Supply quality for shared bike systems

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***Abstract*— All over the world urban areas struggle with increasing daily traffic and expensive road infrastructure. It is therefore necessary to find a sustainable travel alternative to encounter the negative effects of widespread car use. One alternative that planners are promoting is cycling. Bike sharing systems have been adopted by a growing number of cities throughout the world. But there has been done very little research in the past on how cities can plan and implement bikeshare system in a way that best suits. On the basis of a literature study five factors were selected. These factors were assumed to have the greatest influence on the likelihood to use a system. A survey was conducted to determine if and to what extent the factors encourage people to use a bike sharing system. Considering the selected factors the travel cost and the availability of enough bikes at the desired station at the time needed have the greatest influence on the likelihood for use.**

Keywords— Bicycle, Bike share, Multinomial logit model

I. Introduction

Public bikeshare have existed for almost 50 years. In recent years, the system has experienced immense growth. It is currently one of the fastest growing mode of public transport with China showing the strongest growth [1][2]. Due to the current problems of transport systems all over the world it is necessary to find a solution for a more sustainable urban transport system. The bike could be part of this solution. It has clear advantages compared to cars and motor cycles. Bicycles need less space, do not require fuel and therefore produce significantly lower emissions. But despite the clear advantages of bicycles, very little research has been done in the past on how cities can plan and implement bikeshare system in a way that best suits their unique transportation, weather and demographic markets. In the scope of this work is to assess how does (potential) users of a bike sharing system evaluate its quality? In first step a literature review of the current researches was made. To complete the literature research an Interview with Urs Walter was conducted. In a next step, based on these results, the factors influencing the quality from the user's point of view are summarized. Within the framework of a survey, the factors influencing quality are investigated. The evaluation of the survey determines whether the selected factors influence the quality of bike sharing systems and to what extent.

II. Literature Review

This chapter gives a brief overview of some of the literature examining bike sharing and the use of bicycles. With its widespread expansion, more studies on bike sharing have been published.

A. Factors of influence

In the following , the research on the factors contributing to the use of bike sharing is summarized. The factors can be grouped into “environment”, “impact on traffic system”, “travel pattern”, “financial issues”, “demography”, “technical issues”, and “individual characteristics”.

The environmental factors can be divided into different sub-categories. One major impact on the use of bike sharing is the weather. Cyclists are sensitive to bad weather. Therefore the likelihood of cycling decreases when it rains or snows and while temperature is low [3]. But this factors cannot be influenced by an operator. Furthermore, the built environment as the infrastructure, the bike network or the topography have an impact. According to [1] bike sharing is mostly used in areas with dense networks and where high frequencies of trips are found. As well it was stated that land use and environmental factors such as the presence of metro- and bus stations, restaurants, and universities, contributed to bike sharing usage [4]. Looking at the travel pattern most commonly, the purpose of bike sharing trips is work- or school-related [5]. According to [6] people with a travel time of less than 30 minutes are more likely to use bike sharing frequently. Moreover, it was stated that there is a significant correlation between bike sharing use and degree of satisfaction with bike sharing. Another influencing factor is the demography. [1] stated that the age of the user is an important factor and, furthermore, the only demographic that impacts. It was stated that males are generally more likely to use a bike sharing program [6]. An impact of education or income on the use of bike sharing was not found. By far the most important factor are technical issues. According to [1] bike sharing is most sensitive to effort and comfort. In addition to that, a large number of small to medium-sized docking stations increase access and lower the travelling distance by placing stations closer to trip ends. [4] found that bike sharing ridership increased with increasing numbers of bike sharing facilities such as docking stations. Easy of check in and check out might be an important factor [6] as well. [1] found that it is beneficial to have a bike sharing system with an automated access technology.

B. Bike sharing in Switzerland

As part of this work, I had the opportunity to interview Urs Walter. He is responsible for bicycle traffic at ASTRA (Federal Roads Office). In the following the most important points are summarized.

The potential for a functioning bike sharing network in Switzerland exists. But Switzerland has invested heavily in its public transport system which is very reliable. As long as it continues to function as well, a strong increase in bicycle traffic is not expected. Bicycle traffic, however, still can and will be part of the solution for a climate-friendly traffic concept. In order for a system to work, certain prerequisites must be met. On one hand, a city must have a certain number of inhabitants. For this reason, more populated cities such as Zurich, Bern, Geneva or Basel are taken as a basis. In smaller cities with few stations bike sharing systems are not cost-effective, since too few trips per day are generated. The

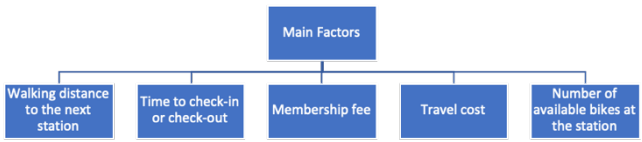
second prerequisite to be fulfilled is thus the number of generated trips per day. Another point to consider is the topography of a city. In cities like Lausanne, the introduction of a bike sharing system makes less sense.

It is further crucial that the bike sharing stations are located in close proximity to each other. Three hundred meters has been established as an ideal distance between the stations. This allows the network to be compared with that of public transport in the city. The development of the station network is not regulated uniformly, but is the responsibility of the respective client, usually a city. Typically, the client will draft a tender in which all minimum requirements are specified, so-called specifications. The specifications contain information on the services to be provided. The bicycle equipment is an important part of it. The bicycles have to be functional so that they can be used by the users. Therefore, the specifications also include a list of technical characteristics which have to be guaranteed. Besides the density of the stations, their accessibility is crucial. Most systems today use an app for access. In order to further increase the use of bike sharing systems, it would make sense to integrate them into the higher-level network of public transport. This means that the use of bike sharing systems would be part of a public transport subscription, thus simplifying access and use. The concept of a multimodal transport service is becoming more and more common.

C. *Chosen factors of influence*

On the basis of the literature review and considering the expertise of Urs Walter the factors that have the greatest influence on the likelihood to use a system are assumed to be the walking distance to the next station, time to check-in or check-out, membership fee, travel cost and the availability of bikes at the station (Fig. 1).

Fig. 1. Chosen factors of influence



III. Survey Methods and Data

A. *Survey administration and response rates*

On one hand the questionnaire was sent by e-mail. With the help of the ETH, it was possible to send it to 409 Bachelor students from the Dept. of Civil, Environmental and Geomatic Engineering, among others. The questionnaire was further sent to friends, acquaintances and fellow students. Furthermore, the survey was shared in the social media. The company PubliBike shared the questionnaire on their Instagram profile and asked their followers to answer it. The data was collected over a period of two weeks. The questionnaire was completed by 187 people. The participants were not reimbursed.

B. *Choice situations*

The aim of the experiment was to investigate how sensitive individuals react to changes in alternative-specific attributes. A D-efficient design with 36 choice situations blocked in four parts was calculated using Ngene [7] assigning nine situations to each participant. The assignment of participants to a block was randomized by insertion of a dummy question. The goal was to see which factors affect the quality of the users of a bike sharing system as perceived by the user and to what extent. In Table I the influencing factors are summarized and the different levels are added.

TABLE I. Influencing Factors and their Levels

Attribute / Factor	**Level**
Walking distance	1min 3 min 4 min 6 min
Check-in or check-out time	10 s 30 s 1 min
Membership fee	25 CHF / year 50 CHF / year 75 CHF / year 100 CHF / year
Availability of bikes	rarely occasionally often always

Furthermore, the questionnaire made certain assumptions about the system under investigation. The bike sharing systems do not include e-bikes. The bike sharing systems are station based. This means that the bicycles have to be picked up and returned at clearly defined stations. These stations are easily found and recognizable locations in the public space. In addition, these stations are easily accessible for users and have as direct a link as possible to cycling routes and transfer points at public transport stops. The bicycles provided at the stations are assumed to always be in good condition. The bike sharing system is automated. This means that check-in and check-out is done with the help of an app. In Fig. 2 an example of a choice situation given in the questionnaire can be seen. The choice experiment was conducted unlabeled.

Fig. 2. Example of a choice situation

	Velosystem A	**Velosystem B**
Laufdistanz	1 min	6 min
Zeit für Check-in bzw. Check-out	10 s	1 min
Mitgliederbeitrag	100 Fr./Jahr	25 Fr./Jahr
Reisekosten	0.10 Fr./min	0.20 Fr./min
Verfügbarkeit	immer genügend Velos zur Verfügung	gelegentlich genügend Velos zur Verfügung
Welches Velosystem wählen Sie?		

C. *Modelling framework*

The multinomial logit model (MNL) is applied in this report to model how decision makers, in this case participants of the survey, compare and evaluate alternatives. To describe human behaviour, mixed MNL is very popular and frequently used. To describe human behaviour, MNL is very popular and frequently used. Therefore, in this report, a MNL is used to describe how people weigh different influencing factors affecting their use of bike sharing systems. [8]. The utility function describes the relationship between the variables in the data and parameters. Utility is:

$$U_{njt} = \beta_n x_{njt} + e_{njt} \quad (1)$$

The optimal value of the parameter ß is calculated using the maximum likelihood estimation. Thereby an optimization routine tries to find the set of parameters that give the maximum log-likelihood by repeatedly calculating the log-likelihood with different ß until the process converges. The likelihood is the product of the chosen probabilities for each individual [9].

D. Modelling procedure

In a first step, the above-mentioned factors were examined without considering socio-demographic variables. It is assumed that all the chosen relevant factors have a negative impact on the choice behaviour. That means that the ß – coefficients have a negative value. For the availability the possibility "always" was chosen as a reference. Hence $\beta_{availability}$ =0. In a second model it was assumed that age and income have an effect on the sensitivity to the membership fee and the travel cost. As well it was assumed that current bike share user react differently.

The socio-demographic characteristics were modelled as follows: Age (linear), Income (linear, mean normalized) and Bike share user (dummy)

IV. Results

A. Descriptive analysis of the sample

First, it can be stated that about 90% of the participants were between 18 and 35 years old. This result is not very surprising. The survey was mainly sent to students and people under 40 years of age. In the survey, 56.68% of participants were male and 43.32% female. Therefore, the gender distribution can be assumed to be representative. When looking at the distribution of education, it is striking that 50.8% have a university degree and 33.16% have the maturity, here as only about 8% did an apprenticeship. This, again, was to be expected, as the questionnaire was largely sent to students and academic staff. The average household income in this survey is CHF 7594. To calculate this the intervals of income were averaged. It is interesting to see that most of the participants stated that they are either very experienced or experienced in bike usage. In Fig. 4 the frequency of use of a bike and the experience are plotted against each other. As expected, it can be seen that many who use the bike often consider themselves experienced, whereas those who never use the bike consider themselves inexperienced. Furthermore, it was seen that only few participants used the bicycle only to commute. Most of them used the bicycle either in their free time (49.73%) or for both (43.85%) free-time and commuting. Regarding the distribution of participants based on the dummy question, it can be noted that the participants are distributed evenly among the different blocks (Fig. 3).

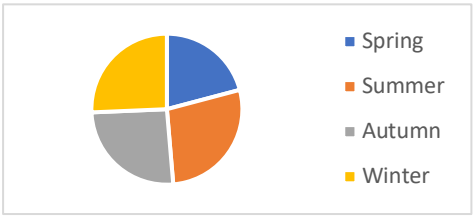


Fig. 3. Distribution Dummy Question

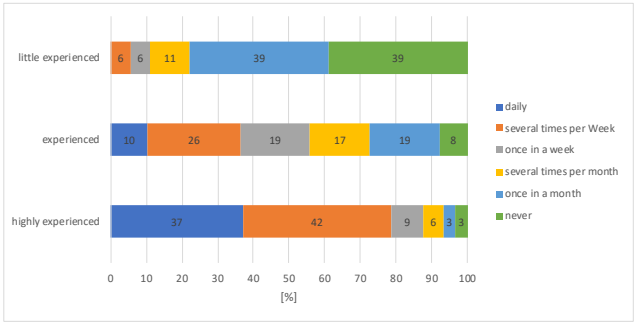


Fig. 4. Experience vs. Frequency of bike usage

B. Descriptive of bike share user

About 30% of the participants stated that they are users of a bike sharing system. In the following figures (Fig. 5-9) it can be seen how these users are characterized.

If we look at the respondent between 18 and 45 years old the proportion of users is highest in the 25 to 35 age range. The results for the age groups older than 45 years are not very meaningful, as only a few participants fall into these groups (Fig. 5).

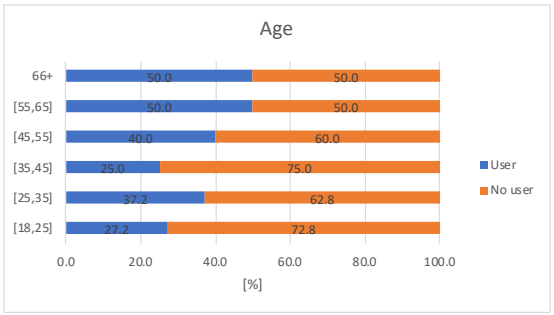


Fig. 5. Age distribution of bike sharing users

The distribution of gender is quite balanced (Fig. 6). The number of male users is slightly higher compared to women. This correlates with [6] which stated that men are more likely to use bike sharing pro-grams than women.

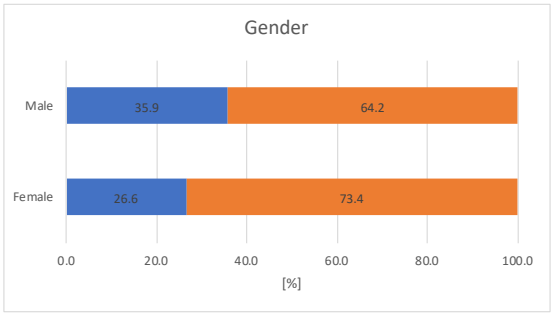


Fig. 6. Gender distribution of bike share users

In Fig. 7 it can be seen that the value for the income lower than CHF 4'000 is the highest. Whereas the income between CHF 4'100 and 8'000 has the lowest. But it cannot be seen that respondent with high income are more likely to use a bike sharing system.

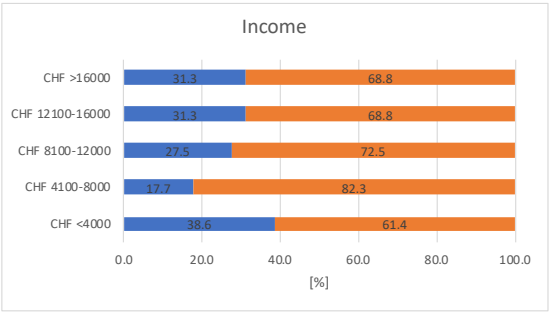


Fig. 7. Income distribution of bike share users

As well in Fig. 8 it can be seen, that 36.3% of the highly experienced bike users are user of a bike sharing system. But still 33.3% are users if they have little experience in bike usage. Additionally if we look at the respondent who use their bikes daily it can be stated that they are more likely to be a shared bike user (Fig. 9). Meanwhile 41.5 % of the daily users stated that they use a bike sharing system only 20.8% of the "once a week user" respond to be a user of a bike sharing system. But interestingly 40% of the respondent who use the bike only several times per month are users. This is contradictory to literature where it was stated that unfamiliarity with using a bike hindered its use of a bike sharing system.

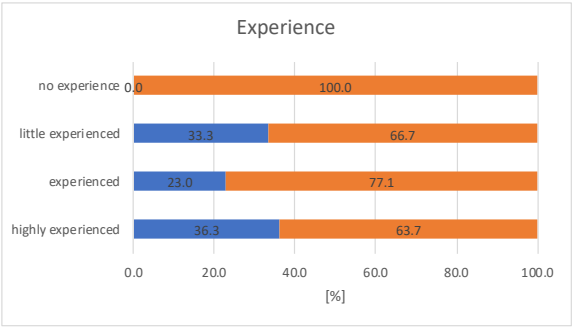


Fig. 8. Experience distribution of bike share users

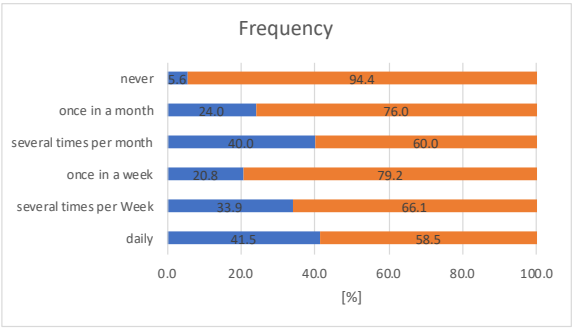


Fig. 9. Frequency distribution of bike share users

C. *Estimation results*

The analysed sample includes 1683 choice observations for 187 respondents. 20.9 % were assigned in the first block, 27.8 % were assigned in the second block, 25.7 % were assigned in the third block and 25.7 % in the last block (Fig. 9). It can therefore be said that the participants were distributed relatively evenly among the different blocks. In Table II the estimation results for the both models are shown.

TABLE II. ESTIMATION RESULTS

	Model 1 Coef./(SE)	***Model 2 Coef./(SE)***
Walking Distance	-0.07*** (0.02)	-0.06*** (0.02)
Walking Distance x Bike share User	-	-0.02 (0.04)
Time to check-in or check-out	--0.44*** (0.09)	-0.33*** (0.11)
Time to check-in or check-out x Bike share User		-0.48*** (0.19)
Membership fee	1.38*** (0.27)	0.57 (0.94)
Membership fee x Income	-	-0.01 (0.04)
Membership fee x Bike share User	1.38*** (0.27)	-0.35 (0.62)
Membership fee x Age	-	0.04 (0.03)
Travel cost	--4.08*** (0.44)	-2.70* (1.55)
Travel cost x Income	-	0.05 (0.08)
Travel cost x Bike share User	-	-1.70* (1.03)
Travel cost x Age		-0.05 0.05
Availability often	-0.03 (0.14)	-0.09 (0.15)
Availability occasionally	-0.45*** (0.12)	-0.46*** (0.13)
Availability rarely	-1.86*** (0.131)	-1.94*** (0.14)
# estimated parameters	7	15
# respondent	187	187
Runtime [s]	10.41	9.35
LL final	-847.57	-862.81
LL choicemodel	-847.57	-862.81
AICc	1709.15	1755.62
rho2	0.27	0.26

The model quality is described with the parameter rho2. Models with values $0 < \text{rho2} < 0.25$ are considered good. The values of both models are only slightly above 0.25. In addition, the value for rho2 is slightly higher for the simpler model. This also makes sense, since this model does not include the additional information from the socio-demographic variables. Additionally the AICc value can be used to assessing the goodness of a model. The model 2 has a better value.

In a first step the simpler model is considered, then the model 2 is examined closely. Unlike as proposed in the hypotheses not all the ß-Coefficient have a negative value in model 1. $ß_{Membershipfee}$ is positive and therefore people react positive if the membership is increased. That means that the likelihood of choosing a bike sharing system increase if the membership fee gets higher. However respondent did not react on walking distances. On the other hand the time to check-in or check-out is important, since the likelihood to choose the bike system decreases with the time to check-in or check-out becoming longer. In contrast to the membership fee, travel costs have a high effect on the sensitivity of the participants. If the travel costs increase the likelihood of

choosing such a system decreases dramatically. This might be interesting since according to statistics most people do not travel more than 30 minutes with the bike and therefore the travel cost would have no impact on their costs. As expected, the participants react very strongly to whether a bicycle is available or not. Above all, the respondents react very sensitively when a bicycle is only rarely available.

In model 2 it is possible to analyse the reaction of the users in comparison to the complete data sample. As well the walking distance has no influence. Time to check-in or check-out is again important, since the likelihood the chose the bike system decreases with the time becoming higher. This effect is even stronger for bike share users. Regarding the membership fee the effects are no significant and therefore not relevant. Travel costs have a high effect on the sensitivity of the participants. Bike share user in comparison react less sensitive to an increase in travel costs. This might be because most of the users drive their bikes less than 30 minutes. Regarding the influence of the age and the income it is not possible to make any statements since these effects are not significant. As in the model 1 respondent react very sensitively to whether a bike is available or not.

V. Discussion

For the model 1 where no socio-demographic variables are included the following remarks can be made. Surprisingly, the ß- coefficient for the membership fee was positive. Therefore, the probability that participants would choose a system increases with increasing membership fee. In other words, participants prefer an expensive system to a cheaper one. On the one hand, this may be due to the fact that participants expect better performance from a more expensive system and are therefore willing to pay more. On the other hand, it is possible that the costs play a smaller role compared to the other factors. Another possible reason is that the prices are too low. However, bike sharing systems are rather expensive compared to public transport. The walking distance has no influence on the sensitivity to choose a system or not. This can be explained on the one hand by the fact that most participants are still young and may therefore accept longer distances. Another point is that public transport stops are also available at a distance of about 300 m. Assuming a walking speed of 1.34 m/s, this corresponds to a running time of about 4 minutes. Since bike sharing is an alternative or extension to public transport, participants are used to walking certain distances to gain access to the network. The participants reacted most strongly to travel costs. The ß- coefficient has a value of -4.08. In comparison, the value for the time to check in and check out is only -0.44. This strong influence of travel costs on the perception of the system may be explained by the fact that participants are not willing to incur further costs besides the annual membership fee. As it is difficult for the participants to estimate how high the additional costs due to travel expenses are. Therefore the respondent might be willing to pay a higher membership fee and have no further costs to reckon with. The other important factors is the availability of bikes at the desired station at all time. If we look at the results in Table II, it is clear that people do not react while there are bikes availability often at the chosen station but if it rarely has enough bikes at the desired station at the desired time the probability of using such a system decreases dramatically. This is easy to understand and is in line with what was expected before this survey was conducted. Furthermore, this factor has also been identified important in the literature.

If we look at model 2, for users of a bike sharing system the time for check-in or check-out is even more important. This may be because the users are already familiar with the system. They can better assess how tedious or easy it is to unlock such a system. Users of a bike sharing system react less to travel costs, compared to all participants. This corresponds to the assumptions. Since most people only use bike sharing for trips shorter than 30 minutes, the travel costs are not of interest in this case.

VI. Conclusion

This thesis tries to give an insight into how the quality of a bike sharing system can be improved from the user's point of view. The research of recent years serves as a basis for this. However, it is difficult to evaluate the quality. The boundary conditions are different in every city. In addition, a large number of factors influence the perceived quality. Some of these cannot be influenced by an operator, such as the weather. Other factors such as the cycling infrastructure and the traffic concept are determined by politics and government.

In the context of this work, an attempt was made to investigate this influence on the basis of se-lected factors. These factors were walking distance, time to check-in or check-out, membership fee, travel cost and availability of bikes at the desired station. The effect was investigated by means of a survey. This survey was mainly sent to students. The distribution of participants should not have been so one-sided in terms of age and education in order to achieve a better, more representative result.

As an operator looking at the mentioned factors it is important to aware that at all the stations have always or often enough bike are available at all times. It might be better to implement a sys-tem without additional travel cost besides the membership fee. Therefore people know exactly how much they have to pay for the service in advance. These results are only a trade-off be-tween the selected factors. If more factors are added, the result would look different. Besides the factors examined in this report it is necessary to integrate the bike sharing system into the higher-level network of public transport. This means that the use of a bike sharing system would be part of a public transport subscription, thus simplifying access and use. Additionally a good marketing is essential for a successful implementation.

But since there are a long list of influencing factors it is possible to supplement the list of factors in a further step. Since e-bikes got very popular in the last years an extension of the survey in-cluding the possibility of e-bike usage would be reasonable.

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