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Analyzing the Potential of User-Based Relocations on a Free-Floating Carsharing System in Cologne

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Abstract

Free-floating carsharing (FFCS) concepts have gained popularity in recent years and offer a maximum level of flexibility for the user, while the operator is confronted with spatiotemporal demand asymmetries. To offer an appropriate level of service in areas with high demand, the operator has to relocate the vehicles. Those transfers are often executed during the day to optimally supply the high demand during peak hours. The transfers are limited by both budget and capacity constraints. Therefore, it would be beneficial to support the fleet rebalancing by user-based relocations. In this paper, an FFCS system in Cologne is analyzed where the operator has introduced a special incentive system in August 2017. The operator created the possibility to reward customers for the relocation of cars from the peripheral to the central area with up to 20 bonus minutes. This study evaluates the effectiveness of this measure by comparing rental data sets from two periods of 6 weeks each: one period before and one period after the new incentive system was applied. Results show that idle times in the peripheral area can be reduced significantly and customers can be influenced to return a vehicle in a desired area.

Keywords: free-floating carsharing (FFCS); user-based relocation

1. Introduction

Since the start of carsharing (CS) in Switzerland in 1948, the numbers of users, operators and cars are constantly growing. The two major concepts, station based carsharing (SBCS) and free-floating carsharing (FFCS), provide their users with two different short-term rental systems. While in the SBCS customers can reserve a vehicle in advance, pick it up at a station for a fixed period of time, and return it to the origin afterwards, the users in the free-floating

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concept can pick up vehicles spontaneously for short trips and return them anywhere within a defined operating area. The car does not have to be returned to its origin and can be parked on every legal parking spot inside the operating area.

FFCS systems provide a high level of flexibility for customers, while the operator has to handle spatiotemporal demand asymmetries. To offer a reliable product with an appropriate vehicle availability, it is important to rebalance the asymmetries as proven in several studies, see e.g. Weikl et al. (2015). However, operator-based relocations are expensive. The research objective of this paper is to assess, to which extent it is possible to rebalance the fleet by user-based relocations. To this end, rental data of an FFCS operator in Cologne are analyzed. The operator started the FFCS service in Cologne in 2012. During the first 5 years of operation, the operator identified areas with lower demand, which are mainly located in the peripheral area. In these areas, high idle times can occur. The first measure to improve the situation was the introduction of reduced rates. Vehicles with a high idle time are marked manually by the fleet manager with special rates (20ct or 24ct instead of 31ct/34ct per minute). In August 2017, a new approach was introduced. The operator replaced the former business area in Cologne by a two-staged operating area consisting of a central area and a peripheral area, as illustrated in Figure 1. In order to improve the vehicle distribution, the operator started offering special incentives for vehicles parked in the peripheral area. A customer can earn between 5 and 20 bonus minutes if the vehicle is returned in the newly defined central area. By analyzing the customer rental data, service bookings and offer data, we want to answer the following five questions:

- Can the idle times of vehicles parked in the peripheral business area be reduced when offering incentives?
- Is the vehicle distribution improved after the incentivized rentals are performed, i.e. is the vehicle returned in the central business area after an incentivized rental?
- To which level can the customer be influenced to return a vehicle in a predefined area?
- Which incentive leads to the best results from the operator's point of view?
- To what extent can operator ordered transfers be substituted with the incentivized rentals?

2. Related literature

The different aspects of CS systems have been studied by several researchers in the last years. A good overview of the historical market evolution and impact of CS services has been provided by Shaheen et al. (2013).

The most common research topic in the car sharing field is the analysis of car sharing customers' booking behavior and demand patterns considering booking data, customer surveys or interviews with experts. The spatial and temporal distribution of bookings was analyzed by Schmöller et al. (2015). To predict future demand, Müller et al. (2015) presented a time series analysis of CS bookings. In both papers, spatiotemporal demand asymmetries were identified as a major challenge for the CS system. The authors stated that demand can be influenced by specific operations. Niels et al. (2017) analyzed app call and booking data and found out that a customer only books a vehicle via the mobile phone application if there is one nearby. This indicates that the key factor for the performance of the CS system is a good spatial vehicle availability. The studies by Weikl et al. (2015) and Boyacı et al. (2015) focus on the improvement of the spatiotemporal distribution of vehicles. The operator can achieve this improvement by relocating vehicles from low demand areas to high demand areas. This leads to a higher number of bookings and improves the utilization (Weikl et al. 2015). The achievable improvements are limited by the capacity and budget of an operator.

In recent studies the concept of so-called user-based relocations have been considered. The idea is to offer a discounted rate for a trip with a specific vehicle to a specific location. Wagner et al. (2015) created a simulation where a user first has to share his destination. Based on this input the user receives a proposal for a specific return area as well as a discounted price. Wagner et al. presumed a dependency between the acceptance rate of the relocation offer and the distance between the desired destination of the customer as well as the proposed relocation destination. While this relocation system can be very powerful in terms of accuracy, it results in a highly complex price system for the CS operator. Additionally, the major obstacle in a free-floating system is the unknown destination of the user. There is no requirement for the user to state the target destination before starting a rental. Jorge et al. (2015) suggested an optimization scheme for user-based relocations with discounted rates based on the assumption that the price elasticity is -1.5, which corresponds to an increase in demand of 15% if the price is reduced by 10%. This price elasticity factor was published in a vanpooling study by York et al. (2001). Nevertheless, these studies rely on assumptions based on the price elasticity for other transportation modes. An overview can be found in the work of Litman (2017 and 2013). However, price elasticity of CS customers is hard to assess and is further impeded by the fact that each CS system has its own price scheme (Hardt et al. 2016).

Our paper contributes to this research by analyzing data obtained from an FFCS system in Cologne, where different incentives are offered to customers for using a vehicle parked in an area with low demand. Customers can either book an incentivized vehicle with a reduced rate or obtain 5, 10, 15 or 20 bonus minutes. In order to obtain the bonus minutes, customers have to park the vehicle in the central area (see Figure 2a). The respective offer type is shown to the customer before the rental in the app. We analyze the acceptance rate of these incentives and assess the success rate from the operator's point of view. With the indicator attractiveness, a combined indicator of idle time and amount of trip starts we compare the attractiveness of the zones before and after the measure was implemented. The expected results are a lower idle time for incentivized vehicles, the increase of the number of trips to the central business area as well as a reduced number of operator-based relocations.

3. Methodology

We analyzed more than 140,000 rentals and more than 16,000 offer data sets for two periods of 6 weeks each. The first period started on the 5th of June and ended on the 16th of July, 2017. The second period started on the 28th of August and ended on the 2nd of October. Both time frames were chosen carefully in order to assure comparability. We excluded the summer holiday season and selected two periods with a stable number of rentals per day. In the first period of time, the only available type of incentives was the reduced rate, whereas in the second period of time, both the reduced rates and the bonus minute offers were available. Additionally, we started with the second period two weeks after the business area was redefined and the bonus minute incentive was introduced, to give customers some time to understand the new feature. We compared the two periods of time considering rentals, average idle times, i.e. how long vehicles are parked between two consecutive rentals, and the effect of offered incentives.

First of all, we sorted the booking data into the different clusters using the geo-analytical software ArcMap. Figure 1a shows the two-stage operating area in Cologne. In the first period of time there was no explicit central area defined. The whole operating area was just one zone containing the same total area. However, we matched the start and end points of each trip into the peripheral and central area in order to obtain the percentages of trips within and between the two zones for both time periods. Based on the origins and destinations the following four categories have been created: peripheral-central (PC), central-peripheral (CP), peripheral-peripheral (PP), central-central (CC).

Figure 1 gives an overview of the analyzed data in the first period: Figure 1b shows the share of data which was taken into account for the detailed analysis. 81.1% of the total rental data are customer rentals that can be analyzed – only 3.9% of rentals are incentivized and 77.2% are customer rentals without incentives. 3.5% of all rentals are service drives ordered by the operator. Cologne is a special case for the FFCS operator: The operator's service is also available in Düsseldorf and drives between those two cities are allowed (the distance is approximately 45km). Rentals starting in Cologne and ending in Düsseldorf or vice versa had to be excluded from the detailed analysis for consistency reasons – this applies to 15.4% of rentals as shown in Figure 1b.

The data, which were analyzed in detail, were segmented into four clusters based on their origin and destination (OD). Figure 1c shows the percentages of customer rentals in each cluster. Most of the rentals (43.2%) start and end in the peripheral zone. However, with more than 80km², the peripheral zone is nearly 6 times as big as the central zone with only 13.7 km². This means, that it can still be considered as a low demand area as compared to the central area. 20.8% of the customer rentals start in the peripheral area and end in the central area. For the opposite direction the share is 22.1% and the 13.2% of the customer rentals start and end in the central area.

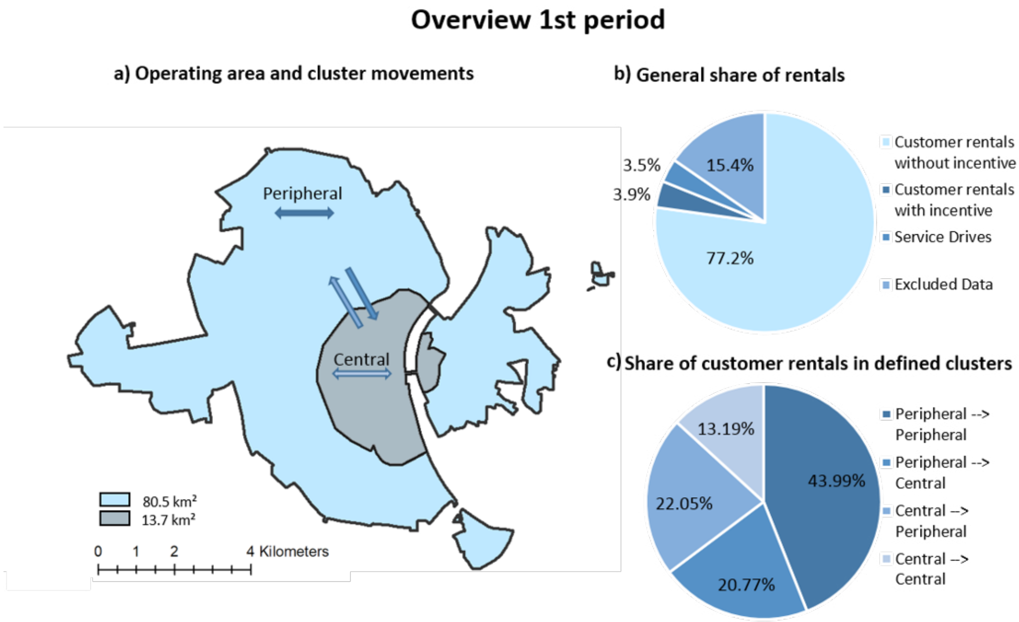


Fig. 1. Overview (a) operating area and cluster movements; (b) general share of booking starts (c) share of customer rentals

By offering incentives, the operator aims at increasing the number of rentals starting in the peripheral and ending in the central area. To provide an offer to a customer, the fleet manager has to mark the vehicle manually with the respective incentive. In the second period of time, two different types of incentives were available. With the first type the fleet manager can reduce the price per minute to either 20ct per minute or 24ct per minute. The decision is based on experience but also on the idle time. For activating the bonus minute incentive on the respective cars, the fleet manager used a zone model as visualized in Figure 2a. The amount of offered bonus minutes is based on the distance from the central area. Still the offers are applied manually and therefore some minor displacements have been identified. In our first research period the fleet manager was limited to offer the reduced rate as possible incentive, while in the second period both incentives have been available but the focus laid on the offer of bonus minute incentive.

Figure 2 shows an overview of the second period of time. As shown in Figure 2b, in the second period we had to exclude less data: only 14.1% of the rentals started or ended in Düsseldorf. The share of service drives remains the same as in the first period. While the share of customer rentals without an incentive decreased, the percentage of customer rentals with an incentive was doubled. However, in total we can see a plus of 1.3% for the considered customer rentals in the second period compared to the 81.1% of the first period. Figure 2c shows some minor changes in the overall share of customer rentals in each cluster for the second period compared to the first period. More details are discussed in the following section.

In a second step we calculated the average idle times per cluster to compare the results as shown in Table 1. To obtain the idle time we subtracted the end time of the previous rental from the start time of the considered rental. The average idle times for the rentals starting in the central area without an offer increased in the second period from 271 to 324 minutes. The average idle times for rentals without an offer and starting from the peripheral area are nearly the same with 420 minutes in the first period and 429 minutes in the second period. Analyzing the average idle times per OD cluster showed nearly no change for the PC rentals without an offer but an evident decrease for the PC rentals with an offer. The detailed analysis is done in section 4.

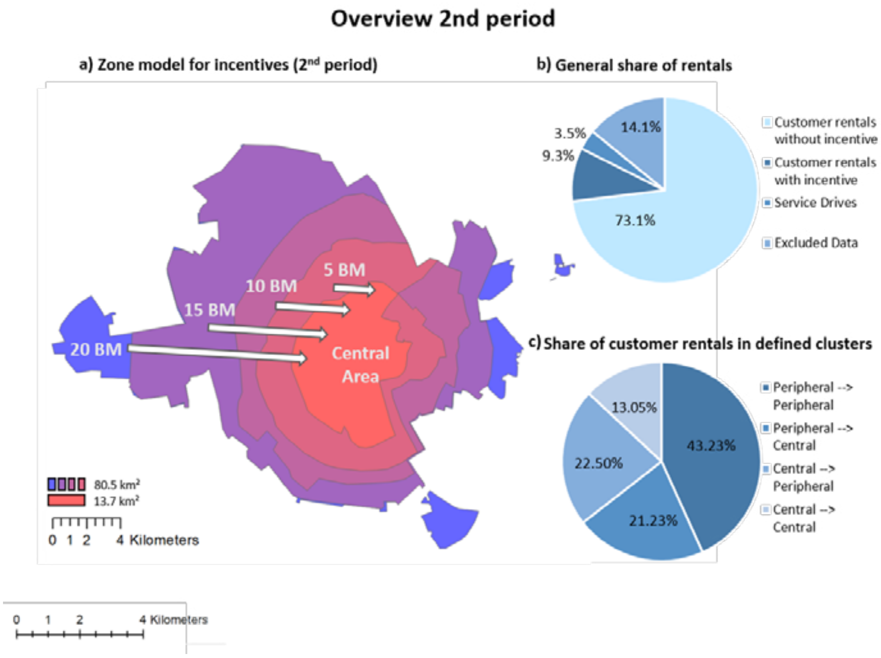


Fig. 2. Overview (a) Zone model; (b) general share of booking starts 2nd period; (c) customer rental share in 2nd period

To analyze the effect on the vehicle distribution we tried a microscopic approach first. We applied a raster on the operating area of nearly 1,243 squares with 0.09 square kilometer each (app. 0.035 square miles). For both periods we counted the number of rental starts and calculated the average idle time in each square. We then evaluated the 0.2, 0.4, 0.6, 0.8 quantile for both the number of rentals and the average idle times. The quantiles were used as separator in order to rate the data from 1 to 5. A zone with a number of rentals in the 0.2 quantile was rated with a 1, in the 0.4 quantile with a 2, and so on – if the number of rentals belonged to the last quantile we rated it with a 5. We used the same approach to rate the idle times but with a reversed ranking; a high idle time was ranked with a 1 and the lowest idle time was rated with a 5. With this method we prevented an overrating of zones with e.g. only one rental and a very short idle time. Zones with no rental and/or no idle time were rated with 0. Finally, the ratings of each grid cell received for its number of bookings and its average idle time were added. With this approach each zone received a ranking of attractiveness between 0 and 10 points which we visualized in ArcMap and displayed in Fig. 3a and b.

The operator applied nearly 12,000 offers in the second period, of which 92% were applied to cars parked in the peripheral business area. 90% of all offers are the bonus minute incentive, the remaining 10% offered a reduced rate. Not every offer was taken by a customer. Incentive offers are only applied for a certain period, which is defined by the fleet management and if no customers take the car during the offer time, the rate changes back to the normal rate automatically. In some cases, the vehicles were relocated before the expiration time which also ends the offer. Therefore, we calculated the take rate as well as the success rate for the examined PC cluster. The quotient between the number of all incentive rentals and the number of all offers is defined as take rate. A bonus minute incentive rental was counted as success if the vehicle was returned in the central business area. Both indicators are used to analyze the effectiveness for the operator and the results are discussed in the following section.

4. Results and discussion

Five research questions are in the focus of this study. To answer the first one, we compared the average idle times per cluster before the measure was introduced with the idle times per cluster after the new incentive was offered.

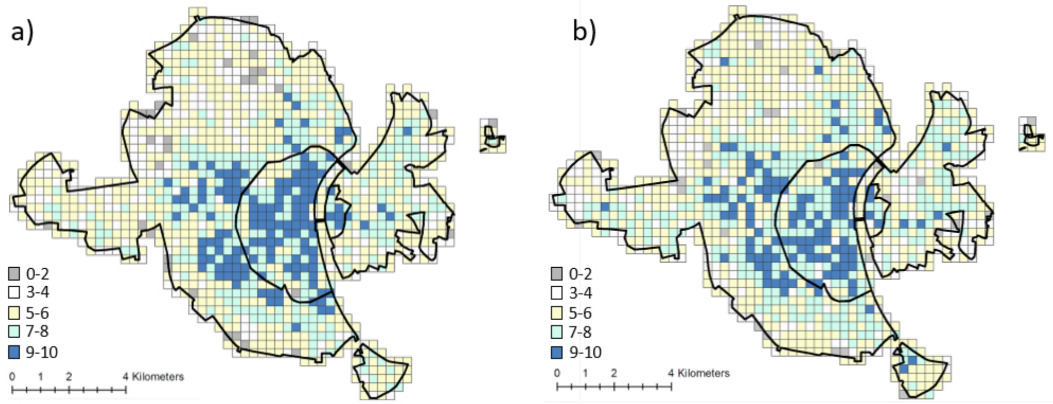
Table 1 Average idle time in minutes per clusters without service rentals

Cluster	Average idle time in period 1	Average idle time in period 2
Central without Offer	271	324
Peripheral without Offer	420	429
Peripheral / Central without Offer	378	382
Peripheral / Central with Offer	1,381	**873**
Detail Peripheral / Central		
Reduced Rate 20ct	1,763	2,169
Reduced Rate 24ct	1,276	1,173
Bonus Minute Offer	-	806

In general, the average idle times are slightly higher in the second period compared to the first period. This can be explained with the overall lower number of rentals. Compared to the first period we observe a decrease of 13% for the total amount of rentals. After checking the daily average number of available vehicles in the research periods, we saw a decrease of ten cars (in average per day) for the 2nd period. The operator explains the drop with the in- and defleeting cycles as well as some asymmetries due to the vehicles leaving to Düsseldorf. Nevertheless, we still observe a considerable reduction of the idle time in the second period for all rentals with incentives. In our focus cluster, i.e. rentals with offers starting in the peripheral and ending in the central area, the average idle time was reduced from former 1,381 minutes to 873 minutes, a reduction of 37%. We have identified the rentals with bonus minute offers as main driver for this effect. The average idle time before bonus minute rentals was 806 minutes as shown in Table 1.

For answering our second research questions we first tried to compare the attractiveness before and after introducing the measure as explained in section 3. Figure 3a and 3b show the visualization of the calculated attractiveness in each grid cell. As the share of incentivized rentals (compared to all rentals) was 3.9% in the first and 9.3% in the second period there are only minor differences to be spotted in the figures. The overall effects cannot be visualized with this method. Therefore, we used a different approach to analyze the effect of incentivized rentals. Comparing the rental shares in the different OD clusters as shown in Table 2, we can see an increase of the share of rentals starting in the peripheral area and ending in the central area of 0.5% after the measure was applied. Again the main driver for this effect are the incentives as we can see a decrease in the PC cluster for all rentals without an offer while we observe an evident increase of 9.3% for the share of rentals with an incentive. We have combined this information with the results from the analysis of the take and success rates (explained in section 3). As shown in Fig. 3c and 3d the bonus minute incentive with 20 minutes lead to a high take rate of 65% and the highest success rate of 46% compared to the other bonus minute incentives. The bonus offers with 10 and 15 minutes seem to be less attractive to customers. The lowest take rate but second highest success rate resulted from the bonus offer with 5 minutes. Hence, it can be concluded that customers can be influenced up to a certain point. The rentals with the reduced rate of 20ct also had a 50% success rate in the second period but as the share of this offer type was only 2% in the second period and lead to a success rate of 33% in the first period, the effect will not be considered as a representative measure. In the research periods, the share of incentive rentals lay between 3.9% (1st period) and 9.3% (2nd period) of the total amount of rentals. Therefore, the overall effect is low but we expect that they have a high potential if the number of offers will be increased as well as the incentives will be placed immediately on all cars with an expected high idle time in the areas of low demand.

In order to evaluate the incentives from the operator's point of view, we also assessed the associated costs. According to the operator, an average rental duration is between 20 and 40 minutes. If the customer earns the maximum amount of 20 bonus minutes he will have an average discount of at least 50% and up to 100% on the next rental. The reduced rates lead to a maximum discount of 41% (20ct rate) or 29% (24ct rate) per minute. The respective gain for the customer depends on his use case and trip length in minutes. For the operator, the effects are two-sided: the loss of revenue on the discounted trips but the potential of cost reduction for the relocation. Due to the lack of



c)

Take Rate	Period 1	Period 2
Reduced Rate 20ct	54%	65%
Reduced Rate 24 ct	67%	72%
5 Bonus Minutes	-	41%
10 Bonus Minutes	-	48%
15 Bonus Minutes	-	47%
20 Bonus Minutes	-	65%

d)

Success Rate	Period 1	Period 2
Reduced Rate 20ct	33%	50%
Reduced Rate 24 ct	33%	36%
5 Bonus Minutes	-	45%
10 Bonus Minutes	-	36%
15 Bonus Minutes	-	39%
20 Bonus Minutes	-	46%

Fig 3. (a) and (b) Spatial changes in raster values; (c) take rates; (d) success rates

relocation cost information and detailed information on the different types of service drives, we are not able to evaluate the potential of cost savings or can analyze how many relocation drives have been substituted. However, in the two research periods the share of service rentals remained stable at 3.5%, which indicates that no additional service rentals have been conducted. The provided data were not sufficient for a clear result if the bonus minute offer will substitute operator-based transfers, but the rental flow results and idle time reduction indicate the potential.

5. Conclusion and Outlook

This paper evaluated the potential that incentives have for rebalancing an FFCS fleet. It could be shown that a bonus minute offer can evidently reduce the idle time of a vehicle in a low demand area. In our research-cluster a reduction of 555 minutes (42%) compared to the average idle time of incentivized vehicles in the first period was observed. Some customers can be influenced in their rental destination by offering a reward for the return in a specific area. We can see the evidence in the increased shares of rental flows for the research cluster PC. Based on all customer rentals, we see an increase of 0.46% for the rentals from the peripheral area to the central area. This effect is a direct result of the bonus minute incentive. While we observe a decrease for the rental share without any offer in the PC cluster, there was an evident increase for the rental share with offers. The absolute number of service rentals was 15.4% less in the second period compared to the first period but the overall share was stable with 3.5% in both periods of time. The operator has different types of service orders such as cleaning, refueling or charging and relocation. Due to the lack of detailed information on the type of service orders, we were unable to differentiate a clear result if the operator-based relocations were reduced as a result of the incentivized rentals. It must be analyzed in further studies with some constraints for the fleet management. The risk of additional relocations as a result of free capacity because of the user-based relocations must be eliminated. We consider a high potential if the operator will increase the number of offers. Therefore, a second test period, where the number of offers is raised and the number of operator-based transfers in the research cluster is reduced, is recommended. A similar study for a different city but the same operator showed comparable results. The authors assume, that this form of incentive can have the same effects in other cities.

The reduced rates are not targeting a specific return area and therefore lead to a comparably smaller effect regarding the rental flows but with the comparably high take rates, they seem to be attractive for customers and can lead to a success rate of 50% (Figure 3d).

Table 2 Changes in the share of rentals in all clusters

Cluster all	**Period 1**	**Period 2**	**Difference**
Central / Central	13.19%	13.05%	-0.14%
Central / Peripheral	22.05%	22.50%	+0.45%
Peripheral / Peripheral	43.99%	43.23%	-0.76%
Peripheral / Central	20.77%	21.23%	+0.46%
Cluster without Offer *(based on all customer rentals without offer)*			
Central / Central	13.62%	14.24%	+0.62%
Central / Peripheral	22.79%	24.60%	+1.81%
Peripheral / Peripheral	43.21%	41.68%	-1.53%
Peripheral / Central	20.38%	19.48%	-0.90%
Cluster with Offer *(based on all customer rentals with offer)*			
Central / Central	*2.66%**	*0.41%**	*Not relevant*
Central / Peripheral	*4.09%**	*0.52%**	*Not relevant*
Peripheral / Peripheral	62.79%	59.43%	-3.57%
Peripheral / Central	30.27%	39.64%	+9.37%

*the majority of the offers have been placed in the peripheral area

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References

Boyacı, B., Zografos, K. B., Geroliminis, N., 2015. An Optimization Framework for the Development of Efficient One-Way Car-Sharing Systems. European Journal of Operational Research, Vol. 240, No. 3, pp. 718–733.

Hardt, C., Bogenberger, K., 2016. The Price of Shared Vehicles – On Current and Future Pricing Strategies in Mobility Sharing Systems. Proceedings of the 95th annual meeting of the Transportation Research Board.

Jorge, D., Molnar, G., Correia, G., 2015. Trip Pricing of One-Way Station-Based Carsharing Networks with Zone and Time of Day Price Variations. Transportation Research Part B, Vol. 81, pp. 461–482. https://doi.org/10.1016/j.trb.2015.06.003.

Litman, T., 2017. Understanding Transport Demands and Elasticities How Prices and Other Factors Affect Travel Behavior.

Litman,T., 2013. Transport Elasticities: Impacts on Travel Behaviour. In Transport Policy Advisory Services, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn.

Müller, J., Bogenberger, K.,2015. Time Series Analysis of Booking Data of A Free-Floating Carsharing System In Berlin. Transportation Research Procedia, Vol. 10, No. July, pp. 345–354. https://doi.org/10.1016/j.trpro.2015.09.084.

Niels, T., Bogenberger, K.,2017. Booking Behavior of Free-Floating Car Sharing Users : Empirical Analysis of Mobile Phone App and Booking Data Focusing on BEVs. Transportation Research Record: Journal of the Transportation Research Board, Vol. 2650, https://doi.org/10.3141/2650-15.

Schmöller, S., Weikl, S., Müller, J., Bogenberger, K., 2015. Empirical Analysis of Free-Floating Carsharing Usage: The Munich and Berlin Case. Transportation Research Part C, Vol. 56, pp. 34–51. https://doi.org/10.1016/j.trc.2015.03.008.

Shaheen, S. A.,Cohen, A. P., 2013. Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends. International Journal of Sustainable Transportation, Vol. 7, No. 1, pp. 5–34.

Wagner, S., Willing, C., Brandt, T., Neumann, D., 2015. Data Analytics for Location-Based Services: Enabling User-Based Relocation of Carsharing Vehicles. Proceedings of the 36th International Conference on Information Systems.

Weikl, S., Bogenberger, K., 2015. Integrated Relocation Model for Free-Floating Carsharing Systems: Field Trial Results. Transportation Research Record: Journal of the Transportation Research Board, Vol. 240, No. 3, pp. 19–27.

York, B., Fabricatore, D., 2001. Puget Sound Vanpool Market Assessment. Washington State Department of Transport.