


Article

# New Operating Strategies for an On-the-Road Modular, Electric and Autonomous Vehicle Concept in Urban Transportation <sup>†</sup>

Christian Ulrich \* , Horst E. Friedrich, Jürgen Weimer and Stephan A. Schmid

German Aerospace Center (DLR e.V.), Institute of Vehicle Concepts, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany; Horst.Friedrich@dlr.de (H.E.F.); Juergen.Weimer@dlr.de (J.W.); Stephan.Schmid@dlr.de (S.A.S.)

\* Correspondence: Christian.Ulrich@dlr.de

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**Abstract:** Today commercial transport in urban areas faces major challenges. These include making optimal use of limited space, avoiding empty trips, meeting driver shortages as well as reducing costs and emissions such as CO<sub>2</sub>, particulate matter and noise. The mutual acceleration and reinforcement of technological trends such as electrification, digitization and automation may enable new vehicle and mobility concepts that can meet these challenges. One possible vehicle concept is presented in this article. It is based on on-the-road modularization, i.e., a vehicle that can change different transport capsules during operation. The vehicle is divided into an electrically propelled autonomous drive unit and a transport unit. Standardized interfaces between these units enable the easy design of capsules for different uses, while the drive unit can be used universally. Business models and operating strategies that allow optimal use of this vehicle concept are discussed in depth in the article. First, the current situation is analyzed followed by a detailed description of an exemplary business model using a business model canvas. The operating strategies and logistics concepts are illustrated and compared with conventional concepts.

**Keywords:** business model; city traffic; freight transport; mobility concepts; public transport

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## 1. Introduction

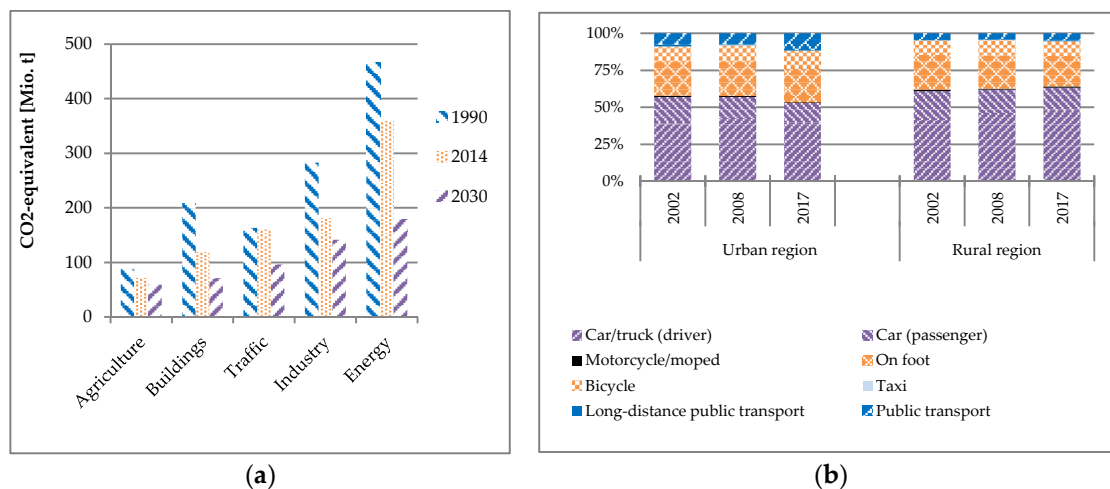
The article is structured as follows: the Section 1 highlights the current situation of urban transportation with its challenges as well as a benchmark of existing ideas for modular vehicle concepts; Section 2 introduces the methodology (new section compared to [1]), while Section 3 details one specific on-the-road modular vehicle concept, which is being developed within our institute (the detailed technical description and the in-depth derivation of the vehicle architecture are not part of this paper; this is covered in Ulrich et al. (2019) [2]); the business models and operational strategies for this specific vehicle concepts are described and discussed in Section 4; conclusions and an outlook are drawn in Section 5.

### 1.1. Urban Transport Challenges

Major technological trends currently have an impact on the transportation system, especially in urban regions. The technological trends of autonomous driving, electrification and digitalization amplify each other, thereby initiating a transformation process in the mobility sector. Intensive research and public awareness in these technology areas increase the speed with which new technologies become market-ready and accepted in society. For instance, battery prices are decreasing while energy

density and mileages are increasing [3]. The intensified contribution to the electrification of vehicles has been reflected in a growing market for electric vehicles; according to the International Council on Clean Transportation (ICCT), 60% more electric vehicles were sold worldwide in 2017 compared with the previous year [4]. Furthermore, legislative questions for testing autonomous and highly-connected vehicles are increasingly clarified and manufacturers are intensifying their research on safe and reliable technological solutions [5].

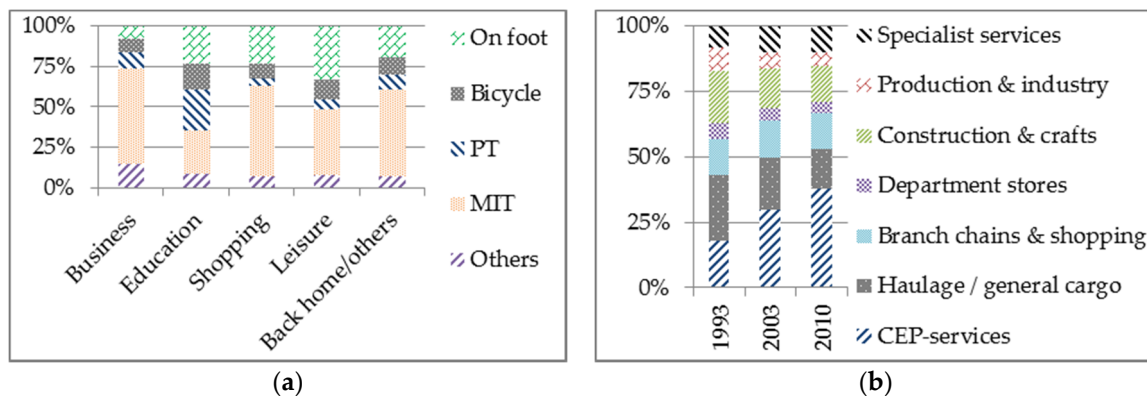
Apart from the technological trends (“push factors”) that enable new vehicle concepts, current traffic issues demand new solutions (“pull factors”). Worldwide, urban regions are challenged with air pollution and traffic congestion [6,7]. Continuing with the status quo, this issue will become even more severe in the future, as urban regions are massively growing: at present, 55% of the global population lives in urban regions and it is expected that two-thirds of the whole population will live in “global cities” by 2050 [8]. In order to tackle issues induced by urban transport and to comply with legislative emission limits such as the Paris 2° target [9], nations as well as municipalities react with action plans (e.g., [10,11]) while simultaneously looking for new transportation concepts. Figure 1a reveals that traffic-induced CO<sub>2</sub> emissions remained almost constant from 1990 to 2014, given that the transport volume increased while the vehicles became more efficient. A further increase in transport volume can be expected in the future, whereby gains in vehicle efficiency will not be able to compensate for this rise. In addition to a consistent electrification of the fleet, the transport concept and thus the vehicle concepts have to be fundamentally reconsidered; otherwise, urban access restrictions for specific engine types—currently the ultima ratio (e.g., Stuttgart (Germany) has denied access to the city for vehicles with diesel internal combustion engines ( $\leq$ Euro 4) since January 2019 [12,13])—might become the new status quo.



**Figure 1.** (a) Greenhouse gas emissions per industry in Germany; values for 2030 are target definitions to achieve the 2016 action plan (own visualization, data from [10]); (b) development over time (2002–2017) of the modal split according to main means of transport in Germany, sorted according to regional types (own visualization, data from [14–16]).

But not only on an international or national level, reasons for new vehicle concepts can be found. A demand for new transport and vehicle concepts can also be derived from a detailed, individual view at vehicle- or user-level. Figure 1b combines data from the statistics series “Mobility in Germany” from 2002, 2008 and 2017. It becomes apparent that in most cases (regardless of the region) that the car, the main vehicle for MIT (‘motorized individual transport’, defined as car drivers and passengers, as well as motorcycles) continues to be the main means of transport. A classification according to the purpose of the journey (Figure 2a) results in a similar distribution. MIT dominates this statistics. Unfortunately, MIT is very inefficient in terms of assets (cars, etc.) standing idle. In fact, studies have shown that individually-owned cars are parked for more than 95% of their lifetime (e.g., [17,18]).

Hence, it would be better to have autonomous, connected cars, which could relocate themselves (more parking spaces) and could be called on demand in a shared model (higher efficiency).



**Figure 2.** (a) Modal split divided by travel purpose in Germany (own visualization, data from [16]) (PT, public transport; MIT, motorized individual transport); (b) share of commercial vehicle trips by industries in urban areas in Germany (own visualization, based on internal analyses).

When developing a new vehicle, it is necessary to know what shall be achieved and what will be the business case behind the concept: is substituting one propulsion system by another (e.g., battery electric vs. combustion engine) enough [19] or is there a demand for totally new vehicle concepts in terms of architecture. The “Mobility in Germany” [16] statistics provide evidence that there is no such thing as a “standard” car (neither for urban nor rural regions). While compact class cars were sold most in Germany in 2017, cars from “the mini” class (mostly in cities) prevail over SUVs and luxury cars. The statistical evaluation indicates that travel purpose-optimized vehicles would be best for the consumer, choosing the perfect car for each trip. This cannot be achieved by a substitution-only principle, but rather requires a new architecture. However, not only passenger transport has to be enhanced, but also the transportation of goods. As shown in Figure 2b, a wide variety of operational purposes prevail for urban commercial transport, with the share of parcel service providers (CEP, courier, express, parcel) significantly increasing. In Germany alone, the CEP industry grew by 98% from 2000 until 2017 (in terms of the number of shipments) [20], mainly due to e-commerce [21]. For all purposes, different requirements have to be met, recognizing that parcels, construction materials, other goods and persons possess different formats, dimensions and weights. New vehicle concepts that can adapt to specific, application-optimized needs (such as variable vehicle length or interior) can prove suitable for commercial freight as well as passenger transport.

Similar results have been derived from an internal project of the German Aerospace Center on urban mobility: based on stakeholder analyses, different user groups (personas) have been created. Apart from the persona group of “urban bike lovers”, all others perceived vehicles with adaptable dimensions ideal as this facilitates a strong flexibility in purpose optimization during everyday application [22].

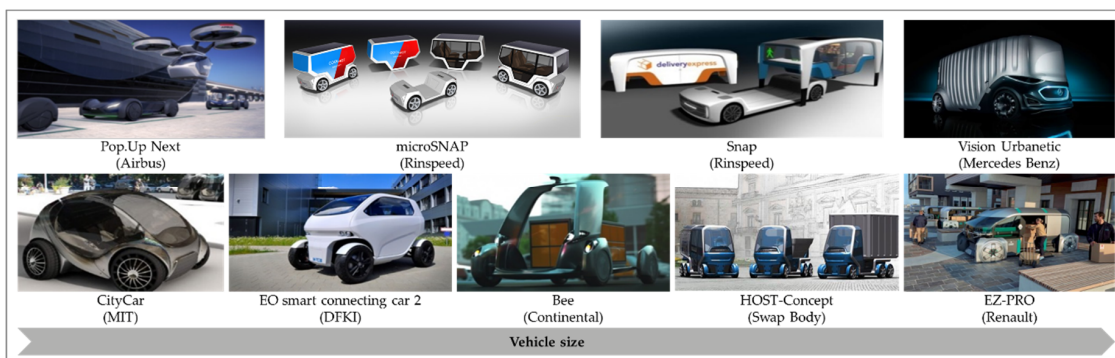
Modular vehicles are a promising approach to meet purpose optimized vehicles. This paper is mainly focused on use cases and operational strategies of an on-the-road modular vehicle concept. Before describing our own approach to an on-the-road modular concept, the next chapter introduces a few well-known modular vehicle concepts.

### 1.2. Modular Road Vehicle Concepts as a Possible Contribution to Improving Urban Transport

Modularization ex-factory has already been a common production strategy of automotive manufacturers for decades. This approach separates the car into different standardized components during the manufacturing process. The benefits of this approach are the strong variety of vehicle derivatives and lower costs for production and development at the same time (see [23,24]). Accordingly,

use-case-optimized vehicles like people-movers with different lengths, cargo movers or a combination can be produced on the same platform. An example is the “Urban Modular Vehicle” vehicle concept by the German Aerospace Center [25]. However, while being optimized for one specific application, it is not possible to change their dedication after leaving the factory.

On-the-road (OTR) modular vehicle concepts use a similar modularization strategy as ex-factory modular concepts, although they remain modular even after leaving the factory, namely during operation. Here, the strategy is to divide the vehicle into two parts: a driveboard (chassis, including all components and functions for driving) and a transportation unit (capsule/hat), which is designed in an application-optimized manner in terms of equipment for the interior and external dimensions. Depending on the upcoming task, the required capsule is attached to the driveboard and when finished, the capsule is changed. While there are OTR modular vehicles on the market that do not drive autonomously (e.g., the “Hubi 55” by “Heimann Fahrzeugbau” (<https://heimann-fahrzeugbau.de/hubi-55-en>, accessed on 26 September 2019)), recently-presented OTR modular vehicle concepts utilize an autonomous, highly-connected driveboard, as this improves the efficiency of the costly driveboard (24/7 operation). Figure 3 shows a compilation of published OTR modular vehicle concepts. Section 3.6 and [23] compare the most relevant concepts in detail. In the chapter, after the methodology section, we propose another OTR modular vehicle concept that was developed at the German Aerospace Center, Institute of Vehicle Concepts, which solves key functions differently than competing concepts.



**Figure 3.** Demand-oriented, flexible vehicle concepts—examples from previous concepts and prototypes (own compilation, picture sources: vehicle manufacturers and Wikipedia).

## 2. Methodology

To develop (a) a new vehicle concept, and (b) related use cases and business models, we followed a multistep process. As the operational concepts are closely bilaterally linked to the vehicle concept, e.g., the use case defines requirements for the vehicle and technical options and limits determine the possible fields of application, both developments are executed in a parallel manner. First, the current market situation of urban passenger and goods transport as well as trends in this field, have been analyzed by literature research. Based on this initial research and experience from prior projects, we focused our research on new road vehicle concepts, i.e., not only new propulsion and autonomous driving but also new vehicle architecture, namely modular vehicles. A benchmark of existing concept has been conducted and can be found in the previous chapter. Based on these findings, several design ideas of modular vehicles have been drafted in the project team. For discussing and validation of our insights, we then initiated two stakeholder workshops: the first was about technical feasibility and was conducted with about 40 representatives from German small and medium sized companies (Refer to Ulrich et al. (2019) for more details, as this paper focusses more on the use case and operational concept side of the vehicle concept, and less on the technical aspects [2]). The other workshop addressed the potential applications and their requirements for the concept. Beside us and colleagues from our institute, associations of different industries participated in the workshop: “BIEK” (Bundesverband Paket und Expresslogistik e. V.) for CEP service providers,

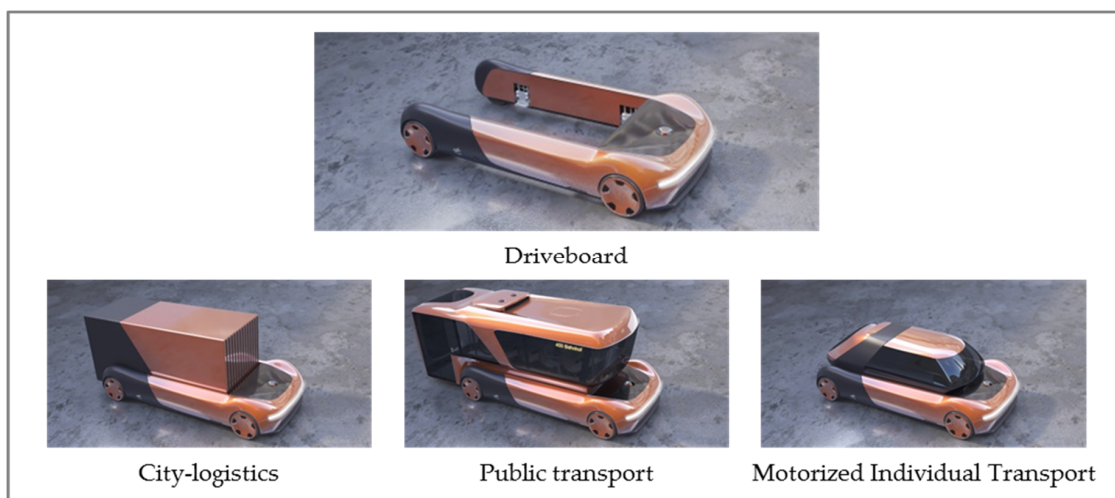
“VSL” (Verband Spedition und Logistik Baden-Württemberg e. V.) for the haulage industry, “HBW” (Handelsverband Baden-Württemberg) as a representative of retailers and “VDV” (Verband Deutscher Verkehrsunternehmen-Landesgruppe Baden-Württemberg) for public transport. The findings and requirements were collected in a specification book, which now defines the technical parameters of the vehicle and also includes characteristics of different transportation tasks. Our initial premise, that loading and unloading the capsule at ground level and a practical, rectangular base of the capsule are very important, was confirmed in the workshops. Since the modular concept also inherently requires many more capsules than driveboards, our third premise was also supported that the capsules must be as simple and inexpensive to produce as possible (in our case: without a lifting system). These findings led to the further development of the vehicle architecture, which will be described in the next chapter.

Based on the discussion with the industry associations and the results of our literature review, we then detailed a fictional use case including three different stakeholders (CEP, public transport and supermarket haulage) and a logistics-as-a-service approach, which is described and examined in Section 4. This detailed operational concept with the hourly schedule for the disposition of driveboards and use case-optimized capsules, was then discussed and validated with seven representatives from the public transport and parcel delivery industry.

One drawback of our process is that our sample of interviewees was rather small. For a more representative result, more experts should be involved. Thus, we are currently working on an online-survey to reach more people from different industries. In addition, the study currently refers mainly to Germany—an international perspective would also increase the significance. The method for disposition is currently based on a manual configuration of the distribution or rather the schedule. In the future, the multi-depot vehicle problem will be solved software supported for an more realistic and efficient utilization rate, e.g., by approaches as described in Barbuscha (2013), Bianchessi and Righini (2007), Dethloff (2001) and Liu et al. (2014) [26–29].

### 3. MAUDE: An On-The-Road (OTR) Modular Vehicle Concept

Following the OTR modularization strategy, our proposed vehicle concept MAUDE (short for: modular, autonomous, updateable, disruptive, electric) comprises a driveboard and various capsules (Figure 4). In the following sections, first the driveboard and then the capsules will be described in detail. Sections regarding automation and energy management follow, before a comparison with different OTR modular concepts summarized in the section. Ulrich et al. [2] provided more detailed information on the technological background of the MAUDE OTR modular vehicle concept.



**Figure 4.** Driveboard and selected application-optimized capsules (visualization by our colleague Mr. Robert Hahn).

### 3.1. Driveboard

The driveboard is an electric, standardized, autonomous and highly-connected platform comprising all functions for driving. Furthermore, the lifting system to attach the capsules is integrated into the driveboard, as this reduces the capsules' costs and avoids additional infrastructure costs. This is a major difference compared with competing concepts, which integrate the lifting system in the capsules or use handling robots. The driveboard is shaped in form of a lying "U" with the capsule between the "U-limbs". This structural design requires sophisticated packaging since the space available for the chassis, power unit, battery pack, automation sensors, computational hardware and lifting system is very limited. Moreover, the additional components for the modularization typically reduce the payload. For a Sprinter-sized (Mercedes-Benz Sprinter: a N1-class vehicle (<https://www.mercedes-benz.com/en/mercedes-benz/vehicles/transporter/mercedes-benz-presents-the-third-generation-of-the-sprinter/>, accessed on 26 September 2019)) MAUDE vehicle (comprising a driveboard and capsule), the payload is reduced by approximately 10% (depending on the battery dimensioning) compared with equally-sized electric light commercial vehicles without OTR modularization. Extra-large as well as large and possibly medium-sized capsules are intended to operate on the same driveboard size. While this increases the complexity of the driveboard's structural design, it offers the required flexibility for various use cases. The "U" shape with the rear opening enables the transportation of capsules with different lengths, allowing for even more flexibility in applications. Finally, the lifting concept offers the benefit that the capsules are discharged at the ground level. This facilitates the loading and unloading of the capsules for urban applications and reduces the conceptual payload shortcoming.

### 3.2. Capsule

The capsules are application-optimized, have standardized interfaces for the lifting system and can be produced in a lightweight and cost-efficient manner as they do not need an own integrated lifting system. They can be designed to be multi-purpose for (1) the transportation of goods (cargo mover), (2) the transportation of people (people mover for public transport) and (3) optionally for individual mobility. Detailed use cases are discussed in the following chapter. The capsules are shaped like a basic rectangular box with a thin and lightweight frame. A major gain of this simple capsule design is that it could become a standardized format. In the future, they might be normed transport units similar to ISO containers. ISO containers are not applicable to MAUDE as their width of 2.438 m [30] is too large to fit between the "U-limbs" and still comply with the regulatory maximal width of road vehicles (2.55 m in Germany [31]). For freight transportation, the utilizable capacity is limited by the base (defined by the area between the "U-limbs"). For example, for a pallet transport application, an extension of the capsule's width above the limbs does not make sense. However, for other use cases such as public transport or the delivery of parcel boxes, a side extension increases the applicability.

### 3.3. Automation

Recently-introduced urban cargo- or people-movers (refer to Section 1.2.) usually aim for SAE5 level of automation [32], which means that the vehicles are driverless, autonomous robots, i.e., without human drivers. This is an advantage not only from a financial perspective (human drivers are the main cost factor in, e.g., parcel delivery [21]) but also from a demand vs. supply perspective. Companies in the logistics and public transport industries are desperately looking for new drivers. A decreasing number of people are applying for such jobs because they are often poorly paid and the working conditions are comparatively unfavorable relative to other industries [33,34].

The MAUDE concept will also be designed to drive autonomously, albeit following a different automation strategy. Instead of a "conventional" vehicle-focused strategy, we pursue an automation based on the infrastructure. Most car companies as well as companies promoting people-movers such as Navya or EasyMile integrate all necessary sensors, communication hardware and computation

power in the vehicle itself, which significantly increases the costs and energy consumption of the vehicle. Nonetheless, there are other approaches that follow an automation strategy based on vehicle control within the infrastructure, e.g., Bosch has already introduced valet parking based only on sensors in the infrastructure [35], while China follows the infrastructure-based strategy at a national level in their “Intelligent Connected Vehicle” project [36,37]. In the EU, ERTRAC has already introduced infrastructure based automation levels in 2019, so called ISAD levels [38]. From a financial perspective, it makes sense to outsource the sensors to the infrastructure as much as possible and thus distribute the costs among many different vehicles/users. In addition, the fleet can be coordinated more efficiently and controlled like a swarm via a central traffic control center. Of course, the concept only works in defined, fully-developed spaces, which would define it rather as a SAE4 than a SAE5 automation concept [32]. City districts are therefore more suitable than rural regions. However, a compromise between the two strategies is probably required for MAUDE to provide maximum safety. Ulrich et al. [2] discuss this question in depth.

### 3.4. Energy Management and Sector Coupling

The drive system of delivery van-sized MAUDE vehicle is defined with  $2 \times 45$  kW and 1600 Nm [2]. These are sufficient values for urban applications with a maximum speed of 70 km/h and a gradeability of 8%. As for the energy supply concept, MAUDE also follows a modular strategy. The central battery is installed in the driveboard and some capsules will be equipped with additional batteries. Capsules for the transportation of passengers as well as specific energy-consuming capsules, such as refrigerated capsules for temperature-sensitive goods, are a logical choice for an extra battery. The driveboard should be in operation close to 100% of the time for maximum workload of the costly components. However, the battery in the driveboard alone cannot be designed effectively for 24 h operation (let alone the time for charging). Furthermore, fast charging affects the battery’s lifetime. When the capsules stand idle for a longer time, they can be charged in a battery-friendly manner with lower currents. During operation, the capsule’s battery will be used to charge the driveboard’s battery. Despite the significantly more complex design considerations (e.g., high-voltage interface between capsule and driveboard), the modular battery approach is promising. First battery designs have been specified in [2]. Next to a battery-only propulsion concept, which is the current focus, the packaging of the driveboard is also dimensioned to fit other propulsion systems such as fuel cells.

As the capsules stand idle most of the time (refer to the business model section), the ones which contain a battery can be integrated in the energy grid for sector coupling. For a reliably functioning power grid, its stability must be guaranteed at all times. A grid is considered stable if the frequency and voltage of the grid are within a specified range at any location and at any time (e.g., in Europe at 50 Hz). The measures for controlling and correcting the grids have so far been provided by, e.g., coal-fired power plants. In the future, when all electricity shall be obtained from renewable sources, this system service must be provided by new energy storage systems (e.g., power-to-gas systems) [39,40]. In addition, electric vehicles are part of the energy supply system, as well, and can help to maintain grid stability as soon as they are connected to a charging station. For instance, they can improve the voltage quality locally or compensate for frequency changes. In the event of a blackout, it is possible to use the vehicles as energy storage devices to rebuild the power supply at regional level [41]. MAUDE addresses exactly this possibility of sector coupling, by installing batteries in capsules. The capsules or rather their energy storage capacity forms an energy buffer for the power grid. As there are far fewer driveboards than capsules (refer to the following chapters) there are always some capsules connected to the power grid, thus coupling the energy and traffic sectors and improving network stability. For the owners of the capsules, this allows for new business models for capsules that are “out of service” in terms of V2G-services, i.e., vehicle-to-grid-services [42].

### 3.5. Legislative Considerations of the Vehicle Concept

As MAUDE shall not stay a theoretical research concept, issues regarding legislation, liability and registration need to be addressed. In the interest of completeness, this section has to be included, but only two key elements will be discussed. This is because these questions go beyond the topic of this paper and additionally have not yet been fully clarified. It is therefore planned to discuss these questions in detail in a later publication.

Vehicles in the EU are registered according to different classes, as defined in [43]. Due to its novel vehicle architecture, in particular the differentiation between a multi-use driveboard and purpose-specific capsules, MAUDE cannot be classified in one of the previously defined classes. The previous definition distinguishes strongly between pure goods and passenger transport. One approach could be registering the concept use case-specific (class N for transport of goods or M for persons) or splitting the concept in driveboard and capsules (additional identifiers BX and CX would be required) [43]. However, the differentiation between goods and person transport is still a hurdle for registration. New registration classes for disruptive vehicle concepts would be beneficial.

There are currently no concrete answers that cover the whole topic of registration and legislation of autonomous driving. There are advances to open mixed traffic for testing autonomous cars, especially in the US but also in the EU, e.g., Germany. But the tort liabilities (is the car owner or the manufacturer liable for accidents) as well as data privacy in highly connected cars are still under consideration. Literature discusses this extensively, see [44–47]. When following the infrastructure-based automation concept, pursued by MAUDE, an additional third party next to the manufacturer and the car owner enters: the infrastructure provider. For testing MAUDE under specific conditions in mixed traffic, there will be exceptions permissions, but in the long term this issue has to be discussed on a national or international level with different stakeholders like Original Equipment Manufacturers (OEMs), society, users and policy makers.

### 3.6. Analysis of Different OTR Modular Vehicle Concepts

In Table 1, selected OTR modular vehicle concepts including MAUDE (rows) are compared based on four factors (columns). The table is adopted from [23], which also explains it in more detail.

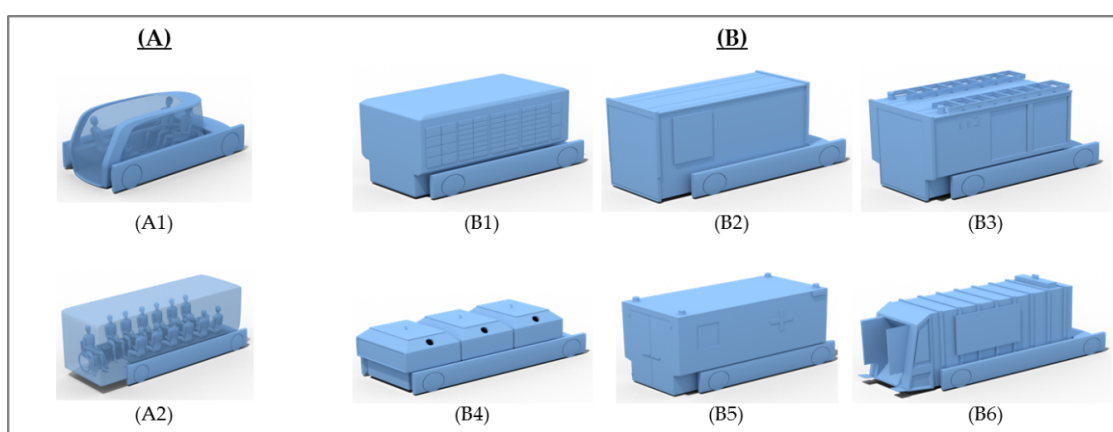
**Table 1.** Juxtaposition of on-the-road modular vehicle concepts (reprinted by permission from Springer Nature, 2019 [23]).

	Use	Standardization	Loading	Module Change
Snap (Rinspeed)	Flexible (various purposes)	Individual solution	Lateral	Vertical, lifting system in the capsule
MicroSNAP (Rinspeed)	Flexible (various purposes)	Individual solution	Lateral	Vertical, auxiliary robots needed
Vision Urbanetic (Mercedes Benz)	Flexible (various purposes)	Medium potential	Back, at ground	Forward (gauge actuation)
BEE (Continental)	People- and cargo-movers	Individual solution	Front	Auxiliary robots needed
Pop.Up Next (Airbus, Audi, Italdesign)	People-movers	Individual solution	Lateral	In the air, lifting done by a drone
MAUDE (DLR)	Flexible (various purposes)	High potential	Back or side, at ground	Forward, lifting system integrated in the driveboard



#### 4. Business Models and Operational Concepts for MAUDE

Key factors for a successful and lasting market penetration of a new transportation solution are ease-of-use, cost-effectiveness and an improvement of today traffic issues (aggregated from [48–52]). There are two major differences compared with today's road vehicles for the transportation of passengers and cargo: (1) MAUDE is autonomous and (2) OTR modular. Electrified commercial transporters are already on the market (e.g., Streetscooter's "Work" (<https://www.streetscooter.eu/models/work/>, accessed on 26 September 2019)). Electrification (and automation) allows for night deliveries even in residential areas and complies with possible future urban access restrictions. (1) Autonomous driving at SAE level 5 is the key element of MAUDE's fundamental business model, namely mobility-as-a-service (MaaS). Instead of a possessive model (status quo), within MaaS vehicles or rides are shared, thus increasing the fleet's efficiency [53–55]. In particular, the driveboards should be used to capacity, as they account for the most costs in the concept. Moreover, high personal costs can be reduced by automation. (2) The OTR modularization is ideal to increase the utilization of investment goods (driveboard) while equipment that stands idle (capsules) is designed in a particularly low-cost manner. This should also encourage small and medium-sized enterprises to design or buy their own capsules tailored to their individual needs. Due to the low acquisition costs of the capsule and the pay-per-use model for the use of the driveboard, this is an ideal business model for a variety of different stakeholders. Possible applications are illustrated in Figure 5, although many more are conceivable.



**Figure 5.** Selection of capsule designs for possible applications: (A) urban passenger transport, (A1) private capsule, (A2) people-mover, (B) other urban applications, (B1) mobile packing station, (B2) freight capsule, (B3) fire department capsule, (B4) recycling capsule, (B5) ambulance capsule, (B6) disposal capsule (visualization of a former design by our colleague, Mr. Robert Hahn).

##### 4.1. Preliminary Considerations on the Current Supermarket and Parcel Delivery Situation

The goods for a supermarket (based on the typical size of supermarkets in suburban areas) are delivered once per day in the morning [56–58] (often between 8:00 and 12:00, when most urban commercial traffic takes place [59]). With OTR modularization, the refrigerator capsule is deposited at the supermarket autonomously in the night and unloaded by the supermarket employees in the morning. The driveboard can deliver other capsules and is not bound to the supermarket during the night.

Van Duin (2016) found out that only 75% of all parcels are delivered in the first attempt; the others are delivered to neighbors, retail stores or back to the depot for a second attempt [60]. Parcel lockers have the benefit that the recipients do not have to be present to receive the parcel; instead, they are informed via smartphone when their parcels are ready for collection. According to Müller et al. (2018), parcel lockers should be switched twice a day: once in the night and once during early afternoon [61]. Uncollected parcels remain in the capsule and can be fetched during the next turn. A survey and analysis conducted by McKinsey on last-mile delivery models in 2016 claims that “in the next ten

years” automated guided vehicles with parcel lockers will deliver more than 80% of regular parcels (not same-day, courier, etc., and no groceries) [21]. They base their assumption on their cost model with the (unsurprising) key finding that personnel costs have the strongest impact on delivery costs. With most of their survey respondents mentioning the price as the main decision factor and 40% of the respondents already open-minded to parcel lockers, their conclusion seems to be coherent [21]. For the MAUDE concept, we assumed a  $2750 \times 1350 \times 1250 \text{ mm}^3$  (derived from the dimensions of the driveboard) parcel capsule as one possible locker solution. Based on standardized parcel sizes [62] and the statistical distribution between large, medium and smaller parcels [63,64], an optimization algorithm was used to calculate the possible number of packet boxes per capsule: the assumed capsule can contain one very large, 22 medium and 100 small-sized parcel boxes as well as one service terminal.

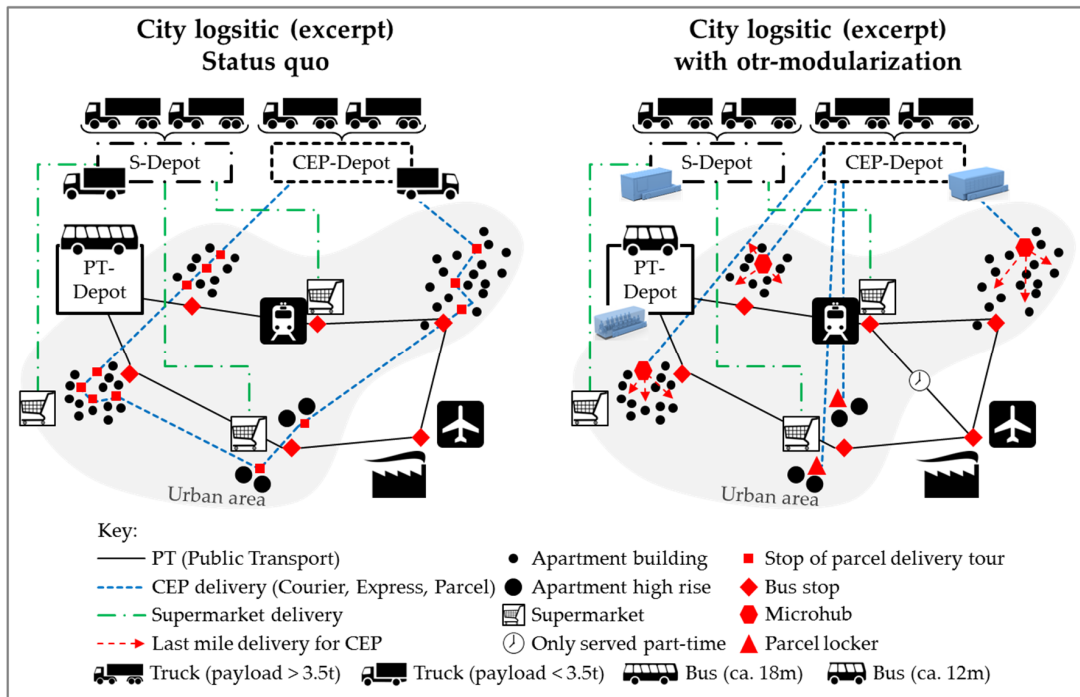
Parcel lockers are a suitable choice to deliver standard parcels (not express or courier) to recipients who are closely located to the locker (e.g., ideal for apartment high rises) [65,66]. If these two requirements are not fulfilled, other delivery concepts need to be pursued. For less densely-populated areas within the city, micro hubs offer a viable alternative, as small mobile depots [19,59,67]. Other vehicles such as small electric vehicles [68] or city cargo bikes can deliver the parcels on the last mile to the final customer [19,65]. For the MAUDE concepts, ultimately a whole family of different vehicle sizes is planned. Thus, the most suitable vehicle can be used for the respective specific task. For the last-mile delivery, a very small version should be utilized. Projects, e.g., in Hamburg and Barcelona have analyzed the potential benefits of micro hub implementation for the last mile [59,69,70], finding that for their individual setups this new logistic concept results in a significant reduction of emissions and traveled ton kilometers.

#### 4.2. Exemplary Use Case “Urban PT Operator with MAUDE Vehicles Offering LaaS”

The following exemplary use case shows how the MAUDE concept could enter into operation in different applications. A local privately-owned bus company operates in the public transport sector in an urban region currently needs large articulated busses (typically 18 m) on some bus routes to cope with peak passenger flows. However, these peaks occur only during the morning and the afternoon (commuter or school traffic), which means that the bus is underutilized most of the day [71]. These large busses could be replaced with smaller busses of about 8–12 m lengths to reduce this inefficiency. The “small” bus is cheaper in acquisition as well as consumption [71]. In addition, MAUDE driveboards and passenger capsules are employed to assist the busses during peak hours. Accordingly, the company still complies with the statutory duty towards the municipality to supply transportation, even in peak hours [72]. In “off-peak” phases, the driveboards unload the capsules at the main station or industrial area/airport (Figure 6). The passenger capsules serve as bus shelters during this time.

The driveboards are free for other applications during these “PT off-peak” phases. Thus, the bus company signs contracts with a hauler specified in transporting goods for supermarkets (“HAUL”) and a parcel delivery operator (“PDO”). HAUL has bought cargo capsules with refrigeration, while PDO owns capsules in the form of (a) parcel lockers and (b) micro parcel hubs. The driveboards deliver HAUL and PDO capsules in “off-peak” phases as shown in Figure 6. The parcel company as well as the hauler pay the bus company for the time and distance their capsules traveled on the driveboards (pay-per-use, logistics as a service (LaaS)). As the driveboard will operate autonomously, they can deliver during the night. Night delivery is ideally applicable for CEP as well as supermarket delivery [59,67]. The PT and HAUL capsules need a battery for their task (air-conditioning unit and infotainment; refrigeration unit). A larger battery dimension and the modular battery strategy in the previous chapter enable an increased range of the driveboards for nearly 24 h/day. Thus, potentially only short breaks for charging of the driveboards are sufficient.

The business model canvas in Table 2 according to the methodology introduced by Osterwalder [73] concentrates the key components of the use case, while Figure 6 illustrates how OTR modularization enables new operational concepts for urban logistics. Table 3 sketches a typical operation schedule of the driveboards in the exemplary business model.



**Figure 6.** Excerpt of the (left) current city logistic regarding public transport, parcel service and supermarket delivery and (right) possible changes through OTR modular concepts. The urban area (gray) is filled with houses, stores, streets, etc., although they have been removed for improved clarity (own visualization with symbols from Pixabay ([www.pixabay.com](http://www.pixabay.com) (accessed on 26 September 2019)). The symbols are used under the CC0 license)).

**Table 2.** Business model canvas for the exemplary use case.

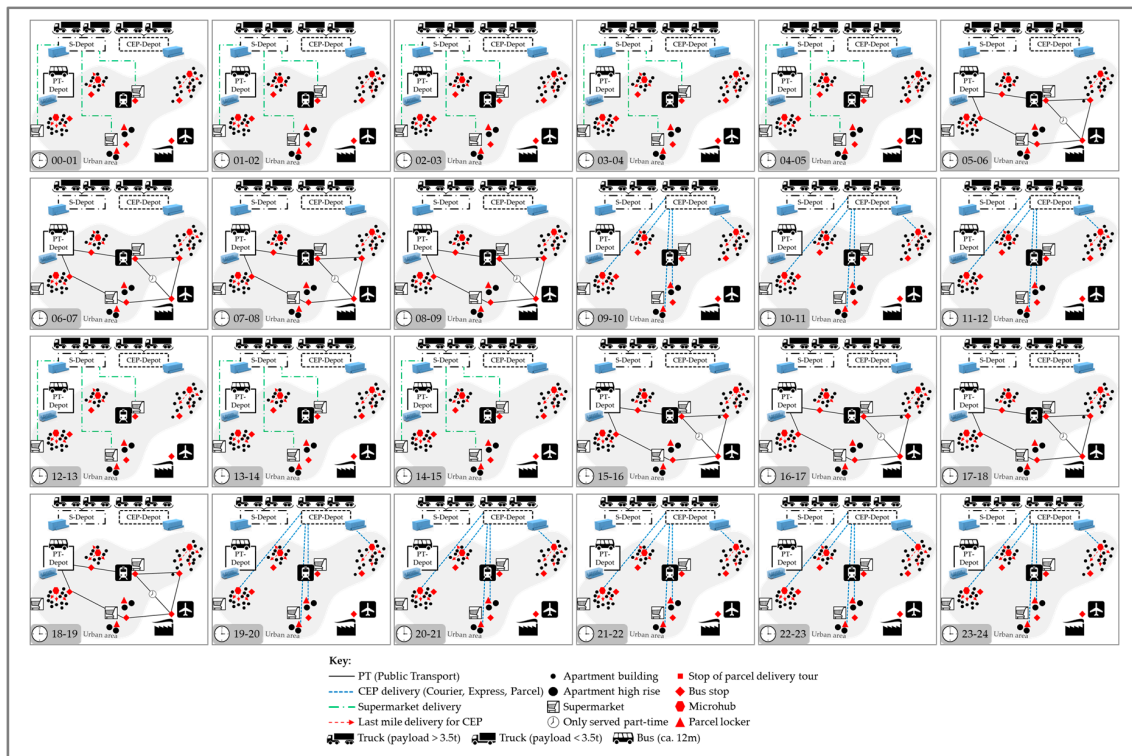
<b>Key Partners</b> Manufacturers of driveboards and capsules; municipalities	<b>Key Activities</b> Operate and maintain the fleet for PT 1 and LaaS 1 in B2B 1	<b>Value Proposition</b> LaaS 1; lower risk for B2B 1 partners; increased efficiency; new time windows for delivery; use-case-optimized capsules	<b>Customer Relationships</b> B2C 1: Individual B2B 1: Contracts	<b>Customer Segment</b> B2C 1: people using PT 1 B2B 1: parcel service operators, haulers for supermarket goods
	<b>Key Resources</b> Fleet of driveboards and PT 1 capsules; fleet management skills		<b>Channels</b> B2C 1: apps, website B2B 1: personal contacts	
<b>Cost Structure</b> Purchase costs for driveboards and PT 1 capsules; low personnel costs (no driver, maintenance and operational staff); maintenance and operating costs; remote control equipment			<b>Revenue Streams</b> B2C 1: pay-per-ride for PT 1 B2B 1: cargo transport either on pay-per-use or contractual basis	

<sup>1</sup> LaaS: logistics as a service; PT: public transport; B2C: business to customer; B2B: business to business.

**Table 3.** Typical operation schedule of the driveboards.

Time vs. Capsule Type	Public Transport	Supermarket Delivery	Parcel Delivery
00:00–05:00		×	
05:00–09:00 (peak)	×		
09:00–12:00			×
12:00–15:00		×	
15:00–19:00 (peak)	×		
19:00–24:00			×

Based on the exemplary use case, which was derived in this chapter and the details in Figure 6 and Table 3, a typical daytime sequence for one driveboard of the vehicle fleet is presented in Figure 7.



**Figure 7.** A typical day for one driveboard: the different operation purposes are represented by an hourly arrangement; see Figure 6 for an aggregated illustration (own visualization with symbols from Pixabay ([www.pixabay.com](http://www.pixabay.com) (accessed on 26 September 2019)). The symbols are used under the CC0 license)).

This is an exemplary business model, while other concepts are also viable and partly discussed in [23]. For instance, the fleet owner does not have to be the bus operator and other stakeholders such as control unit operators or maintenance companies can also benefit in the MAUDE environment.

## 5. Conclusions and Outlook

In this article, a new OTR modular vehicle concept is presented, comprising an electrified and autonomous driveboard and separated low-cost capsules that can be easily switched during operation. This model enables new unique operational strategies for urban logistics. Furthermore, a possible business model is described as an example.

However, there are still challenges on the way to realizing this vehicle concept, whereby technical solutions are being developed in an ongoing project. In addition, the business models have to be quantified for a real use case and initial estimates have to be verified. This creates a reliable database that allows for meaningful comparisons with existing concepts.

For the OTR modular approach, an open platform seems appealing: the capsule's external dimensions and interface requirements are predetermined, while stakeholders suggest designs and applications. As with apps on smartphones [74–76], this strategy would be extremely beneficial for a successful and fast market penetration. In this analogy, the driveboards would be the smartphones (hardware), while the capsules equal apps.

In the future, we envision a fleet of OTR modular vehicles that are closely connected to other urban transportation systems such as trains, ropeways or drones for an ideal intermodal transportation

of passengers and goods. For a maximally efficient transportation, new logistic concepts specialized on autonomous carriers need to be developed, e.g., tour planning based on artificial intelligence [77,78].

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## References

1. Ulrich, C.; Friedrich, H.; Weimer, J.; Schmid, S. A highly innovative on-the-road modular vehicle and operation concept to solve today traffic issues. In Proceedings of the 32nd Electric Vehicle Symposium (EVS32), Lyon, France, 19–22 May 2019.
2. Ulrich, C.; Friedrich, H.E.; Weimer, J.; Hahn, R.; Kopp, G.; Münster, M. Technologies for a modular vehicle concept used in passenger and goods transport. In 19. *Internationales Stuttgarter Symposium*; Bargende, M., Reuss, H.-C., Wagner, A., Wiedemann, J., Eds.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2019; pp. 587–598, ISBN 978-3-658-25938-9.
3. Winkel, R.; Cuijpers, M.; Jerram, L. Overcoming the Barriers of Mass EV Introduction. In Proceedings of the EVS30 Symposium, Stuttgart, Germany, 9–11 October 2017.
4. Lutsey, N.; Grant, M.; Wappelhorst, S.; Zhou, H. *Power Play: How Governments are Spurring the Electric Vehicle Industry*; The International Council on Clean Transportation (ICCT): Washington, DC, USA, 2018.
5. McKinsey & Company. *Automotive Revolution—Perspective Towards 2030*; Advanced Industries: Valenzuela, Metro Manila, 2016.
6. Falocchio, J.C.; Levinson, H.S. Historical Perspective of Urban Traffic Congestion. In *Road Traffic Congestion: A Concise Guide*; Springer: Cham, Switzerland, 2015; Volume 7, pp. 19–31, ISBN 978-3-319-15164-9.
7. European Commission Urban. Air Pollution—What Are the Main Sources Across the World? Available online: <https://ec.europa.eu/jrc/en/news/what-are-main-sources-urban-air-pollution> (accessed on 8 December 2019).
8. United Nations. *World Urbanization Prospects: The 2018 Revision*; United Nations Economic & Social Affairs: New York, NY, USA, 2018.
9. United Nations. *Paris Agreement*; United Nations: San Francisco, CA, USA, 2015.
10. *Der Klimaschutzplan 2050*; BMU: Bonn, Germany, 2016.
11. *Roadmap to a Single European Transport Area*; European Commission: Brussels, Belgium, 2011.
12. ADAC. Dieselfahrverbot: Alle Fragen und Antworten. Available online: <https://www.adac.de/rund-ums-fahrzeug/abgas-diesel-fahrverbote/fahrverbote/dieselfahrverbot-faq/> (accessed on 14 December 2018).
13. Landeshauptstadt Stuttgart Diesel-Verkehrsverbot. Available online: <https://www.stuttgart.de/diesel-verkehrsverbot> (accessed on 8 December 2019).
14. *Mobilität in Deutschland 2002*; BMVI: Berlin, Germany, 2003.
15. *Mobilität in Deutschland 2008*; BMVI: Berlin, Germany, 2010.
16. *Mobilität in Deutschland 2017*; BMVI: Berlin, Germany, 2018.
17. Bates, J.; Leibing, D. *Spaced Out: Perspectives on Parking Policy*; RAC Foundation: London, UK, 2012.
18. *Urban Mobility System Upgrade*; OECD—International Transport Forum: Paris, France, 2015.
19. Bogdanski, R. *Nachhaltige Stadtlogistik Warum das Lastenfahrrad die letzte Meile gewinnt*; Huss-Verlag: Munich, Germany, 2019; ISBN 978-3-948001-02-5.
20. *KEP-Studie 2018—Analyse des Marktes in Deutschland*; BIEK: Karachi, Pakistan, 2018.
21. Parcel Delivery. *The future of last Mile*; McKinsey & Company: New York, NY, USA, 2016.

22. Kopp, G.; Klötzke, M.; Gebhardt, L.; Friedrich, H.E. *A Mixed-Methods Approach to Derive Vehicle Concepts for Urban Mobility*; Springer: Berlin/Heidelberg, Germany, 2018.
23. Friedrich, H.E.; Ulrich, C.; Schmid, S. New vehicle concepts for future business model. In *19. Internationales Stuttgarter Symposium*; Bargende, M., Reuss, H.-C., Wagner, A., Wiedemann, J., Eds.; Springer: Wiesbaden, Germany, 2019; pp. 815–829, ISBN 978-3-658-25938-9.
24. Braess, H.-H.; Seiffert, U. (Eds.) *Vieweg Handbuch Kraftfahrzeugtechnik*; Springer: Wiesbaden, Germany, 2013; ISBN 978-3-658-01690-6.
25. Vohrer, S.; Münster, M.; Kriescher, M.; Kopp, G.; Kopp, G.; Friedrich, H.E. DLR Next Generation Vehicle Concepts-Urban-Regional-Interurban. In *18 Internationales Stuttgarter Symposium*; Springer: Berlin/Heidelberg, Germany, 2018.
26. Barbucha, D. A Multi-agent Approach to the Dynamic Vehicle Routing Problem with Time Windows. In *Computational Collective Intelligence, Technologies and Applications*; Bădică, C., Nguyen, N.T., Brezovan, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2013; Volume 8083, pp. 467–476, ISBN 978-3-642-40494-8.
27. Bianchessi, N.; Righini, G. Heuristic algorithms for the vehicle routing problem with simultaneous pick-up and delivery. *Comput. Oper. Res.* **2007**, *34*, 578–594. [[CrossRef](#)]
28. Dethloff, J. Vehicle routing and reverse logistics: The vehicle routing problem with simultaneous delivery and pick-up: Fahrzeugeinsatzplanung und Redistribution: Tourenplanung mit simultaner Auslieferung und Rückholung. *OR Spektrum* **2001**, *23*, 79–96. [[CrossRef](#)]
29. Liu, R.; Jiang, Z.; Geng, N. A hybrid genetic algorithm for the multi-depot open vehicle routing problem. *OR Spectrum* **2014**, *36*, 401–421. [[CrossRef](#)]
30. International Organization for Standardization. *ISO 668:2013: Series 1 Freight Containers—Classification, Dimensions and Ratings*; ISO: London, UK, 2013.
31. *Straßenverkehrs-Zulassungs-Ordnung (StVZO) § 32 Abmessungen von Fahrzeugen und Fahrzeugkombinationen*; BMJV: Berlin, Germany, 2019.
32. SAE. *SAE J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*; SAE International: Warrendale, Germany, 2018.
33. Meck, G. Spediteure werben um Migranten—Interview mit Bernhard Simon. *Frankfurter Allgemeine Sonntagszeitung*, 9 December 2018.
34. Völklein, M. Nahverkehr: Lokführer Werden Dringend Gesucht. *Süddeutsche Zeitung*, 30 November 2018.
35. Automated Valet Parking. Available online: <https://www.bosch-mobility-solutions.de/de/highlights/automatisierte-mobilit%C3%A4t/automated-valet-parking/> (accessed on 15 January 2019).
36. Li, Y.; Cao, Y.; Qiu, H.; Gao, L.; Du, Z.; Chen, S. Big wave of the intelligent connected vehicles. *China Commun.* **2016**, *13*, 27–41. [[CrossRef](#)]
37. Becker, J. Weltkonzerne—Hallo, Robo-Taxi! *Süddeutsche Zeitung*, 10 July 2018.
38. ERTRAC. *Connected Automated Driving Roadmap*; ERTRAC Working Group “Connectivity and Automated Driving”: Brussels, Belgium, 2019.
39. Bundesregierung Erneuerbare Energien und stabile Netze. Available online: <https://www.bundesregierung.de/breg-de/aktuelles/erneuerbare-energien-und-stabile-netze-422384> (accessed on 16 July 2019).
40. HAW. Hamburg Speicherregelkraftwerk am Windpark Curslack ist Messehighlight. Available online: [https://www.haw-hamburg.de/fileadmin/user\\_upload/Presse\\_und\\_Kommunikation/Downloads/Faktenblatt\\_NEW4-0\\_20181123\\_NEUES-TITELBILD.pdf](https://www.haw-hamburg.de/fileadmin/user_upload/Presse_und_Kommunikation/Downloads/Faktenblatt_NEW4-0_20181123_NEUES-TITELBILD.pdf) (accessed on 16 July 2019).
41. Komarnicki, P.; Haubrock, J.; Styczynski, Z.A. *Elektromobilität und Sektorenkopplung: Infrastruktur- und Systemkomponenten*; Springer: Berlin/Heidelberg, Germany, 2018; ISBN 978-3-662-56248-2.
42. Chapman, N.; Corchero, C.; Sanmarti, M. *Task 28: Home Grids and V2X Technologies Final Report (2014–2018)*; HEV-TCP; IEA: Paris, France, 2019; p. 24.
43. European Parliament and of the Council. Commission Regulation (EU) No 678/2011 of 14 July 2011. *Off. J. Eur. Union* **2011**, *40*, 274–300.
44. Demiridi, E.; Kopelias, P.; Nathanail, E.; Skabardonis, A. Connected and Autonomous Vehicles—Legal Issues in Greece, Europe and USA. In *Data Analytics: Paving the Way to Sustainable Urban Mobility*; Nathanail, E.G., Karakikes, I.D., Eds.; Springer: Cham, Switzerland, 2019; Volume 879, pp. 756–763, ISBN 978-3-030-02304-1.
45. Fafoutellis, P.; Mantouka, E.G. Major Limitations and Concerns Regarding the Integration of Autonomous Vehicles in Urban Transportation Systems. In *Data Analytics: Paving the Way to Sustainable Urban Mobility*;

- Nathanail, E.G., Karakikes, I.D., Eds.; Springer: Cham, Switzerland, 2019; Volume 879, pp. 739–747, ISBN 978-3-030-02304-1.
46. Schreurs, M.A.; Steuwer, S.D. Autonomous Driving—Political, Legal, Social, and Sustainability Dimensions. In *Autonomous Driving*; Maurer, M., Gerdes, J.C., Lenz, B., Winner, H., Eds.; Springer: Berlin/Heidelberg, Germany, 2016; pp. 149–171, ISBN 978-3-662-48845-4.
  47. Smith, B.W. Model Legislation for Automated Driving. In *Road Vehicle Automation 4*; Meyer, G., Beiker, S., Eds.; Springer: Cham, Switzerland, 2018; pp. 79–88, ISBN 978-3-319-60933-1.
  48. Van Audenhove, F.-J.; Rominger, G.; Kom, A.; Bettati, A.; Steylemans, N.; Zintel, M.; Smith, A.; Haon, S. *The Future of Mobility 3.0*; Arthur D. Little: Paris, France, 2018.
  49. Tyrinopoulos, Y.; Antoniou, C. Review of factors affecting transportation systems adoption and satisfaction. In *Demand for Emerging Transportation Systems*; Elsevier: Amsterdam, The Netherlands, 2019; pp. 11–36, ISBN 978-0-12-815018-4.
  50. Yashiro, R.; Kato, H. Success factors in the introduction of an intermodal passenger transportation system connecting high-speed rail with intercity bus services. *Case Stud. Transp. Policy* **2019**, *7*, 708–717. [[CrossRef](#)]
  51. Cornet, A.; Mohr, D.; Weig, F.; Zerlin, B.; Hein, A.-P. *Mobility of the Future*; McKinsey & Company: Munich, Germany, 2012.
  52. Transportation, Tourism and Logistics. Available online: <https://www.rolandberger.com/en/Expertise/Industries/Transportation/> (accessed on 7 December 2019).
  53. Li, Y.; May, A.; Cook, S. Mobility-as-a-Service: A Critical Review and the Generalized Multi-modal Transport Experience. In *Cross-Cultural Design. Culture and Society*; Rau, P.-L.P., Ed.; Springer: Cham, Switzerland, 2019; Volume 11577, pp. 186–206, ISBN 978-3-030-22579-7.
  54. Kostianinen, J.; Tuominen, A. Mobility as a Service—Stakeholders’ Challenges and Potential Implications. In *Towards User-Centric Transport in Europe*; Müller, B., Meyer, G., Eds.; Springer: Cham, Switzerland, 2019; pp. 239–254, ISBN 978-3-319-99755-1.
  55. Stopka, U.; Pessier, R.; Günther, C. Mobility as a Service (MaaS) Based on Intermodal Electronic Platforms in Public Transport. In *Human-Computer Interaction. Interaction in Context*; Kurosu, M., Ed.; Springer: Cham, Switzerland, 2018; Volume 10902, pp. 419–439, ISBN 978-3-319-91243-1.
  56. Nitsche, B.; Figiel, A. *Zukunftstrends in der Lebensmittellogistik: Herausforderungen und Lösungsimpulse*; Straube, F., Ed.; Schriftenreihe Logistik der Technischen Universität Berlin Sonderband; Universitätsverlag der TU Berlin: Berlin, Germany, 2016; ISBN 978-3-7983-2833-4.
  57. NDR. *Wie geht Das? Nachschub für den Supermarkt*; NDR: Hamburg, Germany, 2019.
  58. Krampe, H.; Lucke, H.-J.; Schenk, M. *Grundlagen der Logistik*; Huss-Verl.: München, Germany, 2012; ISBN 978-3-944281-27-8.
  59. Deutscher Logistik-Kongress. *Digitales trifft Reales: 35. Deutscher Logistik-Kongress: Kongressband = Digitalization Meets Reality*; Wimmer, T., Grotemeier, C., Eds.; DVV Media Group, Deutscher Verkehrs-Verlag: Hamburg, Germany, 2018; ISBN 978-3-87154-632-7.
  60. Van Duin, J.H.R.; de Goffau, W.; Wiegman, B.; Tavasszy, L.A.; Saes, M. Improving Home Delivery Efficiency by Using Principles of Address Intelligence for B2C Deliveries. *Transp. Res. Procedia* **2016**, *12*, 14–25. [[CrossRef](#)]
  61. Müller, S.; Lunkeit, S.; Thaller, C. *ATLaS—Szenarien des Automatisierten Fahrens in der Logistik*; DLR Institut für Verkehrsforschung: Berlin, Germany, 2018.
  62. Deutsche Post DHL Versandmarken Deutschland. Available online: <https://shop.deutsche-post.de/paketversand/dhl-paketmarken/dhl-paechchenmarken-paketmarken-deutschland> (accessed on 8 December 2019).
  63. Statista Research Department. *Anzahl der Paketlieferungen pro Person in ausgewählten Ländern Europas in den Jahren 2012 und 2018*; Statista Research Department: Hamburg, Germany, 2018.
  64. Statista Research Department. *Anzahl der beförderten Pakete durch die Deutsche Post in Deutschland von 2016 bis 2018*; Statista Research Department: Hamburg, Germany, 2019.
  65. Van Duin, J.H.; Wiegman, B.; Arem, B. From home delivery to parcel lockers: A case study in amsterdam. In Proceedings of the 11th International Conference on City Logistics, Dubrovnik, Croatia, 12–14 June 2019.
  66. Iwan, S.; Kijewska, K.; Lemke, J. Analysis of Parcel Lockers’ Efficiency as the Last Mile Delivery Solution—The Results of the Research in Poland. *Transp. Res. Procedia* **2016**, *12*, 644–655. [[CrossRef](#)]

67. Vastag, A.; Bernsmann, A. (Eds.) *Urbane Logistik: Schnell, Stadtverträglich und Wirtschaftlich*; Logistik Praxis 1. Auflage.; Huss: München, Germany, 2018; ISBN 978-3-946350-78-1.
68. Ewert, A.; Brost, M.; Schmid, S. Fostering small electric vehicles on a municipal level. In Proceedings of the 32nd Electric Vehicle Symposium (EVS32), Lyon, France, 19–22 May 2019.
69. Ninnemann, J.; Tesch, T.; Thyssen, R.; Beecken, W.; Hölter, A.-K. *Smart Last Mile Solutions*; Logistik schafft Lösungen: Hamburg, Germany, 2017.
70. Ripa, F.; Lozzi, G.; Mourey, T.; Dondi, S. *NOVELOG—Cities & Regions—Factsheets*; European Union: Brussels, Belgium, 2018.
71. Dreier, D.; Silveira, S.; Khatiwada, D.; Fonseca, K.V.O.; Niewegłowski, R.; Schepanski, R. The influence of passenger load, driving cycle, fuel price and different types of buses on the cost of transport service in the BRT system in Curitiba, Brazil. *Transportation* **2019**, *46*, 2195–2242. [[CrossRef](#)]
72. *Regulation (EC) NO 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public Passenger Transport Services by Rail and by Road and Repealing Council Regulations (EEC) Nos 1191/69 and 1107/70*; European Union: Brussels, Belgium, 2007.
73. Osterwalder, A.; Pigneur, Y.; Clark, T. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*; Wiley: Hoboken, NJ, USA, 2010; ISBN 978-0-470-87641-1.
74. Ickin, S.; Petersen, K.; Gonzalez-Huerta, J. Why Do Users Install and Delete Apps? A Survey Study. In *Software Business*; Ojala, A., Holmström Olsson, H., Werder, K., Eds.; Springer: Cham, Switzerland, 2017; Volume 304, pp. 186–191, ISBN 978-3-319-69190-9.
75. Jain, A. Apps marketplaces and the telecom value chain. *IEEE Wirel. Commun.* **2011**, *18*, 4–5. [[CrossRef](#)]
76. Laugesen, J.; Yuan, Y. What Factors Contributed to the Success of Apple’s iPhone? In Proceedings of the 2010 Ninth International Conference on Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR), Athens, Greece, 13–15 June 2010; pp. 91–99.
77. Nirmal, S.; Pathare, A. Swarm intelligence for logistics controlling. *IRJET* **2017**, *4*, 5.
78. Zhang, S.; Lee, C.K.M.; Chan, H.K.; Choy, K.L.; Wu, Z. Swarm intelligence applied in green logistics: A literature review. *Eng. Appl. Artif. Intell.* **2015**, *37*, 154–169. [[CrossRef](#)]



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