable BMC.
- Info Utilization: Defining the scope of utilization of the information
- Setting up the Discussion Forum: Explain the rationale for having the meeting as a discussion and the importance of the responses for the research and modelling the DtV Framework

The agenda/discussion points for the interview 1 with Stakeholder1 were set as follows:

- Who are the customers of stakeholder 1, from the FTMaaS perspective?
- Is the market multi-sided for stakeholder 1? if yes, then how each stakeholder 1 focus on them?
- More insights on the statement by stakeholder"customer segments could be easy cases or complicated cases"
- Respective customer relations? (relates to the previous sub point) and Customer channels?
- From the BMC, digitization of process can be seen as one of the proposed values owing to performance, better usability (transparency). Any other values which could be drawn as such?
- Insights on revenue streams - how will you charge? Who will get charged? The gains (monetary).
- Insights on cost structures - Type of strategy employed: cost or value driven?

The agenda/discussion points for the interview 2 with Stakeholder10 were set as follows:

- Insights on customer segments - distinction between pre-trip and on-trip
- How does the focus differ for those customer segments?
- Insights on cost structures - Value-driven or cost driven?
- A bit more clearer view on revenue streams
- key partners segmentation - data side and home users

Please reach out to the corresponding author, for any further queries regarding the data collection.

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