Chapter 2
Bike Sharing in the Context of Urban Mobility

The trend of growing interest in alternative urban transportation modes continues. Today's urban transportation infrastructure is often used to capacity and thus suffers from inefficiency. There is need for innovative and sustainable mobility to better use existing infrastructure. Moreover, new mobility concepts should satisfy the requirements of recently changing mobility needs of people while ensuring the viability of urban transportation and living. In this domain, SMS such as BSS or car sharing systems (CSS) have become more and more popular in recent years offering vehicles for collaborative use. Despite the great popularity, a common definition distinguishing shared mobility from traditional transportation services is lacking. However, understanding the characteristics of SMS and mobility behavior of users is essential in order to support the reliable provision of service. In particular, modeling mobility behavior in SMS requires a thorough understanding of mobility itself.

Consequently, bike sharing as a concept of shared mobility is presented and classified within the context of urban transportation and mobility (cf. Fig. 2.1). Therefore, basic definitions of mobility and urban transportation as well as urban transportation challenges are presented (Sect. 2.1). Current trends and drivers of new mobility concepts alleviating addressed urban transportation challenges are discussed. These drivers pave the way for new mobility concepts such as SMS, in particular, bike sharing (Sect. 2.2). Provision of service relies on the understanding of user's mobility needs. Thus, a definition of shared mobility from a user's perspective is given. Based on the definition, business models of SMS are discussed each standing out due to different characteristics. The planning, implementation, and operation of SMS requires considering the individual characteristics of these systems. The functionality of BSS is described accordingly and general guidelines on the planning, implementation, and operation of BSS are outlined.

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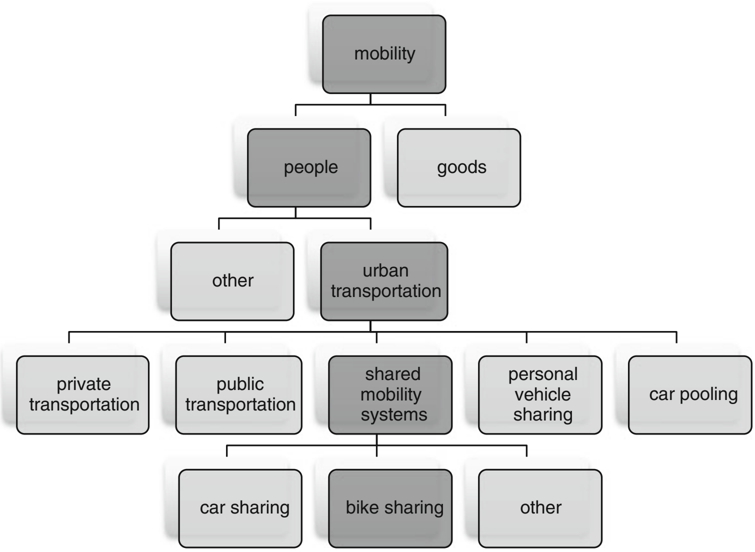

Fig. 2.1 Bike sharing in the context of mobility

2.1 Mobility, Urban Transportation Challenges, and Trends

The growth in population continues. According to the United Nations (Heilig 2012), the world population will reach 9.3 billion by the year 2050. In particular, urbanization progresses: The population living in urban areas will grow from 3.6 billion in 2011 to 6.3 billion in 2050. Urban population will account for 67 % of the population by 2050, whereas the rural population declines. In Europe for example, urban population will increase on average by 5 % until the year 2050 (Booz and Company 2012). Hence, today's demands and requirements on mobility and urban transportation will become even more challenging in the near future. Extending traditional urban transportation concepts will not suffice to solve prospective urban transportation challenges. Based on recent mobility trends, new concepts of shared mobility can alleviate problems regarding urban transportation.

Understanding trends in urban mobility and transportation relies on a comprehensive introduction to the domain of urban mobility and transportation. Therefore, the general mobility needs and behavior of people are presented (Sect. 2.1.1). The focus is on trip purposes being the driver of mobility. Since transportation facilitates mobility, basics of urban transportation are outlined (Sect. 2.1.2). Insights into the characteristics of transportation are essential to recognize prevailing urban transportation challenges (Sect. 2.1.3). Based on the drawbacks of current transportation and changing attitude of people toward mobility, recent trends in urban mobility are illustrated (Sect. 2.1.4).

2.1.1 Mobility Needs and Behavior

In order to understand new mobility concepts and associated model mobility behavior in BSS, foundations of mobility needs are essential. Basic definitions regarding movement in urban areas comprise the terms mobility, transportation, and traffic. In a wider sense, mobility is the movement from one place to another. *Mobility* of people and goods are distinguished (Aberle 2009). Mobility of people comprises the basic need of people for taking part in activities, e.g., social, cultural, and political activities, as well as working activities. Mobility of goods refers to the movement of freight between businesses or to customers. This work solely focuses on mobility of people. In this context, transportation is defined as the process of moving people with a certain mode of transportation such as cars or busses. Accumulation of transports results in traffic (Ihde 2001).

The mobility behavior of people is represented by means of related key figures. Mobility is measured according to realized trips. A trip consists of spatial and temporal attributes, such as origin and destination of the trip, the used route, start time and end time, and the resulting duration. Traffic surveys and polls measure mobility behavior by summarizing the number, distance, and duration of performed trips (Rodrigue 2013). In Germany for example, a person performs on average 3.4 trips traveling 41 km in 83 min per day (Zumkeller et al. 2011). The number and duration of trips are quite stable, but the traveled distance has increased in recent years (Hütter 2013). This observation is related to increasing vehicle ownership, better transportation infrastructure, and increased speed and comfort of vehicles (Aberle 2009). Thus, the overall traffic volume of people in Germany increased from 1045 to 1127 billion kilometers in the years 2000–2010 (Kolodziej 2009). Similar traffic growth is observed in Europe.

Activities are the driver of people being mobile and are linked to specific locations and time. Depending on the *trip purpose*, locations serve as a generator or attractor of trips. An example is commuting from home to work in the morning and back in the afternoon. Different types of trip purposes are distinguished. Trips are either obligatory if activities have a fixed schedule such as trips to work or voluntary if the activities are not scheduled such as leisure activities. Different approaches to categorize trip purposes exist. Here, a categorization according to Aberle (2009) and Follmer et al. (2008) is presented. It distinguishes between work, professional, educational, accompanying, shopping, and leisure trips.

The trip purpose "work" refers to commuter trips between residence and work. Work trips are realized on a regular basis and thus stand out due to obligation and recurrence. Trips to and from work usually occur in the morning and afternoon. Trips during working hours such as meetings or customer services belong to the "professional" category. The trip purpose "education" summarizes trips to educational establishments regardless of the level of education. Accompanying persons on their trips is a separate category, e.g., a mother accompanies her daughter on the way to school. Shopping comprises trips to stores and errands trips to public institutions such as visits to municipal buildings or the doctor. Leisure trips involve

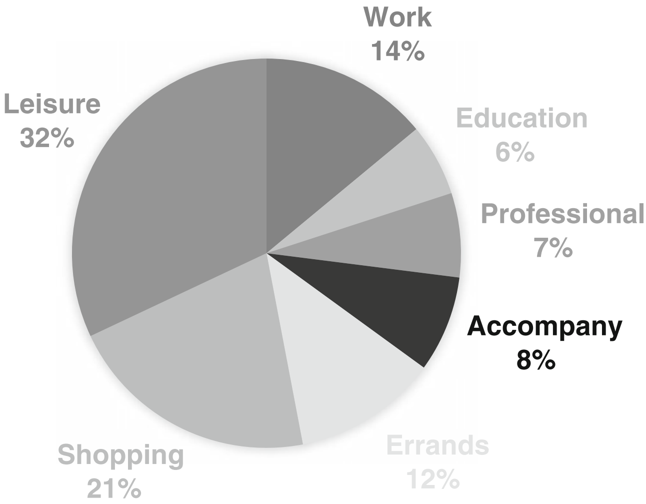

Fig. 2.2 Distribution of trip purposes in Germany [adapted from Follmer et al. (2008)]

social, cultural, or recreational activities. Please note that there is no consistent categorization and terminology of trip purposes. Hence, trip purposes and their distribution may vary in other studies (Ahrens et al. 2009; Zumkeller et al. 2011). For instance, touristic trips or trips heading home are individual categories.

The distribution of trip purposes in Germany (cf. Fig. 2.2) is exemplified according to the study "Mobility in Germany" (Follmer et al. 2008). Here, leisure-oriented trips represent the majority of trip purposes. In combination with the other voluntary errands and shopping trips, they account for almost two-thirds of all trips. In contrast, the share of obligatory trips is rather low. Work, educational, and professional trips only account for one-fourth of trips. Whereas the trip purposes apply for the population in general, the realization of trips depends on the particular characteristics of the individual city, population, and urban transportation systems (Zumkeller et al. 2011). Basics of urban transportation are presented in the following.

2.1.2 *Basics of Urban Transportation*

Transportation facilitates mobility with the help of different modes. It can be broadly classified into *public transportation and private transportation* (Aberle 2009; Rodrigue 2013). Public transportation is a mobility service characterized by public accessibility. In contrast, private transportation is not publicly accessible. Each concept has benefits and drawbacks (Maertins and Schmöe 2008). Private transportation is described by private ownership of vehicles enabling free choice of space and time for trips. Thus, it stands out due to high flexibility and accessibility regarding space and time. It comprises motorized modes such as automobiles and motorcycles as well as non-motorized modes such as walking and cycling. Motorized transport also allows long trip distances, but is usually associated with high costs. Non-motorized transport is fairly cheap, but trip distances are limited. Public transportation provides publicly accessible mobility and includes modes such as busses, subways, and trams. However, public transportation has spatial and temporal limitations affecting the accessibility and flexibility. Due to financial restrictions and sparse location options, stations of public transportation are only available at specific parts of the city. Furthermore, schedules and routes determine locations and times for departures and arrivals curtailing flexibility.

Explanations why *people favor transportation modes* are diverse. Usage depends on internal and external traffic factors (Aberle 2009; Rodrigue 2013). Internal traffic factors comprise automobile ownership, driving license possession, transportation costs, public transportation accessibility, as well as quantity and quality of transportation infrastructure. Obviously, the automobile outperforms public transportation in terms of flexibility, speed, and convenience. Most people will choose the automobile over public transportation. However, only people having a driving license qualify for automobile usage. Moreover, automobile ownership is associated with high costs and is thus not affordable for everybody. In contrast, public urban transportation is usually subsidized allowing comparative cheap transportation, but is rather inflexible. External traffic factors comprise restrictions on mobility given by the urban form and structure. The urban form is shaped by the spatial arrangement of physical infrastructure, e.g., houses and parks, as well as transportation infrastructure and systems. The urban structure results from interactions of freight, people, and information restricted to the urban form. Thus, people have to adapt their decisions on the mode of transportation not only based on their individual circumstances but also according to the specific urban surroundings.

The *modal split* shows differences in urban mobility behavior based on used transportation modes. The modal split is referred to the proportion of the specific modes for trips (Rodrigue 2013). The usage of modes can be further differentiated into multimodality and intermodality. If people use more than one mode during the week, the term multimodality applies, whereas using different modes for one trip purpose is called intermodality (Rodrigue 2013). While trip purposes are quite similar, regional differences in mode choice exist due to differing internal and external traffic factors (Ahrens et al. 2009).

Urban mobility shows differences regarding the modal split. In order to give an overview on the modal split, figures are presented for the two exemplary European cities of Berlin and Vienna (cf. Fig. 2.3). In Berlin, motorized private transportation dominated the mode choice in the year 1998 and accounted for 38 % of trips. Non-motorized private transportation covered 35 % of trips, whereas public transport only covers around 27 % of trips (Zumkeller et al. 2011). The modal split is subject to change. In recent years, walking and cycling slightly increased, because the acceptance and sustainable image of walking and cycling increased.

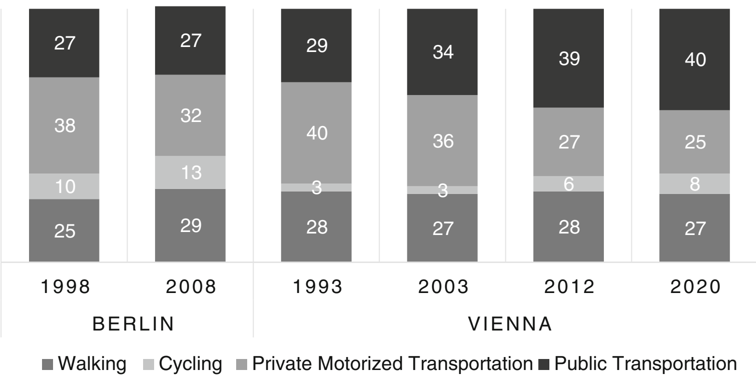

Fig. 2.3 Modal split development in Berlin [adapted from Zumkeller et al. (2011)] and Vienna [adapted from Winkler and Haeusler (2009) and Wiener Linien]

Motorized private transport decreased in favor of multimodality. Public transportation remained at 27 %.

Since data from Vienna's BSS are analyzed in this work, Vienna's modal split is discussed in more detail. In the 1990s Vienna suffered from commuters fighting for insufficient parking space. With the help of the Transportation Master Plan Vienna 2003 (Winkler and Haeusler 2009) this problem is tackled by encouraging traffic reduction and redistribution until the year 2020. Traffic reduction is promoted by local shopping areas as well as nearby residential and working areas. Traffic redistribution shall shift traffic from motorized private transportation to public transportation and cycling.

As a result, Vienna nowadays stands out as offering one of the world's best public transportation systems with a modal share of almost 40 % compared to 29 % in 1993. This share is reached because of the high density of public transportation stations and service intervals. Private motorized transportation dropped from 40 to 27 % of the modal share in the year 2012 and shall further decrease to 25 % in 2020. Promoting park-and-ride and good parking space management are the reasons for this low share. Walking is rather stable and account for 28 % of the modal split, whereas cycling increased from 3 to 6 %. In comparison to other European metropolises, Vienna's bike share is rather low. Until the year 2020, the bike share shall rise to 8 % due to extending bike path infrastructure, campaigns encouraging cycling and Vienna's BSS Citybike Wien.

Insufficient parking space in Vienna serves as one example of urban transportation challenges. It shows the rethinking in urban transportation planning and its effect on mobility behavior. In addition, the different modal splits in urban areas underpin that careful investigation of the specific urban characteristics is required when modeling mobility behavior. A broader overview of urban transportation challenges and resulting trends in urban mobility and transportation is subject to the remaining part of this section.

2.1.3 Urban Transportation Challenges

Cities concentrate people and economy in a dynamic and complex environment. Urban, social, economic, and political structures continuously evolve due to new technology, lifestyles, products, opportunities, and regulations (Button 2002). Transportation systems and infrastructure are the lifeline of modern settlements facilitating the movement of labor, consumers, and freight between origins and destinations (Rodrigue 2013). In contrast to the dynamic urban structures, transportation systems and infrastructure are rather static due to geographical and historical circumstances. Hence, satisfying current and future urban mobility needs is challenging.

Among others, the most notable *urban transportation challenges* are congestion and parking difficulties, public transportation inadequacy, and environmental impacts (Rodrigue 2013). In this work, the focus is on new mobility concepts and their operation in order to use existing transportation infrastructure more efficiently. Thus, the former two challenges are presented, whereas regarding the latter it is referred to Chapman (2007), Button (2002), and Rodrigue (2013).

Two of the most prevalent challenges that cites face are *congestion and parking difficulties* (Rodrigue 2013). Main causes for congestion are increasing private motorization and urban sprawl. Urban sprawl refers to “excessive spatial growth of cities” (Brueckner 2000). Motorization pollutes air with emissions and noise. Moreover, transportation infrastructure and parking space are needed consuming already sparse space. Due to motorization, longer distances are reached within the same time, making people escape from the polluted inner cities to suburbs. This in turn increases traffic polluting the environment—a vicious circle. The resulting mobility demand exceeds the supply of transportation infrastructure leading to congestion and parking space difficulties. For more information, the reader is referred to Downs (2004) who gives an extensive overview of congestion and parking difficulties. Glaeser and Kahn (2004) give further details on urban sprawl and resulting transportation problems.

Public transportation is considered the most efficient mode of transportation in urban areas, but still may suffer from inadequate spatial and temporal access and flexibility (Rodrigue 2013). Reasons for *public transportation inadequacy* are decentralization, connectivity, and fixity. Besides areas of high population density, cities feature scattered areas with low density due to decentralization and urban sprawl. It is difficult and expensive to serve those low-density areas. Missing connectivity between public transportation and other transportation modes impedes the swap of modes. The infrastructure and schedules of transportation systems are fixed, whereas cities and mobility continuously evolve. The spatial structures of cities rather support the needs of individuals than of the collectivity. In addition, ubiquitous and cost-free road infrastructures foster flexible motorized transportation. As a result, the created expectations toward flexibility cannot be served by public modes of transportation (Maertins and Schmöe 2008). In the following, recent trends in urban mobility and transportation are described. For further reading on urban transportation challenges, refer to Rodrigue (2013).

2.1.4 Trends in Urban Mobility and Transportation

Whereas the preceding section is a retrospection on transportation and mobility, in this section a preview on trends in transportation and mobility is given. Without doubt, there is need for innovative and sustainable mobility concepts to overcome the addressed transportation challenges. Increasing mobility will impair the viability of urban transportation systems and infrastructure. While mobility behavior is in a state of flux, transportation systems and infrastructure are rather rigid due to the urban form. Hence, mobility trends focus on using the existing infrastructure more efficiently rather than extending infrastructure. New mobility concepts should satisfy the requirements of changing mobility behavior of people and ensure the viability of urban transportation and living.

A variety of trends toward innovative and sustainable transportation and mobility exist. Among others, technological and social trends tackle the discussed urban transportation challenges (Rodrigue 2013). *Technological trends* involve for instance intelligent transportation systems. Advances in engineering as well as in information and communication technology enable improved accessibility, reliability, speed, efficiency, and safety of vehicles. An example is the collection and provision of real-time data on parking space availability measured by sensors (Mathur et al. 2010). Using this information on parking space availability can reduce the effort of parking space search and therefore reduces traffic.

Social trends confirm the peoples' needs for innovative mobility in western developed countries. Currently, trends follow two directions: The decreasing role of cars as status symbols as well as access and sharing instead of ownership (Lenz 2013). It can be observed that the importance of cars as status symbols and getting a driving license among younger generations is decreasing (Canzler and Knie 2009). Germany serves as an example for these trends (Follmer and Scholz 2013): In the group of 18–24 year olds, the number of driving license holders dropped by three percentage points between the years 2002 and 2008. In addition, daily car usage decreased by twelve percentage points, whereas daily public transportation usage increased by five percentage points. A reason for this is that younger generations rather choose smartphones and internet access over car access (Lenz 2013). Nevertheless, cars are far from being obsolete: The opposite trend is observed for the older generation of 65+ year olds (Follmer and Scholz 2013). For whole Germany, motorized private transportation still dominates the mode choice and accounts for more than 50 % of trips. Non-motorized private transportation covers one-third of trips, whereas public transport only covers around 10 percent of trips (Zumkeller et al. 2011). However, in recent years a decrease in walking in favor of cycling occurred. The acceptance and sustainable image of cycling contributes to this increase. Motorized private transport slowly decreased because of lower acceptance and increased multimodality. On the opposite, better acceptance and multimodality are the reasons for increasing public transportation.

Access instead of ownership is a second trend in mobility. This trend evolved from collaborative consumption. "Collaborative consumption is people coordinating the acquisition and distribution of a resource for a fee or other compensation" (Belk 2014). According to Shaheen et al. (2012) and Beckmann and Bruegger (2013) sharing of resources has advanced to the mobility sector. Quantifying this trend is hard so far, but recent increasing interest in multimodality among younger generations might be an indicator. In Germany, the share of 18–29 year olds using more than two modes per week (walking excluded) grew from 51 % in the year 2002 to 54 % in 2008 (Lenz 2013). Differentiated by city sizes, two-third of metropolitans (cities with more than 500,000 inhabitants) uses multiple modes for their trips (Follmer and Scholz 2013). These figures imply the interest in innovative and flexible mobility services as provided by SMS.

2.2 Bike Sharing Systems as a Concept of Shared Mobility

Shared mobility satisfies the demand of people for innovative and sustainable mobility concepts. It combines the addressed social and technological trends to meet today's mobility needs by bridging the gap between private and public modes of transportation (Maertins and Schmöe 2008). The advantages of both private and public modes of transportation result in attractive, accepted, and flexible mobility. In particular, BSS recently gain popularity due to easy, automated access, and one-way trips enabled by information systems support.

For a successful operation and reliable provision of service, it is of high importance to gain a comprehensive understanding of both the mobility behavior of users and economic interest of SMS operators. Thus, this section provides details on BSS as a concept of shared mobility. In particular, a usage-oriented definition of shared mobility is developed by means of classifying attributes from a user's point of view (Sect. 2.2.1). These attributes help to understand user expectations regarding SMS and distinguish SMS from other modes of transportation. From an operator's point of view, different business models address the desired expectations toward shared mobility (Sect. 2.2.2). In addition, the reader is given details on the functionality of BSS (Sect. 2.2.3). Finally, general guidelines on the planning, implementation, and operation of BSS are outlined (Sect. 2.2.4).

2.2.1 Usage-Oriented Motives for Shared Mobility

The aim of shared mobility as an efficient and sustainable transportation mode is clear and it already enjoys great popularity. However, there is a lack of a common definition of shared mobility. Two rather general characterizations are the following.

According to Beckmann and Bruegger (2013) shared mobility is the access to a mobility service without owning the product offering the service. Sonnberger and Carrera (2012) understand shared mobility as the organized collaborative use of vehicles. To be more specific about shared mobility, here a definition with the help of usage-oriented motives from a user's point of view distinguishing shared mobility from other modes of transportation is developed. The resulting classification illustrates the special characteristics users expect from SMS.

Before identifying the usage-oriented motives, the *organizational forms of shared mobility* are presented. The two distinguished forms comprise private or external organization of the service (Sonnberger and Carrera 2012). Furthermore, the usage of the shared resource is categorized. The shared mobility resource, e.g., cars or bikes, is used for an individual trip or a collective trip. According to the organization and usage, SMS such as car and bike sharing systems, personal vehicle sharing, and carpooling are differentiated. BSS and CSS are services offered by business to consumers for individual short trips. Personal vehicle sharing is peer-to-peer sharing of mobility resources for individual or collective trips. Carpooling is, mostly privately organized, sharing of cars for collective trips.

On the basis of recent literature on shared mobility and related fields (Millard-Ball 2005; Maertins and Schmöe 2008; Büttner and Petersen 2011; Shaheen et al. 2012; Sonnberger and Carrera 2012; Furuhata et al. 2013), *usage-oriented motives classifying transportation and mobility services* are identified. The most important motives stated in the articles comprise accessibility, flexibility, reliability, and costs. The use and definition of the motives are somehow diverse and depend on the context of the articles and background of the authors. In order to present a selective definition of the motives, the meaning used in this work is introduced.

Usage is understood as the individual or collective use of the vehicle. Accessibility refers to the spatiotemporal operationality of the service. It expresses whether the mobility service is available at the desired location and time. Flexibility characterizes the spatiotemporal choices while using the service. Choices comprise the different attributes of a trip such as origin and destination of the trip, the used route, start time and end time, and the resulting duration. Reliability refers to the appropriate provision of the service expressing whether the service is actually available when and where requested. Costs comprise the required expenses to use the service.

The developed classification is depicted in Table 2.1. It distinguishes SMS from private and public transportation (cf. Sect. 2.1) as well as personal vehicle sharing and carpooling. The different transportation and mobility services show the following characteristics:

- *Public transportation* (Maertins and Schmöe 2008; Aberle 2009; Rodrigue 2013) is a public mode of transportation used for collective trips. The accessibility can be considered as rather low compared to private transportation because the service is bound to stations and service times. Furthermore, the offered spatiotemporal flexibility is low due to schedules and lines. However, the "inflexibility" also enables high reliability of the service because of

Table 2.1 Classification of transportation and mobility services according to usage-oriented motives

Motive	Public transportation	Private transportation	Carpooling	Shared mobility systems	Personal vehicle sharing
Usage	Collective	Individual	Collective	Individual	Individual
Accessibility	Low	High	Low	High	Low
Flexibility	Low	High	Low	High	High
Reliability	High	High	High	Low	Low
Costs	Low	High	Low	Low	Low

schedules and lines. Due to subsidies, costs of public transportation are kept low.

- *Private transportation* (Maertins and Schmöe 2008; Aberle 2009; Rodrigue 2013) offers privately owned vehicles for individual trips. Since the vehicle is privately owned, the vehicle is always accessible. The user can drive the vehicle whenever and almost wherever he wants. Thus, private transportation enables high flexibility. The reliability is high, because the owner himself is responsible for the spatiotemporal provision of the vehicle. Nevertheless, private transportation is associated with high investment and running costs.
- *Carpooling* (Morency 2007; Vanoutrive et al. 2012; Furuhata et al. 2013) also provides privately owned vehicles, but for collective trips. Hence, people share their trips. Typically, the accessibility and flexibility of carpooling are low, because participants must have trip characteristics similar to the driver. The reliability can be considered high, because users agree on the terms in advance. Due to sharing of trips, costs are lower than driving alone.
- *Shared mobility services* (Millard-Ball 2005; Maertins 2006; Maertins and Schmöe 2008; DeMaio 2009; Shaheen et al. 2010; Sonnberger and Carrera 2012) such as car sharing and bike sharing offer publicly provided vehicles for individual short trips. SMS commonly have no restrictions on service times and the density of access points is high in populated areas leading to a rather high accessibility. The flexibility is high due to absent schedules and lines. Many SMS suffer from low reliability due to the highly dynamic usage. However, reliability is the key factor contributing to the acceptance and success of SMS. Regarding the costs, SMS are cheap compared to private transportation if a certain mileage is not exceeded.
- *Personal vehicle sharing* (Shaheen et al. 2012) is a new concept within the shared mobility sector. Personal vehicle sharing has the same characteristics like SMS, but here privately owned vehicles are offered for sharing. Therefore, the accessibility is lower compared to SMS since the vehicle is only available, if the owner does not use it.

The *sharing of mobility resources has major benefits*. In particular, car sharing reduces the vehicle ownership and construction of parking spaces (Millard-Ball

2005; Shaheen et al. 2006) and bike sharing replaces trips that would have been made with other private vehicles (Shaheen et al. 2010). Thus, better utilization of transportation infrastructure and resources lead to better economic, ecologic, and social sustainable mobility (Beckmann and Bruegger 2013). SMS are economically sustainable because existing capacities can be better utilized and investment into transportation infrastructure is not necessary. Ecologic sustainability is also achieved by better utilization of capacities. Firnkorn and Müller (2011) summarize that the reduction of gaseous and noise emissions as well as transportation infrastructure are possible effects of car sharing. BSS have a positive effect on the model split of cycling (DeMaio 2009) and cycling in general has positive influences on health (Pucher et al. 2010). SMS are social sustainable, because they foster new forms of collective mobility (Beckmann and Bruegger 2013) and generally increase the attractiveness of cities (Firnkorn and Müller 2011).

However, up to now, in wide sections of the population *SMS lack in reliability* and are thus considered to be inflexible and little spontaneous (Sonnberger and Carrera 2012). Although two-third of the German population know about car sharing, only one percent is enrolled in a CSS and the modal split of car sharing trips is in the per mille range (Follmer and Scholz 2013). The acceptance of BSS is much higher, but still has room for improvement. In the case of Velib, Paris, six percent of the population used the system shortly after was put into operation (Nadal 2007). Desirable is one daily trip per twenty to forty residents (Gauthier et al. 2013).

2.2.2 Business Models of Shared Mobility Systems

People demand innovative SMS offering high accessibility, flexibility, and reliability at low costs. Different business models exist to satisfy the desired mobility needs. For the acceptance and success of SMS, business models have to be carefully tailored the mobility needs of urban population and addressed user segment as well as to the given infrastructure of the specific city. This section presents a taxonomy of SMS business model based on different characteristics.

Characteristics having influence on the business model and thus the design, management, and operation of SMS are divided into endogenous and exogenous factors (Millard-Ball 2005; Büttner and Petersen 2011). Exogenous characteristics are city specific and usually cannot be changed. Exogenous characteristics comprise the city size, mobility behavior, transportation infrastructure, and in the case of BSS also climate and geography. Endogenous characteristics have to be adjusted according to the exogenous circumstances. They are divided further into the organizational structure and physical configuration. The organizational structure comprises the type of the operator and pricing models. The physical configuration involves the type of vehicle and design of the service in terms of the model of provision, offered spatial flexibility, and booking options.

Table 2.2 Taxonomy of SMS business models

	Manifestation
Shared vehicle	Cars; bikes; other vehicles
Operator	Public institution; private company; public–private partnership
Pricing	Linear; progressive; flat-rate
Design	Station-based; station-less
Spatial flexibility	Round-trip; one-way; free-floating
Booking	Reservation; spontaneous

Table 2.2 shows the *taxonomy of SMS* business models according to the manifestation of different characteristics. Details on the characteristics and specific manifestations are given in the following:

- The *shared vehicle* is the most important characteristic regarding the addressed user group. Dominating vehicles are cars and bikes. Electric powered cars and bikes are upcoming. However, other vehicles such as scooters exist. Technological modifications of vehicles are necessary to enable rental processes. In the case of CSS, original cars are extended by specific hardware. In the case of BSS, specially developed flashy and robust bikes are used.
- *Operators* of SMS can be broadly classified into three primary groups of private companies, public institutions, or public–private partnership (Millard-Ball 2005; DeMaio 2009). Examples of public institutions are local governments, nonprofit organizations, or universities. Examples of private companies are transport agencies, for-profit organizations, or advertising firms. Institutions and companies often agree on a public–private partnership. According to Parkes et al. (2013) the dominating operator models of BSS in Europe are advertising firms working alongside with the local government. The advertising firm operates the BSS. Revenue is generated from advertisement on bikes and stations as well as from the right to advertise on city furniture granted by the local government. Commonly, the local government subsidizes the infrastructure of the BSS. In North America, local governments or nonprofit organizations fund and grant BSS operated by for-profit subcontractors.
- Depending on the operator and thus source of revenue, different *pricing* models exist (Millard-Ball 2005; Büttner and Petersen 2011). Pricing models of operators vary considerably, but in general, the aim is to maximize the utilization rate of vehicles. Registration fees and usage fees are distinguished. Examples for registration comprise one-time payments to use the SMS or temporal fees such as annual or monthly registration. Usage fees arise for the time and/or distance of the trips. Commonly, linear or progressive increases in prices exist but also flat rates are possible. In BSS, the first 30 min of trips are free in many systems to encourage bike usage (Büttner and Petersen 2011). Pricing models have a big effect on the intended users. For instance, a pricing model with high annual registration fees and low usage fees will encourage regular users such as commuters.

- The design of SMS differs in the *model of provision* and thus the way the vehicles are supplied to the user. Station-based and station-less systems are distinguished (Millard-Ball 2005; Büttner and Petersen 2011). In station-based systems, vehicles are only accessible at specific locations throughout the city, whereas in station-less systems, a service area is designated. Each model of provision comes with benefits and drawbacks directly effecting the planning, implementation, and operation of SMS. In the case of station-based systems, decisions on the number, location, and size of stations are required. Stations limit the spatial flexibility (see below) but relocation operations are easier.
- Depending on the model of provision, different degrees of *spatial flexibility* for returning the vehicle are possible. BSS and CSS can offer round-trips and one-way trips in station-based systems as well as free-floating trips in station-less systems (Firnkorn and Müller 2011; Parkes et al. 2013). The most restrictive forms are round-trips where the vehicle has to be returned to the same station when it was rented. One-way trips allow returning the vehicle at any station within the system. Free-floating offers the most flexibility by returning the vehicle at any location within the service area.
- Furthermore, SMS can offer *booking* of vehicles. When it comes to the renting process, reservation of vehicles and spontaneous use are differentiated (Millard-Ball 2005; Büttner and Petersen 2011). In SMS providing reservation, information on the trip, e.g., origin, destination, and duration, is needed beforehand to rent a vehicle. By means of reservation, it is ensured that a vehicle is provided at the desired location and time. For spontaneous trips, no reservation in advance is necessary. Reservations will increase the reliable provision of service but may exclude users that demand spontaneous trips.

In order to get a better impression of SMS business models, three exemplary systems are presented (cf. Table 2.3).

In particular, the SMS stand out due to the following manifestations:

- “Quicar” (www.web.quicar.de) is a CSS operated by the German car producer Volkswagen. The station-based system offers 200 cars at more than 50 stations

Table 2.3 Examples of SMS business models

Attributes	Quicar	Call a bike Flex	Citybike Wien
Shared resource	Cars	Bikes	Bikes
Operator	Volkswagen (car producer)	Deutsche Bahn (transportation agency)	Gewista Werbegesellschaft mbh (advertising company)
Pricing samples	6 Euro for first 30 min, then 20 Cent/min	6 Cents/min	First 60 min free, then progressive
Design	Station-based	Station-less	Station-based
Spatial freedom	Round-trip	Free-floating	One-way
Booking	Reservation	Spontaneous	Spontaneous

in Hannover. Commonly, reservations are encouraged, but spontaneous trips are also possible. Except for some selected routes, only round-trips are supported. The first 30 min cost 6 Euro, after that, 20 Cents/min are charged while driving and 10 Cent/min while parking.

- An example for a station-less BSS is “Call a bike Flex” (www.callabike-interaktiv.de) by the German railways agency “Deutsche Bahn.” This free-floating system offered more than 1600 bikes in Berlin, but was suspended in favor of a station-based system in summer 2013. Until then, bikes could be returned at any street crossing within the service area. Users transmitted the bike’s location via phone calls to the operator. When renting a bike, users requested the bike’s unlocking code via phone calls. 6 Cents were charged per minute.
- The “Citybike Wien” (CBW) (www.citybikewien.at) serves as a representative for BSS operated by advertising companies. CBW offers 1500 bikes and around 3000 bike racks at more than 120 stations as of early 2015. Using the CBW is almost free of charge, since no subscription fees are required and the first 60 min of trips are for free. The station-based system offers spontaneous one-way trips. Reservation of bikes is not possible.

The concepts, models, and methods presented in this work are, with some restrictions, applicable to SMS in general. The different characteristics show that various business models are possible each having its advantages and limitations. In the domain of BSS, station-based BSS offering spontaneous one-way trips without usage fees in the first minutes seem to become the dominating business model. This way of providing mobility would not have been possible without information systems support. Therefore, information systems support of BSS is described in the following.

2.2.3 Information Systems Support of Bike Sharing Systems

Over the past years, BSS have evolved from unsupervised to fully automated systems. In the beginnings, bike sharing suffered from anonymous use that led to theft. In recent years, the implementation of information systems in bike sharing overcame theft and enabled easy and quick access supporting rentals and returns at automated stations providing one-way trips. The implementation of BSS is rapidly growing. According to Midgley (2009), about 80 systems with almost 27,000 bikes and more than 4600 stations were in operation in May 2009. About 400 BSS have been introduced in Europe during the last 10 years (Büttner and Petersen 2011). Markets in America and Asia are catching up (Shaheen et al. 2010). The bike sharing world map (http://bike-sharing.blogspot.de) shows that BSS were implemented in 776 cities around the globe providing almost 820,000 bikes by the end of the year 2014.

In order to give more details on BSS, a brief overview of bike sharing evolution is presented. Furthermore, the automated service process enabled by information systems is discussed. Information systems also provide a vast amount of data reflecting the mobility behavior in BSS.

For a better understanding of BSS, a brief summary of *bike sharing evolution* is given according to DeMaio (2009a) and Shaheen et al. (2010). Three generations of BSS can be identified, whereas a fourth generation is evolving. The idea to provide bikes for inner-city trips to the public was put into practice in Amsterdam in the year 1965. This first generation of BSS started with ordinary bikes painted white. The system was open to anyone and bikes could dropped off anywhere. Theft and vandalism caused the system to collapse within days. The second generation was developed almost 30 years later in the 1990s. The Copenhagen “Bycyklen” (www.bycyklen.dk) introduced special designed robust bikes with advertising plates on the spokes. The bikes were locked at special stations distributed over the city. A coin deposit was necessary to pick up the bikes. Therefore, users were still anonymous and the program suffered from theft. The program was terminated at the end of 2012 and a new system is currently under development (http://gobike.com). The third and nowadays dominating generation of BSS is smartened with electronically locked bikes or bike racks. Users have to register with a smartcard or credit cards to rent bikes. Furthermore, information and telecommunication systems for a better user and bike tracking are established. The fourth, currently developing, generation integrates new technology such as electric bikes, GPS tracking of bikes, and smartcards facilitating intermodal integration.

BSS provide likewise public but individual mobility with the help of self-service rental stations. The introduction of information systems started the success of BSS by *enabling automated easy, quick, and convenient service.* In particular, information systems support rental and return processes. In contrast to the easy use on the front-end side, BSS operators have to execute effortful and thus costly measures in order to enable reliable service on the back-end side. In the following, a process-oriented view on services is given showing the interplay of users and service providers. Additionally, the role of information systems in the service process aligned to BSS is described focusing on the provision of service.

Service providers offer services. Incorporating users as an external factor is special about services. Consequently, the *service process* is divided according to the user transaction phases. These phases comprise initiation, agreement, and execution (Mertens et al. 2007). Each phase consists of individual tasks, whereas a distinction between tasks with and without direct user contact, i.e., front office and back office, is made (cf. Fig. 2.4). The initiation phase specifies services with the help of marketing measures and the associated services are provided. Next, users select services according to their needs based on available information and consulting. In the subsequent agreement phase, service provider and user conclude an agreement on the service. Finally, the service is executed, billed, and paid.

Information systems can support all phases of the service process in BSS. Especially from a user’s point of view, easy and immediate access to the shared mobility resource is most important for the acceptance and success of BSS. From an

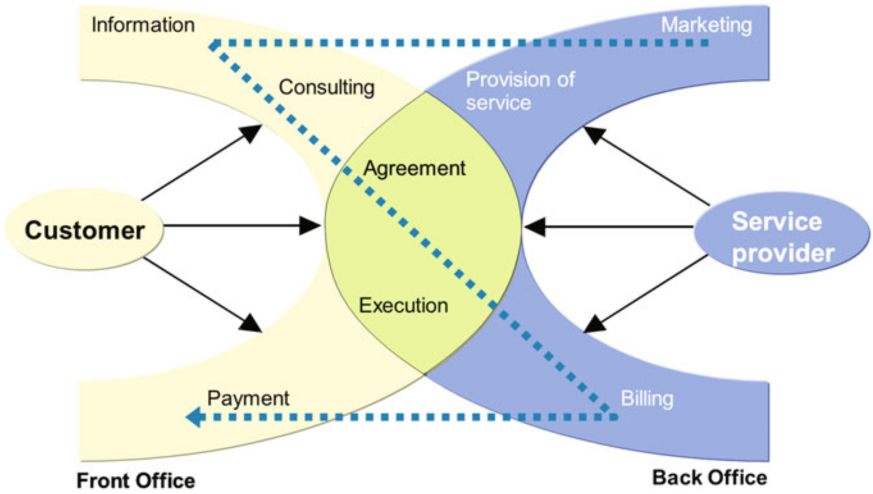

Fig. 2.4 Service process [adapted from Bodendorf (1999)]

operator's point of view, the costs of operation have to be kept reasonable and theft has to be avoided. In BSS, registration usually requires a debit or credit card for authentication and payment. Self-service rental stations facilitate full spatiotemporal accessibility and flexibility. Moreover, information systems ensure tracking of users and their rented bikes. Thus, users can rent and return bikes at any station and point in time and all user trips are recorded automatically for tracking and billing purposes.

In particular, the individual tasks and their information systems support adapted to BSS are the following (Bodendorf 1999):

- *Marketing* in the service process aims at identifying and addressing potential users. Market research in the service sector is characterized by direct user contact. Data on the user and his use of the services are usually recorded. Polls can further support the identification of user needs and support creating user profiles. A major drawback of market research in the service sector regards the quality evaluation. Services are intangible goods and therefore evaluation by physical properties is not possible. Service quality relies on the subjective measurement of the execution and result. In the case of BSS, the analysis of recorded trip data and user surveys can be used to evaluate the service quality and determine mobility needs of users. Findings help to improve the service.
- The *reliable provision of service* is a crucial part of the process. Each factor needed for the service has to be in right place and time since services are intangible. If user demand outstrips capacity of bikes and bike racks, "lost sales" are induced. Lost sales refer to users that cannot rent or return bikes and therefore might abandon the system. BSS show a high variation regarding the bike demand. As a result, the provision of service has to be tailored to the user

demand. In BSS, provision of service involves controlling supply or demand. Controlling supply means that the operator actively provides bikes or bike racks. With the help of service vehicles, bikes are relocated from full to empty stations. Controlling demand refers to indirect control of bike demand by means of incentives. For example, returning a bike at an uphill station grants some kind of bonus. The efficient provision of service is supported by approaches and methods from the field of logistics (cf. Chap. 3). IDA supports modeling of mobility behavior in BSS and generation user demand scenarios (cf. Chap. 4).

- The *information and consulting* phase shows problems similar to the marketing phase. The service is intangible and must be tailored to the user's needs. Thus, information on the costs and availability of the service has to be up to date and trustworthy. Furthermore, information has to be easily accessible and understood. In BSS, information on the availability of bikes and bike racks is provided by means of the operators' homepages, applications for smart phones, or at the self-service terminals. Since each rental and return at every station is recorded electronically, information on the service availability can be provided almost instantly.
- Because of the information and consulting phase, the user is aware of offered services and prices. The user can either *agree* on the given offer or change the offer. Changing the offer might affect the scope of the service and induce altering costs. BSS have a fixed pricing model based on trip duration and therefore negotiating prices is not possible.
- Service *execution* brings the user as an external factor and internal factors, e.g., people, goods, or information, together. In particular, execution is associated with a transformation of the service object. Service objects can be the user himself, an item or money. Transformation comprises change of the service object, location, or time. The integration of user and service involves the front-end, the back-end, or both. In BSS, the provision of service and the execution are directly interconnected. The shared mobility resource has to be provided at the right time and place according to the users' mobility needs. As a result, the reliable provision of service is crucial for the viability of the system.
- After execution, the BSS operator charges the users for the trip. *Billing* can either be product- or process-oriented. In the former, a previously defined fee for the whole service is charged. In the latter, total costs are derived based on the individual components of the service. BSS usually have product-oriented billing.
- *Payment* finalizes the rental process. With the help of the registered debit or credit card, open trip fees are debited automatically from the user's account.

After gaining insights into the information systems support for BSS, general guidelines on the planning, implementation, and operation are presented. Furthermore, different configurations of BSS are depicted.

2.2.4 General Guidelines on the Planning, Implementation, and Operation of BSS

Whereas the previous section portrayed BSS from a more theoretical point of view, the upcoming section gives a more practical view on the planning, implementation, and operation of BSS.

The booming of bike sharing in Europe led the European Commission to fund a project on "Optimising Bike Sharing in European Cities" (OBIS) (www.obisproject.com). The project involved 16 partners from different European countries to assess BSS in the years 2008–2011. Information about more than 50 BSS were collected. Outcome is the OBIS handbook (Büttner and Petersen 2011) for stakeholders participating in the planning, implementation, and operation of BSS. Based on the OBIS handbook, general guidelines on the planning, implementation, and operation of BSS are outlined (cf. Fig. 2.5). The aim is to understand the requirements and prerequisites of successful bike sharing better. The course of action gives a general impression on the planning steps in order to present the necessary steps. Since this work focuses on the quantitative optimization of BSS from a scientific point of view, the reader is referred to the OBIS handbook for a detailed presentation of the general planning steps. A similar planning guide with an international focus was issued by the Institute for Transportation & Development Policy (Gauthier et al. 2013).

Planning of BSS

Sophisticated planning lays the foundation of successful implementation and operation of BSS. Planning tasks involve the specification of overall urban mobility goals and goals of the BSS in particular, bringing stakeholders together, defining the rough concept of the BSS in a business plan, and finally writing a tender.

BSS can contribute to a change in urban mobility behavior. Therefore, it is advisable to *specify urban mobility goals* in accordance with a cycling master plan. In order to lower the entrance barrier of cycling in general, investment into cycling infrastructure is necessary. As seen above, different business models and implications of BSS exist. Thus, the business model of the future BSS has to be tailored according to the urban mobility goals of the municipality or operator. For instance,

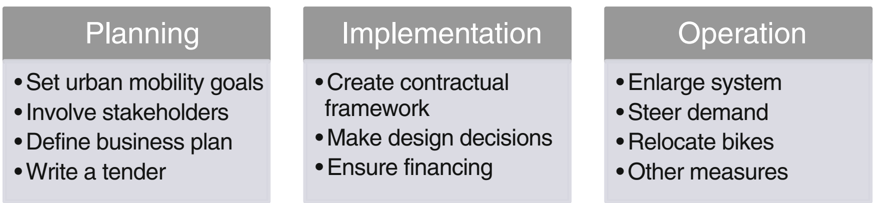

Fig. 2.5 Overview of planning, implementation, and operation tasks of BSS

a BSS addressing daily commutes requires short rental times and high service reliability in peak hours. Tourists, for instance, show other mobility needs. The most notable implications resulting from BSS comprise the increase of bike share, enhancement of public transportation options, image advances of a city as modern and sustainable as well as improvement of people's health. In the next step, planning guidelines recommend informing and *involving politicians and municipal stakeholders* in the decision process as early as possible. Without the support of stakeholders promoting bike sharing, BSS will likely fail. A rough concept then captures defined objectives gathered by stakeholders. The concept requires a feasibility study examining basic decisions on the BSS configuration such as a station-based or station-less system, high- or low-tech bikes, pricing schemes, etc. Based on the study, a *business plan* defines planning and implementation procedures. Specifying financial aspects and service level requirements as well as public and private involvement by *writing a tender* completes the planning phase.

Implementation of BSS

Decisions and specifications determined in the planning phase are deployed in the implementation phase. The implementation settles the contractual framework, finalizes decisions on the actual design, and explores financing sources.

The *contractual framework* regulates tasks between municipality and operator. Main tasks comprise the provision of BSS infrastructure and actual operation of the BSS. Different contract models exist depending on the underlying circumstances of the city. The two most prominent models are public–private partnership and outsourcing. Public–private partnership involves the municipality implementing and owning the BSS infrastructure, whereas the operation is contracted to a third party. Outsourcing means concluding a complete contract with a third-party implementer and operator.

Design decisions stipulate the terms of implementation and affect operation. According to Büttner and Petersen (2011), the implementation of BSS is associated with high investments. Their survey among BSS operators reveals that capital costs amount to 2500 to 3000 Euro per bike. In order to get a better impression of the composition of investments, the share of capital costs is exemplified by means of the Barcelona BSS "Bicing" (www.bicing.cat). Bike stations and bikes contribute to the highest costs. The implementation of stations results in the highest proportion of costs with 70 % due to the acquisition of terminals, bike racks, electrification, and data connections. The acquisition of bikes still holds a share of 17 %. Other items are marginal. The setup operations such as a workshop and logistics amount to 6 %. Communication and administration add up to 5 and 2 % of costs, respectively.

In the following, design decisions are presented in more detail. Design decisions cover the used hardware, software and technology, design of stations and bikes, as well as service level requirements.

The ultimate objective of implemented *software, hardware, and technology* is providing usability from a user's point of view. In contrast, easy maintenance and manageable costs are essential from an operator's point of view. Recent success of BSS is related to advances in technology allowing for automated identification of users involved in rental operations. Especially, spontaneous usage is a necessary characteristic in modern BSS. Thus, convenient and fast registrations at bike stations and via the operator's web side are essential for the acceptance and success of BSS. In particular, the installed technologies such as smartcards, credit cards, or public transportation cards support fast access. In accordance, the implemented software on the front-end side is obliged to facilitate easy and automated rental operations and provide real-time information on fill levels. The back-end side has to support service level control as well as relocation and maintenance management to successfully monitor and control the BSS.

Also, important are decisions on the actual *design of bike stations and bikes*. Regarding bike stations, station-based and stations-less BSS are distinguished. Implementing stations has the advantages of a high visibility in public space, easy rental operations, and higher perceived availability compared to station-less systems. However, stations are associated with high investments compared to station-less systems. In station-less systems, the rental technology has to be integrated into the bikes, whereas station-based system enables rentals through terminals or bike racks. The stations' design is a tradeoff between recognizability and unobtrusiveness. Flashy stations easier attract users, but may disturb the cityscape. Regarding bikes, the design should meet the standards of many users. Comfortable but likewise robust bikes support user satisfaction. Additional locks at bikes are not obligatory, since bikes are usually locked at the bike racks. However, additional locks enable users to pause their trips and park the bike if desired.

Service level requirements address the reliable provision of the service. Primary requirements involve the covering area and density of the system. A distance of 300 meters between stations is desired to enable a comfortable walking distance to the origins and destinations of bike trips. Derived decisions comprise the location and number of stations as well as the number of bike racks at each station. In particular, the capacity at stations is important to avoid user frustration due to full or empty stations. According to the OBIS handbook, each station should provide approximately 10 bikes, whereas the station's capacity should comprise 1.5–2.3 times more bike racks than bikes. Further recommendations are to provide a station with 10 bikes per 6666 inhabitants.

In order get insights into the design of implemented systems, BSS configurations of three station-based systems are sketched. Table 2.4 shows design and service level key figures of a small, medium, and large BSS differing significantly in size and usage. The CBW, Vienna, is small of size and usage compared to other popular BSS such as Vélib, Paris (www.velib.paris.fr), and Bicing, Barcelona (www.bicing.cat). CBW has 120 stations offering 3065 bike racks and 1500 bikes. The ratio of bike racks to bikes is almost 2:1. Almost 1,000,000 trips occurred in 2014, whereas the average utilization rate per bike and day is 1.8. The Vélib is one of the biggest systems worldwide with 1600 bike stations and 23,700 bikes. Data about the number of bike racks are not available. In addition, the utilization rate is higher with four rentals per bike and day. Bicing shows the best performance with six rentals per bike and day. Bicing offers 6000 bikes at 420 stations with approximately 10,500 bike

Table 2.4 Configuration of exemplary station-based, advertisement-based BSS. Citybike 2012, Velib 2012, Bicing 2013 gathered from the operators' web sides

	Citybike Wien	Vélib	Bicing
Operator	Gewista	JCDecaux	ClearChannel
City	Vienna, Austria	Paris, France	Barcelona, Spain
Start date	2003	2007	2007
Bicycles	1500	23,700	6000
Bike racks	3000	no data	~10,500
Stations	120	1600	420
Rentals/year	980,000	34,145,000	13,271,190
Avg. rentals bike/day	1.8	4	6

racks. For an extensive overview of BSS configuration in various cities, it is referred to O'Brien et al. (2013).

Design decisions are hard to obtain and have a significant effect on the viability of the system. An experience from London shows that "identifying the sites for the docking stations has been a complex process in a city with little available space within the center" (Büttner and Petersen 2011). Furthermore, station planning affects relocation of bikes and has to be anticipated adequately. Planners from Barcelona admit that "… a protocol has been defined to ensure conditions of access to the bike stations for the redistribution vans. This work was not sufficiently anticipated when the stations were being implemented" (Büttner and Petersen 2011). An additional design characteristic is the service time. The operator has to decide whether to provide the service all day or close the system at night. Moreover, a complete shutdown has to be taken into consideration in seasons without cycling friendly weather. These experiences show that possible problems regarding operations already have to be anticipated in the implementation phase.

The *obtained service level* is a fundamental indicator for the viability of BSS. Defining performance measures helps to monitor the service level. The number of rentals per targeted people is an appreciated indicator regarding the impact of BSS. The number of rentals per year or daily rentals per bike reflects the performance of BSS. Well-established systems feature four to six daily rentals per bike (cf. Table 2.4). Furthermore, user satisfaction ought to be measured by means of inquiries and surveys. The operator's contract should define service level standards such as total rentals per year, maximum time for stations being full or empty, relocation effort, maximum down time and defects, and minimum availability of user contact points.

Revenue from trips will likely not be sufficient to cover the costs of BSS. Thus, sophisticated *financing* ensures a long-term operation of BSS. Financing comprises sources such as registration fees, usage fees, and additional funding. Registration fees and usage fees for BSS are commonly lower than for traditional public transportation. Registration for different time periods is usually offered, e.g., yearly, monthly, weekly, and daily registration. However, some operators refrain from registration fees to stimulate usage. Usage fees arise for the duration of trips. Linear or progressive price increases exist but also flat rates are possible. In most BSS, the first 30 min of trips are free encouraging bike usage. Thus, additional funding sources are necessary since revenues from trips will likely not cover invested capital and operational costs. Additional funding may involve direct subsidies, contracts to advertise on street furniture, or sponsorships.

Operation of BSS

The operation of BSS results in not to be underestimated costs. According to Büttner and Petersen (2011) operating costs amount to 1500 to 2500 Euro per bike and year. Thus, total operating costs will exceed investments after a few years of operation. Gauthier et al. (2013) calculate operating costs per trip for different BSS. BSS with a large number of trips per bike stand out due low operating costs per trip, e.g., in Lyon and Barcelona with around 1 US Dollar. On the contrary, almost 5 US Dollar operating costs per trip are estimated for London. In order to get a better impression of the composition of investments, the share of operating costs is exemplified again by means of the Barcelona BSS Bicing. The relocation of bikes induces the highest share with 30 % of costs due to relocation vehicles and staff wages. Relocation is followed by maintenance of bikes and bike stations with 22 and 20 %, respectively. Operation of the information system amounts to 14 % and administration accounts for 13 %. Replacement of bikes and stations due to failure, theft, or vandalism is low and only comes to 1 % of operating costs.

Suitable measures prevent operating costs from getting out of control. Measures of the operator optimizing the system operation involve steering the demand, enlarging the system, relocating bikes, and other measures.

Steering demand is important to encourage or restrict usage, since the actual demand often does not match the expected demand. In the case of excessive demand, it is advisable to restrict the access to a limited number of users or increase fees to avoid user dissatisfaction due to full or empty stations. In the case of demand shortage, increased marketing measures and decreased fees may stimulate usage.

Furthermore, *enlarging the BSS* by extension or densification may reduce operating costs. Here, the nonlinear network effect applies. For each new station, the number of new OD pairs increases by the number of already existing stations. In particular, extending the system exploits so far unserved areas. Densification has the purpose to distribute demand better among nearby stations. In both cases, choosing suitable locations and station capacities avoids full or empty stations and thus contributes to a more reliable service.

However, due to the complex spatiotemporal mobility behavior of people, *relocation of bikes* is inevitable. As seen above, relocation is one of the main cost factors. DeMaio (2009) reports costs of three US dollars per relocated bike for the Vélib. In contrast, revenue generated by trips is unlikely in most systems since the first 30 min are free of charge. Thus, the optimization of relocation is crucial for the cost-effective operation of BSS while providing reliable service. Therefore, insights into the mobility behavior and trip purposes of users are necessary to determine user demand and required relocation effort. Furthermore, improving relocation operations yields an efficient utilization of relocation vehicles and staff. In addition to operator-based relocation of bikes, user-based incentives can indirectly influence the distribution of bikes. For instance, Vélib grants 15 extra free minutes when returning bikes at specially marked uphill stations. However, due to the indirect nature of incentives, the effect is hard to estimate and control.

Other measures to improve the operation of BSS involve additional financing, introducing new technologies, and combining BSS with other modes of transportation. Since most BSS are not financially self-supported, additional financing possibilities provide revenue. Possibilities comprise involving sponsors as a long-term funding source and offering special fees to local companies and their employees to attract more users. Developing and introducing new technologies, such as RFID or GPS, are encouraged to improve rental processes and trip tracking. Combining BSS with other modes of transportation by means of an integrated smart card supports intermodality and multimodality and may increase usage.

Overall, the planning, implementation, and operation of BSS involve different stakeholders and diverse tasks. Especially, ensuring the reliability of service is crucial for the success and acceptance of BSS. Thus, adequate location and density of BSS access as well as a sufficient number of mobility resources have to be provided according to the user's spatiotemporal mobility needs. Methods and models from the field of logistics can support such decisions. Interviews with BSS operators show that (automated) decision support for the reliable provision of service is not exploited yet (Shaheen et al. 2010). However, reliability of service is the key factor demand by users (Büttner and Petersen 2011). The reliable provision of service in BSS can be tackled with the help of optimization models from the field of logistics. Consequently, measures for the reliable provision of service in BSS and related logistical approaches are presented in the following.

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