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MULTINOMINAL LOGIT MODEL OF BICYCLIST ROUTE CHOICE

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Abstract. *The paper presents the multinominal logit discrete choice model that allows determining parameters coefficients of the cyclists' route. The basic model includes six parameters, however, only a number of signalized intersections, speed of motorized traffic and total physical work required from cyclist prove to be significant factors. The model provides a better understanding about cyclist traffic assignment.*

Key words: *cycling, discrete choice models, modeling, multinominal logit model, route choice, physical work, labeling method.*

МУЛЬТИНОМИНАЛЬНАЯ ЛОГИТ-МОДЕЛЬ ВЫБОРА ПУТИ ВЕЛОСИПЕДИСТАМИ

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Аннотация. *Рассмотрена мультиноминальная логит-модель, позволяющая определить коэффициенты параметров пути велосипедного транспорта. Количество регулируемых перекрестков, скорость моторизированного транспорта и общая физическая работа велосипедиста оказались значимыми факторами. Модель предоставляет лучшее понимание закономерностей распределения велосипедного транспорта.*

Ключевые слова: *велосипедный транспорт, модели дискретного выбора, моделирование, мультиноминальная логит-модель, выбор пути, физическая работа, метод маркировки.*

МУЛЬТИНОМІНАЛЬНА ЛОГІТ-МОДЕЛЬ ВИБОРУ ШЛЯХУ ВЕЛОСИПЕДИСТАМИ

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Анотація. *Розглянуто мультиномінальну логіт-модель, що дозволяє визначити коефіцієнти параметрів шляху велосипедного транспорту. Кількість регульованих перехресть, швидкість моторизованого транспорту і загальна фізична робота велосипедиста виявились значущими факторами. Модель дозволяє краще зрозуміти закономірності розподілу велосипедного транспорту.*

Ключові слова: *велосипедний транспорт, моделі дискретного вибору, моделювання, мультиномінальна логіт-модель, вибор шляху, фізична робота, метод маркування.*

Introduction

Cycling has become an important tool for sustainable mobility management. Many cities in Ukraine implementing cycling master plans to ensure long-range planning and efficiency of investments. However, very little is known about cycling patterns in Ukraine, and thus it is impossible to provide quality planning. Modeling cyclists' behavior can provide with better understanding and help to develop recommendations for decision makers.

Literature Review

Recently discrete choice models (DCM) were increasingly used for the simulation of travel behavior, mostly for mode choice but also for route choice. Several models were developed by authors [1-6]. Multinominal logit model (MNL) is a type of DCM and is based on following assumptions:
1) random variable distributed according to Gumbel distribution;
2) random variable components equally and independently distributed among all alternatives;
3) random variable components distributed equally among all observations and cyclists.

Probability that cyclist n will select alternative i in the set of alternatives C_n is described by (1)

$$P_n(i \mid C_n) = \frac{\exp(U_{in})}{\sum_{j \in C_n} \exp(U_{jn})}. \qquad (1)$$

And utility of the alternative i for cyclist n is linear function of alternative's properties

$$U_{in} = x_{in}\beta + \varepsilon_{in}, \qquad (2)$$

where x_{in} – vector parameters; β – vector of bicyclist characteristics and properties of alternatives; ε_{in} – random variable Gumbel distributed [7].

To determine the probability of choosing the route by cyclist it is necessary to determine the coefficients of each parameter of utility function. Literature review shows that safety [3, 8, 9, 10], the shortest route in terms of distance or time [1, 3, 10, 11, 12] and topography [1, 3, 8, 10, 11, 12] is important factors in determining the path of cyclists.

Purpose of the research

The purpose of this research is to develop cycling route choice model that will allow determining parameter coefficients of the route utility and the object is cycling route network.

The hypothesis of the research is that cyclist does not choose simply the shortest route but has more complex set of parameters involved. To test the hypothesis the following tasks have to be completed:

1) based on literature review select route parameters that potentially have impact on route choice;
2) develop a route network for cycling movement and quantify route parameters for each link of the network;
3) create data set of selected route and two route alternatives;
4) run the model;
5) analyze the results.

Modeling of route choice for cycling

Based on literature review of factors that affect decision to cycle and availability of the data that can be observed and quantified for Kharkiv, the list of parameter were created. Parameters of bicycle route model included: total length of the route (km); number of signalized intersections along the route (units); number of left turns (units); speed of motorized traffic (km/h); on-street parking density along the route; total physical work required from cyclist to complete the route (kDj).

Presence of cycling facility is important factor that affects cycling, however, since the total length of cycling road facility in Kharkiv is less than 1 km, this parameter was not included into the model.

Speed of motorized traffic (Table 1) was defined by three categories according to congestion monitoring service maps.yandex.ua.

Table 1 Specification of motorized traffic speed parameter

Categories	Lower speed bound, km/h
Low	10
Medium	25
High	40

Density of on-street parking was observed and quantified by group of experts (Table 2).

Table 2 Specification of parking density parameter

Category	Quantitative attribute
Parking is absent or forbidden	1
Low to medium parking	2
High level of on-street parking	3

Location of traffic lights was geocoded based on city of Kharkiv department of infrastructure's data. Total physical work calculated based on the model described in [13].

The route network for Kharkiv was developed and every parameter including length of the link was geocoded using software package ArcMap 10.2. The graphical representation of the network is shown at fig. 1.

To develop a set of alternatives a labeling method with two labels: shortest distance and smallest work was used. The actual selected alternative was received from the self-reported survey of cyclists conducted in Kharkiv.

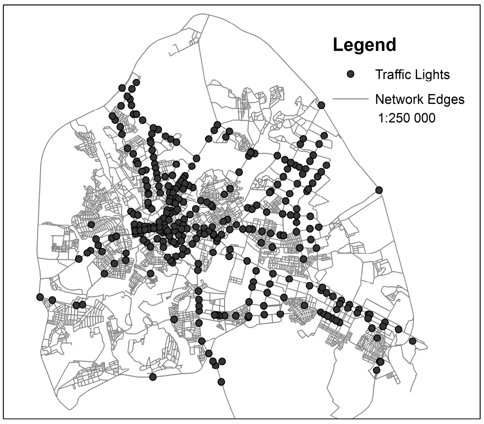

Fig. 1. Cycling route network

The utility function of MNL route model has a form:

$$U_{in} = \beta_L \cdot L_{in} + \beta_I \cdot I_{in} + \beta_K \cdot K_{in} + \\ + \beta_V \cdot V_{in} + \beta_D \cdot D_{in} + \beta_S \cdot W_{in} \cdot + \varepsilon_{in}, \quad (3)$$

where β – parameter coefficient; L_{in} – total length route i; I_{in} – total number of signalized intersections on the route i; K_{in} – total number of left turns on the route i; V_{in} – weighted average speed of motorized traffic; D_{in} – weighted average of on–street parking density; W_{in} – total physical work required to complete the route.

Results

The parameters of the model were computed by using BIOGEME 1.8. Table 3 shows general results of the modeling. It can be seen that the basic model with six modeled parameters has bad predicting abilities.

To identify significance of the modeled parameters several models were developed and ran. In the basic model, which includes all six parameters, only number of traffic lights proves to be significant factor (table 4). Unexpectedly, more traffic lights seem to encourage selection of the route. It can be interpreted as cyclists are likely to choose major roads where more traffic lights are located. When holding for this parameter (table 5) speed of motorized traffic and total physical work of cyclists show to be significant factors. Table 6 shows the results of the model of only two significant factors Speed and Work. In this case negative sign of Speed parameter means that cyclist are likely to select routes with lower speeds of motorized traffic. Based on the data that was geocoded to run route parameters, lower speed values mean that the road is congested during peak hour, so it basically means that cyclist again tend to select major roads with higher traffic flows opposed to detour from traffic. Positive value of work factor suggest that cyclist are more likely to select the route that requires slightly more physical effort from cyclist that the shortest or the easiest route.

Table 3 General results of the modeling

Parameter	Value
Number of estimated parameters:	6
Number of observations:	30
Number of individuals:	30
Null log-likelihood:	-31.742
Init log-likelihood:	-31.742
Final log-likelihood:	-12.061
Likelihood ratio test:	39.362
Rho-square:	0.620
Adjusted rho-square:	0.431
Final gradient norm:	$+2.638 \cdot 10^{-5}$
Diagnostic:	Convergence reached
Iterations:	11
Smallest singular value of the hessian:	0.285392

Table 4 Results of parameters' modeling: basic model

Name	Value	Std err	t-test	p-value
L_{in}	-0.0443	0.0699	-0.63	0.53
D_{in}	1.04	1.82	0.57	0.57
V_{in}	-0.155	0.142	-1.09	0.27
W_{in}	0.00830	0.00638	1.30	0.19
I_{in}	0.569	0.267	2.13	0.03
K_{in}	0.224	0.229	0.98	0.33

Table 5 Results of parameters modeling: TR excluded

Name	Value	Std err	t-test	p-value
L_{in}	-0.107	0.0662	-1.61	0.11
D_{in}	-0.782	1.37	-0.57	0.57
V_{in}	-0.312	0.154	-2.02	0.04
W_{in}	0.0171	0.00688	2.49	0.01
I_{in}	0.00	fixed		
K_{in}	-0.0630	0.177	-0.36	0.72

Table 6 Results of parameters modeling: Speed-Work model

Name	Value	Std err	t-test	p-value
L_{in}	0.00	fixed		
D_{in}	0.00	fixed		
V_{in}	-0.0614	0.0412	-1.49	0.14
W_{in}	0.0160	0.00587	2.73	0.01
I_{in}	0.00	fixed		
K_{in}	0.00	fixed		

Conclusion

The results of the model have shown that parking density and route length is the least significant factors of the route choice model which proves the hypothesis that that cyclist does not choose simply the shortest route. However, the model does not provide the full understanding of the factors that affect decision to cycle.

On the one hand cycling network is one the most diverse transport network (except for walking) and thus cyclist have much more alternatives of the route, so that decision may significantly depend on personal preferences of cyclist. In this case the further analysis of cyclists' behavior is needed.

On the other hand the cyclist might not be aware of the whole set of alternatives and will follow the most obvious route; it can explain why many cycling routes follow the path of public transport. In this case development of cycling infrastructure is less restricted to cyclist preferences and well developed navigation can provide information about alternative routes. This phenomenon is known as «if you build it, they will come».

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