THE BIKE AND THE URBAN RAILWAY TO DEVELOP A SUSTAINABLE TRANSPORT NETWORK

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ABSTRACT: Low cost and operative strategies are necessary in order to reduce the congestion and pollutant levels in our towns. In this context the bike, that is a non – motorised private mean, could be a way to increase the accessibility of the public transport system and in particular of the urban railway.
The principal aim of this study has been the calibration of a demand model able to estimate the demand switching in Palermo (Italy) from the car to the bike & railway system. In order to evaluate the integration between the bike and the urban railway, a specific survey has been carried out to estimate the potential demand of this integrated supply. This transfer could be possible for different O/D relations inside Palermo and especially for those relations with origins and destinations around railway stations. For this reason the University Campus has been chosen, being close to a new railway station and being one of the most important attractive areas of Palermo for the morning rush hour.
In order to calibrate the demand model, the stated preference technique has been used carrying out a survey on university students, clerks, professors & assistants. The results of the calibration process have shown a sensible modal shift in favour of the bike & railway system if there is a save in terms of trip time and if there are the infrastructures and the railway carriages able to make transferring the bike into the train easy. Finally, a cost/benefits analysis has been carried out in order to evaluate the proposed bike & railway system.

RÉSUMÉ : Des stratégies bon marché et opérationnelles sont nécessaires pour réduire les encombrements et les taux de pollution dans nos villes. Dans ce contexte, le vélo, moyen privé non motorisé, pourrait être une façon de rendre le système de transport public et en particulier le chemin de fer urbain plus accessible.

Le but principal de cette étude est de calibrer un modèle de demande capable d'estimer le transfert de la demande de la voiture au système du vélo & chemin de fer à Palerme (Italie). Pour évaluer l'intégration entre le vélo et le chemin de fer urbain, une enquête spécifique a été effectuée pour estimer la demande potentielle de cette offre intégrée. Ce transfert pourrait être possible pour diverses relations Origine/Destination à l'intérieur de Palerme et particulièrement pour ces relations avec des provenances et des destinations autour des stations de chemin de fer. Pour cette raison, le campus universitaire a été choisi, étant près d'une nouvelle station de chemin de fer et étant un des lieux les plus importants et attrayants de Palerme à l'heure de pointe du matin.

Pour calibrer le modèle de demande, la technique de la préférence exposée a été utilisée sur la base d'une enquête auprès d'étudiants d'université, d'employés de bureau, de professeurs et d'assistants. Les résultats du processus de calibrage ont montré un changement modal sensible en faveur du système de vélo & chemin de fer s'il y a une économie sur le temps de déplacement et s'il y a les infrastructures et les wagons capables de transférer facilement le vélo dans le train. Enfin, une analyse de coût/bénéfices a été effectuée afin d'évaluer le système de vélo & chemin de fer proposé.

1 INTRODUCTION: THE TRANSPORT SUPPLY IN PALERMO

Palermo is the main Sicilian city, with a territory of 158 squared km and a population of about 700.000 inhabitants.

Centre of the main directional and administrative functions of the island, as well as of an university that counts about 60.000 students coming from the whole Sicily, the city is also influenced, all over the year, by strong tourist flows. The city is influenced, all over the year, by a flow of about 950.000 tourists (Regione Sicilia, 2001).

The mobility system, inside the metropolitan area of Palermo, is characterised by a strong lack of railways transport systems, lack of suitable parking areas, lack of a politic in favour of collective transport means.

The urban railway system operating in Palermo has been derived from the traditional railway infrastructures crossing the town and, in particular, the railway system linking the Central railway station, the harbour inside the town and Trapani (a town far from Palermo about 100 km).

The principal limit of the present urban railway infrastructure is the single lane that imposes a maximum frequency at the stations equal to 2 trains per hour. A second limit of the urban railway system is the decentralised position of the railway stations from the principal activities present in the town.

For these reasons the urban railway users are a negligible rate in the context of the urban mobility (Palermo City Council, 1999).

In the last year, the works to build a new railway station close to the University Campus have been finished. Many important activities, such as the Sicilian Region Parliament, the Army administrative district, the Bishop Palace, the Cathedral, are present around the new station.

In order to realize a sustainable integrated system, it was supposed the integration between the bike and the urban railway. The aim is the integration between a regular and quick mode, such as the urban railway, and a flexible mode, such as the bike, in order to increase the accessibility of the attractive activities from the railway stations.

2 THE DEMAND MODELLING AND THE SURVEYS

The principal constraints that restrain the joint use of bike and railway are:

- the railway stations are not organised for the cycle flow transferring between different levels;
- the carriages prepared to receive the bikes are not sufficient to cover high demand levels;
- there are not in the transport system reserved lanes for the bikes (Ortùzar, 2000).

The principal aim of this study has been the calibration of a demand model able to estimate the demand switching from the car to the bike & railway system.

This transfer could be possible for different O/D relations inside the town and especially for those relations with origins and destinations around railway stations. For this reason the University Campus has been chosen, being close to the new railway station and being one of the most important attractive areas of Palermo for the morning rush hour.

It has been estimated, in fact, a multimodal demand of 3.000 persons in the morning rush hour (about the 1,5% of the total mobility concerning Palermo in the morning rush hour) going towards the University Campus . It has been also estimated that the 40 % of the 3000 persons usually uses the private car to reach the University Campus.

In order to calibrate the demand model, the *stated preference* technique has been used carrying out a survey on university students, clerks, professors & assistants. In particular, a logit model has been calibrated to quantify the users that leave the car for the bike & railway system.

It has been built a questionnaire that has supposed an hypothetical scenario that has eliminated the constraints of the bike & railway system. In particular, it has been supposed: the presence of cycle reserved lanes close to the railway station (far not over 1 km from the origin of the trip), stations and carriages organised to transfer the bikes to the train.

A part of the questionnaire has been dedicated for the socio-economic identification of the decision-maker and in particular it has been asked:

- the sex;
- the age;
- the availability of the private car;
- the ownership of a bike;
- the origin of the trip;
- the mean usually used to go into the University Campus.

Quantitative attributes, about the trip and able to explain the demand modal split, have been identified.

The quantitative attributes have been:

- the running time in minutes;
- the waiting time in minutes for the bike & railway system and the parking research time in minutes for the private car;
- the cost of the trip in euros.

In order to maintain the realism of the scenarios proposed to the decision-makers, it has been carried out a preliminary analysis to recognise credible values for the quantitative attributes.

In particular, the private car running time, from different origins to the University Campus, has been estimated elaborating a D.U.E. assignment process of the private car O/D matrix (related to the rush hour and the average working day) to the urban network. The bike & railway running time has been estimated taking into account the cycle average speed and using the railway company timetable.

Some levels have been identified for the differences between the quantitative values of the competitive alternative attributes.

The identified levels for the $T_{running(bike\ \&\ railway)} - T_{running(car)}$ attribute have been:

- \- 10 minutes;
- \- 5 minutes;
- 0 minutes;
- \+ 5 minutes.

The identified levels for the $T_{waiting(bike\ \&\ railway)} - T_{parking(car)}$ attribute have been:

- \- 5 minutes;
- 0 minutes;
- \+ 5 minutes.

The identified levels for the $C_{(bike\ \&\ railway)} - C_{(car)}$ attribute have been:

- \- 0,50 euros;
- \- 1,00 euros.

The successive step of the work has been the building of the complete factorial plan, taking into account all the levels for each attribute.

The scenarios of the complete factorial plan have been 32. Then, the complete factorial plan has been divided into 4 blocks composed of 8 scenarios. Each block has been built taking into account the orthogonality of all scenarios as reported in Cascetta (1998). Then, each decision-maker has reported on the questionnaire the choice between the competitive alternatives for each scenario.

In the table 1 is reported the interviewed sample of the population.

Table 1: Interviewed sample of the population

Categories	Population	Sample	%
Students	11992	457	4.0 %
Clerks	524	48	9.0 %
Professors & Assistants	740	47	6.4 %
Totale	13256	552	4.6 %

In the tables 2, 3, and 4 are reported some aggregated results of the survey.

Table 2: Aggregated results about the survey on the university students

	Male	Female	Total
Sample	235	222	457
Car owner	116	137	253
Bike owner	106	129	243
Car user	79	61	140

Table 3: Aggregated results about the survey on the university clerks

	Male	Female	Total
Sample	28	20	48
Car owner	16	9	27
Bike owner	12	8	20
Car user	16	8	28

Table 4: Aggregated results about the survey on the university professors & assistants

	Male	Female	Total
Sample	21	23	47
Car owner	23	23	46
Bike owner	16	11	27
Car user	16	19	35

3 THE CALIBRATION OF THE BINOMIAL LOGIT MODEL FOR THE UNIVERSITY STUDENTS

The expression of the logit model that reproduces the demand modal split can be written as follows:

$$P_m^{OD} = \frac{e^{V_m^{OD}}}{\sum_k e^{V_k^{OD}}} \qquad (1)$$

The utility functions of the competitive alternatives are:

$V_{car} = b_1 {*} T_{running(car)} + b_2 {*} C_{(car)} + b_3 {*} T_{parking(car)} + b_4 {*} car\_availability + b5 {*} mean\_used + CAR$

$V_{bike\ \&\ railway} = b_1 {*}\ T_{running(bike\ \&\ railway)} + b_2 {*}\ C_{(bike\ \&\ railway)} + b_3 {*}\ T_{waiting(bike\ \&\ railway)} + b_6 {*} bike\_ownership$

where:

V_{car} = private car utility function;

$V_{bike\ \&\ railway}$ = bike & railway system utility function;

b1 = running time coefficient;

b2 = cost coefficient;

b3 = waiting or parking time coefficient;

CAR = car constant;

car_availability = 1 if the decision-maker can use the car, 0 otherwise;

mean_used = 1 if the decision-maker usually uses the car, 0 otherwise;

bike_ownership = 1 if the decision-maker has got a bike, 0 otherwise;

b4 = car_availability coefficient;

b5 = mean_used coefficient;

b6 = bike_ownership coefficient;

The calibration of the binomial logit model has been made using the maximum likelihood technique (Ortùzar, 1996) using the Limdep® software.

In the table 5 are reported the results of the calibration process.

Table 5: Results of the calibration process of the logit model for the university students.

Attribute	Coeffi-cient	Value	p-value
Trunning	b1	- 0.05155	0.0000
C	b2	- 0.42791	0.0018
Twaiting/parking	b3	- 0.06850	0.0000
car_availability	b4	0.45817	0.0000
mean_used	b5	0.51189	0.0000
bike_ownership	b6	0.36309	0.0000
CAR	CAR	0.23456	0.0433
b_3/b_1 = 1,33	V.O.T. = 60*b_1/b_2 = 7,23 euros/h		
ρ^2 *(C)* = 0,05	χ^2 [6] = 260,62	Significance (χ^2) = 1,00000	

The results of the calibration process show the correctness of the coefficient signs. The p-values show the significance of each attribute. The CAR constant has a poor significance probably because other variables (car_availability, mean_used) have simulated the a priori preference of the decision-makers for the car. The total significance of the model is shown by χ^2 test (Ortùzar, 1996).

After the calibration of the demand model the elasticity of the demand (the percentage variation of car or bike & railway demand when there is a variation of + 1% in the transport attributes such as $T_{running}$, C or $T_{waiting/parking}$) has been estimated too.

In the table 6 is reported the elasticity of the university students.

Table 6: Elasticity of the university students

Mean	$T_{running}$	C	Twaiting/parking
Car	-0.639	-0.380	-0.242
bike & railway	-0.559	-0.221	-0.235

4 THE CALIBRATION OF THE BINOMIAL LOGIT MODEL FOR THE UNIVERSITY CLERKS

The utility functions of the competitive alternatives are:

$V_{car}=b_1*T_{running(car)}+b_3*T_{parking(car)}+b_4*car\_availability + b5*mean\_used + CAR$

$V_{bike\ \&\ railway} = b_1* T_{running(bike\ \&\ railway)} + b_3* T_{waiting(bike\ \&\ railway)} + b_6*bike\_ownership + b_7*sex$

where:

sex = 1 if the decision-maker is female, 0 otherwise;

b_7 = sex coefficient.

In the table 7 are reported the results of the calibration process.

Table 7: Results of the calibration process of the logit model for the university clerks.

Attribute	Coeffi-cient	Value	p-value
Trunning	b1	- 0.06717	0.0003
Twaiting/parking	b3	- 0.09652	0.0187
car_availability	b4	0.71374	0.0038
mean_used	b5	1.44451	0.0000
bike_ownership	b6	0.58356	0.0165
sex	b7	0.94409	0.0002
CAR	CAR	0.23262	0.3688
b_3/b_1 = 1,44			
ρ^2 *(C)* = 0,19	χ^2 [6] = 84.97	Significance (χ^2) = 1,00000	

In this case the cost has not a significance probably because the decision-makers have weighted the time more than the cost in their choice.

In the table 8 is reported the elasticity of the university clerks.

Table 8: Elasticity of the university clerks

Mean	$T_{running}$	Twaiting/parking
Car	-0.521	-0.222
bike & railway	-0.800	-0.350

5 THE CALIBRATION OF THE BINOMIAL LOGIT MODEL FOR THE UNIVERSITY PROFESSORS & ASSISTANTS

The utility functions of the competitive alternatives are:

$V_{car}=b_1*T_{running(car)}+ b5*mean\_used + CAR + b_8*age$

$V_{bike\&railway}=b_1*T_{running(bike\&railway)}+ b_7*sex$

where:

age = the age of the decision-maker;

b_8 = age coefficient.

In the table 9 are reported the results of the calibration process.

Table 9: Results of the calibration process of the logit model for the university professors & assistants.

Attribute	Coeffi-cient	Value	p-value
Trunning	b1	- 0.05562	0.0055
mean_used	b5	0.98104	0.0002
sex	b7	0.90221	0.0001
age	b8	0.02580	0.0038
CAR	CAR	-1.34110	0.0036
ρ^2 *(C)* = 0,09	χ^2 [4] = 52.49	Significance (χ^2) = 1,00000	

In the table 10 is reported the elasticity of the university professors & assistants.

Table 10: Elasticity of the university professors & assistants

Mean	$T_{running}$
Car	-0.749
bike & railway	-0.625

6 THE COST-BENEFIT ANALYSIS FOR THE PROPOSED SCENARIO

A cost-benefit analysis for the proposed scenario has been carried out. In particular, the costs to realise the reserved lanes (about 30 kilometres) and the parking areas for the bikes (about 1300 per year) and to make ease the transferring between the bike and the railway have been taken into account. The maintenance costs for the bikes and their reserved lanes have been taken into account. The reduction of the transport monetary costs and the level of congestion on the transport network have been estimated too.

A discount rate of 5% has been used and it has been estimated a service life of 20 years for the proposed project.

The cost-benefit analysis can be synthesised then by a net present value of 8.155.073 € and an internal rate of return of 52 %.

This analysis proves the economic convenience in the integration between bikes & railway system in the urban areas.

6 CONCLUSIONS

In the present work the results of an experimental survey carried out at the University Campus in Palermo have been reported. The aim of the work has been the calibration of a demand model, using the stated preference technique, able to explain the potential modal split (stated from the university students, clerks, professors & assistants) between the private car and the bike & railway system.

The results of the calibration process have been quite good and they have shown a sensible modal shift in favour of the bike & railway system if there is a save in terms of trip time and if there are the infrastructures and the railway carriages able to make transferring the bike into the train easy.

As further work, other surveys are going to be carried out on other O/D relations and on other user categories in order to model other segments of the potential demand.

Then the same practise could be exported in similar urban contexts, as well as in developing country cities where public transport and urban mobility as whole is really different characterised. The interactions between public transport system and non motorised means of transport and the improvement in terms of quality, safety, security and attractiveness of non motorised means can contribute to make the developing cities transport systems more efficiency.

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