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Introducing an Intelligent Goods Service Framework

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Abstract: With the increasing diffusion of Internet of Things (IoT) technologies, the transportation of goods sector is in a position to adopt novel intelligent services that cut across the otherwise highly fragmented and heterogeneous market, which today consists of a myriad of actors. Legacy systems that rely upon direct integration between all actors involved in the transportation ecosystem face considerable challenges for information sharing. Meanwhile, IoT based services, which are designed as devices that follow goods and communicate directly to cloud-based backend systems, may provide services that previously were not available. For the purposes of this paper, we present a theoretical framework for classification of such intelligent goods systems based on a literature study. The framework, labelled as the Intelligent Goods Service (IGS) framework, aims at increasing the understanding of the actors, agents, and services involved in an intelligent goods system, and to facilitate system comparisons and the development of new innovative solutions. As an illustration of how the IGS framework can be used and contribute to research in this area, we provide an example from a direct industry-academia collaboration.

Keywords: intelligent goods services; Internet of Things; system classification; theoretical framework

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1. Introduction

Transporting goods has a long tradition and has played an important role throughout history. Today, collaboration between different actors supported by a mix of manual, semi-automated, and automated systems is used to ensure quality of service, for instance, by providing routing and traceability of goods to customers and actors in these ecosystems. Rudimentary status updates are typically shared with end customers as goods pass checkpoints along the transportation route, and rough estimations of expected day of delivery is also a common practice.

Looking at the actors more closely, however, reveals complexities such as a highly fragmented market [1]. The involvement of a diverse collection of actors makes data sharing and smooth handovers of goods and responsibility problematic. While global actors such as DHL and UPS play significant roles, such actors still only make up for a small portion of the actors involved even in major markets such as Germany. Not only are there many actors in this market, but the configuration of actors involved changes constantly, depending on who is available at particular points of handover in order to facilitate the shipping of goods from one place to another.

Presently, the dominant way to maintain control over where goods are, and which goods should be shipped where, is to use manual or semi-automated barcode/RFID scanning of bins, i.e., collections of multiple packages going to the same destination, or individual goods if they are larger or no other goods are going to the same location. This includes, for instance, various stages of sorting, loading onto vehicles, unloading at warehouses for handover to another vehicle, customs checking, and final delivery [2]. Supplying continuously updated information on the state of goods is understandably quite challenging in such a fragmented environment, as information sharing between all actors involved may go beyond such rudimentary manual or semi-automated scanning at checkpoints. Additionally, from a customer perspective, the combination of many actors along the route means many points of potential failure, making it difficult to pinpoint who is liable if goods are damaged or mismanaged during the shipment [3,4]. The checkpoint-based approach for scanning also means estimated time of arrival (ETA) typically has poor accuracy beyond what day or within a fairly large time interval that the goods can be expected. This makes optimization of the customer supply chain difficult, resulting in ripple effects of delays or overstocking, queues forming at docks for unloading, and problems predicting needed personnel for receiving goods.

Embedded and mobile and connected sensor-based systems—popularly referred to as Internet of Things (IoT) technologies—are continuously evolving and could potentially be key to increased quality of service control, new services, and richer data on which to base value-creating analysis for the involved actors [5]. In particular, they can be used to solve or mitigate the above challenges. One area that has been extensively studied in this context is food logistics, mainly due to the related requirements from perishables and frozen food of time and environmental conditions. Research shows that food quality, food safety, and operational efficiency can be improved by using IoT to track product locations, monitor temperatures, control stock, etc. [6,7]. As a consequence, food waste can be minimized, which saves both money and the environment [6,8]. In warehouses, IoT can be used to automatize and increase visibility by interconnecting different assets such as forklift trucks, pallets, products, machines, and building infrastructure [9,10]. On a more general transport level, IoT may assist traffic management, smart parking, route planning (based on congestion, weather, etc.), toll collection, etc. [11].

When using IoT to provide products with higher capability levels than merely being able to communicate an associated ID (such as what barcodes and the simplest form of RFID do), the products are often referred to as *smart* or *intelligent* [12]. Within transport logistics, such products are often denoted *smart goods* and *intelligent goods*, and in this paper, we henceforth use the latter of these two. For heterogeneous and complex areas, such as the transport logistics sector, different types of frameworks can serve as useful starting points, for instance, to conduct comparisons between systems, architectures, or components [13,14], or to study technology adoption [15]. Previous research has provided a few such frameworks related to intelligent goods. For instance, Pedersen et al. [16] present a framework for information and communications systems in transport and logistics, based on input from a number of EU funded research and development projects. Some of these EU projects have particular foci on solutions-related intelligent goods. Consequently, the framework includes some intelligent goods services, but primarily the associated technological infrastructure and architecture are described. Tran-Dang and Kim [17] propose a framework that describes a service-oriented architecture for the Physical Internet (PI), based on IoT. The architecture includes four layers, namely the physical, network, service, and interface layers, the purposes and functions of which are described by the framework. Sallez et al. [18] also focus on PI. They present a descriptive framework that specifies a multilayer conceptual structure for PI containers, which includes both informational and physical aspects. In this multilayer structure, each PI container may contain other PI containers by encapsulation and/or composition in a recursive manner. Finally, Musa et al. [2] compare different RFID product visibility architectural frameworks (Microsoft BizTalk RFID, Sun Java RFID, and SaviTrak) based on user requirements of visibility systems. The frameworks in these types of research studies primarily focus on system architectures, including information and communication. However, we have failed to find any framework that includes a classification of intelligent goods services. This type of framework could be used to increase the understanding of the services as well as the actors and agents involved in an intelligent goods system. It could also be used to facilitate both system comparisons and development of new innovative solutions.

The overarching purpose of this paper is to develop such a framework for classifying intelligent goods-based solutions, using the current state of research in terms of actors, agents, and intelligent goods services. We refer to the framework we develop as the

Intelligent Goods Service (IGS) framework and base it on a literature review of services provided and how these involve the ecosystem of actors related to the transportation of goods. We provide examples of service use and show how the framework can be applied to a commercial IoT-based product called Visilion Logistics [19].

The paper is structured as follows: Section 2 describes the methodology used for the literature review, and Section 3 shows the results from the review, presented as the IGS framework. Section 4 contains a description of Visilion Logistics, followed by an illustration in Section 5 of how the framework can be applied to this service. Finally, the paper is wrapped up with some future directions and concluding reflections in Sections 6 and 7.

2. Methodology

Developing an intelligent goods service framework is the driving objective of this study. To do so, we conducted a literature review based on the guidelines provided by Webster and Watson [20]. These guidelines are a highly referenced part of the prestigious *MIS Quarterly* journal and thus represent a well-established method for conducting literature reviews. The guidelines outline a three-step process, which we applied on studies of intelligent goods and transport logistics that emphasized more non-functional requirements and fundamental motivations for different actors, and studies that discussed specific services and architectures.

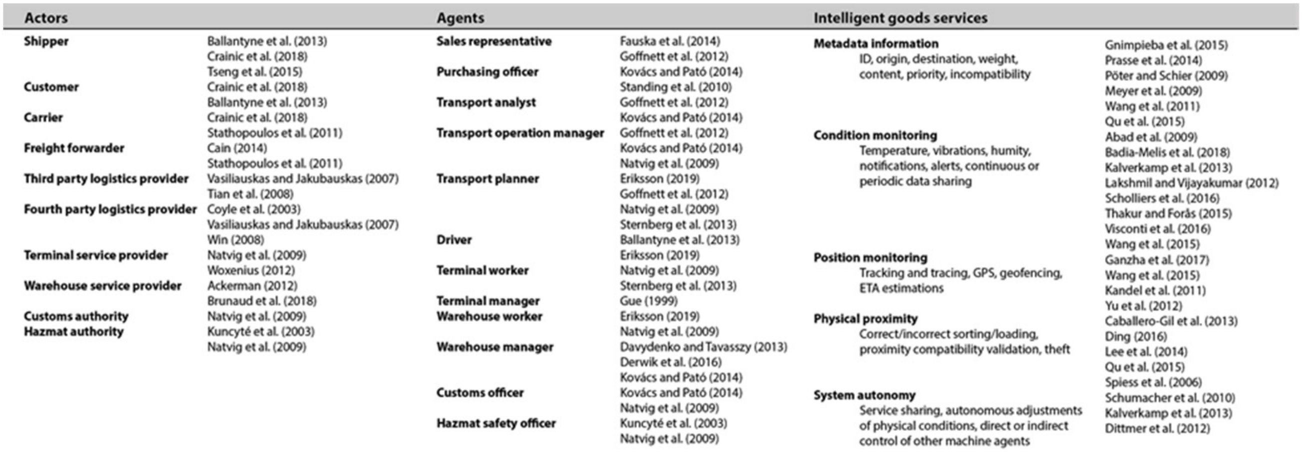
As per Webster and Watson [20], our first step was to conduct a combination of keyword-based searches in scholarly databases targeting well-established journals and conferences. This was done by reviewing the results obtained by searching the databases Google Scholar, Web of Science, and Scopus for research publications related to intelligent/smart goods/cargo/products/packaging in combination with actors, services, agents, personnel, staff, employer, employee, producer, manufacturer, warehouse, terminal, carrier, shipper, and hauler, as well as IoT systems, and freight/goods/cargo transport. For our selection of papers from this initial search, we placed particular weight on papers from high impact journals and conferences.

Based on the results of the initial search, we then looked backwards in time by reviewing citations used within the identified references. Finally, we looked forward by reviewing more recent references that cite those found in the two previous steps, to consider these for inclusion. Studies that contributed with the same information as another already selected study, for instance by describing the same transport actor in the same way as the other study, were excluded from the final set we based our framework upon. Weight was placed on references that were published in strong outlets and were more commonly referenced in recent studies. This iterative process was continued until the emerging IGS framework stabilized and no longer required redesign after further literature was identified. The resulting set included 58 studies that we considered relevant and appropriate for the aim of this paper to support the IGS framework. Of these, 48 were related to the IGS framework, and 10 were related to the concept of intelligent goods.

Development of the IGS framework was thus produced as the main output from the literature review. In order to illustrate the relevance of the framework for classification of intelligent goods systems, we then applied it to the analysis of a recently commercialized IoT-based system, which we had access to through an ongoing industry collaboration. In addition to being able to test the service itself, this collaboration provided us with direct access to documentation concerning system design and pre-launch field trials done together with early adopters of the now commercialized service, including end user feedback on the beta stage of product development. For the purpose of this paper, the IGS framework itself remains our central contribution, while this first case is analyzed only to illustrate intended use of IGS in order to provide direction for future use of the framework for other case studies.

3. The Intelligent Goods Service Framework

In this section, we present the three main components that have come out of our literature review: organizational actors in the logistics ecosystem, specific human agents that play an active role in the network of actors, and a categorization of intelligent goods services. Together, these form the IGS framework, presented in a summarized manner in Figure 1 and in more elaborated form later in this section. The framework represents a high-level classification of the actors, agents, and services involved in intelligent goods systems. This means that, for instance, it does not list all actors involved in the entire supply chain, such as retailer, manufacturer, etc. Instead, these actors are classified into higher-level actor roles, such as "shipper" or "customer".



Actors	
Shipper	Ballantyne et al. (2013); Crainic et al. (2018); Tseng et al. (2015)
Customer	Crainic et al. (2018); Ballantyne et al. (2013)
Carrier	Crainic et al. (2018); Stathopoulos et al. (2011)
Freight forwarder	Cain (2014); Stathopoulos et al. (2011)
Third party logistics provider	Vasiliauskas and Jakubauskas (2007); Tian et al. (2008)
Fourth party logistics provider	Coyle et al. (2003); Vasiliauskas and Jakubauskas (2007); Win (2008)
Terminal service provider	Natvig et al. (2009); Woxenius (2012)
Warehouse service provider	Ackerman (2012); Brunaud et al. (2018)
Customs authority	Natvig et al. (2009)
Hazmat authority	Kuncyté et al. (2003); Natvig et al. (2009)

Agents	
Sales representative	Fauska et al. (2014); Goffnett et al. (2012)
Purchasing officer	Kovács and Pató (2014); Standing et al. (2010)
Transport analyst	Goffnett et al. (2012); Kovács and Pató (2014)
Transport operation manager	Goffnett et al. (2012); Kovács and Pató (2014); Natvig et al. (2009)
Transport planner	Eriksson (2019); Goffnett et al. (2012); Natvig et al. (2009); Sternberg et al. (2013)
Driver	Ballantyne et al. (2013); Eriksson (2019)
Terminal worker	Natvig et al. (2009); Sternberg et al. (2013)
Terminal manager	Gue (1999)
Warehouse worker	Eriksson (2019); Natvig et al. (2009)
Warehouse manager	Davydenko and Tavasszy (2013); Derwik et al. (2016); Kovács and Pató (2014)
Customs officer	Kovács and Pató (2014); Natvig et al. (2009)
Hazmat safety officer	Kuncyté et al. (2003); Natvig et al. (2009)

Intelligent goods services	
Metadata information ID, origin, destination, weight, content, priority, incompatibility	Gnimpieba et al. (2015); Prasse et al. (2014); Pöter and Schier (2009); Meyer et al. (2009); Wang et al. (2011); Qu et al. (2015)
Condition monitoring Temperature, vibrations, humity, notifications, alerts, continuous or periodic data sharing	Abad et al. (2009); Badia-Melis et al. (2018); Kalverkamp et al. (2013); Lakshmil and Vijayakumar (2012); Scholliers et al. (2016); Thakur and Forås (2015); Visconti et al. (2016); Wang et al. (2015)
Position monitoring Tracking and tracing, GPS, geofencing, ETA estimations	Ganzha et al. (2017); Wang et al. (2015); Kandel et al. (2011); Yu et al. (2012)
Physical proximity Correct/incorrect sorting/loading, proximity compatibility validation, theft	Caballero-Gil et al. (2013); Ding (2016); Lee et al. (2014); Qu et al. (2015); Spiess et al. (2006)
System autonomy Service sharing, autonomous adjustments of physical conditions, direct or indirect control of other machine agents	Schumacher et al. (2010); Kalverkamp et al. (2013); Dittmer et al. (2012)

Figure 1. The IGS framework: Key components for system classification.

While many speak about the actors involved in the logistics ecosystem, we have opted to include specific human agents that represent the actual service users and thus are suitable to interview in future user studies (for instance, to investigate how intelligent goods may be used to improve the efficiency of the terminal worker's goods handling). The following subsection describe the actors and agents as well as cross-mappings between these. Thereafter, we categorize the services that build on intelligent goods, being part of the ecosystem. This includes a mapping to the agents affected by these services.

3.1. Transport Sector: Actors and Agents

The transport sector is relatively diversely organized, involving various collaborations and contract configurations between different types of actors [1]. Freight transport can thereby be arranged in many different ways, both depending on actor relations but also depending on the specific transport requirements. From this diverse reality, we have identified a number of actor roles, listed below, as potential stakeholders that might benefit from an intelligent goods system (depending on the provided services) (Table 1). By actor role, we here refer to the role of a private individual or an organization (or part of an organization) that acts in the social economy. One organization may play several actor roles, for instance, as shipper, customer, and carrier of shipments. Similarly, the same actor role can be played by multiple organizations; for instance, a manufacturer, a wholesaler, and a retailer can all be shippers of goods. Different logistics chains have different configurations, which means that the actor responsible for placing the transport order varies. For instance, depending on the logistics configuration, it may be the shipper, the customer, or a 3PL who is responsible for ordering a particular transport.

Table 1. Transport sector actors.

Actor	Description
Shipper	Sender of the goods, e.g., a manufacturer, wholesaler or a retailer [21–23].
Customer	Recipient of the goods, e.g., a supplier, wholesaler, retailer, or consumer [21,22].
Carrier	Performs the transport, e.g., a hauler. Some carriers focus on dedicated transport services to single clients, whereas others focus on consolidated transport services, where different clients share the same vehicle [22,24].
Freight forwarder	Coordinates transports using single or multiple carriers, with the aim of finding the best and least expensive transport solutions. Services that may be provided by a freight forwarder include consultancy, transport, documentation, customs clearance, insurance, and consolidation [24,25].
3PL (third party logistics) provider	More complete services than the freight forwarders and are able to take care of a client's entire supply chain and logistics operations (or at least a large part of it). Often, 3PL is defined as outsourcing of transport and logistics activities to outside companies that are neither consignors nor consignees [26]. However, the 3PL role can also be played by a dedicated in-house logistics department. Relations involving 3PL providers are usually more long-term and built on mutual trust than relations involving other types of transport providers [27].
4PL (fourth party logistics) provider	Integrator that brings together the needs of the client and the resources available through the 3PL providers involved with a company's operations, the IT providers, and the elements of business process management [28]. Thus, a 4PL provider is essentially a non-asset-based logistics integrator and a one-point contact for the client's logistics outsourcing requirements [26,29].
Terminal service provider	Provide facilities for receiving, consolidating, and temporarily storing goods in transit [30,31]. Usually, goods are not stored for longer time periods on a fee basis. Instead, they are redistributed to another location or directly to the consumer.
Warehouse service provider	Stores goods for as long as required by the client, which may, for instance, be a manufacturer, wholesaler, or transport actor [32]. Depending on the relationships between the actors, the client may pay a fee based on the storage time and required space [33]. The warehouses are typically equipped with cranes and forklifts for moving and organizing the goods. Some warehouses have strictly controlled indoor conditions, for instance, in order to keep perishables at a proper temperature.
Customs authority	Responsible for the levying of duties and taxes on imported goods from foreign countries and the control over the export and import of goods such as controls over prohibited goods [30].
Hazmat authority	Responsible for regulating and monitoring of the transportation of dangerous or polluting cargo [30,34].

The actor roles described above include a number of physical agents who perform the designated tasks. Based on previous research, we have identified the agents listed below as relevant for an intelligent good system (Table 2). The tasks of each physical agent may be performed by one or several persons working in the supply chain, and each person working in the supply chain may perform the tasks of one or several physical agents. For instance, the tasks of terminal worker may be performed by several persons, and a person responsible for planning a transport may perform the tasks of both a transport planner and a transport analyst.

Table 2. Transport sector agents.

Agent	Description
Sales representative (S)	Selling a company's products [35–37].
Purchasing officer (P)	Buying products from other organizations [37–39].
Transport analyst (TA)	Gathering business-related transport information, e.g., statistics, for administrative purposes [36,38].
Transport operation manager (TO)	Oversees ongoing logistics operations, including monitoring and follow up [30,36,38].
Transport planner (TP)	Strategical, tactical, and/or operational planning of transports, including coordination and information exchange [1,30,36,40].
Driver (D)	Drives the transport vehicle and is usually responsible for loading and unloading [21,40].
Terminal worker (TW)	Terminal operations like packing, splitting, trans-shipment, and possibly loading and unloading [1,30].
Terminal manager (TM)	Management of the terminal facility in which shipments are unloaded, sorted, consolidated, and then loaded again for outgoing delivery [41].
Warehouse worker (WW)	Warehouse operations like loading, unloading, order picking, packing, unpacking, and organizing the goods [30,40].
Warehouse manager (WM)	Management of the warehouse facility that provides storage for the goods [38,42,43].
Customs officer (C)	Verifying that imported goods follow stipulated rules and regulations, including taxes and other fees relevant for the country [30,37,38].
Hazmat safety officer (H)	Oversight of transports with dangerous or polluting goods [30,34].

Figure 2 shows an illustrative example of possible relations between actor roles and physical agents. In this example, the customer buys products from the shipper, who has a transportation agreement with a 3PL. The 3PL engages a carrier for the transport of the products from the shipper's warehouse to a freight terminal and from the freight terminal to the customer's warehouse. No transport is needed between the shipper and its warehouse or between the customer and its warehouse due to the locations of the warehouses. The warehouse service providers belong to the shipper and customer, respectively, and the freight terminal is owned by a terminal service provider. The transportation in this example involves crossing a border between two countries. The customs authority of the importing country is responsible for the levying of duties and taxes on the products.

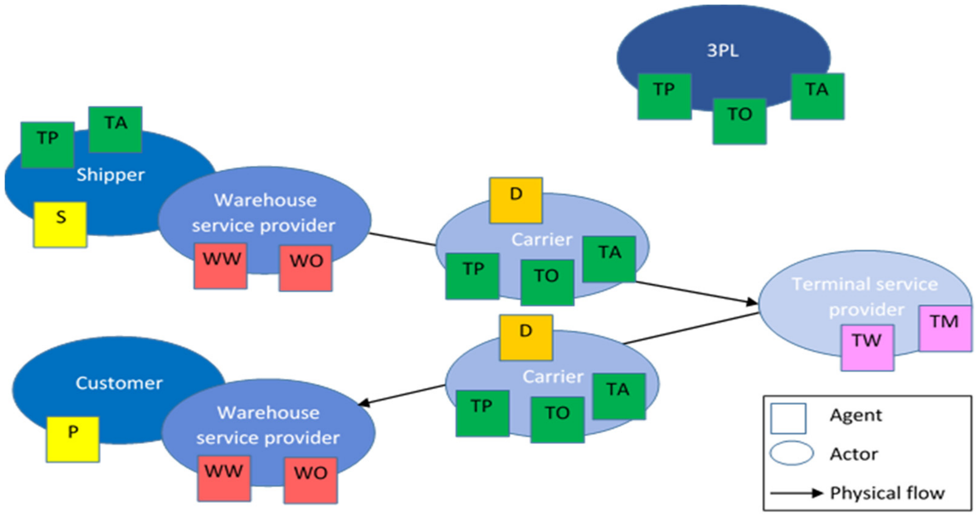


Figure 2. An example of possible relations between actor roles and physical agents, showing the complexity in number of actors and agents that are commonly involved in the physical flow of a single piece of goods.

Both the 3PL and the carrier have travel planners, transport operation managers, and transport analysts. The responsibilities of these agents at the 3PL include engaging the carrier as well as following up and gathering information about the services provided by the carrier. The responsibilities of these agents at the carrier, on the other hand, include planning, coordinating, monitoring, following up, and collecting data from the transport. Additionally, the carrier has two drivers that drive the products from the shipper to the terminal and from the terminal to the customer, respectively. The shipper also has a transport planner and a transport analyst, who are responsible for gathering information about the services provided by the 3PL and the tactical/strategical planning that involves engaging the 3PL. Additionally, the shipper has a sales representative responsible for selling the products, whereas the customer has a purchasing officer responsible for buying the products. Both warehouse service providers have warehouse workers and warehouse managers responsible for handling the products and managing the warehouse operating systems. Finally, the customs authority has a customs officer that controls the products when they enter the new country.

Please note that the description above and Figure 2 only illustrate an example; depending on configuration, the scenario might be quite different. We are sharing this example to draw attention to the many actors and agents that often are involved.

3.2. Intelligent Goods Services

Research studies on goods with some level of intelligence use different names and definitions on concepts similar or equal to *intelligent goods* [12,44]. Some of the names encountered are *intelligent cargo* [45], *smart goods* [46], *smart freight* [47], *intelligent products* [48], and *intelligent packaging* [49]. In recent years, the broader perspective of IoT in freight transport has dominated the research area [50]. The definitions of these concepts vary, both in the number of intelligence levels involved and in the capability requirements. For instance, McFarlane et al. [51] characterizes an intelligent product as having the capabilities of possessing a unique identification, communicating effectively with the environment, retaining or storing data about itself, deploying a language to display its features, production requirements, etc., and participating in or making decisions relevant to its own destiny. Ventä [52], on the other hand, identifies intelligent products as being able to continuously monitor their status and environment, react and adapt to environmental and operational conditions, maintain optimal performance in variable circumstances, and to actively communicate with the user, environment, or with other products and systems. In this paper, we follow the definition of intelligent goods provided by Jevinger [53]. This definition characterizes the intelligence as different capability dimensions, each of which can be supported to different degrees. For instance, in the memory storage capability dimension, the goods may be able to store only an ID, store additional types of data, or to store algorithms/decision rules. The definition suggests that all goods with capabilities above the lowest level in at least one of the dimensions should be called intelligent. This means that more intelligence is required than just being able to communicate the ID of the goods (corresponding to, e.g., the simplest forms of RFID tags or bar codes). Consequently, track and trace systems that rely on readers (scanners) registering the goods upon arrival and departure do not involve intelligent goods unless the goods possess more capabilities than just communicating the ID.

The intelligence of the goods does not necessarily have to be implemented on the actual goods items themselves. It might just as well be implemented somewhere else, as long as it is available when needed throughout the whole transport and acts on behalf of the goods, i.e., acts as an enabler through which the goods may, for instance, make decisions.

Below, we list a number of services enabled by intelligent goods that have been proposed in the literature (Table 3). The list is divided into five main service categories (denoted 1, 2, . . .) that require different types of capabilities of the goods (to form the intelligence). Within each main service category, a number of concrete service examples is also presented (denoted a, b, . . .). The aim with the list is to describe services that utilizes the information provided by intelligent goods as the primary source of information, with no or little processing of that information. Thus, the services included are on a relatively primitive level, which means that many of them can be further developed by the use of more data processing, possibly in combination with external data sources. For instance, temperature data from the entire transportation of perishable food, from the food manufacturer to the retailer, might be used to provide dynamic best-before dates of the food products [8]. Furthermore, information about coloaded goods, in combination with external information about the environmental load caused by the vehicle, can be used to collect and share the environmental load between the individual consignments along the entire transport (possibly involving several transport legs) [54]. Naturally, there are more examples of these types of more advanced services in the literature. However, in this paper, they are out of scope.

Table 3. Intelligent goods service categories, subservices, and main agents involved.

	Intelligent Goods Service Category	
1	Metadata information for goods *For example, Stores and communicates information about goods ID, origin/destination, weight, content (including possible dangerous materials), priority class, or incompatible products* [55,56].	
	Subservice examples	**Involved agents**
1a	Distributed package flow systems in warehouses and terminals *For example, use of autonomous forklifts and roll conveyors that control the goods based on the goods information entities read from the goods* [56,57].	Terminal and warehouse worker
1b	Handling instructions *For example, improved goods handling and maintenance in the supply chain, for instance, by storing information about a product during its entire life cycle* [12].	Terminal and warehouse operator Terminal and warehouse worker
1c	Interconnectivity between transport events and goods information *For example, reading and transmitting to a cloud service all goods information whenever the goods arrive to a stop or are ready for vehicle loading* [55,58]. *This service enables coordination between different actors in complex supply chains where, for instance, goods are co-loaded and transported with different actors along the transport chain. Moreover, the information can be used for inventory control and to notify the final consumer that the goods have reached their final stop and should be picked up* [58,59].	Sales representative Transport operation manager Transportation planner Terminal and warehouse operator Terminal and warehouse worker Purchasing officer

Table 3. *Cont.*

	Intelligent Goods Service Category	
2	Condition monitoring *For example, collects, stores, and communicates information about the physical conditions of/around the goods such as temperature, humidity, light, vibrations, or broken seal* [60–63].	
	Subservice examples	**Involved agents**
2a	Continuously collected condition data, which is read only when there is a reader available *For example, at each stop, and then uploaded to a cloud service* [64].	Sales representative Transport business manager Transport operation manager Transportation planner Driver Terminal and warehouse operator Terminal and warehouse worker Purchasing officer
2b	Continuously collected condition data, which is read and transmitted to a cloud service *For example,* via *an on-board communication unit in real time* [65,66].	Sales representative Transport business manager Transport operation manager Transportation planner Driver Terminal and warehouse operator Terminal and warehouse worker Purchasing officer
2c	Notifications or other forms of alerts *For example, when the physical conditions exceed or fall below certain product specific limits* [67].	Sales representative Transport operation manager Driver Terminal and warehouse operator Terminal and warehouse worker Purchasing officer
3	Position monitoring. *For example, collects, stores, and communicates information about the position of the goods* [68].	
	Subservice examples	**Involved agents**
3a	Tracking and tracing, by continuous collection of position data, which is read and transmitted to a cloud service via an on-board communication unit, in real time *For example, real-time position monitoring of dangerous goods* [66,69,70].	Sales representative Transport operation manager Transportation planner Terminal and warehouse worker Purchasing officer HAZMAT authority
3b	Geofencing, by notifications about the goods entering/leaving a predefined area *For example, an area prohibited for dangerous goods, or an area around the next stop, enabling preparations for the reception* [71,72]. *Geofencing can also be used to notify when the goods deviate from the planned route* [72].	Sales representative Transport operation manager Transportation planner Terminal and warehouse worker Purchasing officer HAZMAT authority
3c	Information about ETA [68] *For example, enabling notifications about goods that are expected to arrive outside the specified delivery time window.*	Sales representative Transport operation manager Transportation planner Terminal and warehouse worker Purchasing officer
4	Collects, stores, and communicates information relating to the physical proximity of the goods *For example, collects, stores, and communicates information about the current transporting truck* [59].	
	Subservice examples	**Involved agents**
4a	Information about correctly loaded goods, missing goods, and goods to unload (remains to be unloaded or mistakenly loaded) onboard a transport vehicle *For example, the information may be transmitted upon request, for instance, using a tag reader installed in the container that scans all goods onboard the vehicle and then transmit the information to a smartphone* [71]. *This may facilitate inspections from customs authorities.*	Sales representative Driver Terminal and warehouse worker Purchasing officer Customs officer
4b	Notifications when goods are too close to other, incompatible goods *For example, different kinds of dangerous goods must be stored in different areas* [73,74].	Driver Terminal and warehouse worker HAZMAT authority

Table 3. *Cont.*

	Intelligent Goods Service Category	
4	Collects, stores, and communicates information relating to the physical proximity of the goods *For example, collects, stores, and communicates information about the current transporting truck* [59].	
	Subservice examples	**Involved agents**
4c	Notifications of theft *For example, when unauthorized removal of content from a container or of the container itself occurs* [75].	Sales representative Transport operation manager Transportation planner Terminal and warehouse operator Terminal and warehouse worker Purchasing officer
5	System autonomy *For example, every single goods item is responsible for a small amount of functionality, but the combination of the single parts results in a quite complex and powerful system if the parts communicate with each other* [76].	
	Subservice examples	**Involved agents**
5a	Service sharing between different goods items *For example, the goods items may query other goods items for information, they may share knowledge, and they may consume services offered by other items* [76].	No human agents involved, as these services are based on machine-to-machine interaction
5b	Autonomous adjustment of physical conditions *For example, the goods items autonomously adjust those physical conditions that are adjustable (e.g., temperature), with respect to all goods present, when physical conditions exceed or fall below certain limits* [61].	No human agents involved, as these services are based on machine-to-machine interaction
5c	Direct or indirect control of vehicle, loading or unloading equipment, or sorting/routing machinery *For example, the goods communicate with ships, cranes, and other objects to route themselves autonomously through the logistics network* [77].	No human agents involved, as these services are based on machine-to-machine interaction

The list below also includes mapping between the intelligent goods services and the agents that may have a direct benefit from using these services. The mapping derives from the intended benefits and user groups as well as analysis of the suggested features, as stated by the reviewed papers.

In addition to the above, the different monitoring services (services 1c, 2–4) indirectly provide information about exactly which goods are on the way, which may enable the sales representative, purchasing officer, transport operation manager, and driver to make sure that the expected orders are fulfilled at an early stage of the transport chain. In the long run, it also provides information about whether transport commitments have been fulfilled, which may help the transport planner in his/her future work (when deciding on new transport assignments). Furthermore, if condition monitoring (service 2) is combined with context awareness (service 4), information about who was responsible in case the goods were damaged can be obtained. This may be of interest to the transport planner, transport analyst, and, in a secondary step, the insurance company [78].

4. Visilion Logistics: A Case Description

Visilion Logistics is an IoT-based system developed by a large multinational company and primarily directed towards shippers and logistics service providers (e.g., carriers or 3PLs). The goal of the system is to increase these actors' control over the goods by providing enhanced tracking information about goods in transit. Aside from exact location at any time, this includes continuously updated expected arrival time, and sensor-based monitoring of selected physical conditions for the goods during transportation. Having these data tied to specific goods is a reaction to the challenges in reliably collecting and sharing such data otherwise. This problem is largely rooted in the transport chain, typically involving a diverse collection of actors with several handovers.

System overview: The system includes a cloud service with interfaces to desktop and mobile phones, and trackers with incorporated sensors that are able to measure temperature, position, shock, and voltage (remaining battery power). The position data is based on GNSS positioning and network positioning from cellular base stations. The frequency of the positioning data collection is automatically decreased when the vehicle stands still (which is detected by the accelerometer). Before the goods leave the shipper, the trackers are attached to the shipment, which typically consists of one or more pallets. Each tracker is responsible for one individual shipment from origin to destination. During the transport, these trackers measure and communicate encrypted sensor data (temperature, position, shock, and voltage) to the cloud service at configurable intervals. The communication is based on the latest cellular technologies for the IoT era (including LTE CAT-1, CAT-M, and NB1); 5G will also be integrated within the near future. In case of lack of connectivity, the tracker stores the sensor data and reattempts to connect at a later time. When the shipment reaches the final destination, the tracker is returned to the service providing company or the shipper (depending on customer preferences) via postal services. This way of returning trackers was suitable during the initial trials; however, the company is working on other solutions. At the service providing company or shipper, the trackers are charged, and if necessary repaired, before they go into circulation again.

End user services: The Visilion Logistics services can be accessed from a web client or by integrating an ERP system with Visilion Logistics. As the sales representative adds the order, it is possible to also set which notifications of events and deviations are communicated. Notifications are possible to receive in the web client/ERP system, via email, or as text messages, and are shared to personnel in the shipping chain considered relevant to the particular order by the sales representative. Notifications contain a direct link, which does not require user login, to a richer view of the information. Notifications may include events and deviations such as departure, arrival, late departure, late arrival, delay warning, shock, temperature, and waypoint, depending on what is configured at order time. The delay warning is based on predicted ETA, which is calculated from origin, destination, waypoints, and types of vehicles. The late departure, late arrival, and the waypoint detection are based on route plan and position. The temperature and shock notifications are sent when the sensor data exceeds (or falls below, in case of temperature) certain configurable limits. For temperature, these limits can be set by default values or manually specified by the user. However, for shock, no default value is given, since the damaging limits depend on the individual characteristics of the goods, such as weight and packaging. The service interfaces also show detailed information about the events as well as the physical locations of the events, the transport route travelled, and all temperature measurements from the route.

Figure 3 shows the Visilion Logistics interface displayed to the user after logging into the system. To the left in the figure, the generated events are listed with the most recent ones on top. The list shows event type, time, route origin, and destination for each of the generated events. To the right, a map shows where along a route the events were generated. The user may click on the map to obtain a closer view and more detailed information about the events.

If the user clicks on a particular event in the event list (late arrival, in this case), the interface shown in Figure 4 is displayed. In the upper left corner, more detailed information about the event is shown, including order number, origin, destination, event time, current voltage, and current temperature. The rest of the page shows a map of the entire transport route, including where different events were generated along the route. As before, the events displayed in the map are clickable.

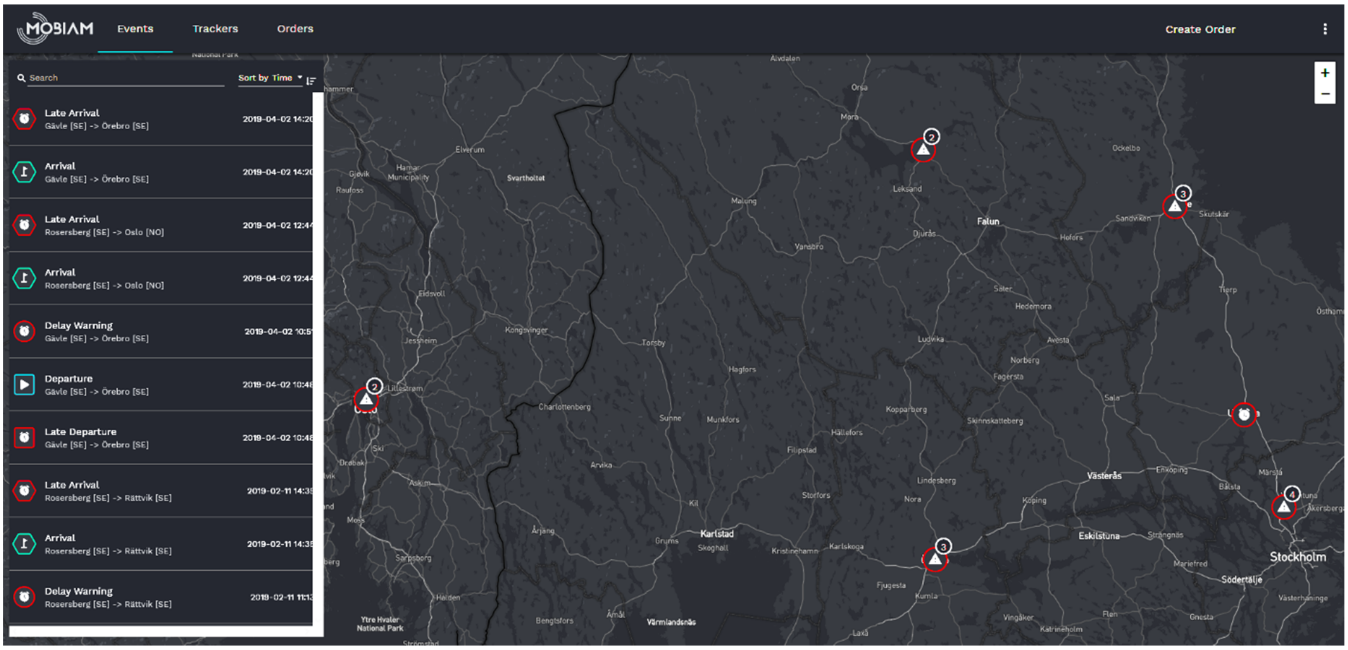


Figure 3. List of all events and a map displaying where these events were generated.

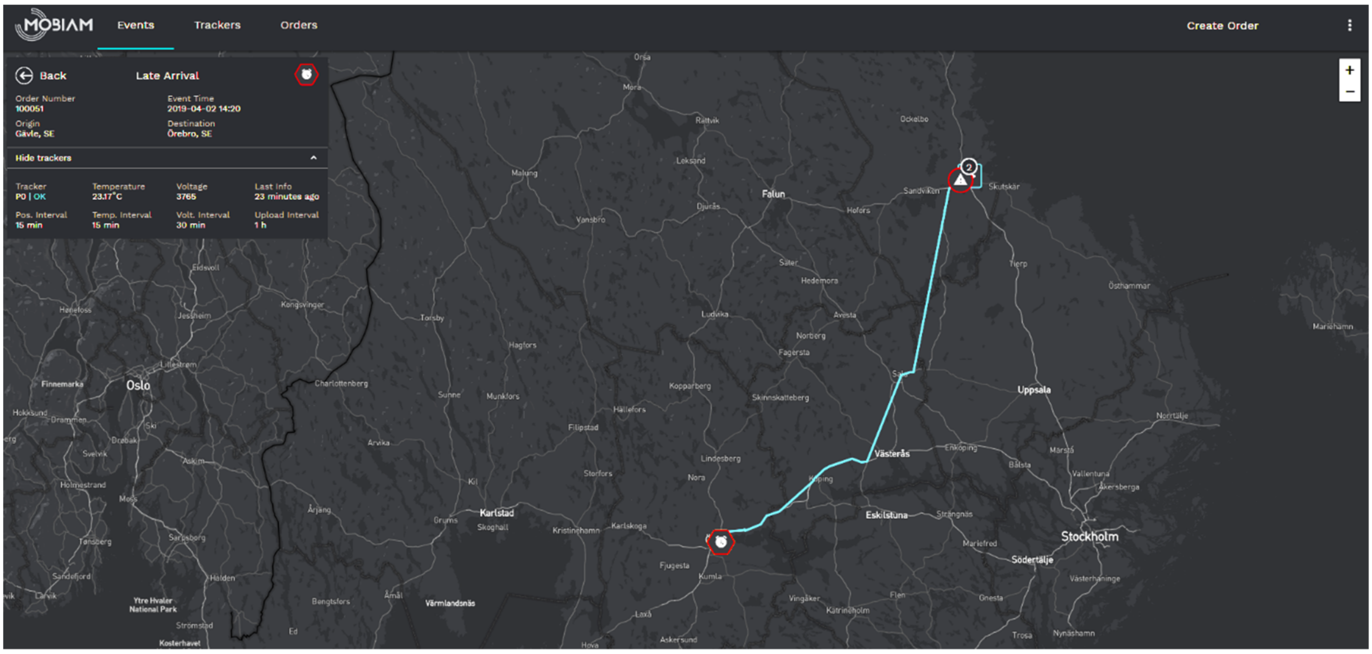


Figure 4. Details from a particular event (late arrival) and the associated transport route.

If the user clicks on "orders" in the menu at the top left, all active orders are listed, and a non-clickable map shows the routes of all transports related to different orders in this list. If the user then clicks on a particular order (order 100051 in this case), details of the transport related to this order are displayed, as seen in Figure 5. The information provided on the left includes status of the order (e.g., completed), planned versus actual departure and arrival times, origin and destination addresses, latest measured temperature and voltage, and a compact list of generated events. To the right, a map of the entire transport route related to the order, and the different places of the events, is shown. The events displayed in the map are clickable.

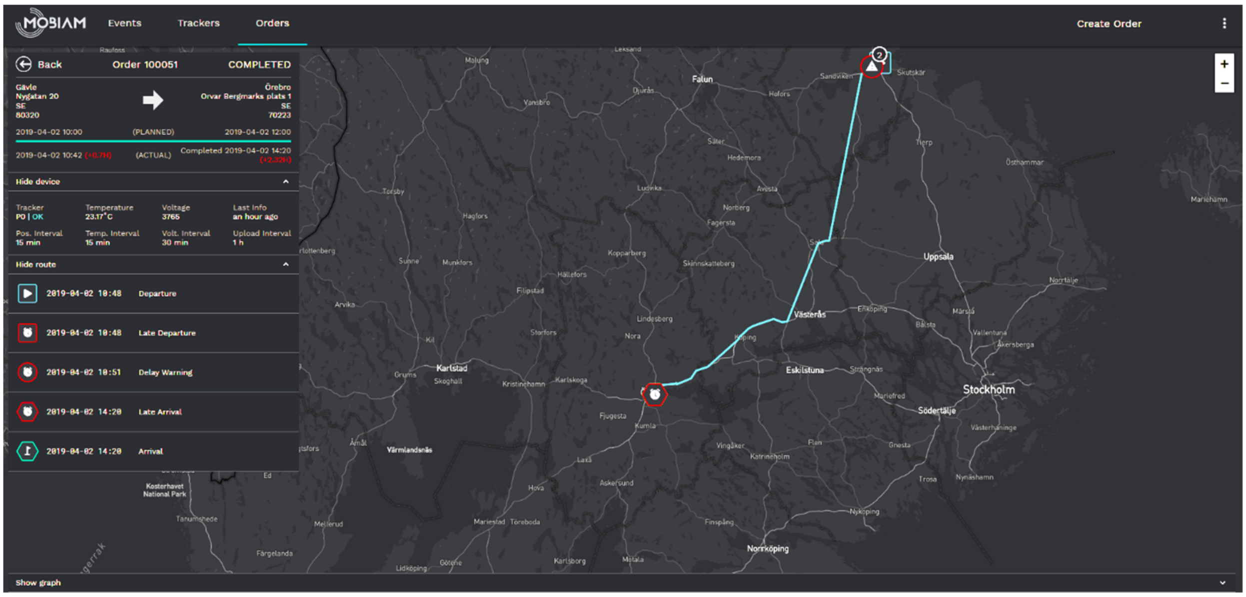


Figure 5. Details from a particular transport (order number 100051) and the associated tracker, as well as all events that have occurred during this transport.

At the bottom left of Figure 5, "show graph" is displayed. When this is clicked, a graph with measured temperature and voltage levels, as well as time of events and data uploads, is presented. Figure 6 shows the graph when only temperature and events are selected.

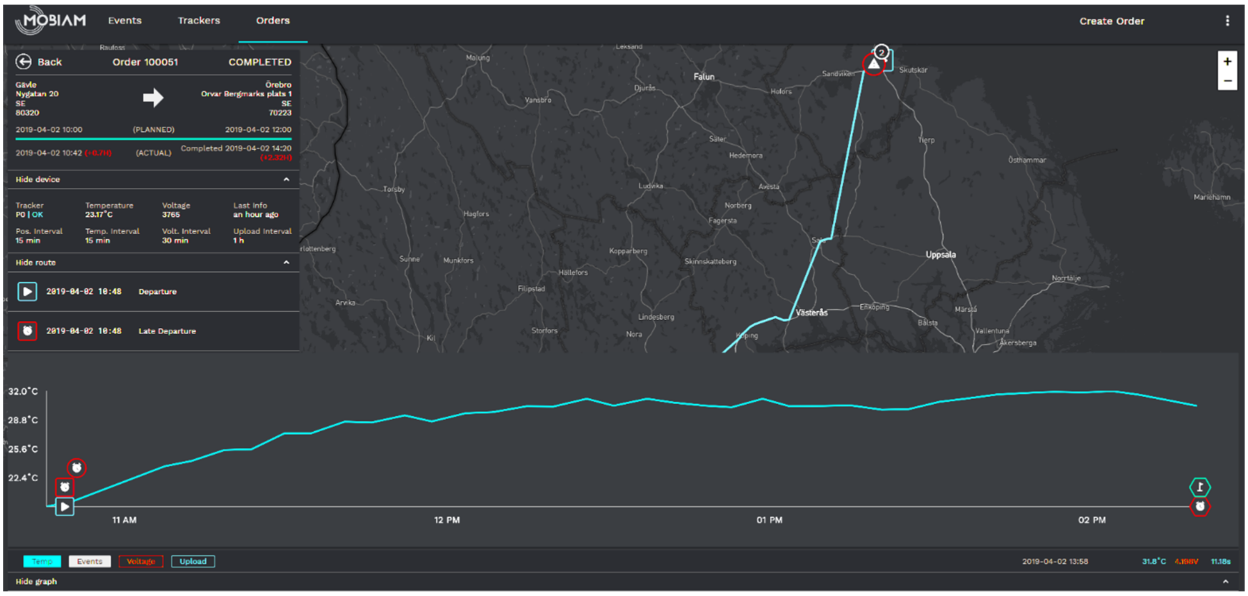


Figure 6. Graph with measured temperature and events along the entire transport.

Finally, by clicking "trackers" displayed in the top left, a list of all trackers is displayed together with a map showing their current physical position. When selecting a tracker in the list, more detailed information about that particular tracker is provided, such as latest measured temperature and voltage.

5. Classification Process

As a first step towards analysis of particular aspects related to intelligent goods systems lies classification of the system in question. In Table 4, we present the general process for classifying intelligent goods systems that we recommend, as well as how we specifically did so for the Visilion Logistics case. As part of our long-term research objective to follow and contribute to the development of Visilion Logistics with our industry collaboration partner, our goal as we apply the framework is to focus on classifying the current state of Visilion Logistics first and foremost, and based on this, identify potential future directions for study that hold both practice and research relevance.

Table 4. Classification process for using the Intelligent Goods Service (IGS) framework. The left side explains the general process, with main objectives of each step and examples for what this may be. On the right, we illustrate how this was done as we followed the general process for analyzing the Visilion Logistics case.

	General Process	Visilion Logistics Case
1	**Initial Classification**	
	Objective: Using information known about the system at hand. Example: Depending on system access, this could include, for instance, results from previous studies of particular aspects, direct system access, key actor feedback, and documentation.	Activity 1: System beta access from one of the customers' part of the proof-of-concept development. Activity 2: User feedback from interviews with proof-of-concept customers.
2	**Missing information**	
	Objective: Which type of information listed in IGS is lacking? Example: Typically, the particular type of information that is relevant to add is related to specific research objectives. The IGS framework could, however, also be used as a lens for comparisons of multiple intelligent goods systems. In such cases, this step would instead be a step for comparing the included systems.	Activity 3: Defined interview questions, with the intent to: (1) validate our initial classification (correct agents, actors, intelligent goods services, and technology mediation), (2) complement our understanding of the involved agents, actors, intelligent goods services and known technology mediation with detailed information, and (3) identify future product development of relevance.
3	**Data collection**	
	Objective: Collect missing information. Example: Using multiple types of data sources may be advantageous for triangulation and thus ensure that, e.g., interview questions and answers are not misunderstood. If direct system developer access is not feasible, relying on user feedback becomes particularly important.	Activity 4: Interview with product manager. Activity 5: Insider access to product design documentation.
4	**Revised classification**	
	Objective: Based on collected data, update the initial classification. Example: In itself, a classification of a system may serve many purposes, such as to identify starting points for future feature development or key interest areas for particular actors.	Activity 6: Validation of main focus for system intelligence being on condition monitoring and position monitoring. Activity 7: Additional nuances in service descriptions. E.g., this included a new type of notification service concerning temperature, a new type of metadata information service concerning voltage levels, and the geofencing service revised as a result of the specific way that late arrival/departure as well as waypoints are addressed. Activity 8: Through the identified potential other services, future development plans on short, intermediate, and long term were presented. While we touch upon those that we can in the text below, these primarily serve to help our collaboration planning with the industrial partner and are not fully elaborated on here given the NDA we are working under.

Figure 7 illustrates our classification in relation to the IGS framework. This allows us to make use of the IGS components to contrast the current implementation of Visilion Logistics with what other intelligent goods systems address. For future collaboration with our industrial partner, this visual representation will continuously be updated as service intelligence evolves, and additional customers are included—in itself allowing longitudinal comparisons to be made.

Actors	
Shipper	Ballantyne et al. (2013) Crainic et al. (2018) Tseng et al. (2015)
Customer	Crainic et al. (2018) Ballantyne et al. (2013)
Carrier	Crainic et al. (2018) Stathopoulos et al. (2011)
Freight forwarder	Cain (2014) Stathopoulos et al. (2011)
Third party logistics provider	Vasiliauskas and Jakubauskas (2007) Tian et al. (2008)
Fourth party logistics provider	Coyle et al. (2003) Vasiliauskas and Jakubauskas (2007) Win (2008)
Terminal service provider	Natvig et al. (2009) Woxenius (2012)
Warehouse service provider	Ackerman (2012) Brunaud et al. (2018)
Customs authority	Natvig et al. (2009)
Hazmat authority	Kuncyté et al. (2003) Natvig et al. (2009)

Agents	
Sales representative	Fauska et al. (2014) Goffnett et al. (2012)
Purchasing officer	Kovács and Pató (2014) Standing et al. (2010)
Transport analyst	Goffnett et al. (2012) Kovács and Pató (2014)
Transport operation manager	Goffnett et al. (2012) Kovács and Pató (2014) Natvig et al. (2009)
Transport planner	Eriksson (2019) Goffnett et al. (2012) Natvig et al. (2009) Sternberg et al. (2013)
Driver	Ballantyne et al. (2013) Eriksson (2019)
Terminal worker	Natvig et al. (2009) Sternberg et al. (2013)
Terminal manager	Gue (1999)
Warehouse worker	Eriksson (2019) Natvig et al. (2009)
Warehouse manager	Davydenko and Tavasszy (2013) Derwik et al. (2016) Kovács and Pató (2014)
Customs officer	Kovács and Pató (2014) Natvig et al. (2009)
Hazmat safety officer	Kuncyté et al. (2003) Natvig et al. (2009)

Intelligent goods services	
Metadata information ID, origin, destination, weight, content, priority, incompatibility	Gnimpieba et al. (2015) Prasse et al. (2014) Pöter and Schier (2009) Meyer et al. (2009) Wang et al. (2011) Qu et al. (2015)
Condition monitoring Temperature, vibrations, humity, notifications, alerts, continuous or periodic data sharing	Abad et al. (2009) Badia-Melis et al. (2018) Kalverkamp et al. (2013) Lakshmil and Vijayakumar (2012) Scholliers et al. (2016) Thakur and Forås (2015) Visconti et al. (2016) Wang et al. (2015)
Position monitoring Tracking and tracing, GPS, geofencing, ETA estimations	Ganzha et al. (2017) Wang et al. (2015) Kandel et al. (2011) Yu et al. (2012)
Physical proximity Correct/incorrect sorting/loading, proximity compatibility validation, theft	Caballero-Gil et al. (2013) Ding (2016) Lee et al. (2014) Qu et al. (2015) Spiess et al. (2006)
System autonomy Service sharing, autonomous adjustments of physical conditions, direct or indirect control of other machine agents	Schumacher et al. (2010) Kalverkamp et al. (2013) Dittmer et al. (2012)

Figure 7. Overview of Visilion Logistics' main (**stronger highlighted**) and complementing (**lighter highlighted**) components; the parts of the IGS framework that presently are outside the scope of Visilion Logistics are left without a background color.

As shown by Figure 7, Visilion Logistics has so far involved the following actors and agents: (1) shippers, and within these sales representatives and transport planners; (2) customers, primarily their purchasing officers; (3) carrier/freight forwarder/3PL/4PL, specifically transport operation managers and transport planners; and (4) warehouse service providers and their warehouse workers (fitting, removing, and posting trackers). Given the central role that the backend configuration of Visilion Logistics has, the central actors that have been of particular focus to the design are carriers and shippers. The main reason for focusing on these actors is that they are both in physical contact with the goods when the trackers are attached at the beginning of the transport chain. Moreover, they represent single points of contact for the service provider, since the shipper most often is responsible for ordering the transport service. A focus on the customer had on the contrary probably involved more diversified transport services.

In terms of intelligent goods services, we clearly see an emphasis on condition monitoring and position monitoring, even if basic metadata information is also provided. The metadata information for goods is today registered manually in the Visilion Logistics backend, where tracker ID is associated with a goods item. Metadata information related to the particular tracker, such as the current voltage level (remaining battery power) is transmitted, at short regular intervals, from the tracker to the Visilion Logistics cloud service. This information is then displayed to the user in the form of current voltage and a graph covering the entire route. For condition monitoring, this includes both notifications or other forms of alerts, as well as continuously collected condition data, which is read and transmitted to a cloud service. In the Visilion Logistics case, the tracker continuously collects temperature data, which is transmitted at short regular intervals to the Visilion Logistics cloud service and displayed to the user (in the form of current temperature and a graph covering the entire route). Moreover, the service notifies when the mechanical shock level exceeds certain limits and when the temperature level exceeds or falls below certain limits. Finally, in terms of position monitoring, this includes tracking and tracing, as well as geofencing and information about ETA. In the Visilion Logistics case, the tracker continuously collects position data, which is transmitted in short regular intervals to the cloud service and displayed to the user on a map (in the form of current position and a trail showing the entire route). Moreover, the service notifies when goods enter and exit an area around the origin, a waypoint, and the destination. When the departure from the origin or the arrival to the destination is late, special notifications about this are transmitted. Finally, the service notifies when the arrival of goods is expected to be delayed, based on the predicted ETA.

6. Identifying Future Directions

For Visilion Logistics, it may be beneficial to integrate some form of hand scanner when associating the tracker with the goods. Presently, this is done manually on the backend, which aside from being more cumbersome also increases the risk for mistakes if the wrong tracker is accidentally put onto/into the goods compared with what has manually been entered in the backend system. Although trackers can be re-assigned to compensate for this to some extent, there are cases where this can be difficult to correct. This includes longer shipments and cases where the tracker may not have sufficient battery power to deliver the type of service that was requested. It is thus noteworthy that even a relatively simple—in terms of complexity and perceived system intelligence—metadata information service can be an important part in the overall service provided. Thus, adding a service to Visilion Logistics that provides different types of metadata (IGS service 1) via hand scanners to local agents may increase the value for the users. The literature presents several examples of such implementations, for instance for updating and using the goods' metadata to provide handling directions, facilitate customs procedures, and enable rerouting of goods to where they are needed the most [12,79]. For instance, depending on the current status of the customer requirements, the goods may be rerouted to a more or less expensive transport alternative or to another destination. Moreover, metadata information such as the goods content, loading date, origin, and destination can automatically be communicated wirelessly to the customs authority. Thus, while the data in itself is not novel compared with before, the sharing of it in an effective way can be highly value creating.

Theft and manipulation of goods as well as strictly enforced route planning may also be interesting further development areas for Visilion Logistics. This implies forcing drivers only to stop at predetermined safe locations for breaks as well as alarms automatically being raised if there are deviations from the planned route. Aside from minimizing the risk for the goods being stolen, this also gives rapid response times for situations where the truck may have been hijacked—something that could even be linked to truck safety/alarm systems to disable the vehicle remotely. This example is thus a combination of all five intelligent goods service types identified in the IGS framework. The metadata information service contains classification of goods in terms of sensitivity to theft, which the condition monitoring service validates is not tampered with using, for instance, light sensors inside the goods or container. Position monitoring further tracks that the goods maintain the planned route to ensure that the carefully planned route and stops are adhered to, while the physical proximity service ensures that any reloading of the goods is correctly managed—including ensuring that incompatible goods are not placed too close. Finally, direct integration with the vehicle's safety system would be managed by an autonomous service empowered to take active control and halt the vehicle. Examples from the literature include Scholliers et al. [63], who present the possibility to improve the integrity of containers by using intrusion sensors. Generally, this is achieved by using light sensors that detect when a container door is opened or when someone crosses the sensor beam. By means of cellular or satellite communication, the integrity of the container can be communicated in real time to a control center. Furthermore, Reclus and Drouard [72] describe a solution for route adherence, where the route is downloaded to, for instance, a container before departure. A set of circular geofences is applied along the entire route, one after the other, and if the container deviates from the route by crossing a geofence, an alert is generated with the deviation location. Finally, Lee et al. [75] suggest the use of "smart containers". These smart containers communicate with each other through Bluetooth transceivers, which enable them to detect when a container carried by a delivery truck suddenly loses contact with all its neighbors or when the carried containers suddenly lose contact with one of their peers. They may then conclude that a theft has occurred and generate an alarm.

7. Concluding Reflections

This paper set out by describing the highly heterogeneous transportation market for goods and elaborating on the challenges that follow this heterogeneity. This included constantly changing collaborating actors, with human agents that may overlap in which role they play for the shipping of goods. Furthermore, from a customer perspective, we recognized that rudimentary and checkpoint-based status updates tend to be what is offered, which makes liability for goods that arrive with damage tremendously difficult to establish. During a longitudinal industry-academia collaboration related to a novel IoT-based product, Visilion Logistics, which in its first minimum viable product version strives to address some of this heterogeneity, we found ourselves struggling to establish suitable means for classifying the solution. As a result, this paper focuses on establishing a classification framework (the IGS framework) that not only consists of intelligent goods services but also the diverse organizational actors and human agents. The development of the IGS framework was based on the current state of research in terms of actors, agents, and intelligent goods services.

In order to illustrate both how the IGS framework can be used and some of the resulting benefits, it was applied to Visilion Logistics. In this case study, all intelligent goods services included in Visilion Logistics, together with the actors and agents involved, were mapped and classified. In addition to providing a deeper understanding of the system, this mapping was used to identify weaknesses and potential further developments, primarily in the form of a number of new intelligent goods services for different actors and agents. The case study showed, for instance, that local agents (e.g., warehouse workers) using Visilion Logistics might benefit from adding a new service that provides goods metadata via hand scanners. This service could, amongst others, be used to prevent trackers from being accidently placed onto/into the wrong goods, compared with what has manually been entered in the backend system. In particular, the additional information provided by such a service has the potential to increase efficiency and reduce costs. To give further guidance, the IGS framework provides examples of different types of metadata services presented in previous research literature. In summary, the case study demonstrates the use of the IGS framework in terms of identifying new innovative solutions as well as better understanding of the actors, agents, and services involved in an intelligent goods system. Since the framework involves a classification of actors, agents, and services, we believe it can also be used to facilitate system comparisons.

The IGS framework has primarily been developed with the aim to increase the understanding of intelligent good systems and to guide further developments and future studies of these systems. Based on this, a number of potential benefits of intelligent goods systems may be put into practice, such as higher efficiency (e.g., more efficient goods handling), lower costs (e.g., smarter route choices), higher security (e.g., theft alerts), and higher levels of sustainability (e.g., minimized food waste).

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