Sustainable PSS in Automotive Industry 40

Christoph Herrmann and Katrin Kuntzky

Abstract

The automotive industry is confronted with an increasing servitization and rising mobility needs. Changing customer requirements and a changing awareness of the environmental impact of transportation generate a demand for new approaches for the realization of transportation. At the same time, the rapid development in information technology sets up new possibilities to create telematic solutions and to strike new paths in the development of mobility concepts. Sustainable product service systems in automotive industry can make a major contribution to foster resource and energy efficiency in transportation. With the combination of products, services, and infrastructure, the customer requirements on mobility can be satisfied and simultaneously the environmental impacts can be reduced. Thereby, the development of new product service systems in automotive industry needs to consider automotive-specific characteristics, the mobility of the automotive, and the exceedingly strong influence of external factors on the main function of the automobile.

Entire mobility concepts as future additional offers of (automotive) companies build on the basic idea of selling the mobility function instead of the product. They allow the usage and combination of different mobility enablers to combine with an integrative service and are part of the classification of result-oriented product service systems. To ensure a contribution

---

An Erratum to this article can be found at http://dx.doi.org/10.1007/978-1-4020-8939-8_130

C. Herrmann (✉)
Technische Universität Braunschweig, Institut für Werkzeugmaschinen und Fertigungstechnik (IWF), Braunschweig, Germany
e-mail: c.herrmann@tu-braunschweig.de

K. Kuntzky
Scientific Research Assistant, Department of Product- and Life-Cycle-Management, Institute of Machine Tools and Production Technology (IWF), Technische Universität Braunschweig, Braunschweig, Germany
e-mail: k.kuntzky@tu-braunschweig.de

J. Kauffman, K.-M. Lee (eds.), *Handbook of Sustainable Engineering*,
DOI 10.1007/978-1-4020-8939-8_56,

of product service systems toward sustainability in automotive, a solution in the conflicting area between the customer's requirements and available technologies is needed. This also influences the ownership structure of automotive transportation.

The high-service complexity generated by the servitization of transportation needs to be controlled. Therefore, future developments in the market of entire mobility systems depend on the development of telematic systems. With the diverse influences on automotive product service systems, like changing customer requirements to higher importance of sustainability, the technology push, or the handling of the immaterial service parts, the exposure and the management of sustainable product service systems in automotive industry across all life cycle phases become a serious challenge. Therefore, the framework for product service system life cycle management enables to consider the product service system life cycle phases, the management perspective, and the life cycle disciplines. Regarding this aspects, the prospective developments in passenger transportation can reach an increasing rate of servitization without losing the advantages of individualization.

1 Introduction

Changing customer requirements demand new mobility concepts and transportation facilities. In urban regions, and especially for younger people, the need to own a car is decreasing. New mobility concepts are based on services and are expected to be more sustainable than the traditional mobility means.

With the public discussions on CO_2 emissions and its consequences on the environment, the environmental concerns of automotive transportation today become more and more focused (European Commission 2012). At the same time, the rising costs, especially for gasoline and diesel, have a deterrent effect. Automotive manufactures are therefore increasingly forced to reduce the environmental impacts of their vehicles in order to fulfill the changing customer requirements.

The reduction of environmental impacts caused by mobility can be pursued by automotive manufacturers on the one hand through changes on the physical product like new drive concepts, improved aerodynamics, and lighter bodies. On the other hand, product service systems (PSS) in automotive industry provide the chance to reduce the ecological impacts of mobility in a holistic approach. The development of sustainable automotive PSS pursues the goal of minimizing ecological impacts and rising economic values.

2 Development in Mobility Structures

Mobility (i.e., the shifting of distance (Braess and Seiffert 2007)) is a basic need for human beings and our mobility activities are a basic requirement for economic

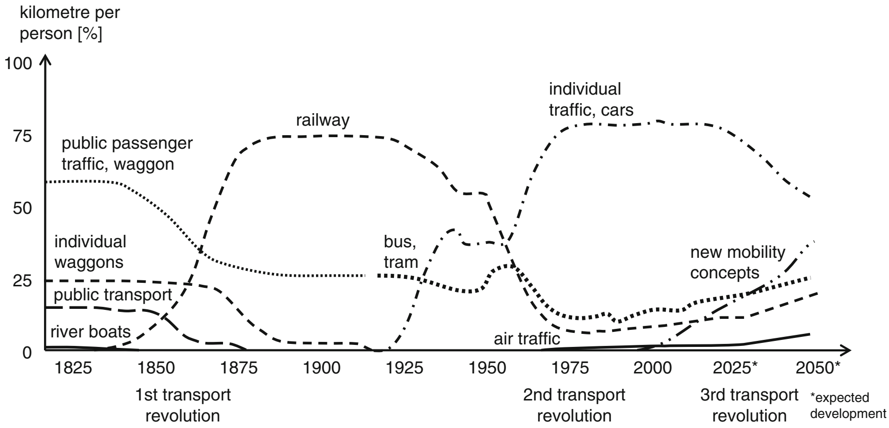

Fig. 40.1 The development of passenger traffic since 1820 using the example of Germany (Burgert 1996) and the expected development in passenger transport until 2050

success (Xu 2000). The goal to move faster, longer distances, with heavy goods and without physical efforts made humans use the available technical options at every time in history. With the development of the car at the end of the nineteenth century the second transport revolution led to more individual and flexible mobility. Today, more than 80% of passenger transportation (in kilometers) in developed countries is realized with a car (Eurostat 2011). The individualization of transport has led to a reduction of service integration during the last century in personal traffic. Figure 40.1 displays the development of passenger traffic using the example of Germany since 1820. Today, mobility starts altering rapidly again with the technical development and living standards in industrial countries as well as in emerging markets (Bundesministerium für Verkehr and Bau und Stadtentwicklung 2009).

During the last years, changes in the choice of transportation means have been identified. As shown in Fig. 40.1, it is expected that the integration of new mobility concepts based on (automotive) PSS may lead to a third transport revolution. Individual and public transportation could become connected, and the advantages of both systems, the individual mobility on the one hand and the economic and ecological advantages on the other hand, get interlinked (Herrmann et al. 2011). At the same time, a change in the technologies for transportation are expected. Figure 40.2 displays the adjustment in the sales figures from conventional cars to hybrid and electrical cars as well as to e-bicycles.

Compared to the overall passenger traffic, in major cities worldwide, only 50% of all driven kilometers are realized with a car. The other half of passenger transportation is today already covered by public transportation, trains, or by bike or walking (Ahrens 2009). Moreover, since 2004, a phenomenon of declining car use per capita can be observed in major cities in developed countries (e.g., in cities in the USA, in Australia, and also in Germany). Six interdependent factors were

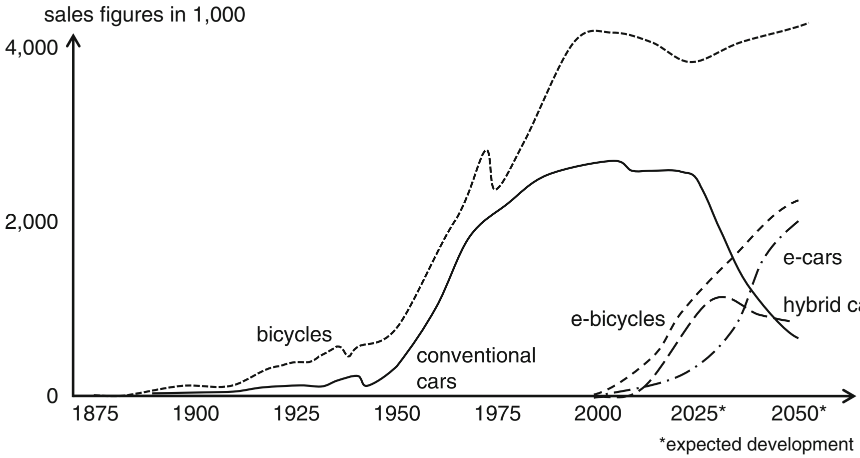

Fig. 40.2 Sales development and expected development of transportation means in Germany (Radverkehrsplan 2011; ibike 2011; urbanbiking 2011; VDA 2011; KBA 2011)

examined by Newman and Kenworthy (2011) to explain the causes for the peak in car use:

- The "Marchetti Wall": cities have a similar average travel time of approximately 1 h. Walking cities therefore cannot be larger than 5–8 km; automobile cities can reach out to 50 km. If cities grow bigger, fast trains are the only technical solution to stay in the travel time limits.
- Growth of public transportation: in developed countries (e.g., in the USA, Australia, and Europe), the public transportation has been growing up to 18% between 1995 and 2005.
- Reversal of urban sprawl: urban density has extremely declined within the last 50 years in industrial countries. This trend seems to have reversed in the last years.
- Aging of cities: the average age of people living in the cities of the developed countries has been getting older. Older people tend to drive less than younger.
- Growth of a culture of urbanization: a movement back into cities from suburbs, especially performed by the older generation, to a life without car dependence can be observed.
- Rise in fuel prices: the continuously rising fuel prices lead to urbanization and to a reduction of car use.

Furthermore, especially for the younger generation, a car is no longer a status symbol or an expression of life style (FOCUS 2010). Rising ecological awareness vary the choice for transportation means significantly. More and more customers are just interested in the satisfaction of their "mobility needs" instead of possessing a car. The trend leads to a demand-driven request of the needed mobility function (Herrmann et al. 2009).

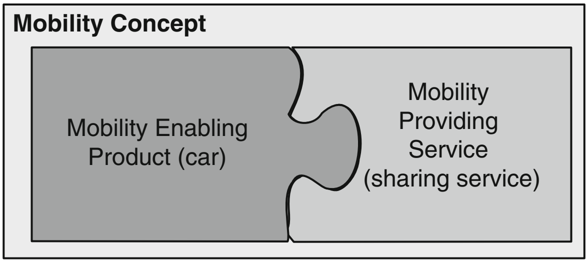

Fig. 40.3 Mobility concept for car sharing (Herrmann et al. 2009)

The average vehicle occupation rate is with less than 1.6 persons per car in the USA and Europe (European Environment Agency 2011; US Department of Energy 2011; Department for Transport 2011) at a very low level, most cars are even registered for five or more passengers. Moreover, the usage time of a car is in average less than 4% compared to the parking time (assuming a kilometric performance of 14,200 km/year (Bundesministerium für Verkehr and Bau und Stadtentwicklung 2009) and an average speed of 50 km/h). Thus, much more cars are on the market than are needed, which influences on the one hand the environmental impact when producing the cars and, on the other hand, the needed parking space for cars and therewith the needed land use, which is limited especially in urban regions, is higher than necessary.

Due to these changes in the mobility behavior and the mobility needs, the automotive industrial sector is particularly confronted with an increasing servitization, the adding of value through services to the core product (Vandermerwe and Rada 1988). New "mobility concepts," which represent an allocation of the function mobility to the customer, occur on the market. This function is realized with the integrative combination of a mobility-enabling product (e.g., car) and a mobility-providing service (e.g., a sharing service, Fig. 40.3). It can be understood as a product service system (PSS) (Herrmann et al. 2009) (e.g., a car sharing service system).

3 Aspects of Sustainability in Automotive PSS

Due to motorization and traffic density, the emission of, for example, greenhouse gases by street traffic is a major problem. In the European Union, the CO_2 equivalent emission by street traffic amounted to 877 million tons per year in 2010 (19% of the overall CO_2 emissions, see Fig. 40.4) (European Environment Agency 2011). The share of CO_2 emission is highest in the more developed countries, but developing countries have the highest emission growth rates (International Energy Egency 2002). CO_2 emissions of street traffic were increasing by 21% during the last 20 years. In the same time, the overall CO_2 emissions were decreasing by 17%. With regard to the whole life cycle of a conventional automobile, the use

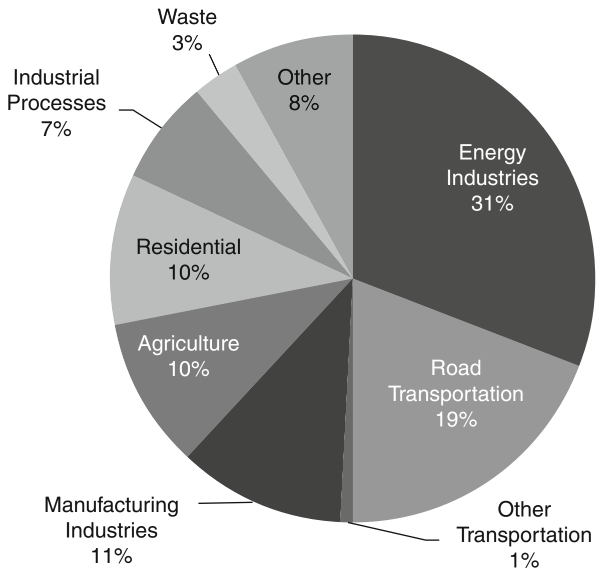

Fig. 40.4 Share of total greenhouse emissions (CO2 equivalent) (%) in 2009 in EU27 (European Environment Agency 2011)

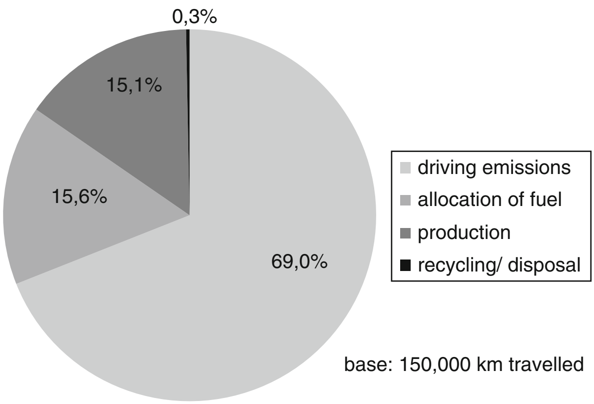

Fig. 40.5 Emissions (CO2 equivalent) of VW Golf VI over life cycle phases (Volkswagen 2011)

phase can be identified as the most important phase from an ecological perspective for detecting reduction potential. This phase causes significant CO_2 emissions compared to the life cycle (see Fig. 40.5).

This clearly indicates the important role of the automotive industry sector with regard to future efforts in reducing CO_2 emissions. Since CO_2 emissions per individual vehicle (especially in new cars) are continuously declining, an exclusive technical solution is not sufficient. Rather, sustainable automotive PSS are needed to achieve real success in reducing the environmental impacts of mobility.

The introduction of sustainable PSS can contribute to increase resource and energy efficiency in automotive industry. With the combination of products, services, and infrastructure, the customer requirements on mobility can be satisfied and simultaneously the environmental impacts can be reduced (Kuntzky and Herrmann 2011). Concurrently, economic and social aspects are of major importance for sustainable mobility as well. As mobility is a relevant condition for economic growth in our society, access to mobility is a requirement for personal welfare. The implementation of automotive PSS reduces obstacles in the access to mobility. Flexible cost structures, for instance, allow an adopted mobility access for different social and economic conditions. Therefore, PSS can contribute to a holistic sustainable mobility.

Different approaches (e.g., Goedkoop et al. 1999; Mejcamp 2000; Stahel 2011) assume that PSS generally have a positive influence on ecological impacts. This idea does not integrate rebound effects, the forfeit of savings due to, for example, changing customer behavior. The saved money or time may be spent in an unsustainable way (Manzini and Vezzoli 2003). Nevertheless, PSS have the potential to be a more sustainable solution for the customer demands than a pure product solution can be. The servitization can lead to a reduction of environmental impacts as well as a reduction of costs by typically influencing three factors: changes on the physical product, changes in infrastructure, and changes in the handling of the user (Brezet et al. 2001). This can also influence the organizational structure and the ownership structure of the offer (Roy 2000) as well as the total amount of products needed. While in conventional individual traffic, the driver is mostly the owner (or at least the lessee) of the vehicle, the driver often becomes a short time renter of the vehicle or even only of a seat in the vehicle with regard to automotive PSS.

Sustainable PSS therefore can be assigned to different categories, depending on their way of influence. Different authors decided on various categories for the sustainable PSS. While Roy (2000) categorizes PSS in result services, shared utilization services, and product life extension services, Behrendt et al. (2003) undertakes a more differentiated division of product service combinations in services additional to a product and service substituting a product. Substituting services are divided into result-oriented and use-oriented services, which are again differentiated into joint use and individual use services. Williams (2006) classifies sustainable PSS in product, use, and result-oriented services.

Combining these classifications, sustainable automotive PSS can be structured as follows:

- Product-oriented automotive PSS: on the one hand, aiming to reduce the impact of the mobility enabling product itself and on the other hand aiming to extend the useful product life through maintenance, repair, reuse, and recycling.
- Use-oriented automotive PSS or shared utilization PSS: mainly focus on increasing the usage rate of the single mobility enabling product by, for example, sharing a car. This leads to higher capacity utilization of the product and therefore reduces the total amount of products needed.

- Result-oriented automotive PSS: realizing a reduction of the material usage by offering the "result" instead of the product, for example, offering a ride, not a car. The provider becomes responsible for the whole life cycle of his offer, from production to recycling. Despite of enhancing the demand for a product, a solution for a sustainable performance is in focus.

4 Characteristics of Sustainable Automotive PSS

With the changing mobility structures, numerous PSS in automotive industry are marketable. With regard to the product "automobile," two main characteristics can be identified that help to describe the requirements for the automotive PSS. First, the "mobility" of the automobile influences the PSS. As the main function of automobiles is the transport, automobiles are not stationary. It is not known before where the automobile is located when a certain PSS function is needed. Therefore, all PSS have to be adapted to the mobility. Solutions can be that the PSS is as mobile as the automobile itself (which means the PSS provider has to follow the customer) or the PSS is omnipresently available (a network of providers offering the PSS). The second characteristic is the exceeding strong influence of external factors on the main function of the automobile. The accomplishment of the main function, mobility, is not only influenced by the automobile properties itself, the driver's ability, and the driving style. The transport activity also depends on the infrastructure (road conditions), the behavior of other road users, road work, or the weather.

As shown in Fig. 40.1, mobility has changed from a public passenger transport to an individualized means of transportation. Existing PSS in automotive industry therefore have to integrate the customer demands on individual and flexible transportation.

A survey with the target group of commercial customers (fleets) in the branches of passenger transport operators, car sharing providers, and municipalities in Germany regarding their usage of automotive PSS displayed several customer demands on automotive PSS (Kuntzky and Herrmann 2011):

- The surveyed target groups are primarily interested in services to reduce the effort in detecting failures in the vehicle.
- Services simplifying and optimizing the internal processes are as well particularly interesting.
- Environmental orientation is of different relevance in the target groups and can only be in focus if it is not leading to higher complexity and is easy to realize and at the same time reduces costs.
- Original equipment manufacturer enclosing solutions for the whole fleet are demanded.
- Services that lead to a positive impact on the driving behavior without addressing every driver personally are of interest.
- A positive public image coming with the use of sustainable automotive PSS is important for commercial customers, which was indicated especially in the target group of municipalities.
- High initial investments are not tolerated, particularly in small fleets.

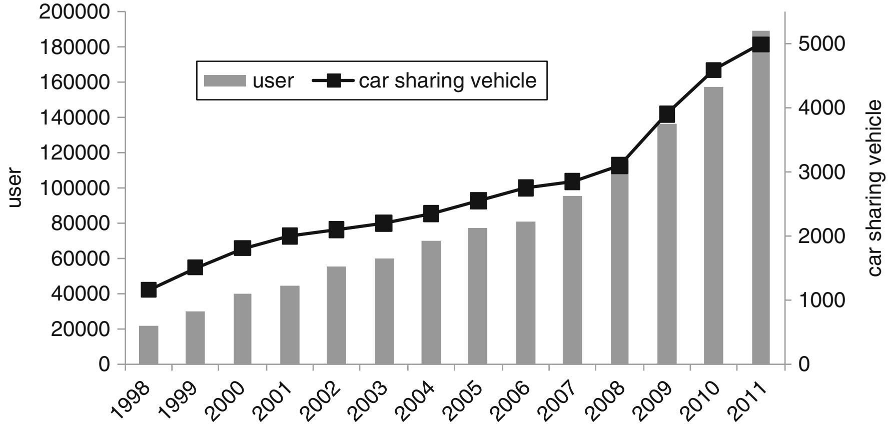

Fig. 40.6 Development of car-sharing market in Germany (Bundesverband Car Sharing 2011)

Offered automotive PSS in the market started with product-oriented services like repair or financial services. Use-oriented PSS can be observed in the area of after-sales services, like maintenance services, concentrating on the reduction of fuel consumption. With the upcoming usage of telematic devices, use-oriented PSS are created to enable services like remote diagnostics, reporting of the driving behavior, or influencing the driving routes toward a more economic or ecological way. Car sharing offers are part of the use-oriented PSS as well (Kuntzky and Herrmann 2011). The car sharing market in Germany is for example expanding (Fig. 40.6). High growth rates of 79% in 2007 can also be observed in other important markets like the USA (Shaheen et al. 2009). First original equipment manufacturers start to develop special cars optimized for car sharing concepts. Car2go for example developed the smart in a car2go edition with specific telematic devices for the car-sharing usage and with solar cells on the roof providing the energy for the telematic devices (Car2Go 2011).

Entire mobility concepts as future additional offers of (automotive) companies build on the basic idea of selling the mobility function instead of the product. They allow the usage and combination of different mobility enablers to combine with an integrative service and are part of the classification of result-oriented PSS. They are intensively discussed in literature but not available on the market today or only in simple and local solution like, for example, park and ride or combined bus and train tickets (Herrmann et al. 2009).

Therefore, the dimensions of mobility concepts have to be investigated for applying the technology and market concept. To ensure the aspects of sustainability (especially the ecological advantage) of the PSS mobility concept, a solution in the conflicting area between the customer's requirements and available technologies is needed. Figure 40.7 illustrates the product "mobility concept" within these conflicting areas: "technology" and "market."

With the integration of PSS in automotive industry and at the latest with introducing entire mobility concepts, new pattern of ownership occurs on the

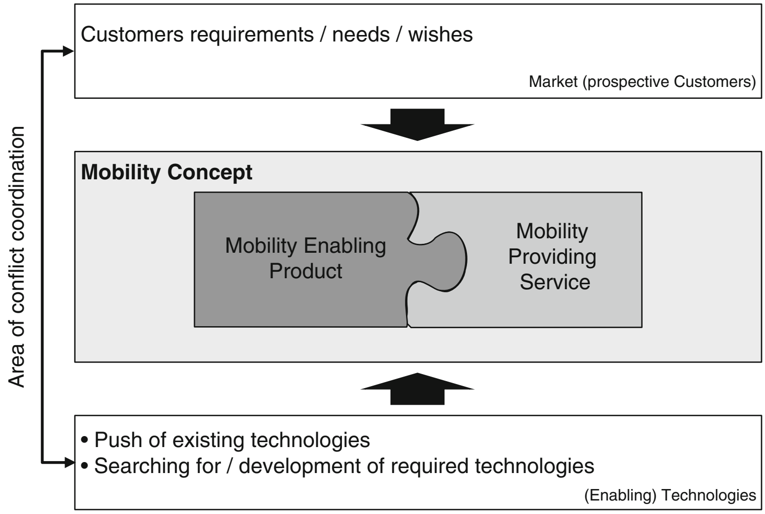

Fig. 40.7 Components of a mobility concept and market pull, technology push (Herrmann et al. 2009)

market. Starting with leasing systems, the provider gets more interested in designing durable and resalable vehicles. When car sharing systems are in focus, the ownership structure is radically changing. The user is only in possession of the car during the actual usage time itself. Therefore, in total the responsibility for the car is with the provider. He is also responsible for repair and maintenance. At the same time, car sharing concepts lead to higher usage time of the car itself. An increasing average of passengers in the cars can only be reached by ride sharing concepts.

For the area of street mobility, beside the car several other mobility systems are available. Figure 40.8 represents one hypothesis of the (ancestral) relationship between those mobility systems. The starting point is represented by the "walker." Then two big groups of mobility systems can be differentiated (Herrmann et al. 2011).

Both sectors start with bicycle-based mobility enablers. In the upper sector, the user is the owner of the product. Here, only the product is providing the realization of the required mobility. From the starting point, the drives are changing from muscularity drive and the usage of muscularity of animals to the usage of electric and combustion engines. Going from left to right the reachable velocity, the coverable distance and the number of passengers are rising with growing distance from the starting point as well as the environmental impact and the variable costs.

In the lower sector, systems with a higher level of servitization are displayed and the point of departure is changing from completely flexible to station-based systems. The stations itself can be fixed (like busses) or flexible (e.g., taxi). From left to right the environmental impact, the velocity and the traveled distance are rising as in the upper sector. In the mobility systems "rickshaw," "motor rickshaw," "public bus"

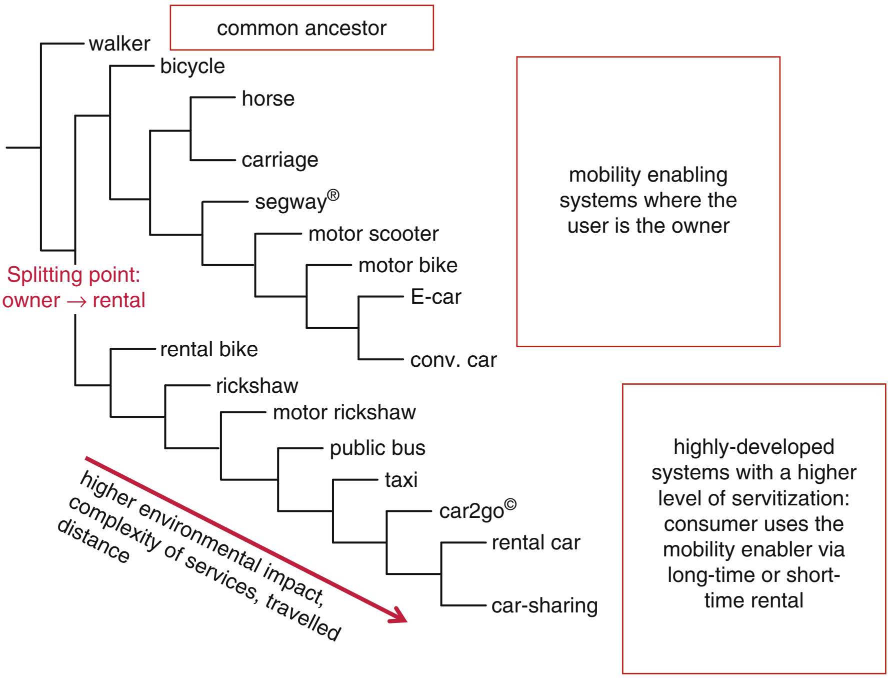

Fig. 40.8 Cladogram of mobility enablers (Herrmann et al. 2011)

and "taxi," the user is a passenger and is only renting a seat; in "car2go®," "rental cars" or "car-sharing," the whole vehicle is rented and the user is also the driver. Further differentiations in this sector are the length of the rental (from short-term rental, e.g., taxi, to long term, e.g., rental car), the amount of passengers per vehicle (e.g., one for rental bike to several in busses), and the time and route flexibility of the system (scheduled and fixed point of departure and arrival, e.g., busses, and flexible time and point of systems, e.g., rental cars).

This cladogram points out that rental car, car sharing, and car2go© today are the most enhanced mobility systems for passenger transportation. This mobility PSS enable the user to travel with high-velocity long distances and comparatively flexible. The service complexity is already very high. Due to the allocation of the car for more than one user, and therefore the sharing of the product part, the cost per user as well as the environmental impact becomes less. Nevertheless, these systems are not supporting a higher range of passengers per car. Furthermore, the systems are based on a single mobility enabler. Therefore, they allow further improvement in the area of result-oriented automotive PSS.

To control the high service complexity, particularly car sharing and car2go© are dependent on telematic systems for sharing solutions. Therefore, future developments in the market of entire mobility systems depend on the development of telematic systems.

5 Technology Push for Sustainable Automotive PSS

A substantial requirement for the integration of sustainable PSS in automotive industry is the provision of service-enabling technology. Preconditions coming from different disciplines had to be established to enable sustainable automotive PSS without any losses in functionality and comfort, respectively, to enhance functionality and comfort. The rapid development in information technology sets up new possibilities to create telematic solutions in automotive industry and is particularly involved in the development of automotive-related PSS (Herrmann et al. 2011).

The term telematics integrates telecommunication and informatics (Nijkamp and Pepping 1996), whereas the science telematics means the integration of telecommunication, automatics, and information technology (Mikulski 2010). It describes the use of modern technology to increase the efficiency in transportation processes, to enhance security and travel comfort, and to reduce the environmental impact. A central task of telematics is the traffic management through information, communication, regulation, and monitoring (Siergiejczyk 2008).

The market for telematic devices has risen with the factor 30 within the last 15 years. In contrast, the market for telematic-related services grew very slowly in the beginning but is expanding fast since the year 2000 (Wallentowitz and Reif 2006). Navigation systems, which are integrated in 37% of new cars today (FOCUS 2010), extend, together with mobile telematic systems or navigation functions in mobile phones, the car by functions for a faster navigation, shorter or optimized routes, and the avoiding of traffic jams.

This technology allows the communication between the vehicle or the driver and an external server, other vehicles, or the infrastructure (car2-X communication). Therewith, innumerable PSS in the area of driver assistant systems, security systems, and communication and infotainment systems have become possible. Permanent information on the actual position of all vehicles in a fleet allows, for example, the planning and optimization of transport routes in real time and adapts to the ongoing traffic conditions or imports new information and orders directly into the navigation system. A constant controlling of the vehicle conditions via an external server is enabled with this technology as well.

Radio receivers in the vehicles (from the early 1930s) and traffic information on the radio (starting in the 1960s in Germany) are the basis for telematic systems. One of the first telematic solutions was the "trip computer" from 1980, a computer system to collect travel and vehicle data. Navigation with the Global Positioning System (GPS) (first available in 1989) (Winner et al. 2009) and the integration of Traffic Message Channel (TMC) in the early 1990s expanded the options for the application of telematic systems. With the online capability of modern telematic devices by Wireless Application Protocol (WAP) or General Packet Radio Service (GPRS), the sending and receiving of almost any form of data has become possible (Wallentowitz and Reif 2006). Modern traffic management systems like the Vehicle Information and Communication System (VICS) in Japan measure the current traffic situation and generate real time traffic information for the traffic participants.

Systems for commercial vehicles, such as the Brabender R2©, enable the combination of tracking, monitoring and reporting to workshops, navigation, information, communication, and order processing as well as timekeeping (Brabender 2011). The expected offers of entire mobility concepts are only rendered possible with the technical development in information technology and telematics. The availability of control units to monitor vehicle conditions and positions has fostered the car-sharing concept and therefore assures economic reasonable and user-optimized systems (Herrmann et al. 2011).

Figure 40.9 gives an overview on telematic systems and their similarity mode in the form of a cladogram. It shows the changes in techniques, starting from the trip computer as the common ancestor. The characteristics are concentrated on different classes of systems. None of the systems combines all characteristics. Instead, special systems are available in different areas. The systems in sector six for sharing services can be identified as highly developed. Automotive PSS like car sharing offers in a large scale and with an exactable effort for service organization can only be provided with the integration of these systems into the car. For further development in automotive PSS, the integration of telematic systems that monitor vehicle data, as the telematics for commercial vehicles, can help to reduce the service-related complexity for car sharing or to optimize the route planning, the used driveways, and the reduction of standby times due to traffic jams, which will also directly reduce the environmental impacts (Herrmann et al. 2011).

6 Automotive PSS Life Cycle Management

With the diverse influences on automotive PSS, like changing customer requirements to higher importance of sustainability, the technology push, or the handling of the immaterial service parts, the exposure and the management of sustainable PSS across all life cycle phases become a serious challenge. To handle this complexity, a holistic approach for sustainable automotive PSS is needed. Similar to the approach for total life cycle management (Herrmann 2010), all aspects of the PSS dimensions, the PSS life cycle, and the different PSS management phases need to be regarded.

As in a PSS, neither the product nor the service is solely important but the total system as a result of the product and service combination. A suitable PSS life cycle management approach brings into focus the management of this multidisciplinary, sociotechnical system. In various life cycle phases, an exchange and coordination between the life cycles of offered services and related products are needed. Between the levels of management, there has to be a link as well. Therefore, the existing framework for total life cycle management (Herrmann et al. 2007) and the life cycle of the PSS have to be integrated into one consistent framework for PSS life cycle management. Therewith, a framework is created supporting the introduction, implementation, and anchoring of the various management programs and tools in the PSS life cycle. The framework clarifies all relevant life stages of a PSS and

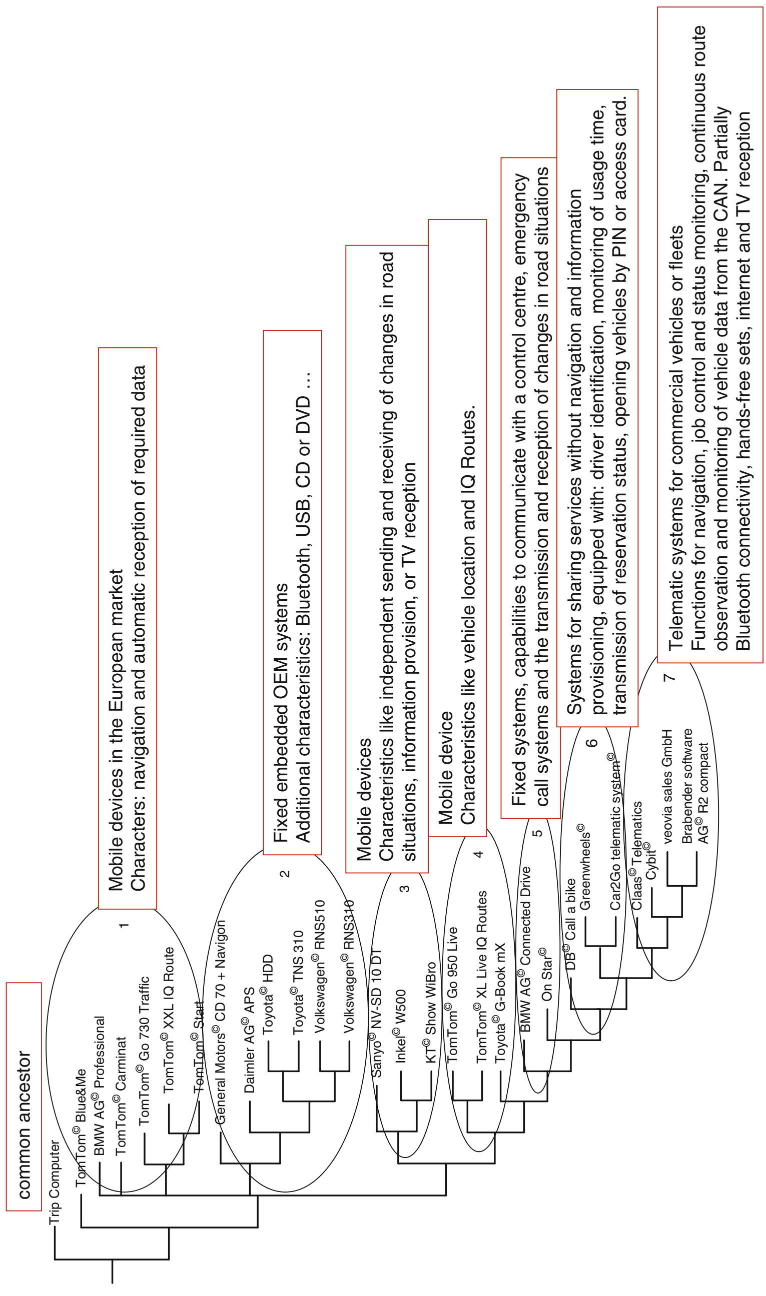

Fig. 40.9 Cladogram of telematic systems (Herrmann et al. 2011)

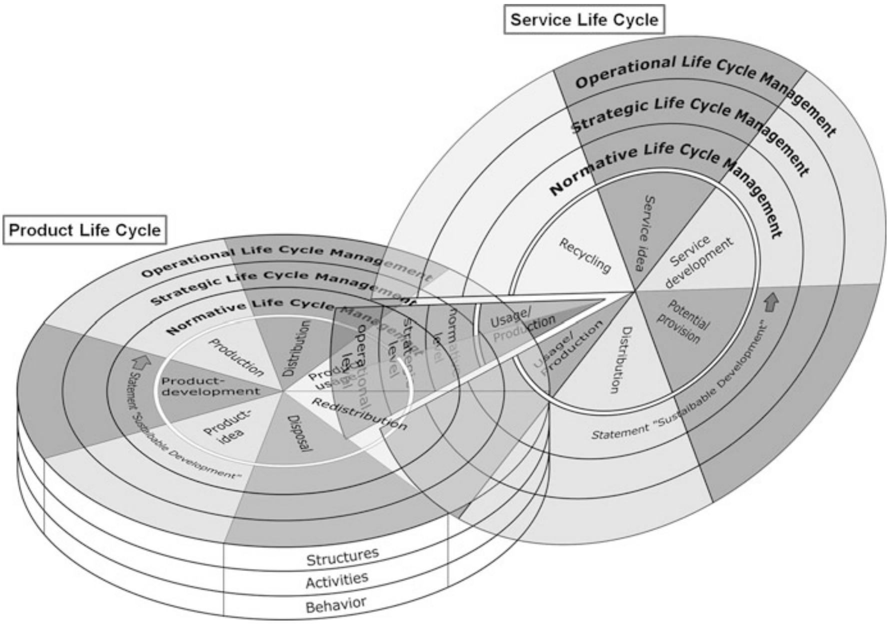

Fig. 40.10 Connected framework of total life cycle management and service life cycle management (Herrmann et al. 2010)

enhances the understanding of the economical and ecological relationships between the PSS life stages (Herrmann et al. 2010).

The total life cycle management of a product and of a service can be implemented in diverse depths. As displayed in Fig. 40.10 the usage phase of the product and the usage and production phase of the service can be connected to a joint offer for the customer. Thereby, the life cycle management of the product and the service are still represented separately, but interdependences are considered.

Figure 40.11 displays the joint framework for PSS and life cycle management, based on the total life cycle Management framework. In this joint framework for PSS life cycle management, the management of services and products is combined to a unit. It deals with the required function and regards the needs of the embedded services and products as equally important. To achieve this, an integration and connection of the life cycles of services and products to a common life cycle is needed. The management perspective and the life cycle spanning disciplines are integrated to the common life cycle as well (Herrmann et al. 2010).

6.1 Life Cycle Perspective

Considering PSS in automotive industry, the life cycle phases in the center of the framework (Fig. 40.11) describe the activities from the idea of an automotive PSS to the recycling of immaterial service parts and the redistribution, disposal,

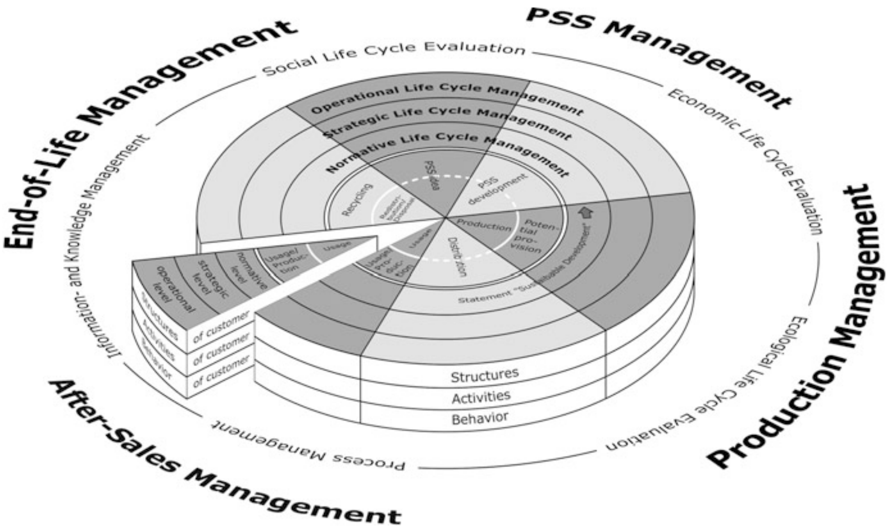

Fig. 40.11 Framework for PSS life cycle management (Herrmann et al. 2010)

and recycling of the automotive parts. The automotive parts can, for example, be redistributed and disposed, whereas the service or service characteristics are recycled to be used with another product or starting a new life cycle of another PSS with new automotive parts. In the development phase, the automotive-related product parts and the service parts which enable the use of the automotive PSS are developed and integrated with a particular attention to the interfaces between the immaterial and the material parts.

In the next life cycle phase, the automotive parts are produced, and a parallel provision of the required potential for the service part of the automotive PSS, for example, the infrastructure for the integration of telematic devices and car2-X communication, takes place. This division is ascribed to the different characterization of services and products. While the product needs to be manufactured before using, the immateriality of services is linked to the subsequent usage and production phase and the potential provision phase (Herrmann et al. 2010). Afterward, the automotive PSS is marketed and the physical parts are distributed to the required positions. Simultaneously to the usage of the automotive parts by a customer, the isochronous production of the service parts and the usage take place. The disjunction into two parts in this phase reflects the integration of the external factor, the customer that needs to be integrated in the life cycle.

6.2 Management Perspective

The integration of normative, strategic, and operational management levels as well as structures, activities, and behavior as fields of action allows using the framework for PSS life cycle management for incorporation of the automotive parts and the service parts into the management perspective. The customer part is explicitly considered by the integration of the external factor with its own normative, strategic, and operational (management) level as well as own structures, activities, and behavior in the service production and usage. Thus, for example, evolving customer requirements in terms of environmental awareness or the decreasing importance of the automobile as a status symbol can be met.

6.3 Life Cycle Disciplines

With the integration of life cycle disciplines into the management of automotive PSS, a holistic view on the automotive PSS is rendered possible. The life cycle spanning disciplines – process management, information and knowledge management, social life cycle evaluation, economic life cycle evaluation, and ecological life cycle evaluation – take into account the holistic view on the automotive PSS with regard to the whole life cycle. Thus, trade-off effects over the life cycle or rebound effects, for example, the possibility for an intensified usage of a car due to lower initial investments for the customer for car sharing can be disclosed.

The life-cycle-phase-related disciplines PSS management, PSS production management, PSS after-sales management, and PSS end-of-life management finally regard the automotive PSS specific management operations. For the optimization of the PSS over the whole life cycle, these disciplines need to interact. The management of each of these phases needs to be considered. Only with the incorporation of each of the life cycle phases in the management disciplines and with the interaction of the single disciplines all aspects of the automotive PSS – network, infrastructure product, and service – are included. Properties of products as well as the service dimensions become part of a harmonized management.

For automotive PSS, the consideration of the framework for PSS life cycle management therefore is an important aspect with regard to the interaction of the different management perspectives and for the holistic view on the life cycle of both aspects, the automotive product and the service.

7 Summary

The influence of changing customer requirements and the need for a more sustainable transportation necessitate rethinking in the market of mobility. The demand for sustainable PSS in automotive industry is rising consistently. It becomes obvious that new trends and developments in mobility today are more and more relying on the development in information technology and telematics. The level of service integration is rising significantly due to new potentials in countervailing the high-service complexity. In passenger transportation, prospective possibilities to pursue trends to a product service orientation and to connect technical developments with service offers can be extended. Furthermore, the developments in telematics depict that today's mobility concepts are only using a part of the available functions in telematic systems. A great potential for progress in new mobility approaches exists as well for the improvement of the design and for processes in existing concepts. For further developments in passenger mobility, it is essential to change the view on the product "vehicle," leaving the idea of a single product, coming to the idea of a combined system with vehicle, telematic system, and services.

New car concepts, like electric vehicles, rely on integrated service structures. Functionality without distinctive abdications of comfort due to the reduced range of distance can only be realized with PSS, which allow an omnipresent access to information about the charging level and other automotive functions.

Obviously, today's PSS in automotive industry show some deficits:

- The economic benefit of automotive PSS is not sufficiently realized or not communicated well enough to the potential customers.
- The combination of the mobility offered via cars with mobility offered via other transportation means is hardly realized.
- The ecological benefit of automotive PSS does not emerge in a clear manner.
- The concepts have significant deficits regarding flexibility and convenience (compared to the use of the private vehicle).
- The concepts are not implemented all over the country let alone worldwide.

With introducing an entire mobility concept, these deficits can be partially corrected. Car-sharing concepts for example can be integrated with ride-sharing concepts. Instead of booking the whole car, the user only books a seat in the car, when the integrated software tool recognizes that different drivers are about to use the same route. Those services can also be extended to an individualization of the routes and schedules of public transportation or to revised opportunities for the personal adoption of different transportation means.

At the same time, a life-cycle-related view on all aspects of automotive PSS is distinguished to assure a provision for all life cycle phases and related trade-off and rebound effects in development and implementation of automotive PSS.

The prospective developments in passenger transportation can reach an increasing rate of servitization without losing the advantages of individualization.

8 Cross-References

►Engineering PSS (Product/Service Systems) Toward Sustainability: Review of Research
►Modeling Services and Service-Centered PSS Design
►Product Design Considerations for Improved Integrated Product/Service Offerings

References

G.A. Ahrens, Sonderauswertung zur Verkehrserhebung 'Mobilität in Städten SrV 2008' – Städtevergleich. Dresden (2009)

S. Behrendt, C. Jasch et al., *Eco-Service Development – Reinventing Supply and Demand in the European Union* (Bookcraft, Midsommer Norton, 2003)

Brabender, (2011), www.brabender-group.com/de/home.html

H. Braess, U. Seiffert (ed.), *Handbuch Kraftfahrzeugtechnik* (Vieweg, Wiesbaden, 2007)

J.C. Brezet, A.S. Bijma et al., The design of eco-efficient services, Design for sustainability program. Delft University of Technology, Delft (2001)

Bundesministerium für Verkehr, Bau und Stadtentwicklung (ed.), *Verkehr in Zahlen 2009/2010* (Deutscher Verkehrs, Hamburg, 2009)

Bundesverband CarSharing e.V., Jahresbericht 2010. Hannover (2011)

W. Burgert, Tendenzen im Karosseriebau, in *VDI-Bericht 1256- 150 Jahre Wilhelm Maybach*, ed. by Verein deutscher Ingenieure (VDI, Düsseldorf, 1996), pp. 29–50

Car2Go, (2011), www.car2go.com

Department for Transport, (2011), www.dft.gov.uk

European Commission, Climat action (2012), http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm

European Environment Agency, (2011), www.eea.europa.eu

Eurostat, (2011), http://epp.eurostat.ec.europa.eu

FOCUS (ed.), *Communication Networks 14.0* (FOCUS Magazin Verlag GmbH, München, 2010)

M. Goedkoop, C. van Halen et al., Product services systems, ecological and economic basics, report 1999/36. The Hague, Zoetermeer (1999)

C. Herrmann, *Ganzheitliches Life Cycle Management – Nachhaltigkeit und Lebenszyklusorientierung in Unternehmen* (Springer, Berlin/Heidelberg, 2010)

C. Herrmann, L. Bergmann et. al., Total life cycle management – A systems and cybernetics approach to corporate sustainability in manufacturing, in *Sustainable Manufacturing V – Global Symposium on Sustainable Product Development and Life Cycle Engineering*, Rochester (2007)

C. Herrmann, J. Stehr et al., Automotive life cycle engineering – Understanding the interdependencies between technology and market of environmentally conscious mobility concepts, in *Proceedings of the 6th International Symposium on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign 2009)*. Sapporo, (2009), pp. 231–236

C. Herrmann, K. Kuntzky et al., Joint framework for product service systems and life cycle management, in *Proceedings of the 2nd CIRP International Conference on Product-Service-Systems 2010*, Linköping University, Linköping, (2010), pp. 353–359

C. Herrmann, K. Kuntzky et al., Pathways of servitization in mobility systems, in *Functional Thinking for Value Creation – Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems 2011*, Braunschweig, ed. by Hesselbach J, Hermmann C (Springer, Berlin/Heidelberg, 2011), pp. 249–254

ibike, (2011), www.ibike.org

International Energy Egency (ed.), Dealing with climate change: policies and measures in iea member countries 2002. Organization for Economic Co-operation and Development, (2002)

KBA, (2011), www.kba.de

K. Kuntzky, C. Herrmann, Application of eco-services in automotive industry for commercial customers, in *Functional Thinking for Value Creation – Proceedings of the 3rd CIRP International Conference on Industrial Product Service Systems 2011*, Braunschweig, ed. by J. Hesselbach, C. Hermmann (Springer, Berlin/Heidelberg, 2011), pp. 279–284

E. Manzini, C. Vezzoli, A strategic approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italien price. J. Clean. Prod. **11**, 851–857 (2003). Elsevier

R. Mejcamp, *Changing Consumer Behavior Through Eco-Efficient Services* (Delft University of Technology, Delft, 2000)

J. Mikulski, Using telematics in transport, in *Transport System Telematics, 10th Conference, TST 2010*, Katowice, ed. by J. Mikulski (2010), pp 175–182

P. Newman, J. Kenworthy, Peak car use: understanding the demise of automobile dependence. World Trans. Policy Pract. **17**(2), 31–42 (2011). Los Angeles

P. Nijkamp, G. Pepping, The relevance and use of information and telecommunication networks as strategic tools on the transport sector. Annal Reg. Sci. **30**(1), 111–133 (1996). Springer

Radverkehrsplan, (2011), www.nationaler-radverkehrsplan.de

R. Roy, Sustainable product-service systems. Futures **32**, 289–299 (2000). Elsevier

S. Shaheen, A. Cohen et al., North American carsharing – 10-year retrospective, in *Transportation Research Record* (The National Academy, Washington, 2009), pp. 35–44

M. Siergiejczyk, Quality of telematic services in transport, in *Third International Conference on Dependability of Computer Systems*, (Szklarska Poreba, Poland, 2008), pp. 422–429

R.W. Stahel, Sustainability and services, in *Sustainable Solutions*, ed. by M. Charter, U. Tischner (Greenleaf, Sheffield, 2011)

urbanbiking, (2011), www.urbanbiking.de

US Department of Energy, (2011), www.eere.energy.gov

S. Vandermerwe, J. Rada, Servitization of business: adding value by adding services. Eur. Manag. J. **6**(4), 314–324 (1988). Elsevier

VDA, (2011), www.vda.de

A.G. Volkswagen, Life cycle assessment of VW golf (2011), www.umweltpraedikat.de

H. Wallentowitz, K. Reif (ed.), *Handbuch Kraftfahrzeugelektronik* (Vieweg, Wiesbaden, 2006)

A. Williams, Product service systems in the automobile industry: contribution to system innovation? J. Clean. Prod. **15**, 172–184 (2006). Elsevier

H. Winner, S. Hakuli et al. (ed.), *Handbuch Fahrerassistenzsysteme* (Vieweg, Wiesbaden, 2009)

Y. Xu, Development of transport telematics in Europe. Geoinformatica **4**(2), 179–200 (2000). Springer