Bicycle parking preferences: costs versus walking time

Eric Molin

Delft University of Technology

Faculty of Technology, Policy and Management

P.O. Box 5015, 2600 GA Delft, The Netherlands

Email e.j.e.molin@tudelft.nl

Kees Maat (corresponding author)

Delft University of Technology

Faculty of Architecture and the Built Environment

Faculty of Technology, Policy and Management

P.O. Box 5030, 2600 GA Delft, The Netherlands

Email c.maat@tudelft.nl

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ABSTRACT

Successful bicycle stimulating policies may increase the need for bicycle parking capacity, especially at main railway stations located in city centers. A potential solution for this problem involves combining paid surveyed indoor parking near the platforms and free open-air parking without surveillance at larger distances. In this paper, the preferences of train travelers who use a bicycle as egress or access mode are examined with respect to this solution by reporting the results of a stated choice experiment (n=866). In this experiment respondents chose among paid and free bicycle storage facilities and two base alternatives involving another mode of transport and using another station. Based on the observed choices, a MNL model and a five-class Latent Class Model (LCM) were estimated. The results suggest preference differences among the segments with respect to all attributes, but especially with respect to type of surveillance. An important finding is that under the researched solution, only a small part of the train travelers stop using bicycle as access and egress mode and of this group, only a very small part will switch to car. Based on these results we conclude that the paid bicycle parking is a feasible solution to distribute scarce parking capacity at main railway stations.

1. Introduction

Cycling is an increasingly popular mode of transport in many parts of the world (Bachand-Marleau, 2011; Pan et al, 2011, Martens, 2004). It is believed to positively contribute to sustainability, public health (Humphreys et al., 2013; Saunders et al., 2013) and reduction of car use (Heinen et al., 2013) and is therefore encouraged worldwide by policymakers. Furthermore, cycling is regarded as an important link in the multimodal trip chain (Krizek and Stonebraker, 2010; Pucher, 2009, 2010). For example, approximately 40% of all rail passengers in the Netherlands use the bicycle as an access mode, that is, cycles between home and the railway station. Another 15% use the bicycle as an egress mode (Statistics Netherlands, 2011). The increased use of bicycle as an access and egress mode is regarded as an important factor in the explanation of the increased train ridership (Rietveld, 2000; Pucher & Buehler, 2009). However, the growth in bicycle use comes at costs in the sense that decent infrastructure needs to be provided for both bicycle traffic and bicycle parking.

In the Netherlands, the main stations are now facing such high demand for bicycle parking that accommodating the total demand in the usual way has reached its limits (Van Boggelen and Thijssen, 2008). The severest capacity shortages are in university towns. To illustrate, the 24,000 available bicycle parking spaces around the Central Station in Utrecht are no longer sufficient to accommodate bicycle parking demand. Clearly, capacity shortages weaken the role of the bicycle as access and egress mode as cyclists have to cruise to find a free parking space, increasing trip time and walking distances. The more difficult it is to find a parking space, the more often cyclists will park their bicycles outside the designated racks, which obstructs walkways and increases the risk of bicycle damage or even bicycle theft. This results in chaotic parking situations in which cyclists are more inclined to use cheap low-quality bicycles, which are more likely to be abandoned when they are no longer of use to the owner. These abandoned or 'orphaned bicycles' occupy parking spaces for a very long time and therefore contribute to parking scarcity. As this chaotic parking situation is visually unappealing, railway station managers and local authorities in the Netherlands now increasingly consider developing bicycle parking garages often incorporated in the railway stations, with the Dutch cities Groningen, Nijmegen and Den Bosch as good examples.

Since bicycle parking facilities and especially advanced bicycle parking garages are expensive to build and to maintain, there is now an ongoing policy debate on whether it is reasonable and sensible to offer only paid parking facilities at railway stations. Opponents argue that paid bicycle facilities may reduce the use of bicycle as an access and/or egress mode, which consequently may result in the decrease of train travel. On the other hand, economic theory holds that pricing may be an effective mechanism to distribute scarce space that in the end benefits most users. An analogy can be drawn with car parking: if parking prices decline with the distance to the destination, the most expensive parking spaces will be occupied by drivers with the highest willingness to pay while the cheaper parking places will be occupied by drivers with a lower willingness to pay who accept a larger walking distance. Hence, this mechanism results in vacant parking places everywhere with the result that cruising to find a vacant spot is limited. If, on the other hand, all parking is free, the free spaces near the final destination are distributed on a first-come, first-served basis (Shoup, 2006) resulting in fewer vacant parking spaces and more cruising as a result. The literature on the distribution of scarce car parking spaces has shown that free parking is indeed undesirable as it generates much extra traffic (Shoup, 2006; Arnott and Rowse, 2009; Kobus et al., 2013).

The pricing mechanism may work in the same way in the case of bicycle parking. If only free facilities are offered and vacant parking places are scarce, cyclists are forced to cruise or to park their bicycle outside the racks. Also cyclists with a high value of time may then be unable to find a space nearby the platform, with the result that cycling to the railway station and consequently train travel becomes less attractive. This is particularly undesirable as this group is more likely to switch to driving as they have on average a higher rate of car ownership (Maat and Timmermans, 2009). On other hand, in analogy with paid car parking discussed above, paid bicycle facilities may distribute the scare bicycle parking locations in a better way. Hence, a solution to the problem of scarcity of bicycle parking spaces at main railway stations is to introduce paid high-quality bicycle parking near the platforms, that is indoor parking surveyed by personnel while at the same time offering free but lower-quality parking facilities at larger distances. This typically involves bicycle racks in open air without any type of surveillance. Currently, the walking distance between the parking locations and the platforms is not a distinctive feature between paid parking and free parking; at many stations the walking distance is even longer for paid parking. Hence, to design this proposed solution, several questions with respect to the choice behavior of the travelers need to be answered, such as: Which share of the travelers is willing to pay for bicycle parking? How do they trade-off price, walking distance, and parking surveillance? Which share of the travelers will choose another mode of transport to the station or even stop traveling by train?

The aim of this paper is to answer these research questions by reporting the results of a stated choice experiment. In this experiment, respondents chose among paid and unpaid parking facilities and two base alternatives 'other mode of transport' or 'other station'. From these observed choices, a Latent Class (LC) Model (e.g. Greene and Hensher, 2003) was estimated to address the heterogeneity in preferences with respect to bicycle parking at stations. Hence, this paper contributes to the literature by providing insight into the willingness to pay for bicycle parking and the role of walking distance and bicycle surveillance for various segments in the population. In addition, the effect of paid facilities on bicycle parking demand is examined by reporting the probability to switch to other modes of transport or use another railway station. Although parking congestion may currently be limited to a few successful bicycle using countries such as the Netherlands, the result of this study may become relevant for other countries who may face similar problems in the future if their bicycle stimulation policies would become successful.

The paper is structured as follows. The next section first briefly describes the Latent Class Model and then presents the stated choice experiment, the data collection process and the model estimation. The subsequent section presents the results, including the estimated coefficients of an MNL model and the five segment Latent Class Model. In the final section we draw some conclusions.

2. Methodology

This section describes the applied methodology. First, the Latent Class Model will be briefly described. This is followed by the construction of the stated choice experiment and data collection procedure. Finally, the model estimation procedure is discussed.

2.1 The Latent Class Model

For readers who are not familiar with the Latent Class Model, we briefly summarize its main features in this section. The Latent Class Model (LCM) is based on the assumption that a number of segments or classes exist in the population that each have different preferences (e.g. Green and Hensher, 2003). Hence, by applying LCM one estimates a separate set of parameters for each segment. The segments are latent and therefore cannot directly be observed; they emerge in the estimation process. Because, the number of segments is not known beforehand, typically a series of models is estimated that each have a different number of classes. Based on a comparison of the model fit of these models, an optimal number of classes is chosen. As models with different latent classes are not nested (e.g. a model with two classes is not a subset of a model with three classes) the Likelihood Ratio test cannot be applied to make this decision. Instead, the minimum Akaike Information Criterion ($AIC = -2(LLB-P)$), and the minimum Bayesian Information Criterion ($BIC = -LLB+[(P/2)*ln(N)]$) are used to select the optimal number of segments (e.g., Gupta and Chintagunta 1994; Kamakura and Russell, 1989).

Furthermore, it is assumed that each individual has a certain probability of belonging to each of the segments. This class probability is estimated simultaneously with the parameters for each class. By averaging these individual class membership probabilities across all individuals, a class probability can be obtained, which provides an indication of the relative size of each segment in the population. In addition, simultaneously with the parameters, a class membership model can be estimated. This models the class probability of each individual as a function of his or her socio-demographic characteristics or of other individual characteristics such as, for instance, attitudes (e.g. Boxall and Adamowicz, 2002). Hence, the class membership model indicates how the segments are related to individual characteristics. Furthermore, a set of parameters for each individual can be obtained by a weighted summation of the parameters of each latent class, using the individual class membership probabilities as weights. These individual-specific parameters can be applied to predict choice probabilities between various alternatives for each individual separately. These probabilities can be aggregated across individuals to obtain overall choice probabilities of alternatives that take into account heterogeneity of preferences across individuals.

2.2 The stated choice experiment

In this section, the construction of the stated choice experiment is described. As already discussed in the Introduction, the main goal of this experiment is to examine the trade-offs bicyclists make when parking their bicycle at a railway station. In this study, a paid bicycle parking storage offers indoor parking surveyed by personnel, where bicycles are sheltered from all weather conditions. A free bicycle storage refers to bicycle racks located in open air. The specific focus of this experiment is to explore cyclists' parking choices for a situation in which the paid storage is always located closer to the platform than the free storage.

Choice sets with two labeled alternatives each were constructed, that is a paid and free storage. The characteristics of these two labeled alternatives differ in a number of ways, both in attributes varied in the experiment and in attributes not varied in the experiment, which will be discussed in the following.

In accordance with our definition of the paid storage, the characteristics 'surveillance by personnel' and 'indoor facility' are fixed and therefore not varied for this alternative. What is varied in the experiment for paid storage is the walking time between the storage and the platform and the price of using the storage. The walking time was varied in the levels 0, 1 and 2 minutes. The price was varied in the levels 0.30, 0.90 and 1.50 euro per day (see Table 1). As the price for using paid bicycle parking facilities at railway stations at the time of research was € 1.20 per day, the chosen price range allows exploring the effects of considerably lower and higher prices. In addition to price per day, monthly and yearly subscription fees were added to make clear to the respondents that they did not necessarily need to pay per day but that subscription is possible. These subscription fees are completely in line with the real prices and in the same ratios (e.g. € 1.20 per day, € 12 per month and € 100 per year).

In accordance with our definition, the free storage facilities always offer open air parking. Varied in the experiment are the attributes 'walking time between storage and platform' and 'type of surveillance'. Walking time is assumed to be longer than for the paid storage, and varies in the levels 3, 4 and 5 minutes. Surveillance varies in the levels: i) none, ii) camera surveillance, and iii) surveillance by personnel. Table 1 presents an overview of all four varied attributes and their levels.

TABLE 1 Labeled alternatives and their varied attributes and levels

alternative 1: paid indoor bicycle facilities, surveyed by personnel	**alternative 2: free, open air bicycle rack**
walking time towards platform • 0 minutes • 1 minute • 2 minutes	**walking time towards platform** • 3 minutes • 4 minutes • 5 minutes
parking price • € 0.30 per day (€ 3 per month, € 25 per year) • € 0.90 per day (€ 9 per month, € 75 per year) • € 1.50 per day (€ 15 per month, € 125 per year)	**type of surveillance** • no surveillance • camera surveillance • personnel surveillance

The construction of the choice sets and the alternative is based on the smallest fractional factorial design, which resulted in 9 choice sets. In addition, a foldover design is constructed that resulted in another 9 choice sets. The foldover design involves a 'mirror design' which means that where level 1 appears in an alternative of the experimental design, level 3 appears in its comparable 'mirror' alternative of the foldover design. Including the foldover design has the advantage that not only all main effects are uncorrelated with each other across all choice sets, but also uncorrelated with all two-way interaction effects.

Each respondent was presented 9 choice sets, either based on the experimental design on its fold-over design. In addition, two base alternatives were added to each choice set. The first base alternative involves 'traveling via station Delft South' (see next subsection). The second base alternative involves traveling with another means of transport (than by bicycle) to Delft station. These two base alternatives allow examining what respondents will choose when the offered bicycle parking facilities do not meet their preferences. Hence, it provides insight into the extent to which the design of the parking facilities influences the demand for bicycle parking at Delft station. An example of a choice task can be found in Table 2.

TABLE 2 Choice set example

Characteristics	**paid indoor bicycle facility, surveyed by personnel**	**free, open air facility**
Price of parking	€ 0.30 per day (€ 3 per month, € 25 per year)	For free
Indoors or outdoors parking	Indoors	Open air
Surveillance	Surveillance by personnel	None
Walking time between parking and platform	0 minutes walking	3 minutes walking
Imagine this situation applies for Delft station, what would you choose? 1. Paid, surveyed, indoor facility 2. Free, open air facility 3. I will start traveling via station Delft South 4. I will travel with another means of transport to and from the station (for example, walking, bus, tram, public transport bicycle)		

The stated choice experiment was incorporated in an Internet questionnaire that in addition included questions about: i) socio-demographic characteristics, ii) current use of parking facilities at Delft (main) station and at Delft South station, that may be regarded as revealed choices and iii) the importance attached to characteristics of bicycle parking facilities, which will not be reported in this paper.

2.3 Study area and sample

This study was carried out among train users who parked a bicycle at Delft railway station. Delft is a medium-sized university town in the Randstad, the economic core of the Netherlands (Maat and Louw, 2013). Delft station provides an excellent study area since the station is currently being rebuilt: a railway tunnel replaces the current viaduct. Consequently a new underground station and new bicycle parking facilities are constructed. During the construction period, the free bicycle facilities have been relocated several times and the number of free bicycle racks is limited, which resulted in chaotic parking problems discussed before. This means that all current users of the station's bicycle storage facilities are familiar with the problems related to limited parking spaces. Although the reconstruction of Delft station is an unusual situation, we believe that the results can be generalized to other railway stations that have to deal with a high demand for bicycle parking, which applies to almost any main station located in a city center, at least in the Netherlands.

The main railway station is adjacent to the city center. It has surveyed parking facilities for 1,463 bicycle and various bicycle parking areas without surveillance, with spaces for approximately 5,500 bicycles. In the years to come, the area around the railway will be redeveloped and will offer 5,000 bicycle parking places in a storage above the new station. However, this number is expected to be insufficient, hence, several thousand more free open air spaces would have to be realized to fully meet the demand. Another station is located in the south of Delft, adjacent to its outskirts and a business park. As intercity trains do not stop there, this railway station is less attractive for many train users. For passengers who travel with an IC service to Delft, using Delft South implies making an extra transfer. Since Delft South is located closer to part of the University campus, it is a feasible alternative for part of the students and university employees as well for those employed in the business park located in that area. This train station has a free bicycle parking capacity of about 600 places.

Respondents were recruited by handing out flyers at both Delft railways stations. This took place at 5 days in a regular working week in April 2012, of which 3 working days and both weekend days. The weather was normal for that time of the year, both sunny and clouded days with some rain and an average temperature of 10^{o} C. The flyers briefly explained the goal of the survey, which was described as 'to examine optimal parking at Delft station and Delft South'. It also contained the questionnaire's website address both in writing and in QR-code. As an incentive to participate, the flyer indicated that 10 prescription fees of rental public transport bicycle and 10 vouchers each with a value worth € 50 were put up for raffle among the participants that completely filled out the questionnaire.

In total, 7.791 flyers were handed out, of which 6.271 at Delft station en 1.520 at Delft South station. In total 1.109 usable questionnaires were filled out, which resulted in a response of 14.2%. Only those respondents who indicated that they parked a bicycle at Delft station were invited for participation in the stated choice experiment, thus excluding the respondents that use Delft South. In total, 866 respondents completely conducted the stated choice experiment without any missing values. Hence, 7794 observed choices formed the bases of the model estimation.

Table 3 presents the distribution of some respondent characteristics. This distribution reflects the fact that Delft has a University with a relatively large student population. Many students that live elsewhere travel by train towards the university, which is mainly due to the free public transport pass that students obtain in the Netherlands. This is reflected in the distribution of occupation that shows that about half of the respondents is student. It is also reflected in the relatively low average age of 32 years, and in the finding that more than half of the respondents has a net income lower than 1000 euro per month. The slight overrepresentation of males is probably related to the technical character of the

University, which attracts more male than female students and employees. The distribution of revealed bicycle parking choice indicates that about one out of six respondents currently parks its bicycle in the paid storage while five out of six respondents uses the free parking facilities.

TABLE 3 Distribution of respondent characteristics (N=866)

gender			**income – net per month**	
Males	55.3%		<1000 euro	52.2%
females	44.6%		1000-2000	21.1%
occupation			2000+	26.7%
Work	49.2%		**revealed bicycle parking choice**	
student	50.8%		free storage	83.7%
age			paid storage	16.3%
average age	32 years			

2.4 Model estimation

Before the choice of the number of latent classes is discussed, first the applied coding is discussed and what this means for the interpretation of the estimated coefficients. In order to gain insight in the relative utility derived from each of the four alternatives, alternative specific constants are estimated by means of a series of dummy variables. The alternative 'other means of transport to Delft station' is chosen as a reference alternative, whose utility is therefore fixed at zero. Hence, the alternative specific constant estimated for each of the three other alternatives expresses the utility derived from that alternative compared to 'other mode'. By applying dummy coding for the attribute 'type of surveillance' and choosing 'surveyed by personnel' as the reference category, the constant of the free facilities is now also confounded with this attribute level as it is for the paid storage. Thus, the constants of both bicycle parking alternatives are comparable to some extent and express the base preferences for a hypothetical parking alternative that is surveyed by personnel, has zero walking time, and has price zero. The two bicycle parking constants differ from each other in the sense that the constant of the paid storage involves that it is an indoor facility for which one has to pay. The latter mainly expresses the hassle of paying (purchasing a ticket or a subscription), and the general attitude towards paying for parking facilities that are also offered for free. In addition, the difference in constants may also be caused by differences in characteristics that are not mentioned in the experiment but which cyclist may associate with the alternatives. This may be based on their own experience or stories heard from people in their social network, and may result in perception differences between the two bicycle parking facilities, for example, related to the speed of parking and retrieving the bicycle, the effort it takes to park a bicycle, the time it takes to find a vacant parking spot, friendliness of personnel, type of building, the type of route towards the platform, familiarity with the alternative, etc.

In order to decide on the number of segments, a series of models was estimated increasing the number of segments from 1 to 5 classes, which is the maximum number of classes the applied software (Nlogit 4) allows. In addition, a membership function was estimated with the respondent characteristics as presented in Table 3 as predictor variables, that is, gender, age, occupation income, and revealed parking choice. However, although many of the results pointed in expected directions, none of the estimated coefficients of the membership function turned out to be statistically significant. From this result can be concluded that the latent segments are not related with the distinguished respondent characteristics. Therefore, it was decided to refrain from estimating a membership function in the final model.

Table 4 presents the fit measures of the five models (all without membership function), where the single segment model is in fact a basic MNL model. The Table shows that the values of both AIC and BIC decrease with increasing the number segments and are at a minimum level at five classes. As in addition, the five class model can be interpreted well, we choose the five class model as the final model. The adjusted Rho-square value of the single class model (the MNL model) of 0.301 indicates that the model fit of this model was already high, and that this hugely increases towards 0.533 in the five class model. The latter indicates that much heterogeneity in preferences exists with respect to bicycle parking and that this is well captured by the estimated LC model. The estimated coefficients will be discussed in the following section.

TABLE 4 Model fit for 2 to 5 segment latent class models

number of segments	number of parameters (P)	Log likelihood at convergence (LLB)	Adj. ρ^2	AIC	BIC
1	8	-7555.044	0.301	15126.09	7577.05
2	16	-6412.286	0.406	12856.57	6456.30
3	24	-5600.615	0.481	11249.23	5666.63
4	32	-5249.780	0.513	10563.56	5337.80
5	40	-5032.862	0.533	10145.72	5142.89

AIC (Akaike Information Criterion) = -2(LLB-P)

BIC (Bayesian Information Criterion) = -LLB+[(P/2)*ln(N)]

3. Results

The estimated coefficients of the MNL model and of the five segments Latent Class Model are presented in Table 5. First the general tendencies are discussed based on the results of the MNL model, which are later nuanced for the segments by discussing the results of the five segments of the Latent Class Model.

3.1 The estimated MNL model

The estimated MNL model indicates that the constants of both parking facility alternatives are positive and have a relatively high magnitude, while the constant of Delft South is negative (recall that 'other mode' served as a reference category). As discussed before, the coding for the two parking alternatives was chosen such that the estimated constants express the base preferences for the alternatives which are comparable in the attributes varied in the experiment. Hence, the higher constant estimated for the free facilities suggest that travelers generally prefer the free facilities over the paid facilities. This is probably caused by more favorable perceptions associated with the free facilities as discussed before. Furthermore, that both bicycle parking alternatives have a much higher constant than the two other alternatives, indicates that only a relatively small part of the cyclists will stop using the bicycle as an access or egress mode under the presented scenarios. Under the intended solution, only a small share of the travelers will choose for another mode of transport and even a smaller share will choose to travel via Delft South.

Although these results suggests that choosing for another mode of transport under the researched scenarios is rather limited, an important question is to what extent this will increase car use. This question can be answered by reporting the responses to a question posed in another part of the questionnaire. Respondents were asked what mode of transport they would use if they no longer would make use of their bicycle for their travel to a from Delft station. More than half of the respondents (51.2%) indicated they would walk, 39.2% indicated they would make use of public transport (tram or bus), 6.6% said they would no longer travel by train, and only 3% indicated they would use another mode of transport. The latter probably means using a car to travel to the station. These results suggest that if the intended solution would be implemented, that is paid parking close to the trains and free parking at larger walking distances, car use will only increase to a very limited extent.

The estimated parameters of the MNL model are all in expected directions: if parking price and walking time is increased, utility decreases. Furthermore, 'surveillance by personnel' is preferred to 'no surveillance' and to 'camera surveillance', although the difference with the latter is not statistically significant. Furthermore, variation in walking time to the paid storage has a smaller impact on utility than the variation in walking time to the free storage. This seems reasonable as the walking time to the paid storage is always shorter than to the free storage. Finally, as expected, the price for using the paid storage affects utility considerably.

3.2 The estimated Latent Class Model

Comparing the estimated coefficients of LC model and MNL model reveals that the LC estimates generally have a higher magnitude than the MNL estimates. This is mainly caused by the fact the LC model fits the data better, therefore reduces the error component with the result that the estimates have a higher magnitude. In addition, the LC model clearly reveals that some of the coefficients have opposite signs in various classes. These differences cancel out in the MNL model. Most pronounced this is observed for camera surveillance: the coefficient is not statistically significant in the MNL model, suggesting that there is no statistical difference between camera surveillance and personnel surveillance (the reference category). On the other hand, the estimates for camera surveillance are statistically significant in all five classes, showing both negative and positive effects, some of which are relatively strong (class five). This suggests that type of surveillance does play a role in parking bicycle choice in all classes, but that the different classes have opposed preferences with respect to this attribute, which will be discussed later in more detail.

To ease interpretation, the average utilities calculated by averaging the utilities derived from the 18 presented alternatives in the experiment are added to the bottom of the table. The average utilities directly indicate that each of the alternatives is clearly preferred by one of the classes, while the free storage is even preferred by two classes. The latter two classes are the largest: segment 1 involves 30.3% of the cyclists and segment 4 involves 30.6% of the cyclist. Segment 2 prefers *Delft South* and involves 5.5% of the cyclists; segment 3 prefers to *switch to another mode* and involves 14.4% of the cyclists, and finally segment 5 prefers the *paid storage*, involving 19.2% of the cyclist. In the following, we will briefly characterize each of these five segments, thereby only discussing the most distinguished characteristics of each segment in comparison with the general tendencies discussed before.

Segment 1: 'Hard core free storage users'

This segment is one of the two segments that prefers to use the free storage. Compared to the other free storage segment (segment four), this segment has a larger base preference for free parking and is much less sensitive to variations in both walking time to the free storage and price. Hence, especially this segment is relatively insensitive to increased walking distances and continues to use the free storage.

Another remarkable characteristic of this segment it that camera surveillance is preferred above surveillance by personnel. This suggests that this segment not only dislikes the paid storage for the mere fact that one has to pay for using it, but also because it is surveyed by personnel. It may be speculated that this is caused by negative associations with personnel surveillance, like feeling watched over, having to show parking tickets, and the perception that this slows down the speed of parking.

Segment 2: 'Delft South users'

This is the only segment that has a positive constant for the 'Delft South' alternative and its average utility derived from this alternative is highest. This segment especially dislikes the option *other mode*, hence, it prefers to remain cycling and therefore more than the other segments tends to switch from Delft main station to Delft South station. Together with segment 3 ('Mode switchers') it shares a high base preference for the free storage, which suggests a low willingness to pay. Recall that Delft South station offers free bicycle storage.

TABLE 5 Estimated coefficients and average utility per alternative

	MNL		LCM – class 1		LCM – class 2	
			'Hard core free storage users'		*'Delft South users'*	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
price of parking	-1.67	-29.78	-2.78	-11.16	-3.38	-12.21
walking time paid storage	-0.12	-3.86	-0.48	-4.39	-0.27	-1.72
dummy no surveillance	-0.19	-3.28	-0.44	-2.72	-0.87	-4.04
dummy camera surveill.	-0.07	-1.10	0.82	3.69	-0.62	-2.37
personnel surveill. (ref.)	0.00		0.00		0.00	
walking time free storage	-0.43	-14.49	-0.31	-3.25	-1.30	-10.82
paid storage constant	2.80	41.01	4.10	15.88	6.00	9.92
free storage constant	3.55	27.40	5.55	12.36	9.55	13.01
Delft South constant	-0.88	-12.91	-0.55	-1.82	4.86	8.93
other mode constant	0.00		0.00		0.00	
class probability			30.3%		5.5%	
average utility			*1.12*		*2.70*	
paid storage average			***4.45***		*3.85*	
free storage average			*-0.55*		***4.86***	
Delft South average			*0.00*		*0.00*	
other mode average						

Table 5 - continued

	LCM – class 3		LCM – class 4		LCM – class 5	
	'Mode switchers'		*'Free storage traders'*		*'Paid storage users'*	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
price of parking	-3.14	-16.46	-5.06	-33.02	-1.75	-13.34
walking time paid storage	-0.47	-16.46	0.22	3.74	-0.44	-6.08
dummy no surveillance	-0.92	5.44	0.48	4.40	-0.98	-6.16
dummy camera surveill.	-0.50	-0.31	0.38	3.00	-1.33	-7.10
personnel surveill. (ref.)	0.00		0.00		0.00	
walking time free storage	-1.41	-18.59	-1.22	-18.17	-0.28	-3.23
paid storage constant	1.22	8.62	6.79	39.34	5.65	27.81
free storage constant	5.46	17.83	7.93	25.70	2.97	7.79
Delft South constant	-3.79	-21.25	-2.32	-7.47	-0.87	-4.53
other mode constant	0.00	-16.46	0.00		0.00	
class probability	14.4%		30.6%		19.2%	
average utility						
paid storage average	*-2.08*		*2.46*		***3.63***	
free storage average	*-0.66*		***3.33***		*1.09*	
Delft South average	*-3.79*		*-2.32*		*-0.87*	
other mode average	***0.00***		*0.00*		*0.00*	

Segment 3: 'Mode switchers'

This segment prefers using another mode than bicycle as an access or egress mode. It especially dislikes traveling via Delft South, suggesting that this segment travels by an IC service to Delft. Like the previous segment, there are no other noticeable preference differences of this segment with the other segments.

Segment 4: ‘Free storage traders’

Like Segment 1, this segment (‘Free storage traders’) prefers to use the free storage, but the difference in constants with the other alternatives is smaller, suggesting a less pronounced preference. Furthermore, this segment is more sensitive to changes in attribute values than segment 1; it is especially sensitive to price. Remarkable is that in this segment in contrast to all other segments, utility increases with an increase in walking time to the paid storage, for which we do not have an explanation.

This segment shares with segment 1 that camera surveillance is preferred to surveillance by personnel, although the preference difference is smaller. This means that the two largest segments, which both prefer the free storage and together represent more than 60% of the population, prefer camera surveillance above surveillance by personnel. A difference with segment one is that this segment even prefers no surveillance at all to both surveillance by personnel and camera.

Segment 5: ‘Paid storage users’

Segment 5, the paid storage users, is the only segment that has a base preference for using the paid storage as indicated by the relatively high constant and a relatively high average utility derived from this option. As may be expected, of all segments this segment is least sensitive to parking price.

Contrary to the previous segment, this segment clearly dislikes camera surveillance. It clearly derives the highest utility from personnel surveillance. In this segment, variation in surveillance type has a stronger impact on using the free storage than the variation in walking time. This suggests that a strong motivation of using the paid storage is that it allows parking the bicycle in a safe way.

Finally, walking time to the free storage does not have a large impact on choice in this segment, which it shares with segment 1, the ‘hard core free storage users’.

3.3 Choice probabilities of alternative implementations

To get a feeling for the share of travelers that choose each of the alternatives under the proposed solution, that is the paid storage is realized near the platforms while the free storage is located at a larger distance, choice probabilities are predicted for the various alternatives under several alternative implementations. The main interest in this exercise is to explore which effect an increase in walking time to the free storage has on the demand for the paid storage as this may have consequences for size of the paid storage in the new station. A second objective is to explore the decrease in demand for bicycle parking at Delft station, especially the consequences this may have for bicycle storage at Delft South and for a possible increase in car traffic. Currently 14.9% (16.3% of the valid responses) of the respondents indicates that they park their bicycle in the paid storage, 76.2% (83.7% of valid responses) uses the free storage and 8.9% had a missing value on this survey question.

The base scenario involves a paid storage with the current price of € 1.20 per day and located at one minute walking from the platforms, while an unsupervised free storage is located at three minutes walking. In scenario two, the walking time to the free storage is increased from 3 to 5 minutes, while everything else remains the same. In all following scenario’s the walking time remains at 5 minutes. In scenario three it is examined whether the drop in parking demand due to the longer walking time can be compensated for by adding camera surveillance. Finally, the effect of price is illustrated; in scenario 4 parking price of the paid storage is increased to € 1.50 per day, while in scenario 5 the parking price is decreased to € 0.30 per day. This latter is of interest as planners consider offering considerably cheap or even free indoor, surveyed bicycle storage in the new Delft station. The levels of all other attributes are specified as in scenario 2. Table 6 presents the predicted choice probabilities based on the LC model, separately for each of the five classes Cl1 to Cl5 and aggregated across the segments weighed by class membership probability (LC-W).

First, the aggregate effects are discussed as presented in the last column of Table 6. Under the base scenario, the demand for the paid storage is 17.6%. This is only slightly higher than the current use of the paid storage. However, due to the fact that the free storage is located at a larger distance than the current free storage, the total demand for parking at Delft station will drop with more 10.8%, of which 3.5% will use Delft South and 7.3% chooses another mode.

Under scenario two (walking time to free storage increases from 3 to 5 minutes), demand for the paid storage increases to 24.4%, which is considerably more than the current use. At the same time, 22.5% of the cyclist will no longer park their bicycle at Delft station: 6.2% will then travel via Delft South, and 16.3% will switch to another access or egress mode.

Scenario three (introducing camera surveillance) indicates that the effect of the longer walking time towards the paid storage cannot be compensated for by camera surveillance: the effect on the aggregated choice probabilities is negligible.

The results for scenario four (increasing parking price to € 1.50) show that increasing parking price from € 1.20 per day to € 1.50 per day reduces paid storage use compared to scenario two. It is then predicted to have about the same share as under scenario one. The reduction of bicycle parking demand, however, is with 22.9% twice as high as under this scenario one.

Finally, scenario five (reducing parking price to € 0.30) suggests that if parking price for the paid storage is considerably reduced towards € 0.30 per day, the demand for paid storage increases towards a staggering 60%. This indicates that if planners consider offering cheap indoor parking, they have to realize that its capacity should be much larger (up to four times as much) than under current prices to completely facilitate demand.

Now we briefly pay attention to the predictions per segment. To ease presentation, the prediction for the overall most preferred alternative in each segment is made bold in Table 6. The results indicate that under each scenario, the preferred alternative in each segment remains the most often chosen alternative, with only two exceptions. A first exception is observed in segment three ('mode switchers') under scenario one, where the free storage is chosen more often than 'other mode'. A second exception is observed in segment four under scenario five, where this segment chooses the paid storage instead of the free storage, which illustrates the very high price sensitivity in this segment.

TABLE 6 Predicted choice probabilities for 5 scenarios per class and aggregated

	Cl1	Cl2	Cl3	Cl4	Cl5	LC-W
1: Base						
paid storage	1.9%	2.1%	2.0%	2.2%	**82.9%**	17.6%
free storage	**95.8%**	46.8%	56.0%	**96.9%**	11.8%	71.6%
Delft South	0.8%	**50.6%**	0.9%	0.1%	1.6%	3.5%
Other mode	1.4%	0.4%	**41.1%**	0.8%	3.7%	7.3%
2: 5 minutes walking						
paid storage	3.4%	3.7%	4.2%	18.7%	**87.3%**	24.4%
free storage	**92.5%**	6.1%	7.0%	**73.2%**	7.2%	53.2%
Delft South	1.5%	**89.4%**	2.0%	0.7%	1.6%	6.2%
Other mode	2.6%	0.7%	**86.8%**	7.3%	3.9%	16.3%
3: camera surveillance						
paid storage	1.0%	3.7%	4.1%	20.2%	**89.2%**	24.4%
free storage	**97.7%**	7.8%	10.3%	**71.2%**	5.2%	54.3%
Delft South	0.4%	**87.9%**	1.9%	0.8%	1.7%	5.8%
Other mode	0.8%	0.7%	**83.7%**	7.9%	4.0%	15.5%
4: price: 1.50						
paid storage	0.5%	1.4%	1.6%	5.3%	**83.0%**	18.0%
free storage	**98.3%**	8.0%	10.5%	**84.5%**	8.1%	59.2%
Delft South	0.5%	**90.0%**	1.9%	0.9%	2.6%	6.2%
Other mode	0.8%	0.7%	**85.9%**	9.3%	6.3%	16.7%
5: price: 0.30						

paid storage	11.3%	44.4%	41.9%	96.0%	**97.5%**	60.0%
free storage	**87.6%**	4.5%	6.2%	**3.6%**	1.2%	29.0%
Delft South	0.4%	**50.7%**	1.1%	0.0%	0.4%	3.2%
Other mode	0.7%	0.4%	**50.8%**	0.4%	0.9%	7.8%

Furthermore, the segment-specific results illustrate all the sensitivities to the attributes as earlier discussed. For example, the choice probability for the free storage of the 'hard-core free storage users' (segment one) remains to be high even under scenario 5 (cheap price), which illustrates the low sensitivity to changes in attribute values in this segment. However, camera surveillance increases the choice probability for the free storage in this segment with 5% whereas it actually decreases the choice probability in segment four, the other segment with a preference for the free storage. As all the tendencies are in line with the segment preferences earlier described, the segment-specific results are not further discussed.

4. Conclusions

This paper examined one of the solutions to the issue of the growing demand for bicycle parking at railway stations, that is offering high-quality but paid bicycle storage close to the platforms and free but low-quality bicycle storage at larger distances. This solution is based on the premise that pricing is an effective mechanism for distributing scarce parking space. As currently free bicycle parking is also offered close to the platforms, this paper examined how the proposed solution affects the parking choices of travelers who currently use the bicycle as an access or egress mode for traveling by train. To that effect the results of a stated choice experiment are reported, in which respondents choose between a free and paid bicycle storage that varied in price, walking distance and surveillance type. In addition, respondents could choose for another transport mode or travel via another station. The results of the estimated MNL and five-class Latent Class Models are presented and interpreted and the latter model is to applied to predict responses to various bicycle storage scenario's.

The estimated coefficients were all in expected directions: increasing the parking price and the walking time decreases utility. Per minute, the walking time to the paid storage had a smaller impact on utility than the walking time to the free storage, which seems reasonable since the walking time to the latter is considerably higher. Our results further indicate that free bicycle storage is generally preferred, which is in agreement with observed revealed choices. As expected, the price of using the paid storage played a significant role in parking choice. The estimated MNL model suggests that parking facilities 'surveyed by personnel' and 'with camera surveillance' are slightly preferred to 'no surveillance', suggesting only a minor impact of surveillance on bicycle parking choice. However, the estimates of LC model clearly indicates that substantial taste heterogeneity exist with respect to type of surveillance. The two classes that prefer the free storage both prefer camera surveillance to surveillance by personnel, while on the other hand, the class that prefers the paid storage has a very clear preference for personnel surveillance. This makes clear that preference for free parking is partly based on a dislike for surveillance by personnel. Moreover, one of the segments that prefers the free storage prefers camera surveillance to no surveillance, while the other segment prefers no surveillance at all. Based on these results it can be recommended that free storage should not be combined with personnel surveillance, and only half of the free storage may be combined with camera surveillance.

These results also illustrate that heterogeneous preferences cancel out in a MNL model, while they can be identified by estimating a latent class model. As just discussed, these results allow formulation more precise policy recommendations. By estimating a membership function, we additionally tried to predict the membership of any of the five classes based on the individual characteristics gender, age, occupation income, and revealed parking choice. However, none of the estimated coefficients of the membership function were found to be statistically significant. From this result can be concluded that the latent segments are not related with individual characteristics, at least not with those distinguished in this study. Although significant parameters may have been found with individual characteristics in case these were added to the utility function of a simple MNL model, the estimated latent class model provides a richer insight in taste heterogeneity in the sense that the mutual relationships between all attributes of the five segments are revealed.

The results further indicate that three alternatives offered in the experiment are each clearly preferred by one of the five classes, while the free storage alternative is preferred by two classes. The latter two classes are the largest, involving 30.3% of hard-core free storage users, and 30.6% of those who were much more willing to trade-off attributes and who are especially sensitive to price. Of the five classes, only one segment prefers the paid bicycle storage, involving 19.2% of the cyclists.

The introduction of paid storage and more distant free storage showed that only a relatively small number of the cyclists would then switch to another mode of transport to the station: 7.3% to 16.7% depending on the way it is implemented. Among the mode switchers, only 3% would switch to car and 7% would stop travelling by train altogether. This suggests that under the proposed solution, that is paying for all bicycle parking close to the train platforms, only 0.5% (3% from 16.7%), thus only a very small share of travelers would switch to car use. Hence, most cyclists remain cycling to Delft station, while a small share (3.2% to 6.7%) would opt for the other station.

All in all, roughly speaking only 30% of the cyclists, the hard-core free storage segment, is unwilling to pay for parking, but they largely remain using the free storage and accept longer walking times. Considerable shares of the other segments are willing to pay as the price goes down and distance to the free storage goes up. Together with the finding that the increase in car use is very limited, these results suggest that the researched solution of paying for parking places close to train platforms is a feasible solution. Hence, pricing for bicycling parking may indeed be an effective policy measure to distribute the distribution of scarce bicycle places at railway stations. This would leave spaces available very close to the platform for those who are willing to pay a reasonable price, while those who are unwilling to pay would be largely happy with the free storage, either at the main station or at the suburban station. In fact, this would retain the current situation at many railway stations where both free and paid parking are provided. On top of that we suggest to further optimize this according the concept of value of time.

Bicycle parking is not only an issue at railway stations, but also at other locations that attract many people, like for example, city center shopping areas. To realize bicycle parking facilities in those areas similar issues play are role, like for example, whether it should be surveyed or not, whether it should be a paid or a free storage, and what the best locations are to realize these bicycle storage facilities. Hence, also for other areas insight in the cyclists' trade-offs between walking distance, costs, surveillance, quality of parking etc. is important to design bicycle parking facilities that meet cyclists' preferences. Those facilities may contribute to the choice for cycling above driving for short distances. Hence, examining bicycle parking preferences in general is an important topic for further research.

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