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Comparison of Standard and Electric Carsharing Processes and IT-Infrastructures

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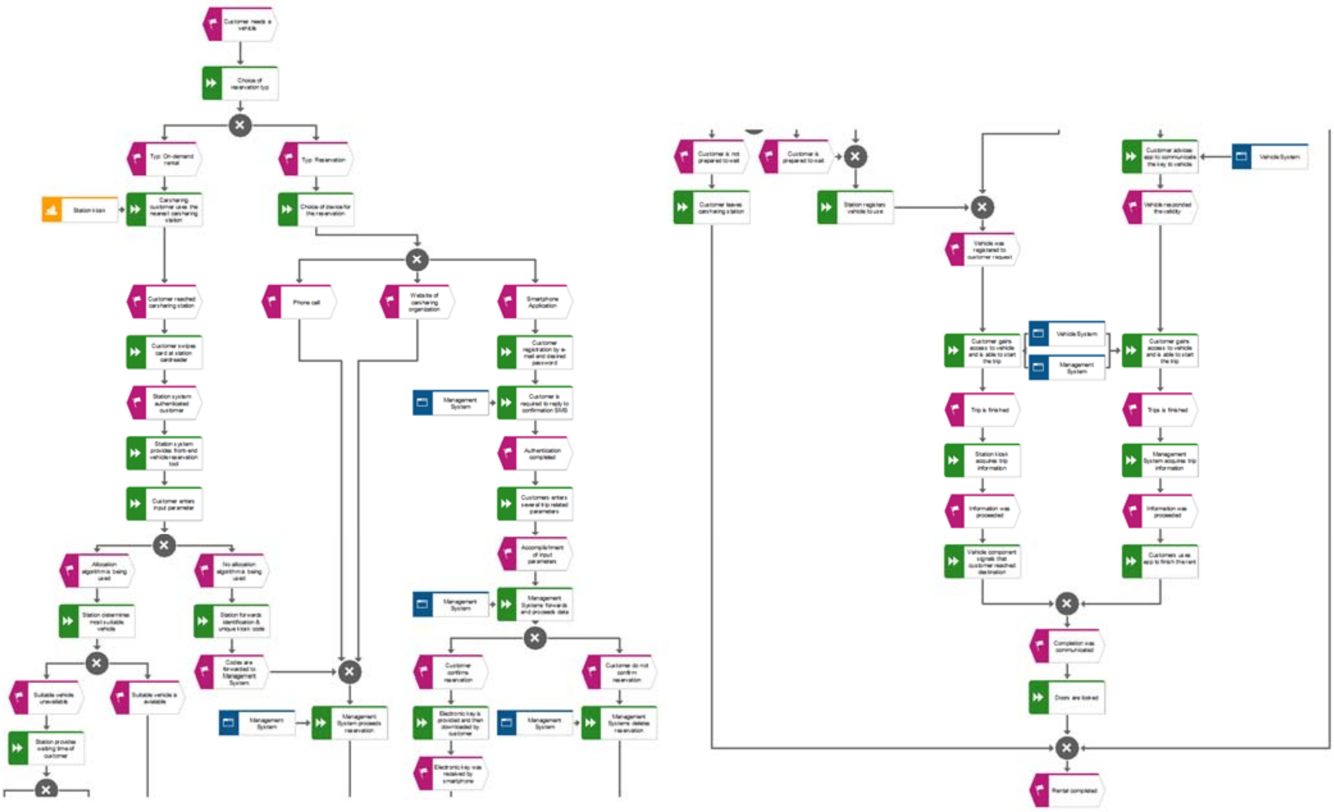

Business Process: Trip Registration

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Abstract

In the last decades, carsharing became increasingly popular as a sustainable alternative to privat car ownership. Carsharing is particularly suitable to cover mediumrange distances and can be linked to the public transport of major cities (intermodal mobility). Within this context, the integration of electric vehicles represents an opportunity to further protect the environment and potentially save energy cost. In order to introduce coherent and successful electric carsharing, the business process has to be developed. Thus five categories (Relocation, Distribution, Evaluation and Simulation, Incentives and Billing, and Infrastructure) are analysed and illustrated in business processes to compare standard carsharing concept with electric carsharing concept. However, as its differences are so minor and therefore hardly representable, the comparison is only verbal presented. The differences mainly concerned the structure of the sub processes, such as the choice and setup of mathematical models and respective algorithms concerning the relocation and distribution of vehicles and the evaluation of the carsharing system itself. The general business processes, which can be used for both concepts, are illustrated as event-driven process chains by the modelling software ARIS. The processes Trip Registration System, Vehicle System and Management System are illustriated in the appendix.

Keywords

Carsharing, business process, electric carsharing, comparison, Trip Registration, Vehicle System, Management System, event-driven process chain

1 Introducation

In the last decades, carsharing, which describes "a distinct business process wherein CSOs [carsharing operators] typically provide their members with short-term vehicle access" (Stillwater et al., 2008), became increasingly popular as an alternative form of transportation. Carsharing providers around the world recorded impressively rising numbers of active members. Within a period of five years, between 2006 and 2010, the worldwide number of registered members almost tripled to a total of about 1.25 million, whereas the fleetsize almost doubled to 31,000 vehicles in 2010 (Shaheen and Cohen, 2013). This development may mainly be accredited to an increasing environmental consciousness and sense of responsibility of vehicle users towards nature, as well as financial factors (Buchinger and Braet, 2013; Shaheen and Cohen, 2013). Including economic uncertainty, rising energy and private car ownership costs, as well as efforts for increasing vehicle efficiency in order to reduce greenhouse gas emissions, those factors are encouraging drivers to actively seek alternatives to a regular vehicle ownership. Therefore, as one of these alternatives, carsharing allows individuals to remain mobile and flexible, thus gaining the advantages of a private automobile, while avoiding responsibilities and costs that result from owning a private vehicle (Shaheen and Cohen, 2013; Markel, 2010; Stillwater et al., 2008; Katzev, 2002). Furthermore, research has shown that carsharing also actively contributes to reduce one's greenhouse gas emissions by 55 percent, while also helping to avoid other negative side-effects of an increased traffic density, for instance unsolicited congestions or air pollution in cities (Shaheen and Cohen, 2013; Lee et al., 2012; Parent and Gallais, 2002).

As worldwide greenhouse gas emissions grow nonetheless due to a continuous increase in overall transportation, the interest in so called smart or innovative mobility solutions like electric vehicles and respective carsharing concepts has grown even further (Alli et al., 2012; Barth et al., 2003; Figueiredo et al., 2002). Therefore, since electric vehicles produce little to none emissions at all, carsharing companies have deployed electric vehicles worldwide in order to test their applicability and economic viability in real environments (Shaheen and Cohen, 2013; Alli et al., 2012). However, the electric vehicle industry and e-carsharing providers are facing various obstacles in penetrating the market (Buchinger and Braet, 2013). Besides economical and organisational challenges, electric vehicles are critically renowned by customers as a result of their short driving ranges, the extensive charging times, or their high acquisition costs (Buchinger and Braet, 2013). Likewise, carsharing companies are facing issues incorporating electric vehicles in their services, since they supposedly require adjusted IT-infrastructures and Intelligent Transportation Technologies, which in turn allow for a maximisation of returns by fully exploiting the vehicles resources and the companies capacities. This is especially important for both conventional and, moreover, e-carsharing companies, considering that they have to think and act economically in the first place (Buchinger and Braet, 2013; Markel, 2010). Furthermore, as electric vehicles are comparably expensive in their acquisition, they consequently reach their amortisation point later than conventional vehicles and thus, require a frequent utilisation by customers, which can only be guaranteed by adjusting and optimising the carsharing companies IT infrastructure and associated business processes (Alli et al., 2012). Yet, since any intrusions, changes, and additions to IT systems used also have an impact on the underlying business processes, the applicable sub processes presumably have to be adapted to the new structures as well.

Despite this urgent need, research has confined itself to mostly analysing and describing essential information technologies and respective carsharing systems, subsequently creating a research gap. In order to fill this gap, this paper tries to analyse the common conventional and e-carsharing infrastructures, based-on which the business processes will be modeled and compared. Therefore, after the introduction and the description of the purpose and value of this paper in chapter one, the differences be-tween casual car rental and carsharing, as well as a brief distinction of the common carsharing systems will be provided in chapter two. The first section of the third chapter, however, deals with specific intel-ligent transportation technologies that are typically being deployed in carsharing systems and the mo-tives for their utilisation, thus allowing for a more universal comprehension regarding the structure of these initiatives. The consecutive section builds on these previous findings and relates the individual technologies with one another, thus establishing a general IT-infrastructure, based on which the model-ing of the business processes will be conducted, although due to their extent, the respective results will be presented in the appendix of this paper. In the fifth and second to last chapter, the actual compari-son of the business processes of conventional and e-carsharing systems will be conducted, therefore giving answers to the initial research question, whereas the last chapter provides both a critical acclaim concerning the results of the paper and a final conclusion.

2 Carsharing: A Distinction

As mentioned in the introduction, the term carsharing describes and encompasses the provision of a variety of vehicles by a company that can be rented by a broad range of customers for either cooperative or profit-oriented purposes, thus presenting an alternative to privately owned vehicles, since customers can easily access and use vehicles if needed without owning them (Katzev, 2002; Barth and Shaheen, 2002; Parent and Gallais, 2002). In this way, carsharing differs notably from casual car rentals, as users don't have to pay for a whole day, but for the actual time or mileage they were using the vehicle (Parent and Gallais, 2002; Katzev, 2002). Moreover, by participating in carsharing projects, individuals can avoid the majority of fixed costs that come with vehicle ownership. Usually, the carsharing companies pay insurance costs, taxes, maintenance and repairs and levy them partly onto the fees that subscribers have to pay per mile or hour (Katzev, 2002; Stillwater et al. 2008). Subsequently, members still pay these fixed costs indirectly, but since shared-vehicles are commonly used by 10 to 15 individuals, these costs are split accordingly (Katzev, 2002). Nevertheless, using shared-vehicles is solely cost-effective, if an individual drives less than 10,000 kilometers a year (Mannan, 2001). However, as the term carsharing is relatively general in nature, often used interchangeably, and gives no further information about the different concepts that companies or groups of individuals might apply; it also complicates the analysis, description, and comparison of shared-use vehicle programmes (Barth and Shaheen, 2002). In order to provide a classification, Barth and Shaheen (2002) came up with a framework that allows for an easy distinction between the commonly applied concepts. According to their framework, shared-use vehicle systems can generally be separated into station based concepts, casual carsharing concepts and a variety of hybrid models in between (Barth and Shaheen, 2002). As for this paper, a rough distinction between both will suffice, since for the purpose of this paper, carsharing and respective systems will be in the focus, whereas the station based concept was omitted.

The main purpose of station based concepts is to support commuters in their daily routine by providing them with vehicles, facilitating their commute to and from local public transport stations, thus providing a comfortable way of transport (Barth and Shaheen, 2002; Parent and Gallais, 2002). Thereby, operators initially intended not only to increase the number of bus or train passengers by providing a comfortable manner of transportation, but also to decrease parking shortages. Typically, individuals use these station vehicles to get from home to a nearby transit station, take the bus or train to their desired destination, and then commute to their workplace by renting another station vehicle or by taking any other alternative form of transportation (Barth and Shaheen, 2002). However, as station vehicles are mostly intended to improve transit connectivity, the user-to-vehicle ratio is lower compared to carsharing, which runs between ca. 10-15 users (Barth and Shaheen, 2002; Katzev, 2002). The latter of both concepts, carsharing serves a more general purpose than station based systems. Instead of solely supporting public transportation and transit, carsharing companies offer their vehicles for a broader range of their subscribers' needs. Although in both concepts the vehicles are usually rented for local trips several times a day by different individuals, carsharing vehicles are being used for rather infrequent needs, such as shopping or the transport of goods (Parent and Gallais, 2002; Katzev, 2002; Barth and Shaheen, 2002). Yet, since varying tasks often require different types of vehicles and carsharing organisations are inclined to satisfy their customers' needs, they commonly proceed to diversify their fleets (Katzev, 2002). This fleet is usually distributed and stationed around strategic spots throughout the city to shorten walking distances, thus providing a convenient access that in turn increases customer satisfaction (Barth and Shaheen, 2002). Once a vehicle is chosen and rented, the carsharing procedure can differ notably between the various organisations according to the type of rental they provide. Historically speaking, carsharing operators almost exclusively offered so called two-way-rentals or round-trips (Weikl and Bogenberger, 2012). Here the user starts his trip at a parking lot or a station, proceeds to finish his business, and once he is done, is obliged to return the vehicle at the exact same station where he started (Jorge et al., 2012; Clemente et al., 2013). As follows, these two-way rentals offer decreased flexibility for customers, but, apart from that, it also facilitates the management of the fleet. Since demand patterns can be more easily assessed and stocks more easily planned, sophisticated relocation strategies and respective systems will not be necessary, which in turn leads to lower prices (Jorge et al. 2012; Clemente et al., 2013). One-way rentals on the other hand allow a more flexible utilisation of the vehicles, because customers do not have to return the vehicle at a specific station, but at any station or parking lot provided by the carsharing organisation (Clemente et al. 2013; Weikl and Bogenberger, 2012; Barth and Shaheen, 2002). An even more flexible form of these one-way systems is the so called free-floating system. Free-floating systems eliminate the constraint that customers have to return their vehicles at a parking station and enables them to leave the vehicles anywhere within the vicinity of a certain district where the carsharing organisation has rented parking lots, thus further promoting flexibility (Weikl and Bogenberger, 2012).

In conclusion, one-way and especially free-floating systems also result in increased managerial requirements (Clemente et al., 2013; Barth and Shaheen, 2002; Weikl and Bogenberger, 2012). As customers can park at any desired station or parking lot, neither an even distribution nor the availability of a vehicle can be guaranteed. This is primarily caused by the customers' demand that can differ strongly between the various spots and throughout the day. So it can come to pass that shared-vehicles are sometimes parked at stations and locations that are far from strategic points of interest where the demand is high. As a consequence, those vehicles might become stranded in these areas of low demand, which in turn might lead to a shortage of vehicles at the other stations (Weikl and Bogenberger, 2012; Clemente et al., 2013; Barth and Shaheen, 2002). In order to tackle these logistic problems, carsharing organisations have to deploy certain relocation strategies which will be discussed later in the paper, as they are important when it comes to modeling the business process.

3 Carsharing-Relevant Intelligent Transportation Systems and Technologies

One of the most important factors that determine the success, economic viability, and user acceptance of carsharing concepts is the use of intelligent transportation systems (ITS) and technologies (Barth et al., 2003). Especially in multi-station, one-way or free-floating shared-use vehicle systems, the application of ITS is crucial. Although these systems are more attractive to the customers since they offer more flexibility, they also complicate the management of the operator's fleet (Barth and Todd, 2000). Considering that in most of these cases, the relocation is passively conducted by the customer and consequently depends solely on their utilisation pattern and only in rare cases, the vehicles are relocated manually by the operator, one-way rentals often result in vehicle stock imbalances among the various available stations (Bruglieri et al., 2013; Weikl and Bogenberger, 2012). This in turn can greatly influence the customer satisfaction, since in case no vehicles are available, a customer request cannot be fulfilled and therefore, he is obliged to take an alternative means of transportation (Lee et al., 2012; Clemente et al., 2013; Barth et al., 2003; Barth and Todd, 2000). Moreover, this so called service-ratio is, according to various studies, the most critical factor for the satisfaction of a carsharing subscribers with their providers and thus, the distribution must be effectively managed to promote carsharing as a feasible alternative to privately owned vehicles (Lee et al. 2012; Barth and Todd 2002; Clemente et al., 2013).

Furthermore, besides an increased service-ratio leading to a higher customer satisfaction, the application of ITS also improves the overall convenience and user-friendliness of the whole rental process, consecutively leading to an expanding market growth (Lose, 2010; Barth and Todd 2002, p. 52; Shaheen and Wipyewski 2003, p. 10). Various processes, such as recording the driven distance or the reservation of and access to shared-use vehicles, that would otherwise have to be documented or conducted manually, can be automated with ITS. For instance, the utilisation of an in-vehicle tracking system in Car Link II, a carsharing pilot programme from the San Francisco Bay Area, replaced the customer's former obligation to manually fill out the travel log after each rental. This in turn not only saved some of the customers time, it also allowed for an automated, accurate billing procedure (Shaheen et al., 2000; Shaheen et al., 2004; Shaheen and Wipyewsk,i 2003). Furthermore, reservation systems allow customers to rent their vehicles in advance, giving both operators and customers planning security, while also allowing management systems to maximise the vehicle usage (Barth et al. 2003). Customers also profit from vehicle access systems that facilitate the check-in and access procedures, as customers nowadays can, provided that the system is very advanced, even access vehicles by solely using their smartphones (Cugola and Rossi, 2012). Moreover, the application of ITS allows an improvement of the overall efficiency of the service and reduces accruing costs. Since respective technologies not only permit determining the optimal fleet size and their distribution based on simulations that estimate the mobility demand, they can also help to manage these resources more economically (Clemente et al., 2013; Barth and Todd, 2000). By constantly logging all vehicle data and data from station kiosks via ITS, a more detailed analysis of the system can be performed. This in turn provides more accurate information on vehicle operation and the effectiveness of the system management techniques, as well as improving the accuracy of the initial simulation through experience (Barth and Todd, 2000). Furthermore, technologies such as ignition immobilisation when a user finished his trip or devices that allow vehicle tracking while the customer is still driving, can lead to insurance discounts, whereas an automated billing procedure reduces labour costs, because the system replaces the task usually being performed by employees (Clemente et al., 2013; Shaheen and Wipyewski, 2003).

All in all, these technologies are very important for carsharing systems and operators, not just because they determine their success, but also because they influence the choice of systems in-use, as well as the system architecture and the underlying processes. Since this paper focuses on modeling the business process of e-carsharing systems and its comparison to conventional carsharing systems, an analysis of the system architecture as well as the pertaining system and technologies is crucial for an understanding of the process. For that reason, both technologies and existing architectures will be described briefly in the following sections.

3.1 Technologies and Function

The following section will concentrate on introducing the various technologies and the reasons for their common appliance in carsharing systems, which in turn results in a better comprehension of the status of the carsharing infrastructures nowadays.

3.1.1 Reservation

The reservation procedure, which comes after the registration of a new user, strongly depends on the applied technology as well as management decisions of the respective carsharing service provider. However, the main purpose of these reservation technologies, such as a reservation software, is to maximise the operators' financial revenues by minimising the unused time of each vehicle (Barth et al., 2003). This is usually accomplished through the application of a selection algorithm that chooses the most suitable vehicle for a certain task or trip (e.g. depending on the estimated distance and the fuel levels or the state of charge (SOC) of the available vehicles) as well as it tries to balance the distribution of vehicles across the various stations or parking lots a company deployed or rented (Barth et al., 2003). These functions are, however, located in station kiosks, or in an integrated management system.

Usually, when a user wants to reserve a vehicle, he has to specify certain parameters, for instance the date and time, his current location and destination, as well as special requests, such as baby seats (Fukuda et al., 2003; Mannan, 2001; Cugola and Rossi, 2012). At this point, the application of intelligent reservation systems can further promote user convenience after multiple reservations by analysing these specifications and identifying preference patterns of the customers. These preferences can then be displayed as trip suggestions the next time the customer logs in (Lose, 2010). In general, reservation systems can be distinguished by whether they are operated manually, automatically or, the most common approach, which is through a combination of both (Barth et al., 2003; Fukuda et al., 2003). Systems relying solely on manual reservations (e.g. via phone) are operated by designated employees of the carsharing organisation that check the availability of each vehicle according to the customer's specifications and reservations of other clients (Barth et al., 2003). Reservations from automated systems on the other hand do not particularly require staff, since the search is mostly automated through the aforementioned allocation algorithms. Customers are consequently provided with a list of suitable vehicles after entering the specifications and thus, can choose their vehicle on their own (Barth et al., 2003; Cugola and Rossi, 2012). However, as reservations sometimes require spontaneous adjustments (e.g. in case of technical problems), they can still be monitored and adjusted by employees (Barth and Todd, 2002). Furthermore, reservation systems allow two different approaches of renting a vehicle. These can either be exclusively in advance, on-demand reservations, or a combination of both. Advance reservations enable customers to reserve a vehicle for a particular date and time, thus blocking its availability for other customers. Yet, there are examples of carsharing systems, where a reservation does not necessarily imply that it is blocked for other customers (see Shaheen et al. 2004). In these systems, the carsharing operator has to offer incentives to other potentially interested users in order to prevent them from taking the vehicle without paying heed to the customer who came first (Shaheen et al. 2004, p. 70). In some systems, customers also have to confirm a reservation up to 15 minutes before the rental period starts. This allows the system to make vehicles available once again in case a customer changed his mind last-minute, which, as follows, facilitates the maximisation of vehicle usage, and additionally provides a certain protection from misuse, as of course vehicles are rented but never paid for (Cugola and Rossi, 2012; Shaheen et al., 2004). On-demand rentals, which can also be regarded as immediate reservations, lead to increased requirements concerning the system and fleet management. Customers can simply choose and rent a vehicle right before the trip, which especially comes in handy, when one could not foresee the need for a vehicle beforehand, hence increasing the overall user-friendliness of the service (Barth et al., 2003). However, charging different fees for both on-demand and in advance rentals can facilitate an even distribution between both types of reservations. When a carsharing system offers on-demand rentals, a so called check-out process takes the place of the reservation process. Users can simply walk up to a station kiosk and use the kiosks terminal or, in more modern systems, using mobile applications instead. In order to successfully rent a shared vehicle, users are then supposed to work through various input data screens entering the required information (Barth and Todd, 2000; Barth et al., 2003). After the check-out procedure, the user can obtain vehicle access and start the trip (Barth et al., 2003; Shaheen et al., 2004; Hara et al., 2000).

3.1.2 Vehicle Access

In carsharing systems, various technologies, including hardware and software solutions, exist that allow customers to obtain vehicle access, while also providing certain degrees of security to the carsharing operators (Barth et al., 2003). These are both external solutions at the proximity of the vehicle and station, as well as internal solutions placed in the vehicle itself, that conduct the authentication procedure.

One of the easiest ways to grant customers access to shared-use vehicles is placing a casual lockbox near the operating carsharing stations (Khan, 2012). This lockbox contains the keys of the vehicles that are parked nearby. When a customer wants to use one of these vehicles, he is required to carry a special key with him that he initially received from the carsharing company upon registration. This key allows access to the lockbox and thus, the vehicles themselves (Barth et al., 2003). An even easier, but less secure technique is to replicate a vehicles key and to distribute these copies among all members, hence allowing anyone access without further requirements. This, however, undermines the security reservations should provide, since the availability of a reserved vehicle can not be guaranteed, because anyone can take the vehicle at anytime. As a consequence, honorary systems have to be introduced that enforce customers to omit already rented vehicles, possibly through monetary incentives (Barth et al., 2003).

A more advanced access technique is the employment of so-called smartcards as a substitute for key-based solutions, thus dispensing the need for both a lockbox and its access key. The smartcard allows access either to the station kiosks, or directly to the vehicles (Barth and Todd, 2000). In order to start the registration procedure, users generally swipe their smartcard at a station kiosk. This, in turn, starts an internal process, in which the station checks and usually validates the owner's card (Barth and Todd, 2000). Afterwards, the user is required to swipe the card next to the card reader, which is usually installed under the windshield. However, there are three different approaches of how users gain access via smartcards. The first approach, which is similar to the common key solution, generally allows all customers to gain access to any vehicle at any time. The second approach grants access exclusively to specific users, which is achieved through an additional personal identification number (PIN). This PIN is transmitted to the smartcard after the checkout and prior to the vehicle access. The desired vehicle can be accessed only when the PIN coincides with the reservation data (Barth et al., 2003). In both of these cases, the smartcard solely grants access to the vehicle, the ignition is usually started via casual keys that are physically chained to the car (Alli et al., 2012). Securitywise, the third approach goes even further, as for the ignition process the user is also required to enter a specific PIN code on a terminal in the vehicle. If both codes, the one being transmitted by the system and the one being entered by the customer, coincide, the ignition starts and the user can begin the trip (Shaheen et al., 2004). In some cases, vehicle access is required multiple times during a trip. Solely when a user leaves the vehicle at his destination, the system will log him out permanently. Otherwise, the user can always gain access anew via the smartcard (Fukuda et al., 2003).

3.1.3 Vehicle Data Acquisition and Supervision

Another essential feature being provided by the application of ITS is the supervision of the shared-use vehicles. Technologies such as special micro-controllers, or Embedded Electronic Boards, are both solutions that are connected with diverse sensors being placed in the vehicle. These integrated and mutually interacting technologies automatically record information like remaining battery charge, current voltage and vehicle location, driven distance, and even door statuses. This in turn enables other systems to process this vehicle-related information for the daily business (Fukuda et al., 2003; Barth and Todd, 2000; Cugola and Rossi, 2012). For example, supervision technologies allow systems or the operating staff to recognise unwanted incidents, such as motor and tire problems or dangerously low fuel and battery levels, early on (Fukuda et al., 2003; Hara et al., 2000). This facilitates the premature taking of preventive measures, consequently avoiding more severe problems. For example, if the battery of an electric vehicle is almost depleted, an employee of the carsharing operator can establish a connection to the respective vehicle and communicate its need to recharge to the user. Otherwise, without supervision, the vehicle would have eventually stalled, hence requiring a road service needing to tow him to the next fuel or recharge station.

These automated supervision processes not only increase the convenience of customers since they do not have to record information such as the driven distances themselves, but they also support and enable additional functions. Monitoring the door statuses for example allows the operators or the operating system to notice when a customer forgot to lock the vehicle, which then can be resolved by manually sending a command that eventually locks the doors (Fukuda et al., 2003). In the UCR Intellishare carsharing system, the micro-controller replaced a card reader, hence controlling vehicle access, as well as not only realised when a user reached his destination, but it also turned off the ignition and locked the doors. Furthermore, the supervision facilitates an automated billing process, because most carsharing operators charge monthly fees both for subscription and based on the duration of vehicle-usage and the driven distance (Shaheen et al., 2004; Barth et al., 2003). However, one of the most important aspects of vehicle supervision is that by providing vehicle information, supervision enables other systems to determine vehicle availability (Shaheen et al., 2004; Barth and Todd 2002, p. 54). As for electric vehicles, their trip range greatly depends on the current state of charge (SOC), thus influencing the availability of the vehicles (Barth and Todd, 1999). Without its monitoring and displaying, many customers would probably be stalled mid-trip once the battery is depleted, which in turn would strongly influence their satisfaction with the service. Therefore, monitoring fuel levels and other parameters allows evaluating whether a vehicle suits a trip or not. Moreover, since the current location of a vehicle can help a system to determine the vehicles time of arrival, vehicle supervision also supports the overall fleet management, because based on this information, the system can estimate the time a vehicle will be available for rental once more (Karbassi and Barth, 2003). Furthermore, constantly monitoring the location of each vehicle by including GPS devices or radio transponders enables relocation systems or the operating staff to identify and prevent an uneven distribution of vehicles (Barth et al., 2003; Clemente et al., 2013; Karbassi and Barth, 2003). Moreover, by tracking vehicle locations during the trips, organisations can analyse driving pat-terns, which facilitates the identification of popular spots where customers regularly make intermediate stops while using the service. This in turn allows carsharing operators to identify suitable places for new carsharing stations. Besides this, tracking technologies could also be used to compare the actual user behavior, demand patterns and trip length with those being predicted by the simulation models, thus providing possibilities to improve the overall accuracy of the latter (Karbassi and Barth, 2003; Barth and Todd, 2000; Millard-Ball and Murray, 2005).

3.1.4 Vehicle Navigation and In-Vehicle Messaging

Beyond vehicle location tracking, GPS and similar devices can also actively assist customers during their trip. Navigation systems relying on these technologies can provide various functions, for instance navigational aids that increase a customer's convenience by consequently directing them to their chosen destination or by displaying points of interests such as filling stations (Barth et al., 2003; Barth and Todd, 2000).Furthermore, carsharing operators can apply additional systems such as Advanced traveller infor-mation systems (ATIS). These systems provide customers not only with more detailed real-time traffic information, allowing them to avoid traffic congestions and to choose the most favourable route to their destination, but they also offer additional public transportation information, which enables them to chose alternative means of transportation (Figueiredo et al., 2001; Kitamura et al., 2000). However, in-vehicle devices (e.g. casual LCD screens) that can display this information are required to enable these functions.

The vehicle data acquisition systems described previously can be connected with those LCD displays, thus adding additional functions such as displaying billing information i.e. rental fees. Moreover, the display can show both messages from the staff or automated warnings, for instance when a user leaves the designated service area or the fuel level is considerably low (Hara et al., 2000). Additionally, as the connection between the in-vehicle device and the operating system is not solely one-sided, the users can also use the display to send messages to the operating staff. This could become useful in case the vehicle has unexpected issues (e.g. flat tires), or when the user has questions concerning their exact location (Kitamura, 2002; Barth et al., 2003). However, in-vehicle messaging can also be arranged by the application of stationary smartphones that can establish a connection with the operating center at any desired time (Hara et al., 2000; Fukuda et al,. 2003). Latest carsharing concepts like the Green Move system are even going as far as that they almost refrain from applying any in-vehicle devices for reasons of communicating, since most of the interactions between the vehicle, the operation center and the users can be arranged via their own smartphones and the respective app (Alli et al., 2012).

3.1.5 Simulation and Relocation

As mentioned at the beginning of this chapter, forecasting and simulation systems play an integral role in the success of carsharing systems. The simulations can help to drastically improve the efficiency of the carsharing system, since they can both aid in planning and determining the best configuration of a carsharing system in advance or by constantly analysing the overall performance of the system (Barth and Todd, 1999; Xu and Lim, 2007; Kitamura, 2002). Moreover, through forecasting the demand and supply of the shared-use vehicles, these simulations could help to save initial setup costs, which emerge from their buying. Thus, by determining the optimal fleet size in advance, carsharing companies could avoid the acquisition of too many vehicles in the first place, which then would supposedly be idle most of the time due to the exceeding supply (Cepolina and Farina, 2012; George and Xia, 2011). Furthermore, simulation models could help to actively ease vehicle imbalances by suggesting relocation strategies; while others can help to identify the best depot locations (Clemente et al., 2013). For example, Clemente et al. (2013) proposed that by applying a user-based relocation strategy drawing from suggestions of a simulation using real-time monitoring of shared-use vehicles, the availability and distribution of the operators fleet could be improved significantly (Clemente et al., 2013). By simulating the future demand and monitoring the current distribution, the simulation system could provide users with incentives (e.g. discounts on their rental fees) that would influence their travel behaviour to such a degree that they would eventually follow the systems suggestions by parking their vehicles at less frequented stations, thus effectively minimising distribution imbalances (Clemente et al., 2013).

Although based on the same idea of simulating the demand and supply, Xu and Lim 2007 suggested a different relocation strategy that involved the companies own staff. If the simulation anticipated an exceeding demand or vice versa, employees would move a vehicle from one station to another, which is also commonly known as operator-based relocation strategies because of the involvement of the operators staff (Xu and Lim, 2007; Weikl and Bogenberger, 2012). Hence, as these simulations improve both the daily business and the initial configuration of the carsharing system, these simulation models can and should be applied throughout the whole carsharing process.

3.2 Integrated Systems Infrastructure

Because of the undeniable importance for the economic viability of carsharing systems, most of the modern carsharing companies have integrated the individual technologies and systems described in section 3.1 into more sophisticated systems that help in facilitating their individual interactions and thus, optimise the whole process (Barth and Todd, 2002). Therefore, in the following chapter a general system infrastructure drawing from the descriptions about the structure and setting of five different carsharing programmes as well as their corresponding findings is proposed. This infrastructure in turn serves as the basis of the carsharing business processes, which will be derived accordingly. However, due to their spatial proportions, these processes will be displayed in the appendix of this paper. Furthermore, both the knowledge about a general infrastructure, as well as the processes occurring within, are vital for the accurate modeling of the business processes, which is one of the main purposes of this paper. In general, many carsharing programmes are comprised of three highly integrated systems that mostly assist different stages of the rental process, which is why they can roughly be divided into a trip regis-tration system, a management system, and a vehicle system. However, although they are seen as dis-tinct, these systems strongly interact with one another and sometimes even share functions (e.g. regis-tration) to provide the most efficient, user-friendly, and easily manageable service (Barth and Todd, 2000).

3.2.1 Trip Registration and Return System

The trip registration system's infrastructure is comparably simple, showing high similarities between the different carsharing programmes, though the input devices can differ considerably. In general, a mixture of phone, Smartphone, web and station kiosk based options were offered for registration and return, thus mainly supporting the beginning and end phase of the business process. However, many of the older carsharing systems used station kiosks both for rental of shared-use vehicle and authentica-tion of customers, whereas modern systems mostly depend on phone plus internet for registration and smartphones plus in-vehicle devices for authentication (Cugola and Rossi, 2012). Since reservations via phone or the company's web site are handled separately by the management system, the process being conducted by the static carsharing stations and smartphone apps will solely be described in the following.

Both the UCR Intellishare as well as the Kyoto Public Car programmes used static carsharing stations, which are generally used for check-out and check-in purposes, thus enabling spontaneous on-demand rentals as well as reservations (Barth and Todd, 2000; Kitamura 2002). After an initial registration for the carsharing programme, users can simply walk up to the station of interest, swipe their smart card at the station kiosk, consisting of a card reader besides a touch screen display, and start the check-out procedure. In order to register a vehicle, after swiping the smartcard at the kiosk, the customer has to enter various trip related information as described in 3.1.1 (Barth and Todd, 2000; Fukuda et al., 2003; Mannan, 2001). Depending on whether the station has a selection program at its disposal or functions solely as an input device, the search request is processed. Concerning the first case, using an allocation algorithm, the station chooses the appropriate vehicle according to fuel-level or state of charge of the battery and frequency of use (Barth et al., 2003). However, if there is no suitable vehicle available, the station will show an additional screen that displays the estimated waiting time (Barth and Todd, 2000). In case the station does not incorporate an allocation algorithm, it solely serves as a host for a web-browser that enables access to the company's website via http, hence providing online registration features. The respective vehicle selection is then carried out via the management system. However, only if the identification codes from the smart card as well as the station kiosk match the ones being saved on the server database, will the registration finally be completed and the user can proceed to retrieve his car (Barth and Todd, 2000; Hara et al., 2000). As for the vehicle access, it is handled by either the vehicle system, or the smartphone app, whereby both are in close communication with the management system (Alli et al., 2012). Concerning return, most carsharing stations only play a subsidiary role, since it is commonly handled by the in-vehicle system. Just in case the in-vehicle system cannot establish a direct connection with the management component, or the station itself manages vehicle registration and selection, a carshar-ing station will be required. Trip information or information indicating that a user finished his trip, such as the keys were placed in the glove box, can then be uploaded from the vehicle system to the station, which in turn can lock the vehicle (Barth et al., 2003; Hara et al., 2000). However, when it comes to carsharing systems using electric vehicles, the deployment of carsharing stations is also essential, since they provide the required infrastructure for recharging the shared-use vehicles (Fukuda et al., 2003; Hara et al., 2000). Furthermore, after the user finished a trip with an electric vehicle, the latter can supposedly signal to the management system that they are being recharged.

An even more advanced technology to both register and unlock shared-use vehicle is the use of external devices such smartphones. One of these examples is provided by the Green Move project from the Politecnico di Milano University. After an initial registration and authentication, which includes the creation and confirmation of the account, the customer can download a smartphone app. This provides a search function, which the customer can utilize to search for and reserve, if successful, suitable vehicles (Alli et al., 2012). Furthermore, the smartphone app accelerates the search process, since it automatically determines information that is required for reservation, such as the current position of the user (Alli et al., 2012). After this procedure, the Green Move Center, which can be seen as a management system, confirms the reservation and issues an electric key. This key is directly associat-ed with the specific reservation and contains all data that is relevant for identifying the rented vehicle, e.g. date, time, as well as an encrypted ticket (Alli et al. 2012; Cugola and Rossi, 2012). Thus, an internet connection is mandatory during the initial reservation process. The user then proceeds to download this key via his smartphone. Once he finishes downloading, he is free to go to the specified vehicle and unlock its doors. This is enabled via communication technologies (e.g. Bluetooth or near-field communication) that establish a connection between the vehicle and the smartphone, where the smartphone sends the key that was previously downloaded to the vehicle sys-tem and its access system that is being integrated in the vehicle. In return, this in-vehicle system downloads the reservations from the management system and unlocks the doors, provided the information and the keys from both systems match (Alli et al., 2012; Cugola and Rossi, 2012). Once the registration is finished, the smartphone is not required to communicate with the Green Move Center anymore but with the vehicle system, which is why the initial internet connection is replaced by a blue-tooth connection that enables the exchange between smartphone and in-vehicle system (Alli et al., 2012). During the trip, the user can leave and access the vehicle at any time, using only his smartphone (Cugola and Rossi, 2012). However, once the user wants to terminate the trip and return the vehicle, he can use a special command being provided by the smartphone app. The smartphone then issues a message to the in-vehicle system which invalidates the user's reservation ticket, thus depriving him from the possibility of opening the vehicle anew (Alli et al., 2012).

3.2.2 Vehicle System

The vehicle system combines a variety of ITS technologies that enable various essential functions, which are primarily related to the trip itself. Besides vehicle supervision and data acquisition, it allows for an external and internal communication, vehicle navigation and access, as well as user authentication, and it strongly interacts both with the management system and the user. As with the Trip registration system, the set-up as well as the functions and processes being supported by the Vehicle system are quite common among the various carsharing companies, despite minor differences concerning the hardware utilised. In general, the first process being supported by vehicle system is vehicle access. Usually, a device like a simple smart card reader is placed within the vehicle. When a customer walks up to the car and swipes the card above the windshield, the card reader automatically checks the specific user ID, estab-lishes a connection with the management system, and compares it with the one being saved in a data-base (Barth and Todd, 2000; Shaheen et al., 2004; Kitamura, 2002). However, as mentioned in the previous chapter, vehicle access can also be performed by the customer's smartphone. Therefore, card readers are not specifically mandatory, as these customised solutions such as the Green Box from the Green Move programme or the so called On-Board Communications unit from the Rent-a-car sys-tem, Japan, can handle authentication as well (Cugola and Rossi, 2012). Nonetheless, in all carsharing programmes an onboard unit assessed user specific identification criteria, established a connection to or received a message from the system management and compared them with those that were either received beforehand or that were saved separately on a database (Barth and Todd, 2000; Shaheen et al., 2004; Fukuda et al., 2003; Hara et al., 2000; Cugola and Rossi, 2012). Once a user is authorised for access, the doors will unlock and, depending on the system, the user either simply starts the engine or can retrieve the required keys from the glove box inside the vehicle (Fukuda et al., 2003; Alli et al., 2012).

The next process being supported by the vehicle system is gathering vehicle information. Vehicle supervision can be seen as the main process, besides vehicle access, of the vehicle system, since it is important for both the management system and respective processes, as well as it enables further functions and thus processes during the trip (Bianchessi, 2013). As said before, a close monitoring of the shared-use vehicles allows for an efficient fleet management, such as determining vehicle availability or relocation strategies, by the management system (Barth and Todd, 2000). In order to do so, devices like the ones mentioned in 3.1.3 can either be connected to sensors that regularly check for the required information or, as for electric vehicles, directly to the electric core unit (Alli et al., 2012). The provided information usually encompasses fuel levels or state of battery charge, charging signals, vehicle miles driven, time of use in and out of the vehicle, vehicle location (usually via GPS) and destination, and door as well as motor statuses (Barth et al., 2003; Alli et al., 2012; Shaheen et al., 2004; Hara et al., 2000). However, some management systems constantly monitored these factors during the whole trip; some deemed it sufficient to download the data at the beginning and end of each trip, while others retrieved it every 30 minutes (Fukuda et al., 2003; Hara et al., 2000; Cugola and Rossi, 2012). Having GPS-based or similar devices installed for reasons of supervision opens further areas of appli-cation of the vehicle system and comprises of another process. A navigational device can, if desired, determine the most advantageous route to a target, as well as provide additional information concern-ing traffic or specific points of interest (Kitamura et al., 2000; Barth et al., 2013). Thus, once a customer enters his destination, the navigational system leads him there by constantly monitoring the vehicle location and calculating the route. Besides facilitating fleet management and user trips, vehicle supervision also allows for an indirect, incident-based communication between user, vehicle, and man-agement system. Since management systems constantly monitor the state of the vehicle, users can either be warned in advance, e.g. in case the battery is low, or when an acute problem occurs (Kitamura, 2002; Cugola and Rossi, 2012). In both cases, management systems can react promptly by conducting effective measures such as calling external services, sending emails or other kinds of alerts.

Apart from an indirect communication between user and vehicle, the vehicle system often comprises of means that enable external communication and thus support another important process. As described before in the assertion of the respective technologies, users can often establish a direct contact to the operating staff of the carsharing provider. By using stationary in-vehicle devices such as cell phones or built-in LCD screens, users can ask for guidance, assistance and even extend the time of rental if needed (Barth and Todd, 2000; Fukuda et al., 2003; Cugola and Rossi, 2012). Since the vehicle system controls vehicle access, it is also responsible for locking the doors once the user reaches his destination. In most cases, the user is simply obliged to return the vehicle keys to the glove box and take his personal belongings. This is registered by the vehicle system, which then locks the doors and, furthermore, sends relevant information such as trip data or current position to the management system (Mannan, 2001; Hara et al., 2000).

3.2.3 Management System

The management system is the most integrated and complex system being used in carsharing infrastructures. Since its functions span fleet management, handling of reservations and vehicle supervision, accounting, simulation and forecasting, and because it is partly required for vehicle access, the management system can also be seen as the core system of the carsharing programme (Hara et al., 2000; Barth et al., 2003; Cugola and Rossi, 2012; Milliard-Ball, 2005). Regarding the various carsharing concepts, the management system is consistently linked to and interacts with a database that saves all the relevant administrative and operative information (e.g. registration, user, and vehicle data) required for the supported processes (Shao and Greenhalgh, 2010; Cugola and Rossi, 2012; Barth and Todd, 2000). Comparing the registration and return component, as well as the vehicle system with the management system, the latter assists processes all over the various stages of the rental and even before. Furthermore, contrary to the vehicle system that merely serves the purpose of collecting vehicle data and granting vehicle access, the management system interprets this information based upon decisions will be made (e.g. initiate relocation procedures or change associated strategies). Thus, the processes are far more complex than the ones taking place in the other system components.

The initial process that is supported by the management system and belongs to the general fleet management process is the interpretation of overall vehicle data, upon which the management system intelligently determines the optimal fleet size, the distribution of vehicles, and relocation strategies (Weikl and Bogenberger, 2012; Clemente et al., 2013). In this regard, dual or single modules can be applied, whereas the first approach consists of utilizing both an offline planning and an online optimization module. The purpose of the offline module is to identify repeating demand patterns by analysing historical vehicle position and booking data that was gathered between each analysis. After finishing the analysis, the results will indicate the demand for each station ranging from highest to lowest. Furthermore suggestions concerning the ideal amount of vehicles per station will be made and therefore, the overall fleet size can be determined (Weikl and Bogenberger, 2012; George and Xia, 2012). However, since the offline module does not continuously monitor vehicle data, these analyses are conducted in chronological, such as daily, weekly, annual and event-based, intervals. Based upon these analyses, the management system then preselects a case-sensitive and viable relocation strategy for each station exhibiting a mismatch between demand and supply with the intention to reach an even distribution of vehicles (Weikl and Bogenberger, 2012). For instance, the system could determine general incentives irrespective of the current vehicle distribution, thus applying a user-based relocation strategy, which would be an effect for the whole day. The goal of these incentives would be to induce a shift of demand from stations of high demand to stations of low demand and vice versa (Weikl and Bogenberger, 2012). After preselecting appropriate relocation strategies, the aforementioned online optimisation module is required to determine and, finally, to choose the most efficient strategy out of these feasible options. Instead of using historical data, the online module continuously monitors the distribution of vehicles and compares the current with the nominal state, which was previously computed by the offline module (Weikl and Bogenberger, 2012). Depending on whether this comparison reveals that a station generally exhibits a surplus or a lack of vehicles, the system operator takes further measures. In the latter case, the operator needs to intervene in order to restore a balanced distribution, whereas in the first case no further actions are required, since the supply is greater than the demand. However, when an intervention and thus, relocation is necessary, the online module compares the suggestions that were made by the offline module. During this comparison, the online module evaluates the cost of each suggestion through the application of a specific cost function, whereby the strategy with the lowest costs will eventually be chosen (Weikl and Bogenberger, 2012). After this initial process, which is to be seen more or less independently from the actual rental procedure, since it is a general process not being bound to a specific rental, the reservation process begins. Provided that the customer previously conducted the registration procedure, where he is required to fill-in a form concerning personal data on the provider's website, he can start the reservation. The management system runs a server that provides a website and, more specifically, an online search function where the customer is required to state the date and time of rental, as well as the desired vehicle, the location and whether he needs further services (Barth and Todd, 2000; Fukuda et al., 2003; Mannan, 2001; Cugola and Rossi, 2012). Therefore, this process resembles the one being supported by the trip registration procedure, provided the carsharing stations dispose of a selection program. However, some of the management systems can identify these preferences (e.g. station and vehicle) and, after some reservations, can show them as suggestions the next time the customer wants to rent a vehicle, thus facilitating the rental process (Lose, 2010). Nonetheless, in case the customer immediately requires a vehicle, the system computes his request automatically and in real-time. Otherwise, the Management System commences the search for an appropriate vehicle using a vehicle allocation algorithm that considers the previously entered specifications, although it is limited to vehicles that are parked nearby the user (Cugola and Rossi 2012; Barth and Todd 2000). This process of distributing available vehicles as a function of specifications also belongs to the overall fleet management function and process. However, further search parameters that were not actively specified by the customer but which are nonetheless considered in the choice of vehicle are, when it comes to electric vehicles, current battery state or when the user wants to rent the vehicle at a later time, the estimated battery charge (Cugola and Rossi, 2012). Additionally, the system determines the distance of the trip, as it is quite important to assess the overall battery consumption and thus, the expected recharge time after rental (Fukuda et al., 2003; Barth and Todd, 2000). In case that at least one shared-use vehicle with the defined parameters is available at the nearest station, a reservation is both issued to the customer, as well as saved in the reservation section of the database (Fukuda et al., 2003; Cugola and Rossi, 2012; Barth and Todd, 2000). Depending on the system in use, some carsharing programmes require the user to confirm the reservation, since it would otherwise be erased (Cugola and Rossi, 2012; Shaheen et al., 2004). However, in most systems the reservation would then be sent to the vehicle system or, in other cases, the vehicle-component would retrieve the reservations itself as soon as that customer approaches the vehicle (Fukuda et al., 2003; Hara et al., 2000). As follows, at this point of rental the management system also plays an integral role for vehicle access because the system indirectly manages it through the vehicle system, as the latter will solely grant access to customers with valid reservations.

After determining relocation strategies, providing and handling the reservation and vehicle distribution, as well as granting vehicle access, the management system also deals with the accumulation and interpretation of vehicle data (Barth et al., 2003; Fukuda et al., 2003). As mentioned before, vehicle information is required to both choose viable relocation strategies and to handle customer requests. However, although these functions can mostly be provided by simply supervising various vehicle parameters, their sole observation sometimes does not suffice to manage a huge vehicle-fleet. Additionally, the great amount of data that accompanies this supervision also needs to be interpreted by native software such as the "T-Rex system", which is deployed at the Green Move project. This software not only enables the management system to identify recurring events and situations, allowing certain actions to be taken for prevention or solutions, but it also facilitates further functions provided by other systems (Alli et al., 2012). For this purpose, so called "event observers" such as the vehicle system send the data to the T-Rex system. Afterwards, the system analyses and processes these observations based on a certain predefined set of rules and automatically forwards them to other systems known as "event consumers" that require this information. These rules are more or less the heart of the event processing engine, since they define certain scenarios and thus, specify how the data is to be interpreted (Cugola and Rossi 2012,. For example, the event observers forward position as well as speed-related event data to the system, upon which it can identify certain events such as traffic congestions or accidents, since the rules imply that in case many vehicles stop abruptly on the same route, the latter occurred (Cugola and Rossi, 2012). Having identified similar situations, the management system can therefore advise the customer to change his route, consequently helping him to avoid these time consuming incidents.

As one of the last processes, the management system is required to calculate the fees of each trip (Fukuda et al., 2003; Hara et al., 2000). However, since the vehicle system constantly supplies the management system with trip related data, this process is less complex than fleet management processes. Usually, the fee is determined automatically by considering both the driven distance and the rental duration and can be displayed either constantly during the trip or upon reaching the destination (Fukuda et al. 2003; Hara et al., 2000). Moreover, since the customers are rarely required to immediately pay for the trip after their rental, the management system is obliged to save the billing information of each customer in the respective section of the operator’s database. This information is then used and summed up each month to determine the fees to be paid by the customer (Shaheen et al. 2004, p. 43).

In conclusion, the management system can be seen both as front-end, as well as back-end system. On the one hand, it directly interacts with the customer since it provides the web-content (front-end) and direct means of communication (e.g. user interface in the vehicle) and on the other hand, it is comprised of underlying sub processes (e.g. fleet management and vehicle supervision), where it interacts with the vehicle system, thus exhibiting back-end system features (Bianchessi et al., 2013; Alli et al., 2012).

4 Comparison of Carsharing vs. E-Carsharing Business Processes

In general, the process being depicted in the previous chapter can be seen as a generic business process. It could easily be adapted for both conventional as well as e-carsharing initiatives, since the applied systems, the infrastructure, as well as the underlying processes are very common amongst the various carsharing programmes that were analysed in this paper. This distinctive overlapping can be ascribed to the circumstances that the application of ITS is a crucial factor for the success of all carsharing programmes, as it not only notably improves the efficiency and manageability on the part of the carsharing providers, but corresponding technologies and systems also increase the customer's convenience before, during, and after the rental process (Lose, 2010; Barth and Todd, 2002; Shaheen and Wipyewski, 2003). Regardless of the vehicle in use, providing customer services such as enabling reservations, implementing vehicle navigation devices, automated billing procedures, and means of communication is very important for the overall customer satisfaction. Moreover, monitoring tools that contribute vehicle data, respective systems that can interpret and process this information, as well as fleet management systems that use this data to continuously determine appropriate relocation strategies, evaluate and improve the systems effectiveness, and handle customer requests are also crucial for these types of carsharing environments. Thus, as the technology and the systems architecture of electric vehicle carsharing programmes can be applied to conventional carsharing initiatives and vice versa, the business process is valid for both cases (Bianchessi et al., 2013; Barth and Todd, 2000). However, although the general business process is quite similar, both types of carsharing exhibit minor differences that primarily can be related to fundamental fleet management processes provided by the management system and, secondarily, more superficial processes located in the vehicle and trip registration system. Furthermore, although it does not affect the processes, some of the specified tasks are more important for e-carsharing than for conventional carsharing concepts and therefore require more attention or they take place in different system due to infrastructural differences. Consequently, as the following chapter aims at comparing these differences, it will be divided into the five sub-sections "Relocation", "Distribution", "Evaluation and Simulation", "Incentives and Billing", and "Infrastructure".

4.1 Relocation

As for the choice of viable relocation strategies, which is a process being provided by the management system, it is also greatly influenced by the selection of the vehicles being used in a carsharing programs. In general, determining the most suitable relocation strategy is achieved by solving optimisation problems which aim at maximizing specific key figures. Concerning carsharing, optimisation features a two-fold issue, in which the aim lies both at increasing the number of fulfilled requests, consequently improving the vehicle availability being especially important for customer satisfaction, as well as reducing the costs accruing from vehicle relocation (Touati and Jost, 2011; Barth and Todd, 1999). However, whereas the availability of conventional vehicles between rentals is only restricted by customer reservations and possible maintenance, further constraining factors have to be considered regarding electric vehicles. One of these additional factors is the remaining charge of the electric vehicle's battery after each rental and/or relocation process. Generally, it can be stated that the residual battery charge directly influences the potential of the distance driven in an electric vehicle in a proportionally linear fashion. This in turn implies that by each missing percent of battery charge, the maximum range decreases by the exact same amount. Following this logic, a vehicle being halfway charged can only cover half the distance (Bruglieri et al., 2013). Since the possible travel range strongly depends on residual battery charge and the travel range determines once again whether a vehicle is suitable for a certain request, it is especially important for e-carsharing operators to choose a relocation strategy that positively affects the battery charge in order to increase vehicle availability and to shorten recharging times (Bruglieri et al., 2013; Touati and Jost, 2011). Therefore, in the paper from Bruglieri et al. (2013), they tested a feasible operator-based relo-cation approach by modifying a common, so-called Rollon-Rolloff Vehicle Routing problem (RRVRP) for the setting of e-carsharing systems (see Bodin et al. 2000). Usually, these Rollon-Rolloff Vehicle Routing problems are optimisation problems, thus belonging to the field of combinatorial optimization, where the target is to minimise the total travel time being required of a certain entity in order to fulfill all the required tasks, consequently also leading to lower costs (Bodin et al., 2000). Although this problem and the pertaining mathematical solution, the mixed integer linear programmeming, were initially developed to minimise the travel time of tractors moving a single trailer from a cer-tain destination to disposal factories, it could easily be transferred to the setting of conventional carsharing and, more specifically, to distribution and relocation. In the latter case, instead of focusing on tractors, one would now aim at operator-based relocation schemes and consequently an employee or sets of employees that can only relocate one vehicle at a time. However, whereas the standard RRVRP and pertaining mathematical solutions would also apply for conventional vehicles, it had to be modified in order to allow for evaluating e-carsharing relocation strategies (Bruglieri et al., 2013). As a consequence, the authors added a specific variables such as one representing the residual charge. In both cases, pickup and delivery, the request would be defined by a certain location (i.e. the carsharing station), time and the residual charge. Regarding delivery request, where a vehicle is relocated to a location lacking available vehicles, this request could either be served when the residual charge was high enough for the trip succeeding the relocation (delivery), or when the minimum required charge level would be achieved through recharging before the vehicle would be required a new by a customer (Bruglieri et al., 2013). However, by modifying the initial problem by adding variables like the residual charge, the authors were not only able to eventually determine that their relocation approach would suit to the setting of e-carsharing programmes, but they were also able to conclude how much staff would be required to serve a given amount of requested relocations, thus helping to reduce operational labour costs (Bruglieri et al., 2013).

In conclusion, the evaluation of the economic feasibility of relocation strategies for electric shared-use vehicle requires the consideration of additional factors, such as recharging times and the remaining battery charge, in order to provide reliable as well as valid results on which carsharing operators can make appropriate decisions. Thus, the process of choosing respective strategies has to and does vary slightly between conventional and electric carsharing programmes. Nonetheless, it has to be mentioned that these differences in most cases solely concern the process of evaluating relocation strategies. Otherwise, the applied strategies are quite analogous among the different observed carsharing programmes and vary between user-based (i.e. incentives) and operator-based strategies (i.e. staff).

4.2 Distribution

The distribution of vehicles, which in fact is the underlying process of reservation systems, also displays various minor differences between e-vehicle and conventional carsharing programmes. One of the more general differences concerns fundamental decisions regarding the type of trips that are allowed for the customers. Although these decisions have the identical outcomes respecting the underlying processes of both kinds of carsharing programmes, they are worth mentioning, since they have rather drastic effects on the overall business process. One of the major disadvantages of electric vehicles is their relatively low travel range which, as mentioned beforehand, ranges from about 40 miles to 140 miles (Cugola and Rossi, 2012; Barth et al., 2003). Additionally, since the battery charge defines electric vehicles possible travel range, respective vehicles experience limitations regarding the customer requests they can serve (Barth and Todd, 1999). However, these limitations are in fact the reason why there is an almost perfect fit between electric vehicles and carsharing. In general, it has been observed in various studies that shared-use vehicles are predominantly used to make trips that take place in the relative vicinity of the customers. For example, Fukuda et al. (2003) observed, that the distances driven by electric vehicles rarely exceeded 15 miles, which lies well within the supported maximum travel range, whereas the mileage driven averaged around nine miles per trip (Fukuda et al., 2003). Because of this, electric vehicles are especially suitable for short one-way rentals, where customers can drop off the vehicle at any desired station, since it guarantees plenty of recharging opportunities while the vehicles are idle between rentals (Barth and Todd, 1999; Fukuda et al., 2003; Shaheen and Wright, 2001).

In contrast, conventional vehicles do not suffer from limited travelling ranges, since they can be refueled during the trip without having to conduct prolonged recharging procedures. This, in turn, is one of the main reasons, why the application of two-way rental schemes especially fits the use of conventional vehicles depending on fossil fuels. Two-way rentals are often characterised by longer trip distances, as customers are required to return the vehicle to the station, where they initially started this trip and not to the station which is close to their destination (Bruglieri et al., 2013). Therefore, the distance of each trip approximately doubles, when carsharing operators only allow for two-way rentals (Shaheen et al., 2004). Although both types of carsharing programmes could apply to two or one-way rentals, it is, respectively, necessary to state these differing applicability's of electric vehicles and conventional vehicles. The decision on which kind of rental should be allowed has strong impacts on the underlying business processes. Since vehicles are to be returned to their starting station when it comes to two-way rentals, corresponding carsharing systems do not require relocation strategies. One-way rentals, by contrast, are often disadvantaged vehicle distributions, since customers can return the vehicle to a station wherever they desire (Weikl and Bogenberger, 2012; Clemente et al., 2013; Barth and Shaheen, 2002). As follows, because conventional carsharing processes often apply two-way rentals, they differ from their respective electric vehicle counterparts in that respect, that they do not dispose of processes that both evaluate and determine appropriate relocation strategies and processes facilitating these relocations. Nonetheless, as carsharing operators have freedom of choice regarding their type of rentals, these disparities are not by default.

Besides these very general differences based upon the distinct applicability of electric vehicles and conventional vehicles, the distribution process of both types of shared-use vehicle programmes also further enact more minor dissimilarities. These are, again, due to the fact that electric vehicles run on electric energy and batteries to drive and thus, are subject to a limited range and need constant recharging. As these factors have to be taken into account while handling customer requests and trip planning, the distribution process has to be adjusted. In conventional carsharing systems, managing the distribution of vehicles is fairly simple. Since the vehicle system constantly provides the management system with vehicle data (i.e. desired destination, current location, vehicle miles travelled, fuel level) and the management system receives, manages, and therefore knows all future reservations, the latter can easily determine the availability of the shared-use vehicles (Barth and Todd, 2003). Unless a vehicle needs to relocated, requires maintenance because of technical issues or is already reserved in the period required by the customer, a vehicle allocation algorithm will intelligently evaluate vehicles suitability for rental and, eventually, will assign it to a customer request (Barth et al., 2003). Albeit most of the parameters of this vehicle allocation algorithm overlaps with the ones being considered in e-carsharing programmes, the use of electric vehicles nonetheless adds further requirements to the distribution process and, consequently, to the allocation algorithm in-use. As for electric vehicles, it is, previous to the trip, a premise for the management system not only to calculate the travel distance that is to be expected from the request, but also to determine the current drain caused by electronic devices and air conditioning, as these factors are linked with battery consumption and, therefore, the ensuing recharge procedure (Barth and Todd, 1999). Considering these variables, the management system can ascertain whether the vehicle disposes of sufficient charge to supply the requested trip. When the charge level matches the estimated travel range, the reservation will be accepted (Fukuda et. al, 2003). Furthermore, when a customer request lies farther in the future, trip time calculations can be conducted and taken into consideration by the management system to determine the future availability of the shared-use vehicles for the requested timeframe. These trip time calculations generally include variables such as boarding, transit, and unloading times as well as the time required to prepare a vehicle for another trip (Barth and Todd, 1999). Furthermore, whereas for conventional vehicles the time required for preparing them anew for another trip is focused on maintenance or relocation procedures, for electric vehicles this variable should also include recharging times. However, the recharging times would presumably only be taken into account regarding availability, when the residual battery charge does not suffice to satisfy a request, otherwise the electric vehicle would not require a recharging procedure. In order to ensure a sufficient battery level as well as an increase of the average battery charge, e-carsharing operators could establish a time-buffer between each reservation, consequently implying an additional process compared to conventional carsharing systems (Barth et al., 2003).

Besides these differences in the vehicle distribution process, the management system also should dispose of additional processes that, otherwise, would not be required in conventional carsharing systems and corresponding business processes. These vehicle routing processes originate from Energy Shortest Path Problem and aim at maximising the battery charge after each rental, therefore increasing the operational profitability and customer satisfaction, both being especially important for e-carsharing initiatives (Touati and Jost, 2011). This so called Energy Shortest Path Problem (EnSPP) is, in general, alike the Shortest Path Problem with Resource Constraints (SPPRC), which could also be applied to conventional carsharing systems. However, instead of being constrained to time resources, one is constrained to battery charge (Touati and Jost, 2011; Irnich and Desaulniers, 2005). Consequently, this problem again belongs to the field of combinatorial optimisation, whereas in this case of ESPP, the feature of electric vehicles to recharge batteries during deceleration phases is considered and used to determine as well as to provide the most appropriate route that would achieve the initial aim of maximising trip related battery charging (Touati and Jost, 2011). In short, the problem can be modeled as a directed graph, in which a set of nodes (representing actual geographical locations) is introduced and connected by a set of arcs. Each arc (representing the route taken), in turn, is related to a certain value, which is either positive or negative, depending on whether the battery loses or actually gains charge. Regarding the conventional SPPRC, this value would represent i.e. the cost and/or the time that is required to take a certain path (Irnich and Desaulnier, 2005). Eventually, the aim would consist of finding an origin-destination route that optimises the travel time while also complying with a set of predefined resources along each node of the path (Irnich and Desaulnier, 2005). Therefore, in case of the EnSPP, the resource constraint is the battery charge, which cannot fall below zero, and, serving as an additional side constraint, specific time windows. Consequently, when the vehicle would be returned to a customer after the designated time window, a path would be deemed unfeasible and therefore, would, eventually, not be considered (Touati and Jost, 2011).

All in all, the major differences between conventional and e-carsharing systems and their distribution processes lie within the underlying fleet management. Processes such as vehicle allocation, which deal with choosing appropriate vehicles for customer requests or planning their routes, have to consider the particular characteristics of electric vehicles. Since factors such as the residual battery charge and recharging schemes strongly influence the availability either through a limited travel range or the constraint to recharge a vehicle, need to be included in corresponding allocation algorithms and processes. Furthermore, through finding routes that maximise the residual battery charge after each rental, the overall vehicle-availability and, consequently, the profitability and customer satisfaction of e-carsharing systems can further be improved, whereas respective procedures of conventional carsharing systems would solely aim at reducing the resources required to handle a request.

4.3 Simulation and Evaluation

Besides varying processes concerning the reallocation and allocation of vehicles, e-carsharing systems comprise of further differences dealing less with the daily tasks and operational processes, but more with initial configuring and continuous evaluating of the system itself. As the limited travel distance of electric vehicles still entails the major drawbacks concerning customer satisfaction with electric vehicles and pursuing carsharing systems, carsharing operators need to ascertain that future customers can draw on an appropriately planned station infrastructure and vehicle fleet (Cepolina and Farina, 2012). This is especially important for electric vehicles, since establishing such an infrastructure is comparably expensive, but nonetheless mandatory for providing sufficient recharging opportunities (Tuoati and Jost, 2011). Furthermore, because the number of vehicles at each station can easily become imbalanced due to a varying demand throughout the day, it is even more important to maintain an appropriate number of stations and parking spaces with rechargers; otherwise customers would periodically not be able to recharge their vehicle, therefore limiting its travel range (Clemente et al., 2013). As for the respective mathematical model, this issue, also known as facility location problem, requires a slightly different approach when adapting it to electric vehicles (Wang, 2008). Although up to now there is a significant lack of literature tackling this issue, certain papers, however, can give an impression of which adjustments might be necessary when projecting the facility location problem on e-carsharing systems. In general, these adjustments consist of changing some of the various parameters and side constraints to fit the new scenario. Usually, the aim of minimising the set-up costs would remain the same for both types of carsharing (Wang, 2008). Nonetheless, additional variables describing the remaining amount as well as maximum battery charge and, moreover, the electric energy that was being recharged, were introduced to evaluate the situation at each station. Hence, a configuration that decreases the set-up costs while providing an appropriate infrastructure was to be found (Wang, 2008; Cepolina and Farina, 2012). As for the side constraints, they also mostly cover aspects pertaining to the required or the remaining battery charges, as well as energy consumption ascribed to recharging processes. Some more general constraints concern the stations service capacities or restrictions that define location capacities, consequently restraining the number of respective recharging stations that ultimately being considered (Wang, 2008).

Besides differences in processes that enable carsharing operators to determine the ideal set-up configuration of carsharing systems through minimising their set-up costs, further distinctions can be identified relating to continuous performance evaluation processes of this system, therefore often being a daily task. In order to test a systems effectiveness, several measures have to be developed providing details about the conditions of the system in-use. These performance indicators usually refer to three categories: "internal", "output", and "outcome" measures (Millard-Ball and Murray, 2005). Internal measures, primarily being used for internal management issues, encompass performance indicators such as vehicle utilisation and vehicle availability, whereas output measures quantify the number of vehicles in-use as well as active and inactive members (Millard-Ball and Murray, 2005; Barth and Todd 1999). Last but not least, outcome measures such as vehicle miles travel (VMT) or vehicle ownership, indicate the progress and impact of carsharing systems in achieving certain targets (i.e. reducing vehicle ownership) that are mainly being tied to and serve the common good (Millard-Ball and Murray, 2005). However, when operating an e-carsharing system, it is advisable to introduce further measures of effectiveness (MOE) that help to capture all additional aspects being entailed when using electric vehicles. For example, as conventional combustion engines use fossil fuels, while electric vehicles require an electrical current being provided by batteries, the deployment of the latter demands the introduction of a MOE that measures the average battery state of charge of all the shared-use vehicles. This, in turn, is very important, since it facilitates the evaluation of the effectiveness regarding the overall energy management of the system, consequently enabling operators to identify potential, respective issues (Barth and Todd, 1999). Besides this "internal" performance indicator, further MOEs can be introduced belonging either to the output measures or outcome measures. Additional output measures could quantify the share of low-emission vehicles of a carsharing system, provided both conventional and electrical vehicles are used. Furthermore, the impact of electric vehicles on the environment could be evaluated by adding an outcome measure called "emissions" that captures changes referring to the overall production of pollutants of the carsharing system (Millard-Ball and Murray, 2005).

In conclusion, most differences between conventional and e-carsharing systems of both simulation and evaluation processes rarely affect the choice of general procedures and methodologies, but rather the underlying parameters that are being used to solve them.

4.4 Infrastructural Differences

Although it was concluded that the applied technologies of both types of carsharing initiatives are largely identical, the deployment of electric vehicles entails additional technological requirements concerning the overall infrastructure, which in turn leads to distinctive processes. In conventional carsharing programmes, carsharing operators commonly used vehicles that either entirely depend on fuel, or utilize hybrid engines (Shaheen et al., 2004). Companies which provide shared-use vehicles solely relying on fossil fuels, such as natural gas or petrol, as well as fuel cards, offer the advantage of increasing flexibility. Thus, the customer's convenience of the whole rental process is greatly enhanced. Since the respective vehicles can easily and swiftly be refueled at any gas station and point of time during rental, customers enjoy fewer boundaries on the supported travel range and consequently, the destinations they can travel to (Shaheen et al.; 2004). Contrarily, electric vehicles cannot provide the same degree of flexibility as conventional vehicles. Since the range of electric vehicles is comparably low and ranges from 40 to 150 miles, customers would either have to refrain from making long trips or they would be forced to make stops for recharging, albeit this recharging procedure is characterised by its slow pace (Cugola and Rossi, 2012; Barth et al., 2003). Either way, because electric vehicles depend on electric energy that is being stored in batteries, they also require a battery charging infrastructure. Therefore, carsharing operators relying on electric vehicles cannot go without the use of recharging stations which can be equated to casual station kiosks on a functional level, albeit they are equipped with charging devices (Kitamura, 2002; Markel, 2010; Tuoati and Jost, 2011). However, although station kiosks may seem a bit outdated, considering that alternative check-out devices like smartphones exist, they can still offer some advantages, especially when it comes to electric vehicles. Provided their internal system operates with a system management algorithm, recharging stations can take additional vehicle-related information into account, which is, since the station is directly connected to the vehicle, more up to date than when the vehicle is solely supervised in fixed intervals (Barth et al. 2003). Since the factor "availability" presumably will not suffice to determine the most appropriate vehicle, considering aspects, such as the current battery level or the frequency of use, as a frequent rotation is desirable, can thus offer advantages (Barth et al., 2003). Now, since the registration and reservation would not necessarily be provided by the management system but the recharging station, the corresponding processes would also differ notably or would be located elsewhere. Additionally, recharging stations can support further smart processes that would otherwise be located in the vehicle system. For instance, features such as user authentication, locking and unlocking the cars as well as providing vehicle information could be handled by the recharging station (Alli et al., 2012).

All in all these infrastructural differences, provided the conventional vehicle programmes do not make use of station kiosks, solely imply a shift regarding the responsibility and location of the underlying processes. Thus, the processes themselves would not differ considerably, although instead of being handled by the management system, they would be managed by the recharging stations.

4.5 Incentives and Billing

When it comes to the billing process, both conventional and e-carsharing systems have very similar procedures commonly being performed by the management system. Due to vehicle supervision technologies, the management system can monitor trip related parameters such as the traveled distance and the length of rental, which, in turn, is able to calculate and display the fee to be paid both during the rental and after finishing the trip (Kitamura et al., 2000). Furthermore, besides analogous billing practices, the choice of financial incentives when applying user-based relocation strategies is, again, quite complementary. As the respective pricing strategies in most cases solely aim at balancing the distribution, the factor "battery" can, for the most part, be excluded. Nonetheless, for instance when a customer wants to reserve a vehicle for a trip in the distant future at a station that lacks appropriate vehicles, it might be advantageous to have a user-based relocation strategy and pertaining algorithms that would also consider the required battery charge for a trip as well as the overall battery charge of all vehicles. This could be helpful since considering the battery charge of all vehicles would allow the system to identify trips and corresponding vehicles that would both be terminated before the aforementioned reservation would be due and where the vehicle would still have a sufficient charge to serve this future request. Now, by offering financial incentives to the respective customer, he possibly would prefer to terminate his trip at the station that lacks vehicles, thus providing the initial request with an appropriately charged electric vehicle. However, as mentioned before, electric vehicles are at disadvantage due to significant range limitations either stemming from limited battery capacities, or because the residual battery charge is insufficient to serve a customer's request after a previous rental. Consequently, electric vehicles are very well suited for short-term rentals, because these trips not only imply small traveling distances, but also an increase in recharging opportunities, since the electric vehicles can be recharged comparably often whilst being idle between each rental (Barth and Todd, 1999). On behalf of the vehiclesharing operators, it thus might be advisable to implement pricing mechanisms and incentives that encourage customers to rent electric vehicles only for short periods of time. One of these possibilities was presented by Barth and Todd (1999). The authors proposed that carsharing operators can implement so-called retention periods that reward customers with fairly low prices per mileage and minute when they remain under these predefined limits. Otherwise, in case customers exceed these periods and drive longer than, for instance, 60 minutes, these fees become very expensive (Barth and Todd, 1999). Nonetheless, applying such pricing mechanisms might also yield some disadvantages on behalf of the operators and customers, since they not only decrease the flexibility of the system and thus lessen the customer satisfaction, but can also increase the waiting time. This can supposedly be accredited to the circumstances that the shorter a trip is, the faster the distribution of shared-use vehicles can become imbalanced. Now, as an imbalanced distribution means that some stations lack vehicles whereas others display an abundance of the latter, some customers are required to wait until some vehicles are either sufficiently loaded or a vehicle gets relocated. Either way, as both processes take up time, the average waiting time may increase when introducing retention periods (Barth and Todd, 1999).

Furthermore, as explained in subchapter 4.2, management systems are able to determine the most viable origin-destination routes for maximizing the residual battery charge after each rental. However, since providing the most viable routes supposedly would not suffice to actively influence the customer's behavior to the extent that they would actually follow these instructions, carsharing operators could and possibly should offer additional financial incentives. By adding respective incentives, the probability of customers taking these routes would probably rise, thus increasing the average battery charge of all vehicles and, consequently, their availability. Another chance of providing incentives would be to vary the mileage fees according to the customers driving pattern. Since higher velocities also require comparably more battery charge, carsharing operators could sanction customers exceeding the advisory speed limit (e.g. 130km/h), by charging more per every mile where the customers did not adhere to the latter. Besides influencing the user's trip behaviour, carsharing operators could also deploy incentives that would influence the customer's choice of their initial starting station. As mentioned before, an imbalanced distribution of shared-use vehicles is an undesirable situation for both customers and carsharing providers, since occasionally some stations would lack vehicles to serve customer requests, whereas at another station there would be an abundance of vehicles. Considering that this problem is especially more complicated when it comes to electric vehicles due to their need for finding free parking lots with recharge opportunities, e-carsharing operators need to find means to respond to these problems that exceed the sole application of relocation strategies. Thus, by providing financial incentives concerning the choice of starting point, carsharing operators could induce a shift in demand from hot spots (stations of high demand), to cold spots (stations of low demand), therefore improving the overall distribution of vehicles.

5 Discussion

The main issue throughout this analysis was to provide an appropriate degree of detail concerning the depiction of the business processes, while also illustrating a rather universal process that would constitute and be comprised of most of the characteristics and systems of the various carsharing programmes. At first, it was intended to outline both conventional and e-carsharing processes separately, based upon which a comparison would have been delineated, wherein the differences would have been discussed in greater detail. However, while consulting the various case studies, it became apparent that the infrastructure and systems of both types of carsharing systems did not differ notably and therefore, could have been used almost interchangeably. Nevertheless, a choice had to be made regarding whether the detail of the pertaining business processes to be modeled should have been increased, thus allowing a graphical comparison, or if the latter should be conducted in writing. Yet, as the differences are quite minor and located in underlying processes such as vehicle distribution, relocation, and simulation, their holistic depiction would have meant such a severe increase in detail that the illustration of both processes would have scarcely fit in this paper. Furthermore, some differences are so minor (e.g. slightly varying variables) that their graphical depiction would have been unnecessary, but nonetheless tedious. Therefore, the choice fell on modeling a universal process, while subsequently discussing the various disparities in the following chapter. However, reducing the complexity of the overall process consequently means lowering its explanatory contribution and value. This lack of detail constitutes a problem and it would, nonetheless, still be of peculiar interest and importance for researches, practitioners, and carsharing operators alike to graphically model the respective business processes in greatest illustrative detail. Therefore, future papers could venture deeper and focus on individual tasks. By specialising in, for instance, relocation processes, it would become viable not only to completely model a representative process, but also to compare it visually to both analogous conventional carsharing procedures, as well as alternative practices being applied in e-carsharing systems.

Another issue of this paper might be the choice of studies that were examined in the course of the paper. Since the initial research was solely limited to German and English research papers, the existence of further relevant studies cannot be ruled out. This could bias the results of this paper, as the studies were conducted in well-developed industrial countries, where the infrastructure of both the road network and electrical grid are highly advanced. As follows, other countries with a less developed infrastructure could require adjustments regarding the infrastructure of the carsharing system itself, as well as respective business processes. Hence, future researchers focusing on carsharing business processes should resolve this issue by either evaluating the additional challenges in these environments, or by comparing carsharing initiatives of industrial with less developed countries.

Furthermore, not only the choice of studies might have biased the depiction of the business process, but also that solely scientific papers, which focused on rather experimental carsharing systems and initiatives, were observed. As business processes highly relate to and have a foundation in reality, examining the carsharing initiatives from a customer’s perspective could have provided further insights towards an integrated business process. This is especially true when it comes to subsidiary processes that are relatively unimportant in scientific evaluations, but, nevertheless, have a high relevance for carsharing operators and customers alike. One of those examples could be the billing process, as in the research papers, it was - if ever - merely described. In most cases, the respective description was reduced to the reference that customers are obliged to pay monthly, as well as fixed fees per mile and minute. Therefore, further information on common and potential pricing mechanisms and corresponding incentives were omitted, since they were not deemed important in the first place. As for the business process, by going through an actual rental and billing process of an established carsharing provider, further knowledge could be contributed.

6 Conclusion

As the business processes of both conventional carsharing companies and their electric vehicle counterparts have probably never been illustrated holistically, the purpose of this paper was, on the one hand, to examine respective and common carsharing infrastructures, their systems in-use, and finally, on the other hand, to model and compare the associated business processes. Therefore, after the definition of terms and distinction of the various forms of carsharing programmes in the first and second chapter, the diverse intelligent transportation technologies and reasons for their implementation in carsharing initiatives were discussed. This was accomplished by including the findings of carsharing concepts being described in a variety of assorted case studies that encompassed both electric and convential carsharing programmes. Thereupon, it has been shown that applying intelligent transportation technologies is highly advisable and very common, since it not only strongly impacts the economic viability of carsharing initiatives through an increased efficiency, but also improves the customers’ convenience and satisfaction thereof.

Furthermore, as the potential of these technologies cannot fully be realized when being utilised individually, they usually are integrated as technology bundles into bigger systems. Generally, these systems would be separated as per their functions and the localisation of the processes being supported by them. Thus, in most studies the carsharing operators applied trip registration, vehicle, and management systems. The vehicle system usually provided data being used by the management system, supported the customer’s trip by enabling navigational aids and means of communication, and partly managed vehicle access. Moreover, the management system comprised of the most processes, also constituted as the prime processes, thus being the heart of the carsharing infrastructure, since it facilitated the general fleet management, as well as vehicle access, billing, and evaluation of the carsharing system itself. Last but not least, the trip registration system, which is localised in either carsharing stations or modern smartphone apps, was found to support processes that generally could be handled by the management system itself, but in some cases is conducted by the former due to certain advantages. Based-upon these systems, their infrastructure, and functions, the underlying business processes were derived in the second part of the third chapter. However, as it was found during the examination of case studies that both types of carsharing programmes tend to apply the systems and technologies, these associated business processes were designed to fit both settings.

Anyhow, the initial purpose of this paper was to conduct a comparison between the business processes of both carsharing systems. However, as their differences were so minute and therefore hardly representable, the comparison was conducted not graphically but written in chapter four. These differences mainly concerned the structure of the sub processes, such as the choice and setup of mathematical models and respective algorithms concerning the relocation and distribution of vehicles and the evaluation of the carsharing system itself. Notably, one should refrain from generalising the discussed findings, as the setup and choice of systems still depends strongly on both contextual and environmental factors, as well as preferences of the carsharing providers and the general purpose of the system. Nonetheless, this paper contributes to a general understanding of what characterises carsharing programmes and which systems and functions might be necessary to operate them sustainably and user-friendly.

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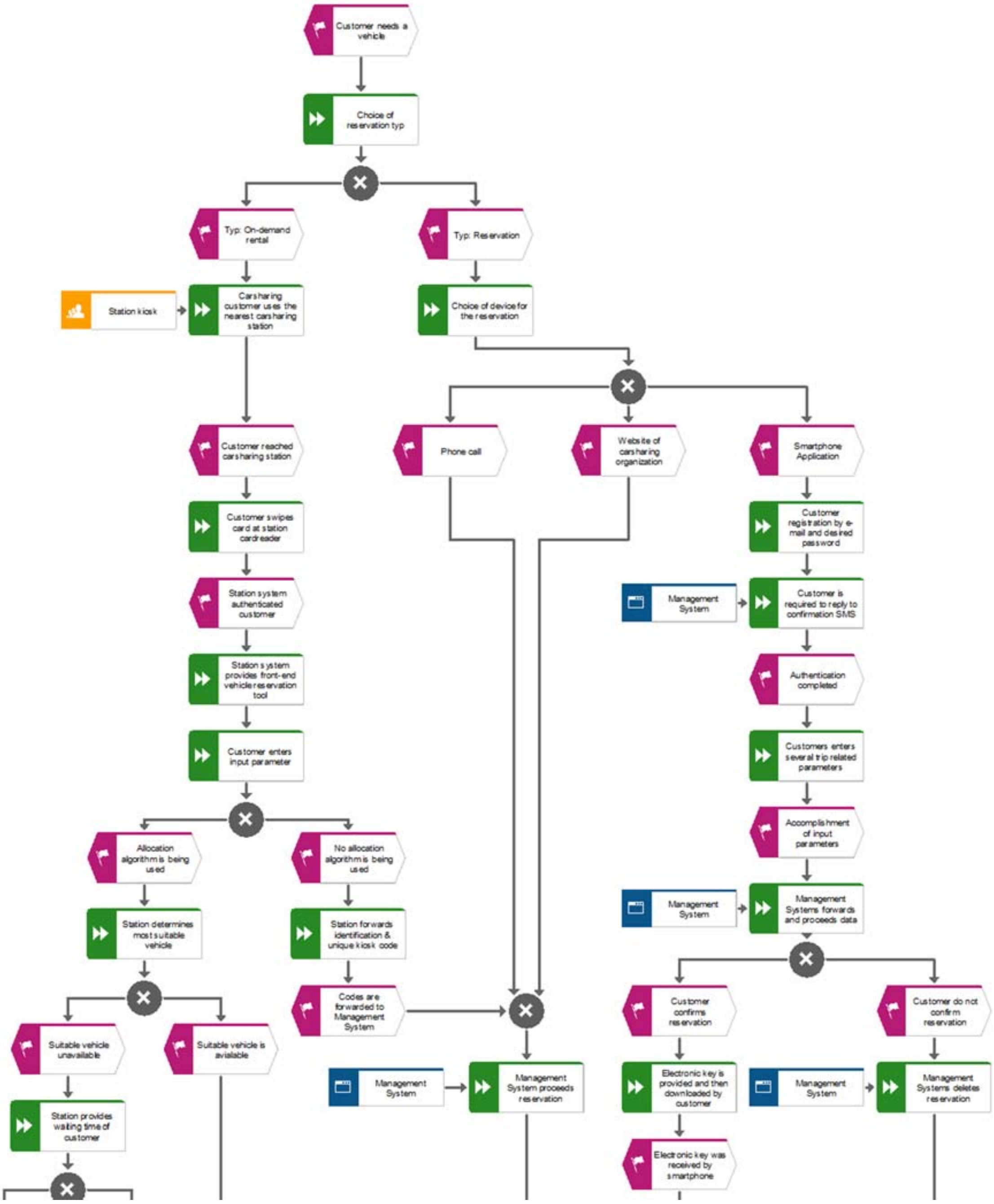
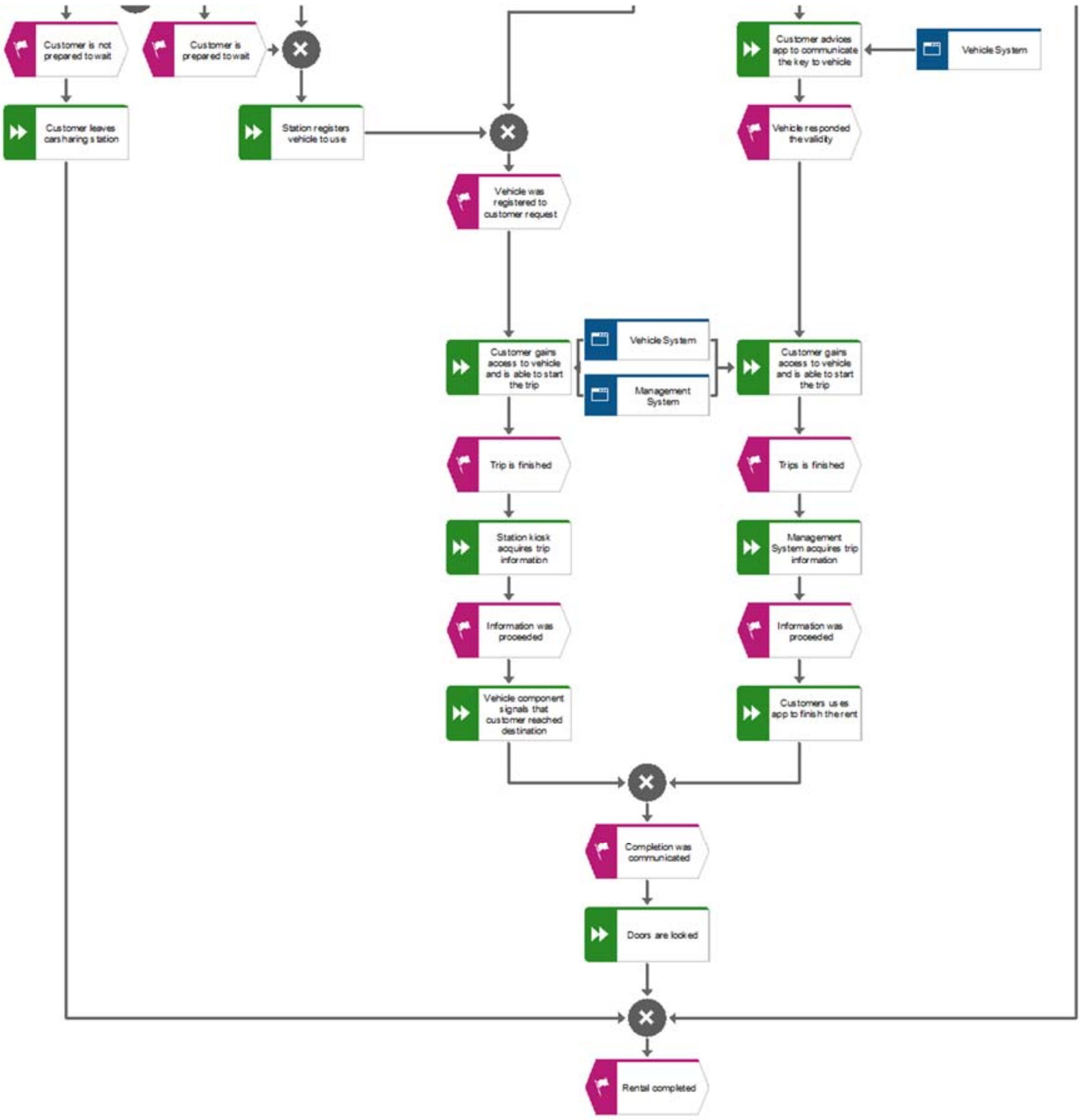
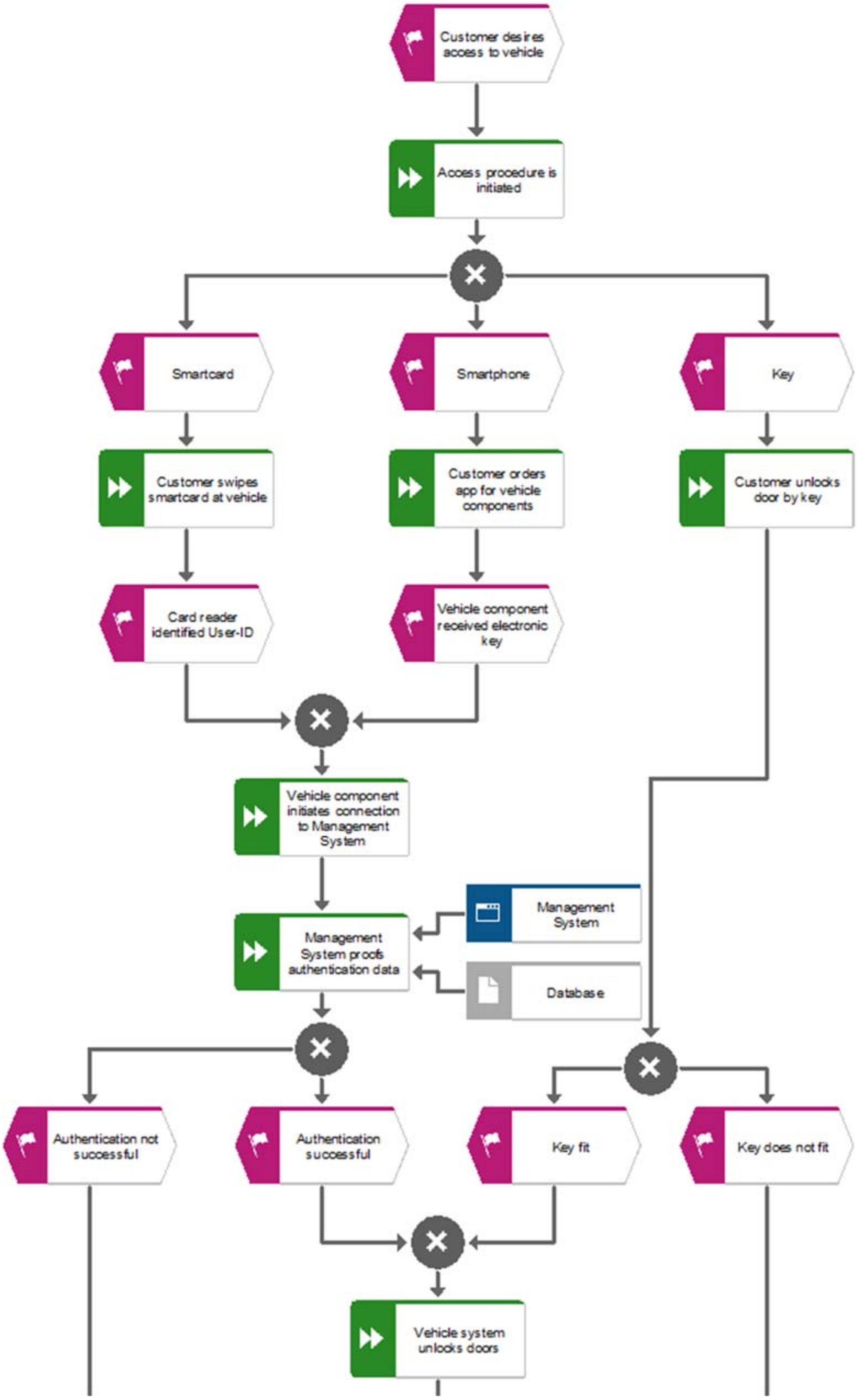
Appendix A: Trip Registration System

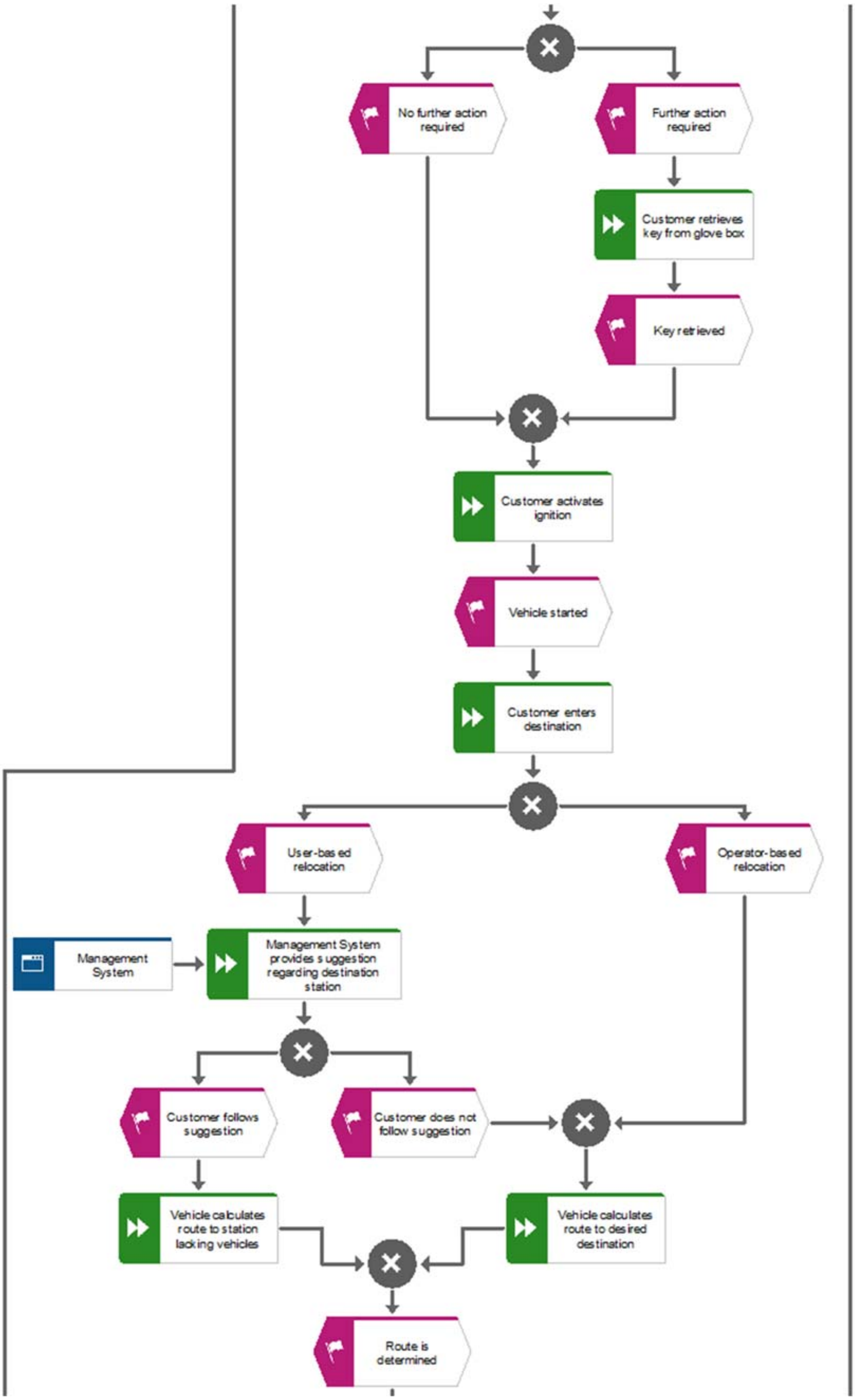


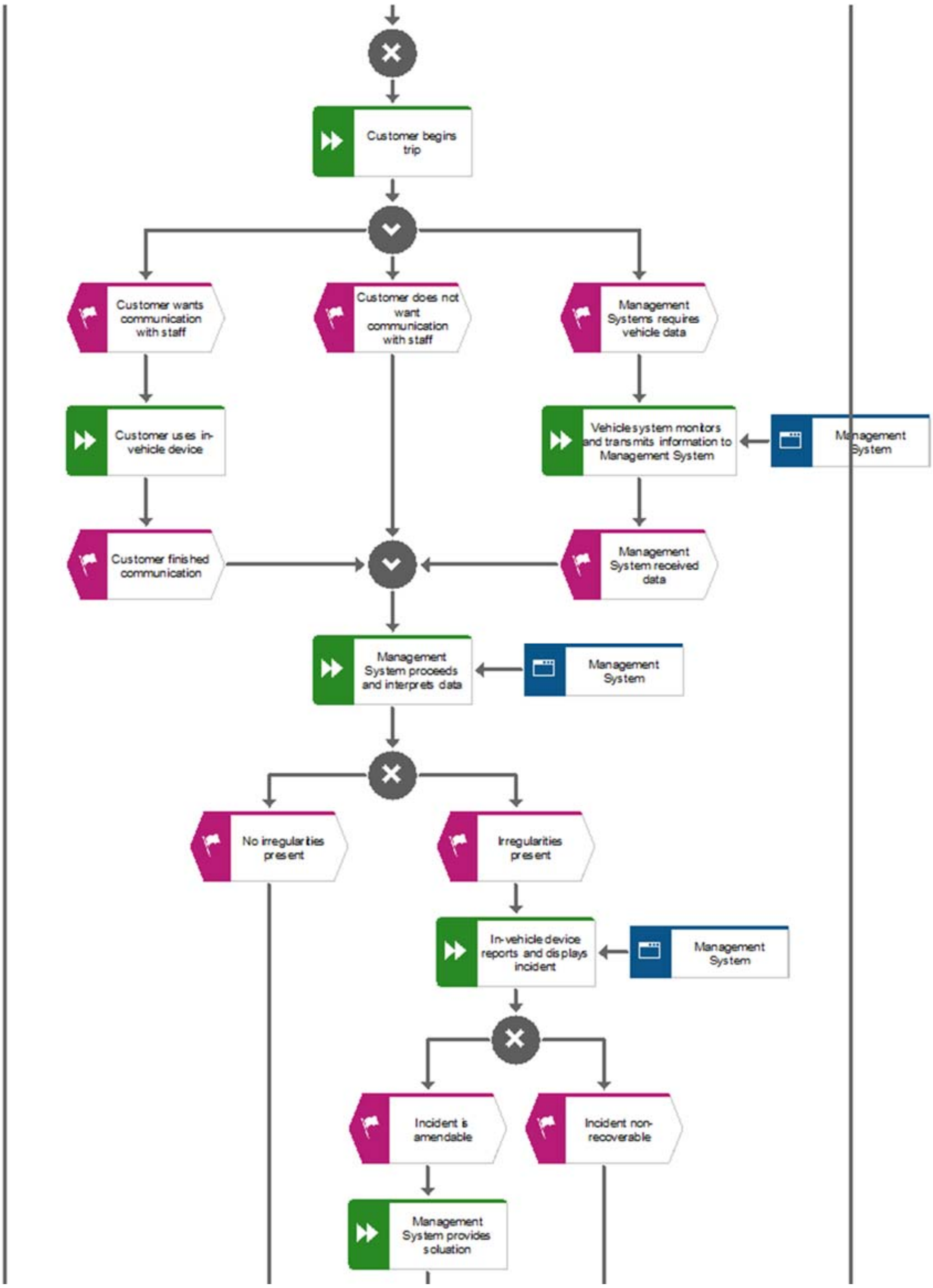


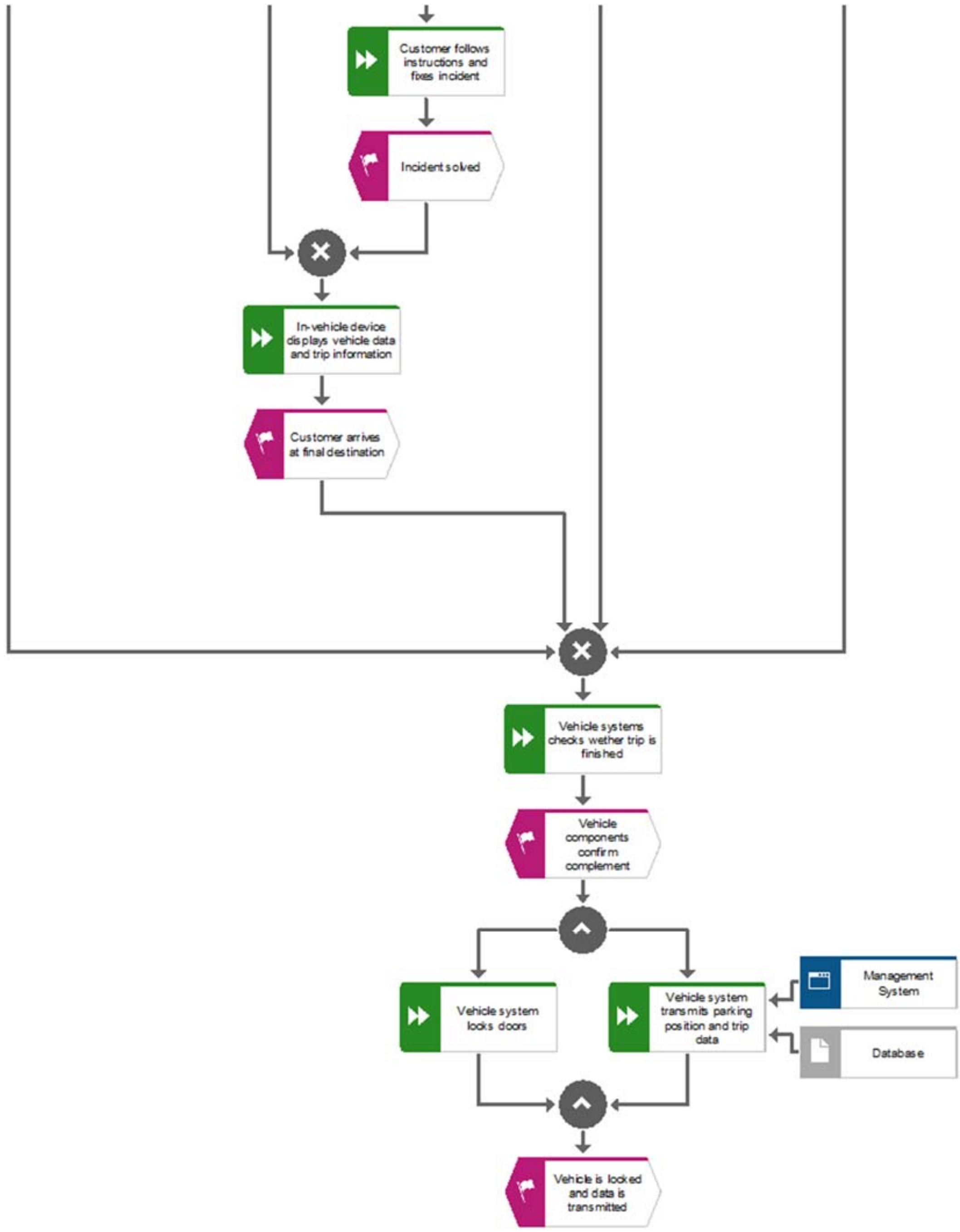
Customer is not prepared to wait
Customer is prepared to wait
Customer leaves carsharing station
Station registers vehicle to use
Customer advices app to communicate the key to vehicle
Vehicle System
Vehicle responded the validity
Vehicle was registered to customer request
Customer gains access to vehicle and is able to start the trip
Vehicle System
Management System
Customer gains access to vehicle and is able to start the trip
Trip is finished
Trips is finished
Station kiosk acquires trip information
Management System acquires trip information
Information was proceeded
Information was proceeded
Vehicle component signals that customer reached destination
Customers uses app to finish the rent
Completion was communicated
Doors are locked
Rental completed

Appendix B: Vehicle System

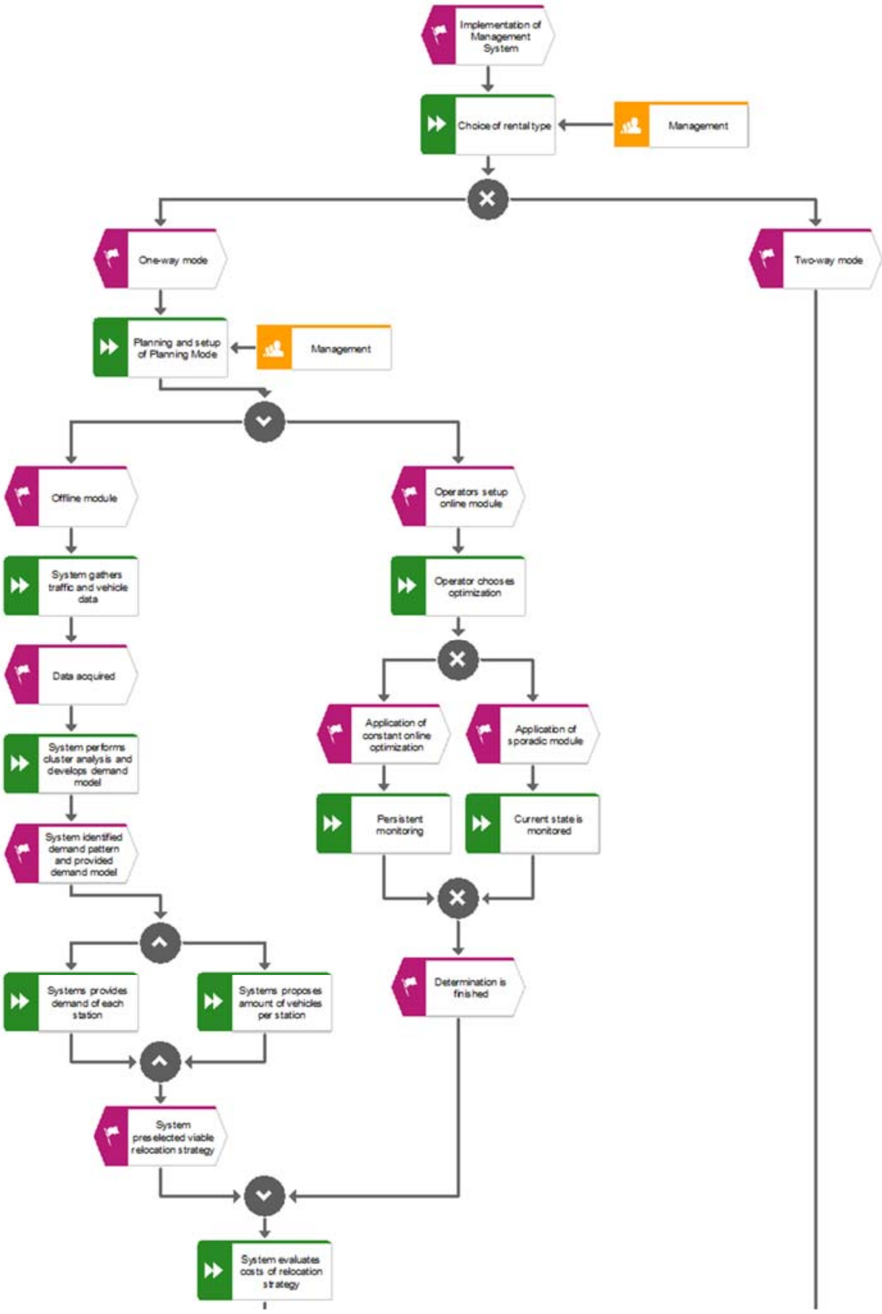


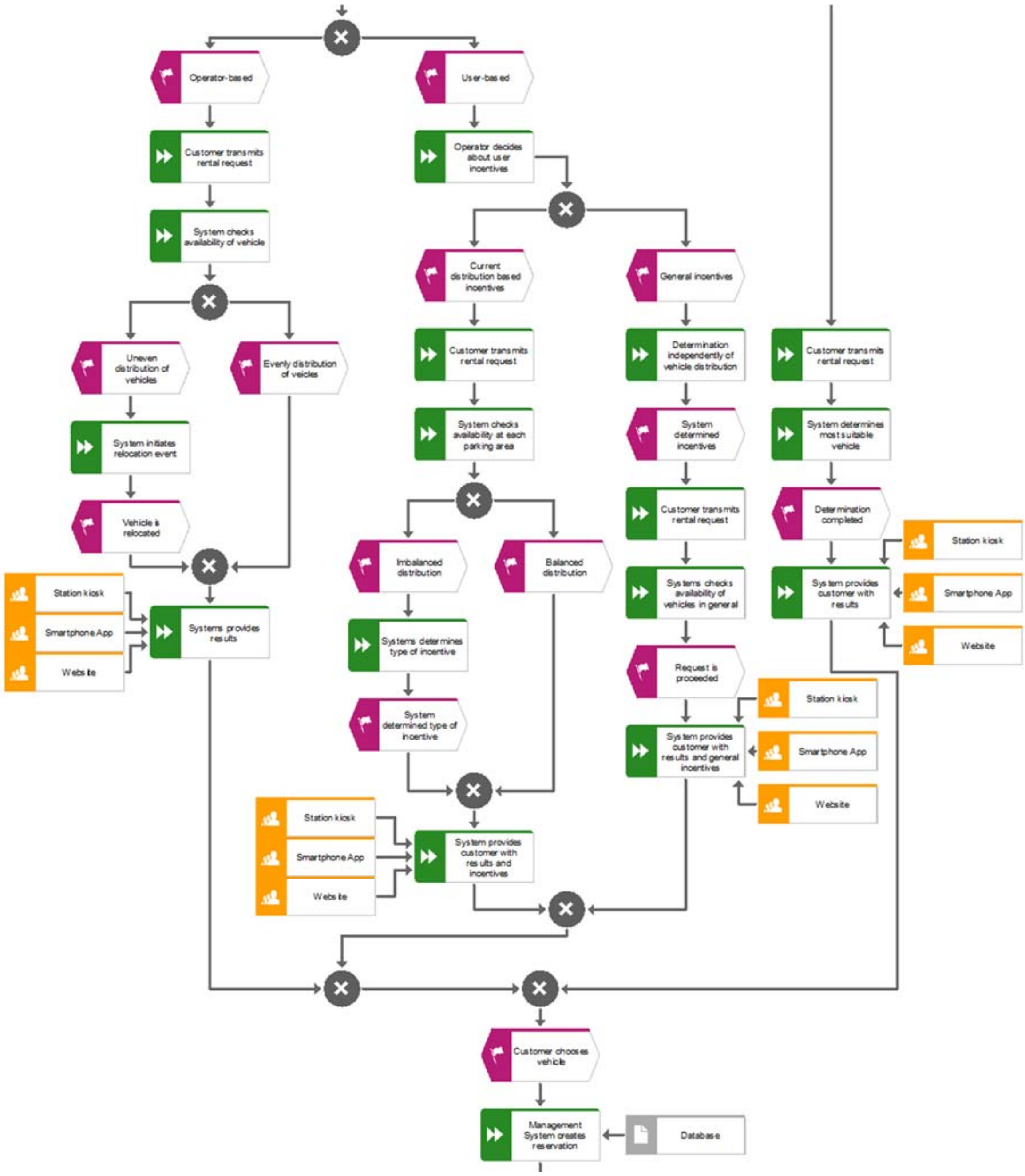

No further action required
Further action required
Customer retrieves key from glove box
Key retrieved
Customer activates ignition
Vehicle started
Customer enters destination
User-based relocation
Operator-based relocation
Management System
Management System provides suggestion regarding destination station
Customer follows suggestion
Customer does not follow suggestion
Vehicle calculates route to station lacking vehicles
Vehicle calculates route to desired destination
Route is determined

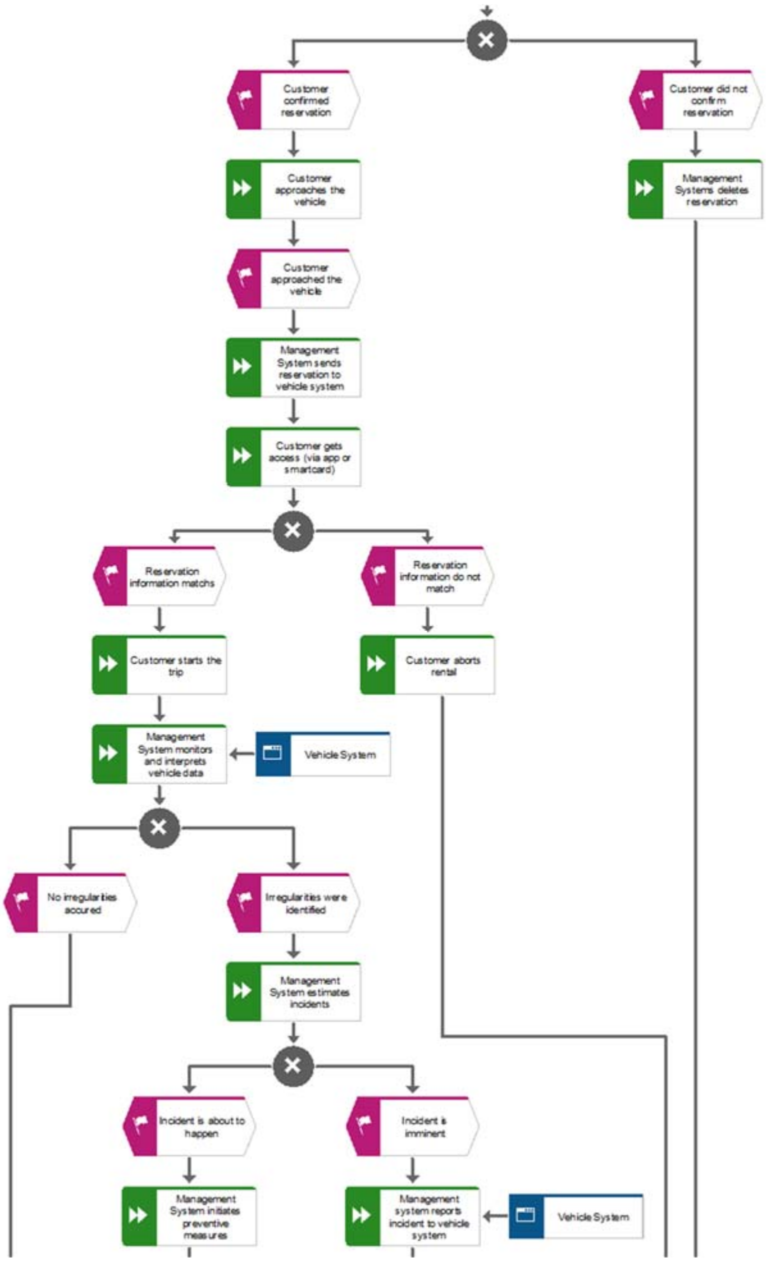

Customer begins trip
Customer wants communication with staff
Customer does not want communication with staff
Management Systems requires vehicle data
Customer uses in-vehicle device
Vehicle system monitors and transmits information to Management System
Management System
Customer finished communication
Management System received data
Management System proceeds and interprets data
Management System
No irregularities present
Irregularities present
In-vehicle device reports and displays incident
Management System
Incident is amendable
Incident non-recoverable
Management System provides soluation

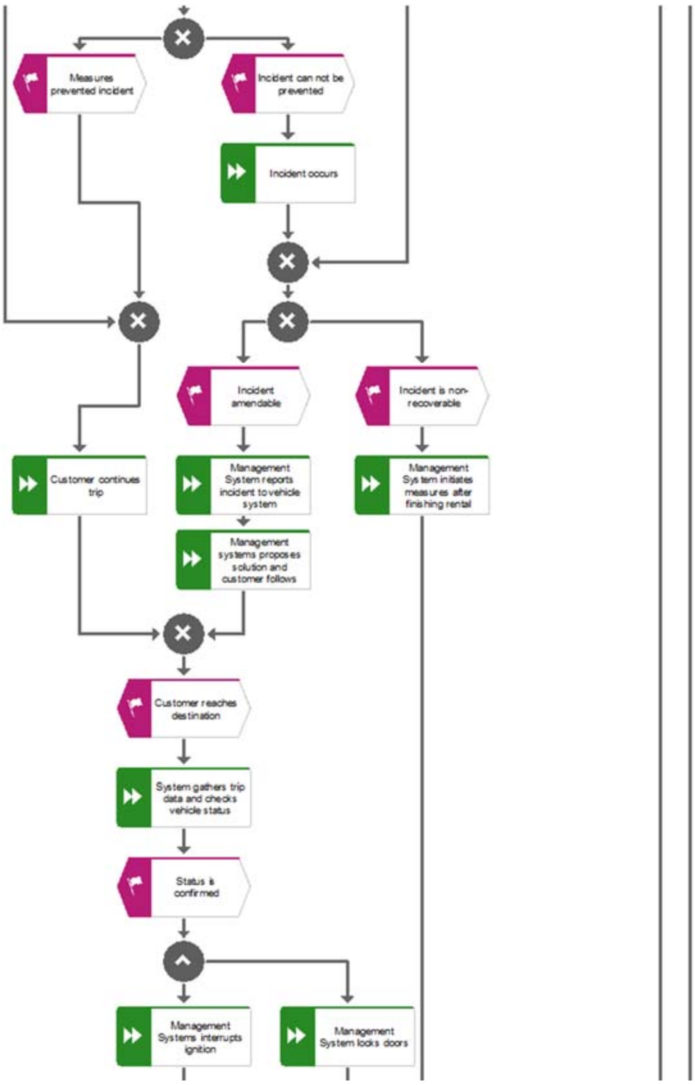

Customer follows instructions and fixes incident
Incident solved
In-vehicle device displays vehicle data and trip information
Customer arrives at final destination
Vehicle systems checks wether trip is finished
Vehicle components confirm complement
Vehicle system looks doors
Vehicle system transmits parking position and trip data
Management System
Database
Vehicle is locked and data is transmitted

Appendix C: Management System

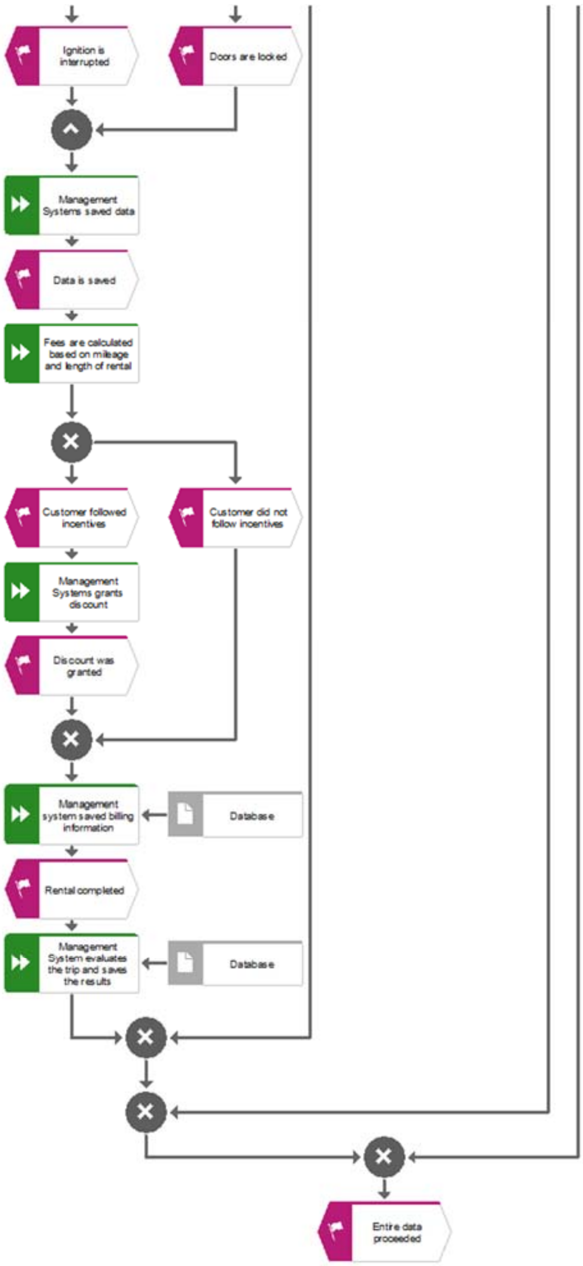



Operator-based
User-based
Customer transmits rental request
Operator decides about user incentives
System checks availability of vehicle
Current distribution based incentives
General incentives
Uneven distribution of vehicles
Evenly distribution of veicles
Customer transmits rental request
Determination independently of vehicle distribution
Customer transmits rental request
System initiates relocation event
System checks availability at each parking area
System determined incentives
System determines most suitable vehicle
Vehicle is relocated
Customer transmits rental request
Determination completed
Station kiosk
Imbalanced distribution
Balanced distribution
Station kiosk
Smartphone App
Website
Systems provides results
Systems checks availability of vehicles in general
System provides customer with results
Smartphone App
Systems determines type of incentive
Website
Request is proceeded
Station kiosk
System determined type of incentive
System provides customer with results and general incentives
Smartphone App
Website
Station kiosk
Smartphone App
Website
System provides customer with results and incentives
Customer chooses vehicle
Management System creates reservation
Database


Customer confirmed reservation
Customer did not confirm reservation
Customer approaches the vehicle
Management Systems deletes reservation
Customer approached the vehicle
Management System sends reservation to vehicle system
Customer gets access (via app or smartcard)
Reservation information matchs
Reservation information do not match
Customer starts the trip
Customer aborts rental
Management System monitors and interprets vehicle data
Vehicle System
No irregularities accured
Irregularities were identified
Management System estimates incidents
Incident is about to happen
Incident is imminent
Management System initiates preventive measures
Management system reports incident to vehicle system
Vehicle System



Measures prevented incident
Incident can not be prevented
Incident occurs
Incident amendable
Incident is non-recoverable
Customer continues trip
Management System reports incident to vehicle system
Management System initiates measures after finishing rental
Management systems proposes solution and customer follows
Customer reaches destination
System gathers trip data and checks vehicle status
Status is confirmed
Management Systems interrupts ignition
Management System locks doors


Ignition is interrupted
Doors are locked
Management Systems saved data
Data is saved
Fees are calculated based on mileage and length of rental
Customer followed incentives
Customer did not follow incentives
Management Systems grants discount
Discount was granted
Management system saved billing information
Database
Rental completed
Management System evaluates the trip and saves the results
Database
Entire data proceeded

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