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Statistics

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How do the car locations affect the car-sharing members' booking frequency?

--An empirical investigation of Falu Bilpool, Sweden

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ABSTRACT

Due to the increasing prices for fuels and steel in the market, the cost for the car-owners goes up. Thus, the demand for alternative solutions for cars is increasing. Car sharing is an environmental friendly alternative offering for low costs in the future.

Car sharing is a new concept in Europe starting in the 1980's. In the car-sharing organization, members share the joint ownership with the others and use the cars when they need. From the early studies, it shows that the dominant reason for people to join is the economic reasons. Car sharing is an inexpensive way to have an access to a fleet of cars and does increase the efficiency of car usage.

In this paper, I will mainly focus on how the change of car locations will influence the booking frequency in a car-sharing organization based on the data from Falu Bilpool. Since the data contains repeated measurements, a Generalized Linear Mixed Model will be estimated with the statistical software, *R*. The car locations are employed as casual variables and other relevant variables are included as control variables. The result shows that the car locations do play an important part when the members decide to use car-sharing cars. In the end, an optimal combination of the car locations is estimated.

Keyword: Car sharing, random effects, Generalized linear mixed model

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1. INTRODUCTION

The development of the modern society requires a convenient and efficient traffic capacity in the city, which results in a big demand for transportation. Most people buy their own cars because of mobility and convenience. On the other hand, the CO_2-emissions from the cars pollute the living environment heavily and recently the cars have been discussed more and more in international debates in terms of the environmental and economical impacts. Then the idea of “car-sharing” comes up.

1.1 Background

To be active and mobile in the society, people and organizations around the world are working to manage the mobility they use to access to the service and to the places they are going to participate in social activities, which stimulates the demand and supply for transportation. Nowadays there are many kinds of travel modes to satisfy the needs, such as private cars and public transportation for long trips and walking and cycling for shorter trips. To some extent, cars have some advantages. Compared to public transportation, one can have an access to a car without waiting for a bus or the subway. And for shorter trips, driving a car can save some time and energy to reach the places.

Because of the car’s mobility and convenience, the need for car-based mobility is increasing. But in most of the countries, cars are luxury and costly. Car prices, taxes, insurance premiums, gasoline prices, repairs and service, maintenance, loan payments (if the person take a loan), instalment interest and parking all add up to one person’s expense. For the people without much money to afford a car or for those who can afford but decide instead to use their money differently, car sharing provides an alternative way of having car-based mobility.

1.2 The concept of car sharing

There are many different definitions about car sharing, in this paper it will refer to the idea that without owning his own car, member in the car-sharing organization share a fleet of cars with other members.

The concept of car sharing is multi-layered. Firstly, members gain benefits of private

cars without the high fixed cost and the ownership. In other words, instead of paying a big amount of money to buy a car, members have access to a fleet of car once they have joined in the car-sharing organization. Besides the low fixed cost which refers to annual fee, the expense per member is quite flexible depending on how much the member is in need of a car.

Secondly, since the cars are used intensively by the members, the cars are replaced more often than the private cars, maximum 3 years. There are even some environmental cars existing in the car-sharing organizations, which are supported by the community and in some communities, environmental cars can park for free. The new-model cars and environmental cars will increase the users' comfort and safety during the trip.

Thirdly, car sharing helps the community to gain space. Instead of building many new parking lots, community can use them for productive uses. Additionally, with less cars, community also experience less air and noise pollution.

A complete car-sharing organization usually includes: a provider with a central-controlled system for bookings; data collection and billing; members that can be persons or companies; a fleet of vehicles that are available for members and several parking places located within the geographically accessible area; an administrative board elected by the members annually and the board members are mostly from the car sharing members in order to lower the possible costs.

The construction of a car-sharing organization is illustrated in Figure 1.

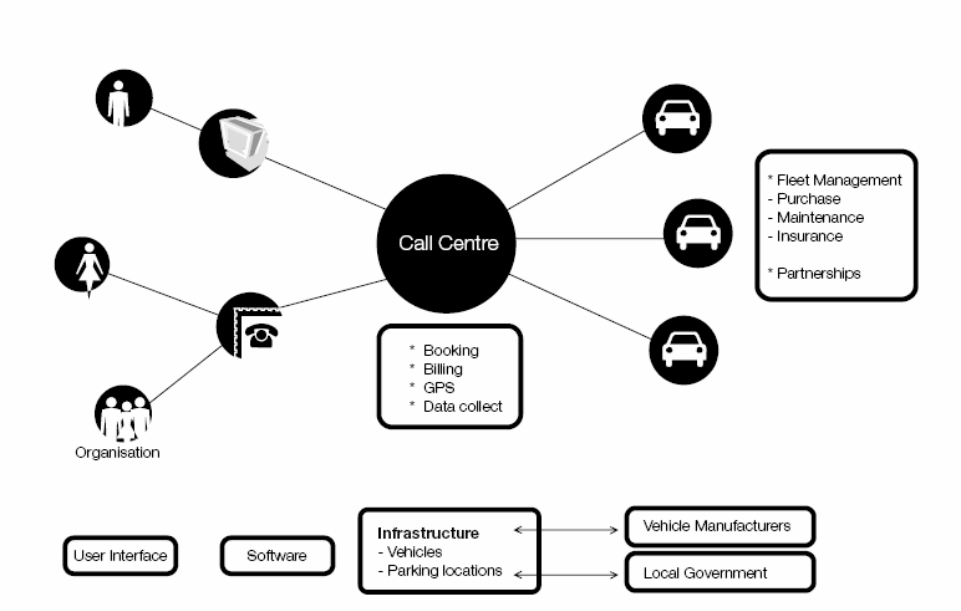

Figure 1. How the car-sharing organization typically works

1.3 Car sharing in Europe

Car sharing has grown steadily in Europe since its beginnings more than 10 years ago, with a growth rate of 50 to 60 percent a year and 40 active organizations currently registered.

Switzerland is at the leading edge of this development, with car-sharing organizations in larger communities. Some 450 shared-use vehicles are available at 220 stations in Zurich, and around 1,200 cars at 800 stations throughout the whole country. It is also very convenient that approximately half of all 700 Swiss train stations provide car-sharing lots, allowing intermodal vacation trips or travel blending from most Swiss cities and towns [1].

In Sweden, Majornas Car Cooperative, founded in 1988, is the biggest car-sharing organization. Now they have 415 private members and 11 company members with 29 active cars. The development of car sharing in Sweden is still in its infancy, and until year 2005, there have been 60 car-sharing organizations with, in total, around 3000 members [2].

1.4 Aim

When we talk about car-sharing organizations, it is of interest to know why certain numbers of people agree to the joint ownership instead of the private car ownership. By visiting the car-sharing organizations' webpages, financial considerations are the advantage which is most emphasized.

As noted earlier, one of the advantages of car sharing is that it is an inexpensive way to have an access to a car. In most countries, it is very costly to purchase and maintain private cars, such as car prices, taxes, insurance premiums, petrol prices, maintenance and parking will add up to a substantial amount of a household's income. The Swedish Consumer Agency estimates this to be around 20% of the total household income. So the economic limitations to car use are a potential important factor for households. In reality, some people consider buying older cars instead of new ones to lower the costs, however, older cars are more frequently in for repairs and pollute more heavily, which is also costly for the society. Potentially, it will also increase the expense for households.

Another common likelihood about membership in car-sharing organizations is the environmental attitudes among the members. Because of the increasing CO_2 emissions and the debate of climate change these years, many people with an environmental attitude would like to reduce the contribution to air pollution by using environmental cars. Since the environmental car is usually expensive, it is possible to have a joint ownership of environmental cars in car-sharing organizations, and a part of the members join the car-sharing organization because of this.

A questionnaire about one of the Swedish car-sharing organizations, Majornas Car Cooperative, was sent out to approximately 195 members on May 17, 1995. They were asked which of the motivations below are most important or best describe why they joined Majornas Car Cooperative. The answers are listed in Table 1[1].

[1] This project is cooperated with Vägverket (Swedish national road administration)

Table 1. Rankings of motivations to join Majornas Car Cooperative, answers given in May of 1999

Most important motivations for joining the cooperative	Frequency	Percent
Economic	209	43
Practical	113	23
Environmental	81	17
Collective	79	16
Social	4	≥1
Total	486	99%

From the table above, the results from the members in the Majornas Car Cooperative confirm the assumptions of motivations why people want to join the car-sharing organizations. Since the economic factors are the most important for decision-making, it is of relevance to be considered in the analysis.

In the next section, I will try to analyze how the car locations affect the booking frequency based on the data provided by Falu Bilpool.

2. AN EMPIRICAL APPLICATION

In the previous chapter, the concept and how the car-sharing organization works have been introduced. In this chapter, I will take Falu Bilpool[2] as an example and analyze how the car locations affect the booking frequency.

2.1 Falu Bilpool

Falu Bilpool, a non-profit origination, was founded on 11th October 2000 with only 1 car and now it has grown up to 45 members and one company member with 3 active cars.

2.1.1 Regulations within Falu Bilpool

As a member in Falu Bilpool, one can book a car on the Internet or on the telephone; the minimum booking time is half an hour. Every member has one identification number to distinguish from others, which is the member's telephone number.

Cars can be picked up and parked at assigned parking places and now the new environmental cars can park for free within Falun Community.

There is a key box at the back of the car where you can pick up the car key. Members will get an extra key to the box.

Members can either pay monthly via postal giro or open an account where one can deposit money in advance.

2.1.2 Charging scheme

There are two ways of having access to cars in Falu Bilpool. One can become a member or one who lives in the household of a member pays a minimal fee to gain access to the cars. In this case, the entrance fee for the first person is 2000 SEK and the second person only needs to pay 500 SEK. People who have paid for the entrance fee in one household make up of one member. The entrance fee is refundable when a

[2] Falu Bilpool is located in Falun, Sweden.

member exits. The annual fee is 500 SEK for each member. All the payments are obligatory even for members who do not book any car within one year.

Besides the fixed cost per year, members have to pay for how much the car has been used. It is 10 SEK per hour and for the whole day, it is 160 SEK (it is free per hour between 23.00-7.00). The charge per kilometer has increased from 1.5 to 2 SEK. There is no starting fee until October 2004 and it has increased from 10 to 20 SEK.

All the members do not need to pay for the petrol and insurance. Comparatively, the cost per year is much lower than owning a private car.

2.2 Data description

All the original data was provided by Ingemar Elb and Torsten Hylén who work in the administrative board of Falu Bilpool. Information concerning the use of cars is collected by the administrative board, which includes the membership number (NR), name, the date, time duration, distance, type of car used, cost, booking fee etc. It is recorded from 2001 to 2006 with 6 different sheets and for the 67 members since the Falu Bilpool was founded. This material is tabulated in Excel files. Since the original data contains some information which is out of concern in this paper, the first step is to filter the irrelevant information and sort out the relevant ones. When the data is transposed, only numbers are used to insure the anonymity of the individual members, which is the membership number.

There are some problems with the data which needs to be addressed. In the original data, there are some columns, which are not directly related or relevant to the booking expenses, such as description and contract number, which will be erased. There are some bookings and costs concerning to the company member (NR is 46400), but since it is not what this paper concerns, the record will be erased as well. The record of NR 0 is internal expense within Falu Bilpool, so it is also taken away. After that, all the information is about the members' expenses. But not all the values directly refer to the expenses based on the car bookings, such as the annual fee and how much money the members put in his account. Based on the same consideration, all the information has been taken away.

It is noticeable that some values which should be plus but have minus signs should be corrected, one of the examples is given in Appendix A. All the distances, which are driven, are recorded by Swedish mile, which is equal to 10 kilometers and is always confused with British mile, so all the Swedish miles are converted to kilometers. After these procedures, the rest of the data is the actual cost based on every booking per member, the cost is marked with minus sign which means the money the members should pay for car uses. It contains the membership number, name, time duration, distance, cost, time fee, driven fee and booking fee. There are 4225 bookings among 67 members[3].

According to the aim of this paper, some more values will be aggregated. Firstly, all the annual data is merged into one Excel file and aggregated monthly. The name of the month is followed. Secondly, the frequency of monthly booking during the registration period per member is summed up, it ranges from 0 to 18. In the end, Extra information obtained from Ingemar, such as if the member has a car of his own and the change of the car locations is added. Then there are 2389 records in total among the 67 members[4].

Table 2 represents the information about the summary of monthly bookings during the 6 years. Detailed information is in Appendix A.

Table 2. Summary of the members' monthly number of bookings from 2001 to 2006

Frequency	0	1	2	3	4	5	6	7	8	9-18
Number of members' monthly bookings	1044	437	307	199	112	74	74	38	37	67
Total	2389									

From the table above, it is easy to see that monthly frequency, which is recorded during the registration period per member, is ranged from 0 to 18 times (note that there is no record with frequency being 17). There are 1044 records with frequency being 0, which means that the members most often have no booking in a single month.

[3] It is a group work organized by Yiqi Yang, Shanshan Yang, Hao Li and Qiguang Gao
[4] Since the first booking and the car location were activated from March 2001 instead of October 2000 when Falu Bilpool was founded, all the bookings start from March 2001.

Besides that, the most common monthly usage of cars is between once to four times, which means that the members do not book cars for daily routine, mainly for some special reasons. Another reason will probably be that since Falun is a small city and everything is quite centrally located, the car-based mobility is perhaps less required than it is in bigger cities. Moreover, the monthly number of bookings per member decreases at higher frequency with only one member who booked the cars 18 times in one month, so I collapse the frequencies from 9 to 18 times into a single class.

As noted earlier, the cars in the car-sharing organizations are rather new, between 0 to 3 years. During the 6 years, Falu Bilpool has owned 7 cars in total, and 3 are active cars now. Five different car locations, which have been used for parking and picking up the cars, are within the walking distances from the members' living places. The map below shows the information about car locations and the members' residential addresses.

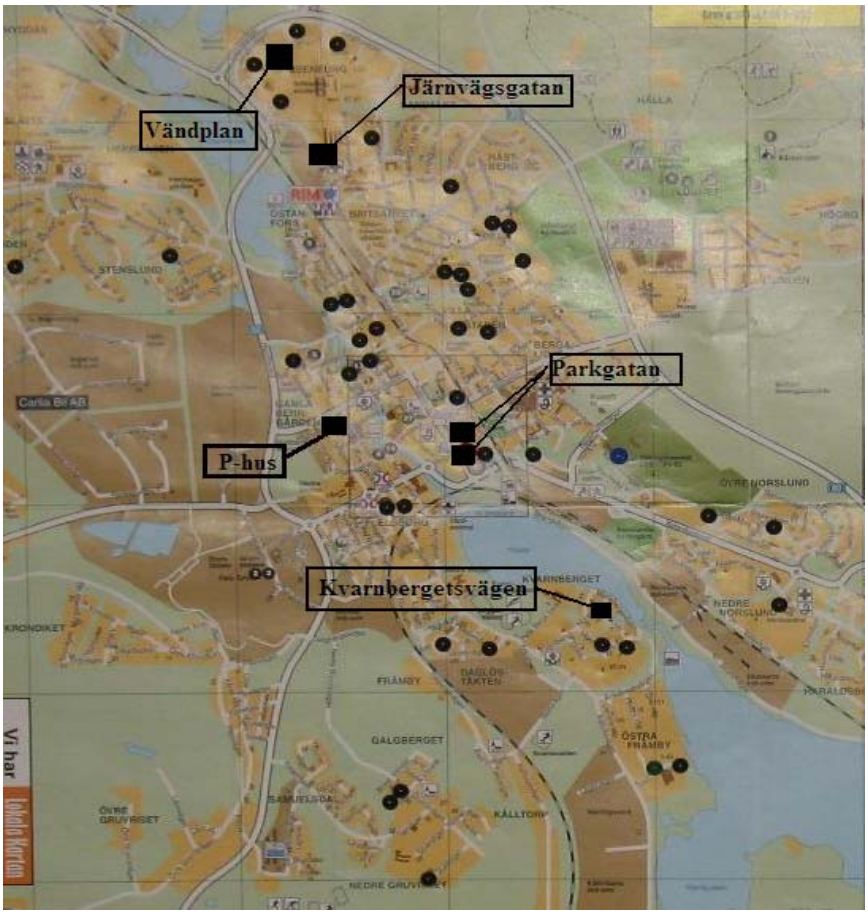

Figure 2. Car locations and members' residential addresses of Falu Bilpool in Falun

Orderly, the car locations, P-hus, Parkgatan, Vändplan, Järnvägsgatan and Kvarnbergetsvägen, are marked with square and the other dots represent the members' residential addresses. Each car location will be used for some time (see Appendix A) and the cars must be parked at the assigned locations after being used. During 6 years, the combination of the car locations is given in table 3.

Table 3. Information of the combination of the car locations

	From	To	Combination of Car Locations
1	2001.3	2002.6	P-hus
2	2002.7	2003.3	Parkgatan&Vändplan
3	2003.4	2005.4	Parkgatan&Vändplan& Kvarnbergetsvägen
4	2005.5	2005.8	Parkgatan&Järnvägsgatan& Kvarnbergetsvägen
5	2005.9	2006.12	Parkgatan&Järnvägsgatan

During 6 years and among the 67 members, 17 members have cars of their own and there are 138 bookings with the frequency being or more than once a month; 50 members do not have private cars and it lead to 1208 bookings with the frequency being or more than once a month.

2.3 Model selection

As mentioned in the previous section, the aim of this paper is to analyze how the change of car locations influences the booking frequency. In this case, it is important to find a proper estimated model to analyze the data.

2.3.1 Model selection

Data that contains multiple observations per case are called "repeated measures data". Repeated measures data are usually obtained from multiple measurements of a response variable. Such multiple measurements are carried out for each experimental unit over time or under multiple conditions. The data which will be used in this paper is obtained from multiple measurements over time which means that at the most there will be 6×12 measurements of a member provided that he has been a member in Falu Bilpool since it was founded. Thus, the data with 2389 bookings and 67 members is called repeated measures data.

There are several statistical methods used for analyzing repeated measures data. These include 1) separate analyses at each time point, 2) univariate analysis of variance, 3) univariate and multivariate analyses of time contrast variables, and 4) mixed model methodology [3]. In this paper, I will use mixed model methodology to analyze the data.

Mixed model are models where some of the independent variables are assumed to be fixed, while others are seen as randomly sampled from some population or distribution. Mixed procedure is based on the general linear mixed model

$$Y = X\beta + ZU + \varepsilon \tag{2.1}$$

Where

Y is a $(N \times 1)$ vector of observations,
X is a $(N \times P)$ design matrix for the fixed effects,
β is a $(P \times 1)$ vector of fixed, unknown parameters,
U is a $(Q \times 1)$ vector of unobservable random effects,
Z is a $(N \times Q)$ design matrix for the random effects, and
ε is an $(N \times 1)$ vector of residual random errors.

The random vector U is assumed normally distributed with mean $E(U) = 0$ and variance $V(U) = G$, and ε is assumed normally distributed with mean $E(\varepsilon) = 0$ and variance $V(\varepsilon) = R$. As a consequence, the observed data vector Y is normal distributed with mean $E(Y) = X\beta$ and variance $V = V(Y) = V(ZU + \varepsilon) = ZGZ' + R$.

In general, the actual effect of the random factors is not of primary concern while the regression parameters, β, is of interest. In R, *lme* can be used for fitting mixed linear models in cases where the response variable is continuous and normally distributed.

As mentioned above, Y is assumed to be independently normally distributed with constant variance. If Y belongs to the exponential family of distributions which include Normal, Poisson, gamma and binomial distributions, a generalized linear mixed model is applicable [4]. Generalized linear mixed models can be fitted using

the function *lme4* in the library *lmer*. The syntax used for model specification is as in *lme* and parameter estimates are based on *PQL* [5].

From the data, we know that the frequencies range from 0 to 18 and may be modelled with a Poisson distribution. So in this paper, generalized linear mixed model will be used to analyse the data.

2.3.2 Model fitting

The main focus in this paper is the effect of change of car locations on the booking frequency, so the car locations are chosen to be casual variable. Additionally, some control variables are also involved in the final model, which are 1) *StartFee*, 2) *PrivateCar*, the status if a member has a car of his own, marked with YES or NO, 3) *NumberofUsers*, Number of users in one household, 4) *DistanceFee*, 5) *NumberofMembers*, the monthly number of actual members and 6) *NumberofCars*, the number of active cars, 7) *Month*, a factor with 12 levels. So the final model is shown as,

$$Bookingfrequency = \beta_0 + \beta_1 CarLocations + \beta_2 StartFee + \beta_3 \mathrm{Pr}\, ivateCar + \beta_4 NumberofUsers + \beta_5 Dis\tan ceFee + \beta_6 NumberofMembers + \beta_7 NumberofCars + \beta_8 Month + \varepsilon$$

Where the variable *CarLocations* involves the combination of car locations which is a factor with 5 levels, individual car locations and the interactive term.

2.4 Results

After employ all the variables in the final model and the result is shown as below:

Table 4. Output from the final model[5]

	Fixed Effects		
	Estimate	Std. Error	P-value
Casual variables			
Combination of Car Locations			
Parkgatan&Vändplan	0.3663	0.1067	0.5307
Parkgatan&Vändplan &Kvarnbergetsvägen	0.4492	0.1645	0.0063
Parkgatan&Järnvägsgatan& Kvarnbergetsvägen	0.6310	0.1819	0.0005
Parkgatan&Järnvägsgatan	0.3232	0.1535	0.0353
Control Variables			
Intercept	0.4967	0.7923	0.5307
Start Fee (SEK)	0.0022	0.0074	0.7679
Private Car-YES	-1.7171	0.1285	< 2e-16
Number of Users in the household	0.3035	0.1123	0.0069
Distance Fee (SEK)	-0.6680	0.5014	0.1828
Number of members	0.0053	0.0066	0.4189
Number of Cars	0.0356	0.0587	0.5444
Month	See Appendix B		
	Random effects		
Groups	Name	Variance	Std.Dev
NR	(Intercept)	0.4781	0.6914
Number of observations: 2389, groups: NR, 67			

From the table above, the combination of car locations is significant to affect the booking frequency. Based on the first parking combination, *P-hus*, there is a positive relationship between the parking combinations and the booking frequency. Among all the coefficients, 0.6310 is the highest, which means the combination of

[5] The code in R is:
R=lmer(Frequency~factor(Combination)+StartFee+PrivateCar+NumberofUsers+DrivingFee+NumberofMembers+NumberofCars+Month+(1|NR),data=FaluBilpool,method="PQL", family=poisson)
summary(R)

Parkgatan&Järnvägsgatan&Kvarnbergetsvägen has the biggest positive effect on the booking efficiency.

StartFee has a positive relationship with the booking frequency but not significant, which means when the *StartFee* increases, the booking frequency will increase by approximately 0.2%.

The number of users in the household and the number of members will increase the booking frequency. In Falu Bilpool, all the users in the same household use the same membership number to book the cars, so when the number of users is increasing, the booking frequency will increase by 30%. The number of cars increases the possibility of the usage of the cars, so it also increases the booking frequency.

If the members have private cars, the possibility of usage will be reduced. And the increasing *DrivingFee* also holds back the members' usage of the cars, about 66%.

Through the whole year, the booking frequency decreases except June when the comparison is based on the booking frequency in January.

2.4.1 Estimate of optimal car locations

For the administrative board of Falu Bilpool, it is of interest to have more members and usage of the cars as much as possible. So it is important to locate the cars near to the members' residential areas and within the walking distances. But as a non-profit organization, the board will try to make the costs, such as parking costs, commercial costs and leases of offices, as low as possible. The parking fees for car locations in center are usually costly though they are convenient. So it is realistic to compare the parking fees with the car locations. Table 5 below shows the optimal combination of car locations.

Table 5. Estimate of Optimal Combination of Car Locations

	Estimate	Std. Error	P-value
Location			
Parkgatan	-0.0728	0.1050	0.4884
Vändplan	0.3889	0.1114	0.0005
Järnvägsgatan	0.3461	0.1567	0.0272
Kvarnbergetsvägen	0.2928	0.0969	0.0025
Interactive			
Vändplan&Kvarnbergetsvägen	-0.2376	0.1177	0.0436

* It is not possible to test with higher-level interactive terms due to the data, so I only use two-level interactive term.

From the table, we can see that based on the first parking place, *P-hus*, the car location at *Parkgatan* will decrease the booking frequencies while the other three locations are beneficial to the usage of the cars so that the booking frequency increases. Among the five car locations, *Vändplan* is the optimal place if there is only one active car in Falu Bilpool.

The interactive term, *Vändplan&Kvarnbergetsvägen*, has a negative effect on the booking frequency, which means that the combination in this way will decrease the members' usage of the cars. So if there are 2 active cars in Falu Bilpool, the combination of *Järnvägsgatan&Kvarnbergetsvägen* is better than that of *Vändplan&Kvarnbergetsvägen*.

From the last section, based on the existing combination of car locations, the combination of *Parkgatan&Järnvägsgatan&Kvarnbergetsvägen* is the optimal for members' usage of the cars. However, the best estimate is the combination of Vändplan&*Järnvägsgatan&Kvarnbergetsvägen.* In the map, *Parkgatan* is located in the centre of Falun and it is usually expensive than the other places. In this case, it maybe interesting for the administrative board to change the car locations.

3 Summary and Conclusion

The rapid development of car-sharing organizations evokes the awareness in public that without worrying about the high purchase and maintenance cost per year on one car, members can have an access to a fleet of cars and can choose freely according to their needs. The cars are also updated approximately every 3 years with more safety.

There are many motivations for members to join in a car-sharing organization, such as economic, practical, environmental, collective and social. Among all the motivations, economic reason is in the dominant position for decision-making. Car sharing is an inexpensive way to have an access to cars.

In this paper, a data is collected realistically from a car-sharing organization, Falu Bilpool in Sweden. And the aim of this paper is to investigate how the car locations affect the booking frequency.

The following procedure in this paper is to focus primarily on the model selection and then to investigate how the car locations affect the booking frequency in Falu Bilpool. The selection of model based on the type of data. In this paper, the data is a repeated measures data with random effects, so a mixed model is applicable. Since the response variable belongs to the exponential family of distributions, a Generalized Linear Mixed Model (GLMM) is applied.

In the statistical software, *R*, GLMM can be fitted in with *lmer*. The result has given in the last section.

The car locations, which are decided by the administrative board of *Falu Bilpool*, play an important role on members' usage of the cars. In the last section, a result is given and maybe valuable as a reference for the administrative board about the decision-making of car locations. From the members' bookings, a conclusion is drawn about which existing combination of car locations attracts more members to book cars and which would be an optimal combination is estimated.

The restriction of the analysis in this paper is that Falu Bilpool is a quite new organization with few members and active cars. Maybe the variables which do affect

the booking frequency are not significant in this paper. For the further study, I would like to investigate more detailed information.

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Appendix A

Table 1. Example of correction in the data

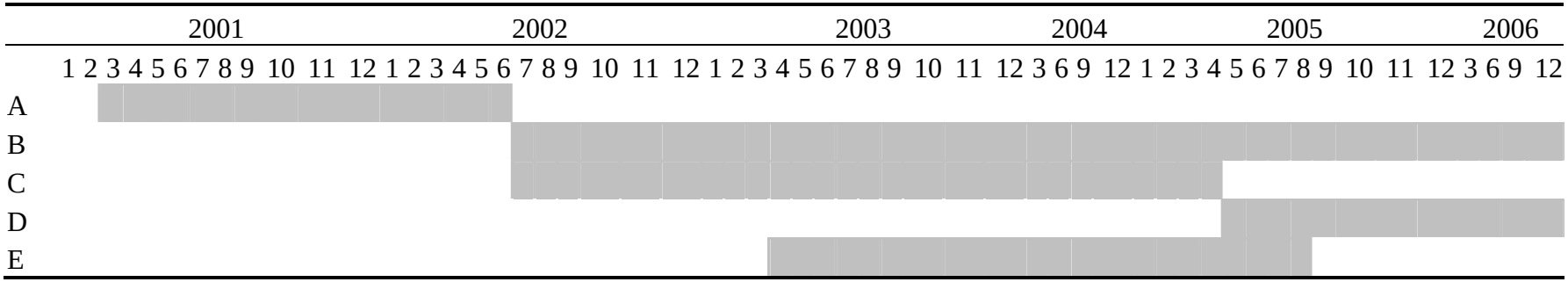
NR	Date	Startfee	Time	Mil	Descritipn	Payment
20737	2005-7-25	0	0	-40	Correction 26 june	80
32142	2005-7-25	0	0	40	Correction 26 june	-80

*NR. 20737 has been charged for 40 kilometres more which 32142 should pay for.

Table 2. Frequency of monthly car use in Falu Bilpool from 2001 to 2006

Year	2001		2002		2003		2004		2005		2006	
Month	Number of booking	Number of actual members	Number of booking	Number of actual members	Number of booking	Number of actual members	Number of booking	Number of actual members	Number of booking	Number of actual members	Number of booking	Number of actual members
Jan.	NA	NA	22	9	69	19	106	24	71	25	66	21
Feb.	NA	NA	21	9	66	16	88	26	72	22	54	18
Mar.	8	5	25	11	56	15	93	24	76	23	75	22
Apr.	8	7	23	13	70	21	79	23	78	25	61	22
May	15	6	29	12	68	20	85	25	93	23	74	23
Jun.	22	6	32	13	84	22	109	25	115	29	85	27
Jul.	9	6	20	10	54	19	53	17	105	27	66	22
Aug.	13	6	32	13	74	25	105	27	74	29	48	26
Sep.	18	7	39	13	80	23	94	24	71	23	72	25
Oct.	22	8	49	15	89	23	84	24	70	23	81	32
Nov.	16	8	47	14	73	25	74	23	64	23	85	29
Dec.	17	8	55	17	61	24	79	27	67	20	78	29

Table 3. The Usage of the Car locations during 6 years (A-P-hus, B-Parkgatan, C-Vändplan, D-järnvägsgatan, E-Kvarnbergetsvägen.)



Appendix B

Table 1. Estimate of control variable- Month

Month	Estimate	Std. Error	p-value
February	-0.1643	0.0794	0.0385
March	-0.1038	0.0777	0.1812
April	-0.1897	0.0796	0.0172
May	-0.1127	0.0803	0.1605
June	0.0251	0.0789	0.7506
July	-0.3027	0.0842	0.0003
August	-0.2215	0.0853	0.0094
September	-0.1296	0.0831	0.1189
October	-0.0975	0.0769	0.2049
November	-0.1960	0.0802	0.0145
December	-0.2673	0.0822	0.0012