Toward User-Based Relocation Information Systems in Station-Based One-Way Car Sharing

Full Paper

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Abstract

Car sharing is an important mobility service to approach urban and suburban mobility problems. It is a sustainable means of transport because it lowers the emissions of each car sharing customer by substituting privately owned vehicles by joint used ones. Nevertheless, car sharing still has to fully unfold its potential and has to overcome certain obstacles. For instance, it is necessary to substitute operator-based relocation by user-based relocation, which is more sustainable and cost-efficient. In this paper, we propose a framework and algorithms for implementing user-based relocation in the context of station-based one-way car sharing. Through a simulated car sharing system with 34.418 rental data we were able to demonstrate, that user-based relocation has the potential to increase the number of accepted rentals. Implementing the proposed system would increase service quality, providers' profits and the positive environmental impact of car sharing.

Keywords

Car sharing, relocation, green IS, user-based, information system

Introduction

Car sharing has been reported to provide various benefits for both its users and the environment. To mention some of them, it encourages collective transportation, is convenient and cost effective for the users (Wagner and Shaheen 1998), and, by offering a sustainable and flexible short-term transportation service, this concept complements classical means of transport by closing the gap between individual and existing public transportation options (Belk 2013; Hildebrand et al. 2015; Nawangpalupi and Demirbilek 2008; Prettenthaler and Steininger 1999). Car sharing could be seen as a means to increase sustainability and approach urban transportation problems, e.g., the lack of parking space and harmful emissions (Baptista et al. 2014; Firnkorn and Müller 2011; Martin and Shaheen 2011; Millard-Ball et al. 2005) and therefore, it is important, that this transportation mode continues to grow (Shaheen and Cohen 2013).

However, lowering operating costs remain a key factor for the success of car sharing services (Jorge and Correia 2013; Shaheen et al. 2012). One of the major cost factors is the balancing of supply and demand at each of the predefined stations (Jorge and Correia 2013). Since the amount of vehicles at each station can vary throughout the day, there may be situations where the supplies cannot meet the demands at some stations (Balac and Ciari 2014; Ciari et al. 2012). Many existing car sharing providers use operator-based relocation, which is more cost- and resource-insufficient than user-based relocation (Clemente et al. 2013; Weikel and Bogenberger 2012). Therefore, it will be more sustainable and cost-efficient, if car sharing providers substitute operator-based relocation with user-based relocation. In order to apply user-based relocation, a specialized information system (IS) is needed (Di Febbraro 2012; Weikel and Bogenberger 2012).

Unfortunately, it can be difficult to provide cost-efficient car sharing, especially when we consider small towns and suburban areas. The reduced number of customers spread on a relative large area hinders some of the possible car sharing operating models and makes the relocation problem even worse (Boyaci et al. 2014; Rickenberg et al. 2013). In this context, we will focus on the car sharing version of station-based one-way car sharing because it could provide an efficient car sharing solution for small towns and suburban areas through a functioning user-based relocation system.

This paper aims to answer the following research questions: (1) *How to design a user-based relocation information system?* (2) *What is the impact of user-based relocation on station-based one-way car sharing systems and providers?*

To answer these questions, we first developed a tri-modular framework for a relocation IS which uses demand predictions based on data analysis to plan relocations, and offers customers incentive pricing to enable user-based relocation. Secondly, we analyzed over 34.000 generated rental data to verify the relocation algorithm and the service quality enhancement. And thirdly, considering that we also intended to include the user perspective, i.e., users' willingness to participate in such a system, we conducted a survey of 26 car sharing users and non-users to determine the incentive sensitivity.

Related work

Car Sharing As Sustainable Means of Transportation

In car sharing concepts, a fleet of vehicles is distributed within the operator's area, which can be used by different customers (Boyaci et al. 2014; Di Febbraro et al. 2012; Jorge and Correia 2013; Katzev 2003). Commonly stated benefits of car sharing are its encouragement for collective transportation, its convenience as well as its cost-effectiveness for the users (Wagner and Shaheen 1998). Adding car sharing as an additional form of transportation to the existing classical means of transport (e.g., bus, train, car) satisfies the common need for a more flexible and sustainable way of travelling (Belk 2013; Hildebrand et al. 2015; Nawangpalupi and Demirbilek 2008; Prettenthaler and Steininger 1999).

For the individual, car sharing transforms the fixed costs of owning a car into variable costs. Unlike car sharing, owning a car has many different fixed cost factors like purchase, maintenance and insurance (Shaheen et al. 1998). Previous research has also highlighted several advantages for environmental sustainability and our society at large scale. Due to the fact that customers pay per usage and that in most cases, the vehicle does not stand right in front of their house or apartment, they seem to evaluate the necessity of a trip differently than car owners. Previous studies have shown that, compared to trips with an individually owned car, car sharing has the potential to decrease individual mobility by up to 30% (Martin and Shaheen 2011). Besides the reduced mobility and the resulting lower emissions, using car sharing results in reduced parking demand and less noise, which makes it an environmentally sustainable means of transport (Martin and Shaheen 2011; Millard-Ball et al. 2005).

Three major operating models can be distinguished: Station-based two-way car sharing, station-based one-way car sharing and free-floating car sharing. In context of station-based two-way car sharing, customers can rent a car from a station, but have to return it at the same station after their rental (Balac and Ciaris 2014; Di Febbraro 2012). Station-based one-way car sharing extends station-based car sharing by giving customers the option to return the vehicle at any available station (Balac and Ciari 2014; Ciari et al. 2012). It is also a very popular type of car sharing (Balac and Ciari 2014), but it has some drawbacks. One major drawback is the problem of supply and demand at each of the predefined stations. The demand of vehicles at each station can vary throughout the day and very often the supply cannot meet the demand at some stations (Boyaci et al. 2014; Ciari et al. 2012). A very similar version of car sharing is free-floating car sharing. This form has no stations and customers can (ideally) pickup and return rental cars wherever they like within the operation area of the provider (Balac and Ciari 2014; Weikel and Bogenbauer 2012).

Relocation Research

Relocation is the process of repositioning a vehicle with the objective to solve the problem of demand and supply imbalances (Boyaci et al. 2014; Di Febbraro 2012; Kek et al. 2009). Station-based one-way car sharing and free-floating car sharing systems have a similar relocation problem. Free-floating can be understood as a station-based one-way car sharing system with an infinite number of stations. Because of

this, even though their relocation methods can be compared, they cannot simply be applied on both of them (Wagner et al. 2015). In the following paragraphs, we will present an overview over the current research for both car sharing systems.

Although research for relocation methods and application options for free-floating car sharing is needed, very little research has been conducted on this subject (Jorge and Correia 2013). For instance, Weikels and Bogenbergers (2013) research considered operator-based as well as user-based relocation as an option. They focused on demand prediction methods and algorithms for computing the optimal vehicle distribution within the operation area of free-floating car sharing. However, they did not evaluate their concept empirically or in a case-study. Recently Wagner et al. (2015) introduced a relocation framework for a user-based relocation support system in a free-floating car sharing context. They tried to minimize the idle time of each vehicle and were able to show that by applying their concept of relocation the idle time would decrease and rentals per car would increase.

In a station-based one-way car sharing the employees of the car sharing company are normally the ones who relocate the vehicles by driving, towing or ride-sharing them to the desired location (Barth and Todd 1999; Cepolina and Farina 2012; Kek et al. 2009). This procedure is called operator-based relocation. Jorge et al. (2014) have shown that operator-based relocation can improve the vehicle balance in a station-based one-way car sharing System. Kek et al. (2009) used optimization-trend simulation to significantly lower the number of relocations and reduce their costs. Taking all this research into account, the costs of operator-based relocation can still be considered a problem. Clemente et al. (2013) have pointed out that operator-based relocation is more expensive and insufficient when compared to user-based relocation. As a consequence, user-based relocation should be preferred.

Developing a Relocation Information System Framework

We developed a framework for user-based relocation information systems (formerly called URIS). As a starting point we used the back-end and front-end architecture in combination with a framework for user-based relocation support systems in free-floating car sharing systems (Wagner et al. 2015).

The URIS framework contains five major parts: rental data, prediction module, relocation module, customer interaction module and the customer (Figure 1). Based on the rental data, the prediction module will identify the stations with a supply and demand imbalance. The information about stations in demand of relocation will be used in the relocation module to calculate appropriate user-based relocations and the incentive. The customer interaction module presents the relocation request to the customer, together with the incentive, and accepts the response (acceptation or rejection) from the customer.
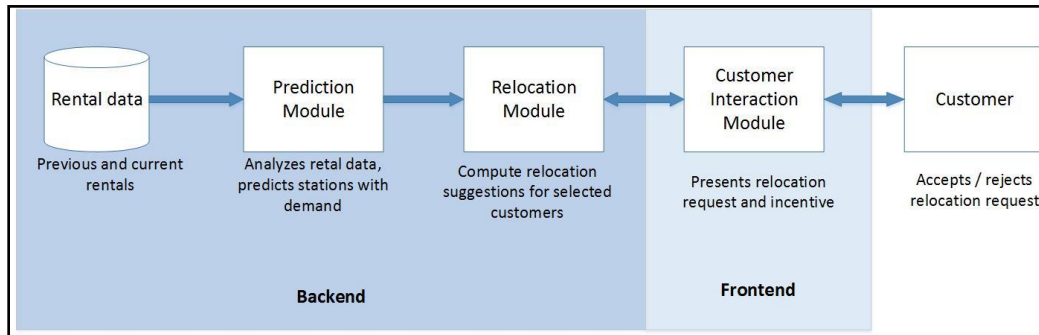

Figure 1: User-based Relocation Information System (URIS) Framework

Rental Data

A rental data record includes many variables, i.e. customer ID, start time, end time, origin station, destination station etc. (e.g., Wagner et al. 2015). In the context of the presented approach a rental r is defined as the following tuple:

$$r = (destination, \tau_{end}, vehicle)$$

$destination$ = destination station

τ_{end} = arrival time

$vehicle$ = rented vehicle

Prediction Module

In order to determine if demand and supply are imbalanced at a station, we propose the following approach. Firstly, assuming that the vehicle fleet is homogeneously, the minimum number of cars needed at a station has to be defined. This threshold T of needed cars can be computed as follows:

$$T_\tau^S = \frac{B^S * nv_{\tau_1,\tau_2}}{K * B} \tag{1}$$

T_τ^S = Threshold for station S at timepoint τ

B^S = Number of rentals at station S.

B = Total number of rentals

nv_{τ_1,τ_2} = Number of vehicles available in the time period between τ_1 and τ_2

K = Risk factor of rejection

τ_1 = Start of time frame

τ_2 = End of time frame

Note, that, by definition, T_τ^S must always be greater or equal to 1. The goal is to set the threshold according to the number of rentals at station S and the number of available cars relative to the total number of rentals. To minimize the number of relocations, a risk factor K is used. The greater K is, the higher is the risk of no available car at station S, but at the same time the number of relocations decreases.

The next step is to compute the number of rentals at a station (B^S) and in total (B). First of all, it is important to define a time frame, which can be the last hour, today, this week or the complete last year. This decision has to be made based on the total number of bookings a car sharing has per day. If it is a very low number, larger time frames can be beneficial. In a second step, the data base has to be defined. The best scenario would be to have complete real-time information about each rental. If the data is only ex-post available, the use of previous data is the only option to complete the missing gaps. To combine previous and real-time rental data, we propose the following formulas:

$$B = B_{\tau_1,\tau_2}^p * f^p + B_{\tau_1,\tau_2}^{rt} * f^{rt} \tag{2}$$

$$B^S = B_{\tau_1,\tau_2}^{S,p} * f^p + B_{\tau_1,\tau_2}^{S,rt} * f^{rt} \tag{3}$$

$$f^p + f^{rt} = 1$$

B_{τ_1,τ_2}^p = Total number of rentals in time frame τ_1, τ_2 in previous data

$B_{\tau_1,\tau_2}^{S,p}$ = Number of rentals at station S in time frame τ_1, τ_2 in previous data

B_{τ_1,τ_2}^{rt} = Total number of rentals in the time frame τ_1, τ_2 collected in real time

$B_{\tau_1,\tau_2}^{S,rt}$ = Number of rentals at station S in the time frame τ_1, τ_2 collected in real time

f^p = Weighting factor of previous rentals

f^{rt} = Weighting factor of real-time rentals

The time frame has to be chosen according to the information supply. For example, the time frames could consist of the last 24 hours in the current (real-time) rental data and the same day last week in the previous rental data. This way, predictions can be made without complete data of all current rentals. The weighting factors f^p and f^{rt} should be chosen according to the data base. If there are only a few real-time rentals in each time frame, f[p] should be larger than f[rt] and if there are a lot of real-time rental information in each time frame, f[rt] should be larger than f^p. By this, the demand prediction can support *static relocation* (decision are based on immediate station need), *historical predictive relocation* (using previous data to predict future demand) (Barth, Todd 1999) or a hybrid form of both. For the purpose of identifying a supply-demand imbalance the following criterion will be used:

$$T_\tau^S \leq ci^S + ct^S \tag{4}$$

T_τ^S = Threshold of a station S at the time point τ.
ci^S = Number of vehicles at station S
ct^S = Number of vehicles driving to station S

If the criterion is not met, the supply does not meet the demand and the station is in need for relocation. We use the sum of ci^S and ct^S, since only using ci^S would lead to more cars parked at stations with low demand and more idle time of some cars. To simplify the algorithm and to lower the information demand, we decided to include ct^S. If the information about ct^S is not available, only considering ci^S is feasible.

Relocation Module

The relocation process contains three major parts: Considering the demand to determine the need of relocation, selecting customers for relocation and computing the incentive accordingly.

A possible demand-supply imbalance is computed in the prediction module and the information is transferred to the relocation module. Once there, the relocations will be determined, a fitting customer will be subsequently selected and the sufficient incentive will be computed. The information about which customer should relocate and about the incentive will be transferred to the customer interaction module. In the following, the algorithms, assumptions and methods will be explained.

To motivate customers not to return their car at a highly supplied station, the user will get a suggestion for an alternative destination and an incentive (Clemente et al. 2013; Di Febbraro et. al. 2012; Kek 2009). Relocation takes place when customers have to change their destination station to return the vehicle to an undersupplied station. The amount of needed successful relocations to balance demand and supply for a station is calculated as follows:

$$R^S = Th_\tau^S - (ci^S + ct^S) \tag{5}$$

R^S = Amount of needed relocation for station S

Customers will be asked to return their vehicle at a station with a high demand for relocation instead of their intended one. The set of customers will be selected as follows:

(1) Identify all rentals with a destination next to the demanding station

(2) Select rentals with a destination, which is not in need for relocation

(3) Sort rentals by arrival time (short arrival times first)

For the individual car sharing system, the stations which are next to each other have to be defined. The system will request customers until a R^S number of accepted relocations is reached or no suitable customers are left to be requested. If this happens, the system will wait until new fitting rentals are available and then proceed to request those customers.

To motivate the requested customers to relocate, an incentive can be used (Clemente et al. 2013; Kek 2009). Therefore, a survey has been conducted with the aim to approximate the incentives. We asked 26 people (car sharing customers and non-customers) in an online survey about their incentive sensitivity in relation to the extra time needed to go back from the station the system proposed to their intended one. The scale for the extra time was chosen according to the walking time between stations (from 10 up to 24 minutes) in the context of suburban areas. The extra time does not include the extra time for driving to a different station, but the participants were told that this extra time does not have to be paid.

Based on our findings, the incentive can be chosen according to the distance or extra time. The price as a function of the extra time (in minutes) is in our case:

$$price = 0.0376 * time^{1,4586} \tag{6}$$

This function is specific to our case and has to be computed individually for each car sharing system. In this study the results of the survey will be used in the discussion to assess the financial benefits of user-based relocation.

Customer Interaction Module

The system-user-interaction through the customer interaction module is bilateral, this means, the user gets a request and can either accept or decline it. In both cases, the customer interaction module will inform the relocation module. When the relocation module computes a relocation request for a customer, the interaction module will both present it to the customer and receive the response (acceptation or decline). To prove whether a customer was relocated or not, the system has to check if the vehicle was parked at the right station and afterwards give the customer feedback, showing that the relocation was completed.

Dataset for Simulation

Ideally, an evaluation of the benefits of relocation consists of a dataset of car sharing rentals without any (operator-based or user-based) relocation activities. However, it has been shown that such a system could not function successfully for a long period of time (Di Febbraro et al. 2012), therefore, this kind of relocation-free data cannot be obtained. In addition, it would also be necessary that this dataset would include denied requests for a rental. There are two causes of denied requests that have to be covered. Firstly, there are rentals denied by the provider because of insufficient supply, which customers could not see beforehand in the system. Secondly there are rentals that have not been carried out by the customers because the system already showed them the insufficient supply. Only by having this dataset, it would be possible to outline the actual impact of user-based relocation. As a conclusion, data from a station-based one-way car sharing with operator-based relocation does not provide a database for testing user-based relocation because of the intrinsically falsification. The only option is to generate this data. As a result of the lack of research on how to generate testing data for a station-based one-way car sharing relocation simulation (Jorge, Correia 2013), we used the following approach:

(1) We collected rental data over the course of thirteen months. In this period of time, the car sharing company was not a station-based one-way car sharing provider, but a station-based two-way car sharing one.

(2) Every rental got a new destination (in the same pattern as the origins – assuming that stations with a high demand will often be the origin and destination of rentals). In addition, long rentals (of over 4 hours) were separated in two rentals of 2 hours. Long rentals are usually the case in two-way car sharing because customers will drive to their destination, park their vehicle there and return it much later in the day. With the possibility of returning a vehicle at any station, this behavior is much more unusual and accrues rarely in case of inner-city (town) car sharing.

(3) To completely exclude the influence of operator-based relocation, it is necessary to randomize the rental data. To randomize the data the vehicles were located at a random station.

By doing so, we got a dataset that could be used as a station-based one-way car sharing without being biased by operator-based relocation. In total we generated 34418 rentals based on the 20855 initial ones. The extra 13563 rentals are the result of splitting long rentals. The station-based one-way car sharing system consisted of 9 stations and 81 vehicles.

Findings

We simulated the station-based one-way car sharing in the time frame of 13 months with 34418 rental requests. Every iteration to determine the parameters was calculated in the following setting. To calculate the best risk factor K, we simulated the whole system with a RAR of 100 and with varying K. The RAR was set to be 100 because this way the results were consistent. As presented in Table 1, $K = 2.5$ has shown the highest effectiveness of relocation.

Risk factor (K)	Accepted rentals	Relocations ($\sum R_{\tau_1,\tau_2}$)	Effectiveness of relocation (E_{τ_1,τ_2})
1	29210	29106	0.21
2	27367	26926	0.16
2.5	26408	14040	0.24
3	25403	16281	0.14
4	25008	11484	0.17
5	24279	5630	0.22
6	24203	5261	0.22
7	23764	3682	0.19

Table 1: Determination of the risk factor with RAR = 100%

To compute the Effectiveness of relocation (E), we used the following formula:

$$E_{\tau_1,\tau_2} = \frac{\sum B_{\tau_1,\tau_2}^R - \sum B_{\tau_1,\tau_2}^N}{\sum R_{\tau_1,\tau_2}} \tag{7}$$

E_{τ_1,τ_2} = Effectiveness of relocation in the time frame τ_1, τ_2

$\sum B_{\tau_1,\tau_2}^R$ = Sum of all accepted rentals with the option of relocation in the time frame τ_1, τ_2

$\sum B_{\tau_1,\tau_2}^N$ = Sum of all rentals without relocation in the time frame τ_1, τ_2

$\sum R_{\tau_1,\tau_2}$ = Sum of all relocations in the time frame τ_1, τ_2

We set a fixed threshold for simulation according to formula 1 and used a K of 2.5.

With the computed threshold (T) and risk factor (K) we tried to find the most desirable percentage for the RAR. It was surprising, that the highest effectiveness was by a RAR of 10 (* in table 2). In contrast, the lowest number of rejections was by a RAR of 90 (** in table 2). This shows that even a small amount of relocation has great benefits and can be effective. More relocation is not automatically more efficient and depends on the car sharing system, but can increase the volume of rentals and decrease the number of rejected rental requests.

RAR	Rejections		Relocations ($\sum R_{\tau_1,\tau_2}$)	Effectiveness of relocation (E_{τ_1,τ_2})
0	11355	32.99%	0	-
10	9490	27.57%	3020	0.62*
20	8918	25.91%	4085	0.60
30	8736	25.38%	4827	0.54
40	8610	25.02%	5801	0.47
50	8602	24.99%	7307	0.38
60	8365	24.30%	8012	0.37
70	7960	23.13%	8848	0.38
80	8383	24.36%	9972	0.30
90	7763	22.56%**	11185	0.32
100	8010	23.27	14040	0.24

Table 2: Results of Relocation

Discussion

Companies strive to improve their business models by finding ways to enhance their value creation for customers and value capture for the firm (Teece 2010). By developing and evaluating the relocation information system, we will demonstrate in the following that user-based relocation could result in a vital competitive advantage for car sharing companies regarding their business model.

Within our pilot case, the stations are on average 13 minutes (between 12 or 15 minutes) by foot away from each other. The incentive for 13 minutes is 1.56€. The payout of the incentive could be done by

coupons or extra minutes and in this way the cost is reduced. Therefore, we calculated with a cost of 1.40€ per relocation. The side costs per kilometer are 0.75€ (ADAC 2015) for a representative vehicle (Volvo V70). In total, the cost for each relocation is 2.15€.

RAR has a big impact on the total costs of relocation. A low RAR of 10 has shown the highest effectiveness of relocation. If the goal is to maximize the profit per relocation, a lower RAR is preferable. If the goal is to maximize the turnover and the customer satisfaction, a higher RAR of around 90 would be suitable. The costs for the relocations are 6493€ with a RAR of 90 with a number of 3020 relocations.

We compared the costs with those of operator-based relocation to set the costs into context. In the following we will use information from the car sharing provider, which gave us the rental data. We assume that user-based relocation could completely replace operator-based relocation. Each day two operators are sent out twice to relocate vehicles. Every time they drive around 40km. With a price of 0.75€ per kilometer, 40 km cost about 30€. The additional costs for the operators are 15.54€ for each one per hour (Destatis 2010). In total, each day of operator-based relocation costs 122.16€. For 13 months (time frame of the simulation) the total cost of relocation would be 44466.24€.

To check out the monetary benefits, we calculated as follows. Each customer pays 0.50€ per 15 minutes of rental. Under the assumption that an average rental takes about 2 hours, the average payment is 4€ per rental. With a RAR of 10 and 1846 additional rentals, the extra revenue is 7384€ and with a RAR of 90 and 3592 additional rentals the extra revenue is 14368€.

In conclusion, user-based relocations reduced the costs of relocation from 44466.24€ for operator-based relocation down to 24047.75€ for user-based relocation with a RAR of 90 in the simulated station-based one-way car sharing systems. This numbers can vary strongly based on the car sharing system and environment, but they indicate that it is cost beneficial to substitute operator-based relocation with user-based relocation. By reducing the driven kilometers for any relocation a positive environmental effect is an inherent part of user-based relocation. Thus, user-based relocation systems have the potential to bolster car sharing as a sustainable mode of transportation by decreasing its operation costs.

While our study focuses on the case of station-based one-way car sharing, our findings are in line with previous research investigated relocation in car sharing (e.g., Clemente et al. 2013; Kek et al. 2009; Wagner et al. 2015). We demonstrate that user-based relocation is a great opportunity to substitute operator-based relocation. In the case of station-based one-way car sharing we were able to show that the proposed version of user-based relocation would minimize costs and increase service quality. Customers have a higher guarantee to rent cars at their desired station even in high-demand times and providers can lower their costs and increase the utilization of their cars.

This study contributes to the field of IS research as follows. Following Watson et al.'s (2010) invitation for more IS research on environmental sustainability, we proposed an IS artifact for user-based relocation that could be adopted to similar cases, f.i. other forms of car sharing or concepts like bike-sharing. Furthermore, by conducting a comprehensive simulation, we were able to assess the economic value of the user-based relocation IS. By doing so, we demonstrated how IS can improve process efficiency in environmental friendly modes of transportation, thus contributing to sustainability within our society.

Moreover, our study provides valuable implications for practitioners. Firstly, our findings indicate that user-based relocation improves process efficiency in station-based one-way car sharing. Secondly, the algorithms and prediction methods developed are relatively easy to implement within existing systems. Car sharing companies could develop their own user-based relocation applications by using the proposed framework.

Limitations and future research

We realized that one major limitation is finding the suitable data. Firstly, using two-way car sharing rental data to simulate one-way car sharing is a major limitation. Secondly, we believe that it would be beneficial to analyze more data and to develop an approach for generating better and more fitting car sharing rental data.

The data based limitation was also due to the focus on one local car sharing provider. In this paper, we were able to demonstrate that, for this one provider, it would be highly beneficial to implement user-

based relocation in the given context. It could be possible that for a different constellation of stations and vehicles, user-based relocation might not improve the station-based one-way car sharing system as much.

In the previous section, we discussed the costs of relocation and the cost reduction of user-based relocation in comparison to operator-based relocation. We derived the cost factors from various sources. Hence, a real-time measurement of the costs would be more accurate and beneficial in order to get more specific assumptions of the cost reduction and environmental impact.

Moreover, the shown function for the incentive is an approximation. For future research, we will adopt machine learning in a simulation to determine RAR, *K* and incentive sensitivity in one model according to other parameters, f.i. the day of the week or the weather. In addition, we will investigate how to generate optimal testing data for such simulations. We will gather and use a bigger set of rental data and combine it with complimentary information when trying to recognize patterns. As a result, according to these patterns, a method on how to generate testing data will be developed. Based on this, a more sophisticated simulation will be possible.

In addition to the improvement of the simulation and the predictions, a field test of the URIS framework is planned. Based on the framework, a mobile application will be developed and tested. Likewise, we want to provide a base for further developments of car sharing as a part of multi- and intermodal traveling. Car sharing with a relocation information system could be used to intertwine other mobility services like e-bike-renting, train or bus. Relocation could be used to relocate vehicle according to the traveling plans of customers and therefore minimize the potential inconveniences, the waiting time of customers and the idle times of vehicles. This should improve the sustainability of car sharing and help the customers to substitute a privately owned vehicle by a car sharing membership, which would have a big positive environmental impact.

Conclusion

In this paper we addressed the relocation problem of station-based one-way car sharing providers. We proposed a framework for an IS for user-based relocation.

In the first part, we described three major modules: the prediction module, relocation module and customer interaction module. Then we explained how they function. The prediction module provides information about the demand and supply situation at each station. We developed indicators for the lack of supply of vehicles at a station. A system using these indicators can predict that a station has a big demand and not enough vehicles to meet this need. Based on this information, the relocation module computes the necessary relocations and the appropriate incentives. We introduced an approach on how and when to relocate vehicles by applying user-based relocation. Eventually, the customer interaction module handles the acceptance or decline of the relocation requests.

In the second part, we described our simulation and the dataset we used. By simulating a station-based one-way car sharing system, we were able to show that the proposed version of user-based relocation has the potential to increase the number of accepted rental requests. For the provider the main benefits are the cost reduction and increase of number of additional rentals. Lastly, we discussed our findings and considered limitations of this study. We also pointed out some questions which could inspire future research.

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