Understanding Data-driven Service Ecosystems in the Automotive Domain

Completed Research

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Abstract

Due to the current digital transformation, even traditional companies are subject to fundamental reorganization. Therefore, the automotive industry, especially vehicle manufacturers, is undergoing a transformation process from offering goods and related services to offering data- and analytically-supported services that meet customers' needs. Though this transformation is already in progress, little is known about the current actors, data flow and collaboration in service development. To improve the understanding, our paper analyses both the actors and the role of vehicle sensor data from an ecosystem perspective. We first apply a literature analysis, which is then enriched with results from expert interviews. Eleven experts are involved in the latter, including representatives of service providers, authorities, data market providers, research institutions and vehicle manufacturers. By combining both results we gain relevant actors in the ecosystem as well as their relationships, data flows and services. Our results thus provide a fundamental understanding of data-driven service ecosystems in the automotive domain and form the basis for future IS research on (big) data flows and analytics within such ecosystems.

Keywords

Data-driven Services, Automotive, Service Ecosystems, Digital Mobility, Connected Vehicles.

Introduction and Motivation

Digital innovation, digitization and digital transformation are on everyone's lips today. Both leading business analysts and strategy consultants such as Accenture (2016), Bain (2017), Deloitte (2017), KPMG (2017; 2018), and McKinsey (2016; 2017) and researchers (Kessler and Buck 2016; Mikusz and Herter 2016; Kohl et al. 2017; Mocker and Fonstad 2017) report on the increasing digitization of the automotive industry. In addition to the importance of current technological trends in shaping the automotive future, such as autonomous driving (Kung and Lin 2018), connected vehicles (Gerloff and Cleophas 2017), intelligent manufacturing and maintenance (Laubis et al. 2016; Gerloff and Cleophas 2017), blockchain (Kaiser et al. 2019), and big data analytics (Dremel et al. 2017), analysts are increasingly focusing on new relationships within digital ecosystems.

Coined by ecologists, the 'ecosystem' term has been taken up in literature on economics (Pilinkienė and Mačiulis 2014) and seems to have gained some attention in the IS community over the last few years (Nischak et al. 2017; Ceccagnoli et al. 2012), too. In recent decades, both hardware-based platforms, such as PCs, mobile computing systems, and video game consoles, and software-based platforms, such as smartphone app stores and online marketplaces, have become increasingly important with regard to the creation of ecosystems (Evans et al. 2006). However, many traditional organizations do still not think in terms of ecosystems. Instead they are thinking of participating in or even controlling a linear value chain (Weill and Woerner 2015). In contrast, there are ecosystem drivers such as Amazon, Apple or Google, which provide platform technology to other participants to enable new business opportunities. In such platform ecosystems, technology owners co-create business value with other organizations that use their platform

(Ceggagnoli et al. 2012). In the automotive domain, vehicles, too, can be understood as a platform technology. This way, vehicle manufacturers can build ecosystems together with other stakeholders, e.g. actors from information technology (Riasanow 2017). Following this analogy further, vehicle manufacturers could even promote the creation of platform ecosystems. As an example of an ecosystem in the automotive domain, Vaia et al. (2012) present a case of one of the largest Italian motor insurers together with a system integrator for telematics-based insurance.

However, vehicles do not only establish platforms, but, as computers on wheels, they also generate valuable data (Stocker et al. 2017). Vehicle data are the main source of data-driven service ecosystems as they can be linked to other data sources to enable innovative uses. As an example, the technology startup Automatic (Automatic 2018) has begun to establish a data-driven service ecosystem based on its core technologies. Automatic acquires a limited set of vehicle sensor data using a branded (external) gateway device (in this case, an OBD dongle) connected to a vehicle's on-board diagnostics (OBD) interface. This enables the synchronization of driving data with a connected smartphone, allowing the driver to keep track of driving behavior via the Automatic smartphone app. On the way to an Automatic data-driven service ecosystem, third-party apps that also use the vehicle data captured by OBD dongles from Automatic have been developed for the Automatic platform (Automatic 2018). Third-party applications in this ecosystem include, for example, the creation of invoices based on mileage (FreshBooks 2018), vehicle cost management (Xero 2018), and management of track earnings and warnings during ride sharing (SherpaShare 2018). The Automatic example shows the potential of data-driven service ecosystems in the automotive sector.

The ecosystem concept seems to be useful to better understand current and future relationships between actors and services. However, it has rarely been applied in the automotive domain as a tool for understanding data and value flows and cooperation between different actors. Furthermore, the concept of data-driven service ecosystems in the context of automotive innovation has not been considered very relevant in IS-related literature. In line with the research agenda for Vehicle Information Systems (Kaiser et al. 2018), we have formulated the following research question: *What are data-driven service ecosystems in the automotive domain and what are their actors and value flows?* To answer this research question, we have conducted an analysis of IS literature to better understand the concept of 'ecosystems' in general. In a second step, we derived a preliminary model of an ecosystem with actors, value flows and services from the literature to understand the genesis of data-driven service ecosystems in the automotive domain. We finally discussed this model and elaborated it using knowledge of eleven experts in an expert interview study.

In the remainder of this paper, we begin by explaining the ecosystem concept and how it can be applied to the automotive sector. This is followed by our findings, including a list of actors, services, a high-level model of the data-driven service ecosystem and detailed views on the underlying data and service ecosystems as described in detail in Section 3. The results show that the ecosystem concept is suitable to understand the challenges of data-driven service ecosystems in the automotive domain.

The Ecosystem Concept and Related Work

Since the goal of our article is to shed light on the components and relations that form data-driven service ecosystems, we first present related work on ecosystems that aims to further explain and clarify the ecosystem concept in the automotive domain. We then refer to related streams of research that address important aspects of such ecosystems. In general, the concept of an ecosystem is inspired by natural ecosystems, where it describes the relationships and interactions between living organisms and their environment (Schulze et al. 2005). The concept of ecosystems has been transferred as an analogy to various scientific disciplines, including Social Sciences, Computer Science and Natural Science (Briscoe and De Wilde 2006). In order to delineate artificial ecosystems from natural ecosystems, some authors add further attributes to the term to qualify it, e.g. *software* ecosystems, *business* ecosystems or *digital service* ecosystems (Immonen et al. 2015). However, a commonly agreed definition of the term does not yet exist. With this in mind, Nischak et al. (2017) conducted an analysis of peer-reviewed articles on ecosystems and information systems that introduced the ecosystem concept based on how it was originally used by biologists. The authors emphasize that three components are essential elements of digital business ecosystems, namely *Value Exchange* (innovation, information, products/services), *Resources* (digital and non-digital) and *Actors* (organizations, individuals, societies). This definition can easily be adapted and specialized to data-driven service ecosystems in the automotive domain (cf. Figure 1, the two leftmost ecosystems are depicted according to Nischak et al. (2017)).

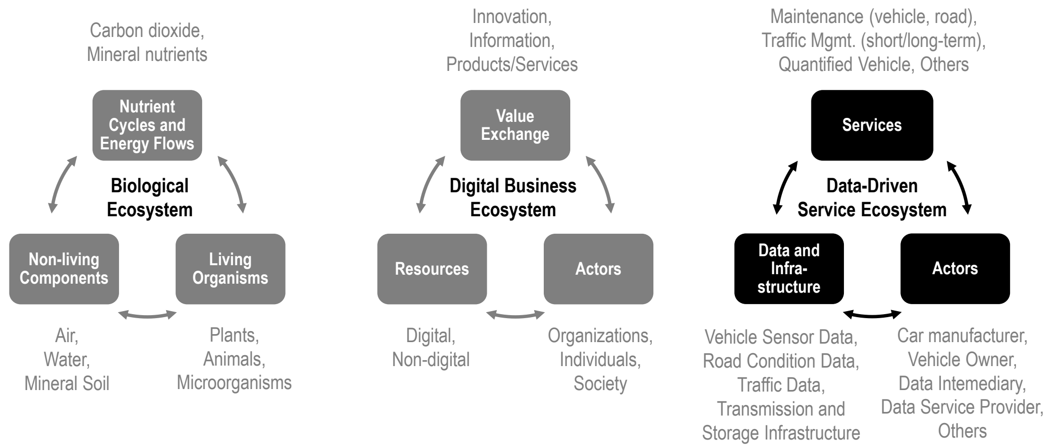

Figure 1. Biological, Digital Business and Data-Driven Service Ecosystem

Similar to a Digital Business Ecosystem, a *Data-driven Service Ecosystem* in the automotive domain contains *Actors* (e.g. car manufacturers, vehicle data service providers, etc.). These actors have access to resources which, in the case of a data-driven ecosystem in the automotive domain, are *Data and Infrastructure* for generating, transmitting and storing data (e.g. vehicle sensor data, road condition data, etc.). With these resources, the actors participate in value exchange by providing or consuming *Services* (e.g. data-driven services for vehicle maintenance, short-term traffic management, etc.).

In general, the concept of service ecosystems is often defined in literature as “relatively self-contained, self-adjusting systems of resource-integrating actors connected by shared institutional logics and mutual value creation through service exchange” (Akaka et al. 2012; Lusch and Nambisan 2015). Despite these works on service ecosystems that also involve data-driven services, research concerning data-driven service ecosystems in the automotive domain is still scarce: The query `(automotive OR vehicle OR car) AND ("digital service ecosystem" OR "data-driven service ecosystem")` executed on Google Scholar produced 22 results (Nov. 2018), but after looking at the title and abstract, we concluded that no research work sufficiently addressed service ecosystems in the automotive domain. Consequently, and to the best of our knowledge, no research work explicitly addresses data-driven service ecosystems in the automotive domain. However, further related research can be found for smaller sub-systems of such an ecosystem. First, the combination of *Data and Infrastructure* with *Services* is subject of many research works that analyze how vehicle sensor data can be aggregated and combined with other data to create meaningful information services along a big data value chain for vehicle data (Kaiser et al. 2018a; Kaiser et al. 2018b). Second, the interplay of *Services* and *Actors* has been extensively investigated in the fields of Value Networks (Pagani 2013) and, more recently, Service Science, where the theory of the Service-Dominant Logic (S-D Logic) is of central importance (Vargo and Lusch 2004). The theory implies that almost any product can be interpreted as a service, meaning thatthe physical component is no longer the most important aspect.

To sum up, the identified research streams emphasize either technical or business aspects but do not investigate the interrelationships and interdependencies between data, services and actors in an integrated way. Furthermore, a systematic account of which actors are involved in which service and which data they can access is still missing. We close this gap by identifying relevant actors and their relationships, data flows and services. In doing so, we apply the perspective of automotive data-driven service ecosystems.

Data-driven Service Ecosystems in the Automotive Domain

Data collection and analysis

After analyzing the relevant literature on ecosystems, we designed a model for data-driven service ecosystems in the automotive domain, which we used as the main input for an expert interview study involving eleven experts in data-driven services from large industries (e.g. automotive manufacturers), small and medium enterprises (e.g. data-driven startups) and research entities. Figure 2 lists background information on experts, e.g. expert 1 is involved in the standardization of Vehicle-to-Infrastructure (V2I) communication and acts as a representative in international committees in the automotive domain. Expert 2 leads a computer science degree program focusing on the automotive sector and deals with data-driven services. Expert 7 leads a project to develop and launch a data marketplace, where the provision of vehicle data for data-driven services is a major issue, while expert 9 leads an automotive engineering company that develops hardware and software components for vehicle manufacturers dealing with vehicle sensor data. In summary, each individual expert has a strong background in data-driven services in the automotive domain.

We had several meetings with these experts, either in person or virtually. We asked each of them for qualitative input on relevant actors and their influences, and on value flows between actors, and for feedback on our originally developed graphical ecosystem model. Semi-structured interviews, each lasting about 90 minutes, started with a set of questions about their background, i.e. their general professional experience and expertise area. The experts were asked to provide a comprehensive description of one data-driven service in the automotive domain they know of. Finally, they were requested to think five years into the future and briefly describe the changes they see. All interviews were transcribed, apart from three cases where audio recording was not allowed, which is common in the automotive sector for confidentiality reasons.

Expert No.	Type of Actor	Personal Expertise w.r.t. data-driven services in the automotive domain	Work Exp. [years]	Expertise Level [1-5]
1	Public Authority	representative in international committees	22	NC
2	Research Organization	leader of computer science degree program	24	2-3
3	Research Organization	researcher involved in vehicle data analytics projects	8	2
4	Research Organization	researcher involved in projects with vehicle manufact.	4	3
5	Vehicle Data Service Provider	senior manager of data-driven service provision	13	2
6	Public Authority	representative in international committees	25	NC
7	Data Marketplace Provider	leader of a data marketplace development	20	2
8	Vehicle Data Service Developer	consultant involved in projects with public authorities	6	3
9	Engineering Service Provider	owner of engineering service company	23	1-2
10	Vehicle Data Service Provider	developer involved in data-driven service provision	4	2
11	Vehicle Manufacturer	head of a data service department	18	1

Figure 2. Background information on the expert interview study participants

The results of the expert interview study were graphical sketches of eleven models of actors and value flows in a data-driven service ecosystem and qualitative statements on cooperation within the ecosystem. While some experts even outlined their own views on paper, others provided stories about such an ecosystem. Some experts mentioned very concrete, data-driven services and how they create value, while others remained on a higher level. Further results were related to a graphical model of the Data-driven Service Ecosystem designed by us and shown to the experts, which gave feedback.

The data generated in the expert interview study were analyzed by two different researchers in a one-day workshop. The input for this workshop were the individual experts' views on the ecosystem. In order to bring together eleven individual views of experts into a unified model, the researchers had to put themselves in the shoes of the experts and try to understand their specific points of view. This also included the coordination of actors (if possible) and the search for neutralized names for actors. At first, both researchers individually attempted to generalize eleven models into one model for data-driven service ecosystems. They then discussed their results with each other before defining the generalized model shown in Figure 4. They assessed whether all eleven expert opinions were adequately reflected in their generalized model, especially by assigning actors and services to the model referred to by the experts. A suitable graphical ecosystem model would make it possible to map common data-driven services, identify typical relationships and data flows between stakeholders or even identify services that have too many service providers or are monopolies. The main result of this design process is a graphical ecosystem model consisting of two interconnected parts to increase readability and usefulness: The first part is a graphical model that relates to the perspective of data acquisition, sharing, and provision, which is similar for all services. The second part focuses on service development, provision, and consumption: The service (something of value) offered by a provider can vary per consumer, making graphical visualization difficult. Each actor's relevance with regard to offering or consuming a data-driven service, as illustrated in the second part of the model, was derived from study statements that were aligned with the literature.

A Model for Data-driven Service Ecosystems

The first result of our paper, as shown in Figure 3, is a summary of the relevant actors in the ecosystem, derived from the individual views of experts on ecosystems. In order to obtain a holistic ecosystem model with actors from different categories, we have not limited the type of actor to a single category (e.g. service providers). Instead, we included all the actors mentioned by the experts, while in some cases, two or more actors were aligned to one actor, which was then represented by a more general term. For example, cloud platform provider, database hosting provider, and web space provider were grouped under the term *backend service provider*; data marketplace, private data platform, public data platform, automotive data platform were summarized under the term *data marketplace provider*; decision taker, EU/EC, and national regulation were summarized under the term *public authority*. In total, the 17 resulting and neutralized actors named by the experts are shown in Figure 3. For example, expert #1 mentioned six actors including vehicle data service provider, vehicle manufacturer, etc., as shown by an 'x' in the matrix. The two rightmost columns indicate whether the actor is included in the sub-parts of the high-level model as introduced later in Figures 4-6.

A definition was created for all actors to provide a solid basis for discussion. As an example, the *backend service provider*, e.g. aws.amazon.com, is defined as *a company offering IT infrastructure services (e.g. servers, a cloud platform, databases management and hosting, load balancing, etc.)*, while the *data intermediary*, e.g. the company HERE owned by the vehicle manufacturers Audi, BMW and Daimler, is defined as *a data aggregator with special relationships to vehicle manufacturers, uses data from various sources, aggregates it and provides it to contractual partners*.

Expert Number / Actor Name	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	Mentions	Participant in Data Ecosystem	Participant in Service Ecosystem
Vehicle Data Service Provider	x	x		x	x	x		x	x	x	x	9	yes	yes
Vehicle Manufacturer	x	x	x	x	x	x	x		x		x	9	yes	yes
Marketplace Provider	x	x		x		x	x	x	x	x		8	yes	
Road User (vehicle driver, biker, public transport user)	x	x	x	x	x	x		x			x	8	yes	yes
Public Authority			x		x	x		x	x	x		6		yes
Technical Infrastructure Provider (e.g. telecommunication provider)	x		x		x			x	x			5		
Backend Service Provider			x	x	x				x	x		5		
Vehicle Hardware/Software Supplier, (external) Gateway Provider			x	x	x				x	x		5	yes	yes
Data Intermediary			x			x			x			3	yes	yes
Fleet Operator			x		x					x		3		yes
Road Operator	x	x	x									3		yes
Vehicle Owner		x			x	x						3		yes
Workshop Operator		x			x	x						3		yes
Traffic Manager / Operator		x	x									2		yes
Automobile Club		x										1		yes
Research Organization								x				1		yes
Insurance Company						x						1		yes

Figure 3. Ranking of actors in data-driven service ecosystem based on expert interviews

In a next step, a high-level, generalized model of actors in a data-driven service ecosystem in the automotive domain was designed based on the contributions of the eleven experts, shown in Figure 4. This model consists of three main elements, the *Data Ecosystem,* which encapsulates actors and data flows (focusing on sensor data from the vehicle only, therefore no data input from drivers such as age or sex is taken into account), the *Service Ecosystem*, which encapsulates actors, service provision, and consumption activities, and finally the two major external influencing factors as indicated by the experts, the *public authority* with all regulations and the *Technical Infrastructure Providers,* which form the baseline for data-driven services.

To shed more light on the perspective of the *Data Ecosystem* (the light blue area in Figure 4), the more detailed model in Figure 5 outlines actors and data flows between actors. It is assumed that every data flow in one direction generates a backflow in the form of money or another tangible or intangible asset to ultimately maintain a business relationship. For the sake of simplicity, only data flows are visualized in the model. The basic idea is that a set of data transformations on different sources and a provision mechanism across different actors are required to finally enable a service development process.

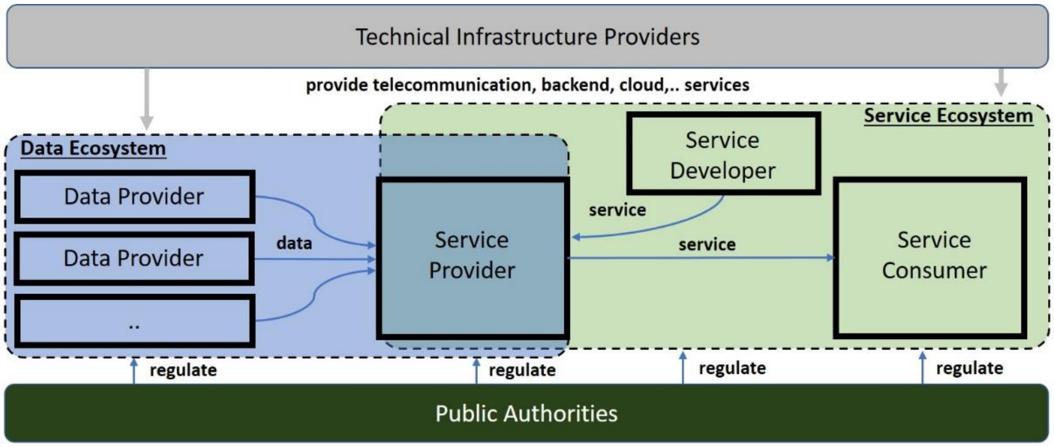

Figure 4. High-level model of data-driven service ecosystems in the automotive domain

First, the vehicle data are collected from a vehicle controlled by a driver (actor: road user) before they are transferred, either directly to a vehicle manufacturer, or via an external gateway provider to a marketplace provider or to a vehicle data service provider. The vehicle manufacturer can transfer all data (or selected data points) to a data intermediary, a marketplace provider or directly to a provider of a data-driven service. The marketplace provider can transfer data to a data intermediary, a service developer, or even a vehicle data service provider. A service provider can use five different data sources to establish a data-driven service (#1 to #5 in Figure 5) from a data intermediary, a vehicle manufacturer, a marketplace provider, a vehicle data service provider (e.g. Automatic), or an external data source provider (e.g. a weather data provider). The graph shows that if there is no data interface in the vehicle for external gateway providers to use (e.g. no OBD interface), the vehicle manufacturer will have a dominant position in the ecosystem and thus data acquisition is contested. This is supported by the expert statements. Expert 6, for example, says that "*OBD dongles are for vehicle manufacturers like a red rag for a bull*". Expert 9 states that *"startups are more like groundbreaking shooting stars that will disappear when big players come onto the market"*, while expert 3 argues that *"all international public authorities should unite at least on European level to create a reasonable counterweight to vehicle manufacturers and data-intermediaries"*.

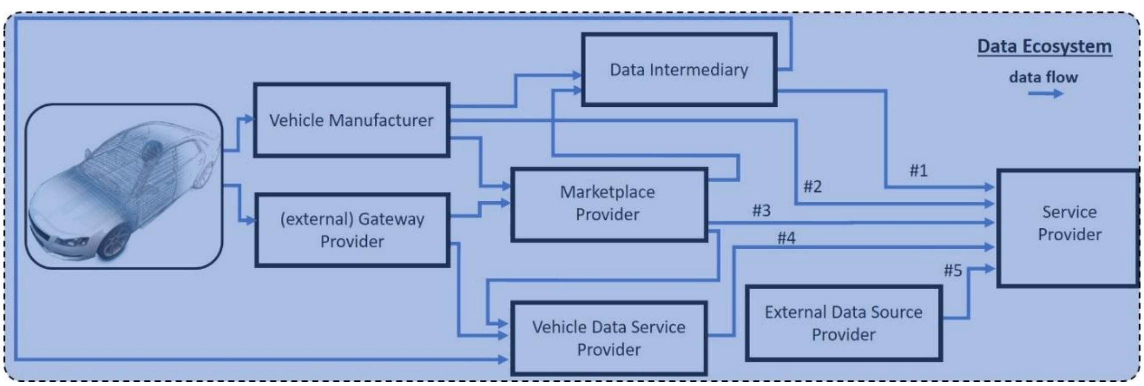

Figure 5. Detailed model of the underlying data ecosystem with actors and data flows

However, vehicle manufacturers have the feeling that they are not in the best position, as illustrated by expert 11, who complains about the "*issue of long development cycles*", meaning that "*if it is not foreseen/enabled already today in the development of the vehicle to share specific data, then it will not be possible until about 2025 to have it present in a vehicle on the street*",. Expert 1 adds that there is "*sensor raw data in the vehicle, which will never leave the vehicle, not even to be transferred to the vehicle manufacturer*".

The *Service Ecosystem* part (the light green area in Figure 4) highlights five services that were mentioned by more than one expert during the expert interview study and were also included in the related literature that was analyzed (e.g. Dremel et al. 2017; Brandt 2013), namely maintenance for vehicles and roads, short term traffic management, quantified vehicle information service, and automotive product improvement.

Expert 3, for instance, states that *"traffic planning and management, road operation companies and infrastructure providers will realize the value of vehicle data sooner or later"*. Other services mentioned only once are excluded from the next figure due to the page limit. These additional services include long-term traffic management, autonomous driving functionalities, tutoring, safety and collision avoidance, vehicle monitoring (e.g. in critical areas), and navigation. It should be noted that interview participants were asked to name and describe a prominent service they knew, rather than listing all the service ideas that came to mind. We did this because capturing the full range of services was less important since the main objective was to identify the actors and connections between actors in data-driven services, which is a prerequisite for understanding the underlying ecosystem in the automotive domain.

The first column of Figure 6 shows possible relationships between actors who provide a service (left part) or consume a service (right part) and can be read as follows: Data-driven services that are offered, such as vehicle maintenance, are displayed in the table header. If an actor decides to offer a service, the IDs of possible service consumers are listed in the table cell: For example, actor *ID 1 automobile club* can *offer a data-driven service for vehicle maintenance* (e.g. statistics on known problems of a certain vehicle type) *to actor IDs 4, 5, 6, (7), and 9*. If there is no actor ID listed in the table cell, the respective actor may not be able to offer this service. Actors, e.g. automobile clubs and vehicle manufacturers may address different customers, which is why the cells of their table rows contain different actor IDs. If it is not clear whether an actor is a targeted consumer, the actor ID is placed in brackets, e.g. "(7)". The shading of the color of the table cell indicates the relevance of an actor for providing a service (each ID is counted as a full point, each ID in brackets as 0.2 points for calculating the color tone) and shows actors who play a major or minor role per service in the ecosystem. Based on results on the left side, the information about which actor can consume a service is presented in the right part of Figure 6 (three columns are cut off due to space constraints), revealing the targeted consumers of a specific service. For example, a fleet operator (ID 5) can consume a data-driven vehicle maintenance service from actors with the ID 1, 2, 3, 7, (10), and (11). The darker the background color of the table cells, the more relevant an actor is as a consumer of services offered by other actors. All actors in the data ecosystem part can also be actors in the service ecosystem part as service consumers, e.g. a vehicle manufacturer, a data intermediary, an (external) gateway provider, etc. can use services provided by external service providers as input for their own purposes.

Actor \ data-driven Service		offers data-driven service for vehicle maintenance	offers data-driven service for road maintenance	offers data-driven service for (short term) traffic management	offers data-driven quantified vehicle information service	offers data-driven service for automotive product improvement
ID	Name	to ID	to ID	to ID	to ID	to ID
1	Automobile Club	4,5,6,(7),9,			4,5,6,(7), 11,12,13	
2	Data Intermediary	(1),3,5,(6), (7),(9),10,11	(1),3,(5),(6), (7),8,9,11	3,(5),(7), (8),9,11	6,8,9,11, (13),(14)	
3	Vehicle Data Service Provider	1,4,5,(6),7,(9), (10),(11),12,14	1,4,5,6,7,8, 9,(10),11,12	1,4,5,(6),(7), 8,9,11,12	(1),4,5,(6),7,(8-10),11,12,(13-14)	4,5,10,11, 12,(13)
4	Road User (vehicle driver, biker, public transport user)					
5	Fleet Operator			(4),(12)	3,4,7,12,(13)	
6	Public Authority				(1),(4),(7), 8,9,(12)	
7	Research Organization	(1),(3-4),5,6, (9),10,11,(13)	(1),(3-4),8,(9), (10),11,(12)	1,(3),(4),5,6, 8,9,(11),(12)	(1),(3-6), (8-13)	3,4,5,8,9, 10,11,12
8	Road Operator		1,3,4,5,6,7, 9,(10),11,12	(1),(3),4,5,(6), (7),9,11,12	(1),3,4,(5), 6,(7),9,12	(4),9,10,11, (12),(13)
9	Traffic Manager / Operator			(1),3,4,5,6, (7),8,(11),12	(1),3,4,5,(6), (7),8,11,12	
10	Vehicle Hardware/Software/ external Gateway Supplier	(1),(5),(7),11, (12),13,(14)				11
11	Vehicle Manufacturer	(1),(4),(5),(7),(9), 10,(12),13,(14)	4,5,6,(8), (9),(10),12	2,(3),4,(5),12	4,5,(7),12, (13),(14)	(1),(3),4,5,(6-9),10,(12),(13)
12	Vehicle Owner					
13	Workshop Operator					
14	Insurance Company				(1),3,5,(6-7), (9),12	

Actor \ data-driven Service		consumes data-driven service for vehicle maintenance	consumes data-driven service for road maintenance	consumes d driven service f (short ter traffic managem
ID	Name	from ID	from ID	from ID
1	Automobile Club	(2),3,(7), (10),(11)	(2),3,(7),8	3,7,(8),(
2	Data Intermediary			11
3	Vehicle Data Service Provider	2,(7)	2,(7),8	2,(7),(8 9,(11)
4	Road User (vehicle driver, biker, public transport user)	1,3,(7),(11)	3,(7),8,11	3,(5),(7 8,9,11
5	Fleet Operator	1,2,3,7, (10),(11)	(2),3,8,11	(2),3,7, 8,9,(11
6	Public Authority	1,(2),(3),7	(2),3,8,11	(3),7,(8),
7	Research Organization	(1),(2),3, (10),(11)	(2),3,8	(2),(3),(8),
8	Road Operator		2,3,7,(11)	(2),3,7,9
9	Traffic Manager / Operator	1,(2),(3), (7),(11)	(2),3,(7),8,(11)	2,3,7,8
10	Vehicle Hardware/Software/ external Gateway Supplier	2,(3),7,11	(3),(7),(8),(11)	
11	Vehicle Manufacturer	1,2,(3),7,10	2,3,7,8	2,3,(7),8,(
12	Vehicle Owner	1,3,(10),(11)	3,(7),8,11	3,(5),(7), 8,9,11
13	Workshop Operator	1,(7),10,11		
14	Insurance Company	3,(10-11)		

Legend: low — actor relevance in offering the service — high

Legend: low — actor relevance in consuming the service — high

Figure 6. Selected services and actors offering/consuming them (figure truncated)

Discussion

The automotive industry is undergoing a digital transformation, from selling vehicles and the provision of related services to the provision of new data-driven services. However, new actors entering the automotive sector are colliding with established players, creating new ecosystems. Expert 8 argues that *"there will be a shift towards a sharing economy"* with a broad range of new players and mobility services challenging the traditional business models of car manufacturers. However, the question raised by expert 10 about *"how many service providers will be able to find services monetizable to all"*, will remain unanswered.

Our results show that the provision of services (left part of Figure 6) is very competitive in most cases, e.g. a data-driven service for vehicle maintenance is provided by four different actors (automobile clubs, data intermediaries, vehicle data service providers, and research organizations) which in some cases indicates an overlapping consumer audience (e.g. actor 5 - fleet operators). Figure 6 allows interested parties to participate in the ecosystem to explore service issues and make better-informed decisions about service development and investments. An improved version of this figure, including additional (and, ideally, all possible) services, should be regularly updated by public authorities to detect market anomalies such as monopolies. Surprisingly, vehicle manufacturers and data intermediaries are key actors with regard to providing vehicle data, but not the main actors with regard to data-driven service provision. According to the expert's inputs, this role is covered best by vehicle data service providers. In a more detailed view, actors such as road operators, traffic managers/operators, or automobile clubs can also play an important role in offering data-driven services. With regard to consuming data-driven services (see right part of Figure 6) road users, fleet operators, public authorities, road operators, traffic managers/operators, vehicle manufacturers and vehicle owners are the target group and thus relevant actors. Workshops only consume certain services, while insurance companies and engineering service providers are not regarded as consumers of any of the five examined data-driven services.

By combining the results of a literature review with data from eleven expert interviews, we have gained a basic understanding of data-driven service ecosystems. The main result of our paper is a model of such ecosystems including stakeholders (actors), data and infrastructure (resources) and data-driven services (value exchange) that helps to understand emerging business relationships. Our model consists of two interconnected parts – the data ecosystem and the service ecosystem. The data ecosystem shows that the vehicle manufacturer is a critical actor with regard to data collection as vehicle measurements can only be retrieved from an external gateway provider or a vehicle manufacturer. If a vehicle manufacturer does not grant direct access to the vehicle data via an interface, data-driven service developers must negotiate directly with the vehicle manufacturer to gain access. This allows manufacturers to control data-driven services without regulation. *"Granting others access to vehicle data via the OBD interface is a safety risk"*, as expert 11 indicates.

Controversial statements about the cooperation dilemma between vehicle manufacturers and vehicle data service providers were made. Expert 5, CEO of a vehicle data service provider, states that "*vehicle manufacturers are currently not doing the services on their own, they look for service providers, as they don't have the hardware and the resources*", while expert 4, a researcher cooperating with vehicle manufacturers, argues that "*vehicle manufacturers find it difficult to give third parties access to vehicle sensors on deeper levels*", meaning that "*vehicle manufacturers will highly regulate the ecosystem. [The ecosystem] will not be as open as other ecosystems we know from the B2C area. Partners will be chosen carefully preferring trusted long-term partners"*. According to expert 9, it is challenging for third parties to obtain data from vehicle manufacturers, as *"we have been discussing with OEMs [vehicle manufacturers] to get access to data for years, not yet a success, although they seem interested"*. In the service ecosystem part of the model, we indicate which services can be provided or consumed by which actors. We focus on five main services only, which is another limitation of our research.

Conclusion and Outlook

In our paper, we have presented relevant actors, relationships, and data flows in a data-driven service ecosystem in the automotive domain. A relevant aspect of our research is how such ecosystems emerge and how vehicle data enable new services. To improve our understanding, we reviewed the literature on the ecosystem concept and enriched the results with a subsequent expert interview study. The fact that we only interviewed eleven experts is a limitation of our research. In order to investigate ecosystem mechanisms in the automotive domain, further studies are needed to determine the ability of two or more actors to cooperate when providing a service, e.g. how likely is it that a vehicle manufacturer (in collaboration with other stakeholders) will provide a data-driven vehicle maintenance service to a fleet operator? In line with further literature analysis, we want to show how external factors such as standardization, data protection, autonomous driving, or taxation can influence the ecosystem and the willingness of an actor to participate.

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