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User habits and multimodal route planning

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Abstract
The results of route planning researches are monitored by logistic and automotive industries. The economic aspects of the cost saving are in the focus of the attention. An optimal route could cause time or fuel savings. An effective driving or an optimal route is a good basis to achieve an economical aim. Moreover the spread of new automotive solutions especially in case of electric cars the optimisation has particular significance regarding the limited battery storage. Additionally the autonomous car development could not be neglected. As a result the society could expect safer roads, better space usage and effective resource management. Nevertheless the requirements of users are extremely diverse, which is not negligible. Supporting these aims, in this paper the connection between the multimodal route planning and the user requirements are investigated. The examination is focused to a sensitivity analysis and a survey to evaluate the data and support the settings of a user habit effect to the final route.

1. Introduction

One of the modern route planning algorithms is the Dijkstra algorithm which was invented by Edsger Wybe Dijkstra (Dijkstra E.W. 1959, Podobni K. 2009). This is an analytic algorithm which can find one optimal solution for every direction. The other widely used algorithm is the A* (Podobni K. 2009, Hernáth Z. 2012). This focuses on the straight line distance, on the other hand this is a heuristic solution. Regarding to this it can not give solution for every path. On this basis the Eindhoven University performed a study to test it in a multimodal environment (Zhang J., et al. 2012). The crucial factor was the size of the network, what effects some limitation during the computation process. In this paper a super network conception was used by Sheffi Yosef (Sheffi Y. 1985).

On the other hand the purpose of the travel may be in the focus. A paper based on the commuter traffic and the P+R facilities is published by Kirchler (Kirchler D. 2013). The SDALT algorithm was used with some territorial demarcation based on the similar difficulties of the size. This also helps to achieve a passable run time.

In 2012 in Bejing a genetic algorithm was coded to a multimodal route planner (Yu H., Lu F. 2011). Here exploited the ability of many variables testing simultaneously.

The environmental effect of the traffic was take into consideration in Finland (Noreikis M., et al. 2014). The algorithm calculates the route to decrease the CO2 emission and it highly uses the P+R facilities if it is possible.

The actual route planner solutions were investigated by Esztergár-Kiss and Csiszár (Esztergár-Kiss D., Csiszár C. 2015). This focused the Hungarian online services and compare their configurations and other possibilities.

The Ant Colony algorithm (Katona G., et al., 2015) and the multimodal route planner conception (Katona G., et al., 2016) were in the focus in my previous papers. This work is continued the path what started in my papers above. This paper is an extraction of a conference paper (Katona G., Juhász J. 2017).

This work is based on an improved Ant Colony algorithm which was originally invented by Marco Dorigo (Dorigo M. 1992, Dorigo M., Blum C. 2005). The development is included the consideration of the user habits. In the online service sector the serving of the individual needs is more pronounced. At the route planning this is extremely important because the travelers expecting personalized results. The traffic information such as traffic jams, accidents, by pass routes and other travelers' feedbacks should be a part of the system to comply the needs of the users. Waze (Google Inc. 2017) route planner is a good automotive solution. It is able to adopt the habit of the user such as the preferred routes or to take into consideration the traffic incidents. The aim is to expand this logic to the whole transportation chain and realize the multimodal travel. This paper fits within this research aim.

2. Methodology

2.1. Ant Colony algorithm

The ant hive has a unique method to collect food, water or any other resource what they need. This system is working based on two main pillars: exploration and contingency. If a resource is found, a sign is made to the other ant as a mark of a possible path. This mark is a special vapor called pheromone. In case the signed thing is near or there is a large amount of it more and more ants will be attracted. The algorithm is graphically visualized in the figure 1.

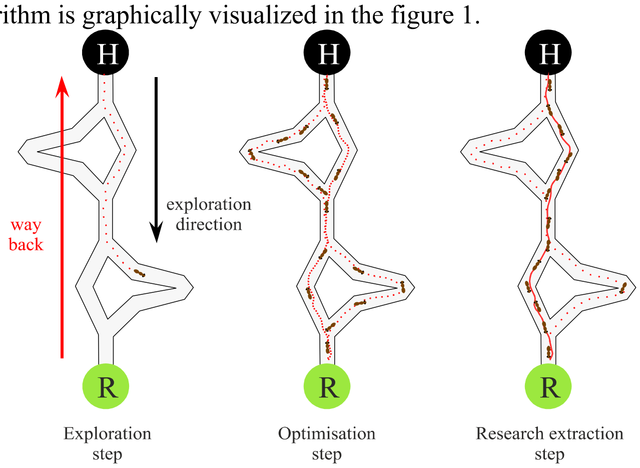

Fig. 1. The basis of the Ant Colony algorithm

The method works based on the probability of path choosing, taking into account the pheromone quantity and the distance.

$$P_{ij} = \begin{cases} \dfrac{(\tau_{ij})^{\alpha} \cdot (\eta_{ij})^{\beta}}{\sum\limits_{u \notin M_k} (\tau_{ij})^{\alpha} \cdot (\eta_{ij})^{\beta}} & if \quad j \notin M_k \\ 0 & if \quad j \in M_k \end{cases} \tag{1}$$

Here i and j are the identifiers of the nodes. The τ_{ij} is the amount of the pheromone, η_{ij} is the inverse distance or the inverse resilience. The α and the β represents the importance of the indicated values. k is the identifier of a specific ant and M_k is the list of the nodes in a trip.

2.2. Multimodal graph

Many parameters should take into account to determine the total resilience of an edge or a connection in a transportation network. The most important factors are time and distance but cost, the number of changes or user habits are also should take into account. The concept was set up in my previous paper (KATONA G., ET AL. 2016) what presents the following (Fig. 4).

The total resilience (Fig. 4) could be defined as a result of the individual attributes. Here $\underline{\underline{R}}$ is the total resilience, $\underline{\underline{T}}$ is the travel time, $\underline{\underline{C}}$ is the travel cost, $\underline{\underline{D}}$ is the travelled distance, $\underline{\underline{S_i}}$ is the special requirement (such as low-flor vehicles, easy access to special needed people…) and $\underline{\underline{U}}$ is the user wishes. Their importance is controlled with weight factors, indicated with Greek letters $(\alpha_1, \beta_1, \gamma_1, \delta_1, \varphi_1)$.

3. Results

A test network is implemented in this model based on the Centre for Budapest Transport's (BKK) General Transit Feed Specification (GTFS) database (CENTRE FOR BUDAPEST TRANSPORT (BKK), 2011-2017). An example trip is assembled to demonstrate this method. The starting point was the metro station called "Pöttyös utca M" and the destination is the Headquarter of MOL ZRt. (1117, Budapest, Október huszonharmadika utca 18). This direction was chosen due to personal experience and the high quality and -capacity of public transportation with several alternatives and connections. The skeleton network is based on the metro line 3 and 4, tram line 1 and 4. These basic connections are demonstrated on the following figure (Fig. 5).

In this example on the basis of the rapidly developing bike share network of the BKK a bike share station is assumed to every stop (Fig. 2 and Fig. 3).

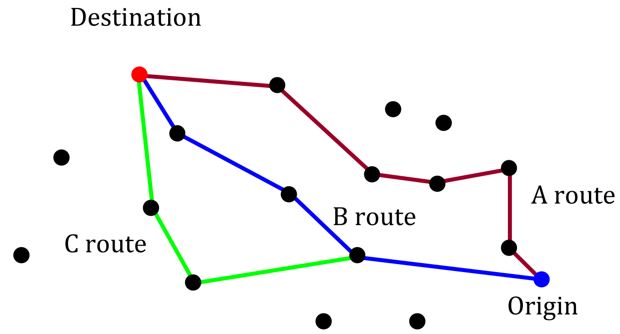

Fig. 2. Schematic network model

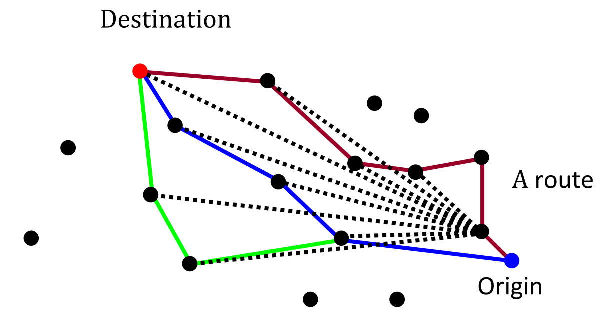

Fig. 3. Schematic network model with bike share connection

Regarding to the Fig. 4 the total resilience can be calculated:

$$\begin{aligned} \underline{\underline{R}} &= \underline{\underline{T}}^{\alpha_1} \cdot \underline{\underline{C}}^{\beta_1} \cdot \underline{\underline{D}}^{\gamma_1} \cdot \underline{\underline{S}}_{i_1}^{\delta_{i_1}} \cdot \underline{\underline{U}}^{\varphi_1} = \\ &= \underline{\underline{T}}^{0,75} \cdot \underline{\underline{1}}^{0} \cdot \underline{\underline{D}}^{0,25} \cdot \underline{\underline{1}}^{0} \cdot \underline{\underline{U}}^{1} = \\ &= \underline{\underline{T}}^{0,75} \cdot \underline{\underline{D}}^{0,25} \cdot \underline{\underline{U}} \end{aligned} \tag{2}$$

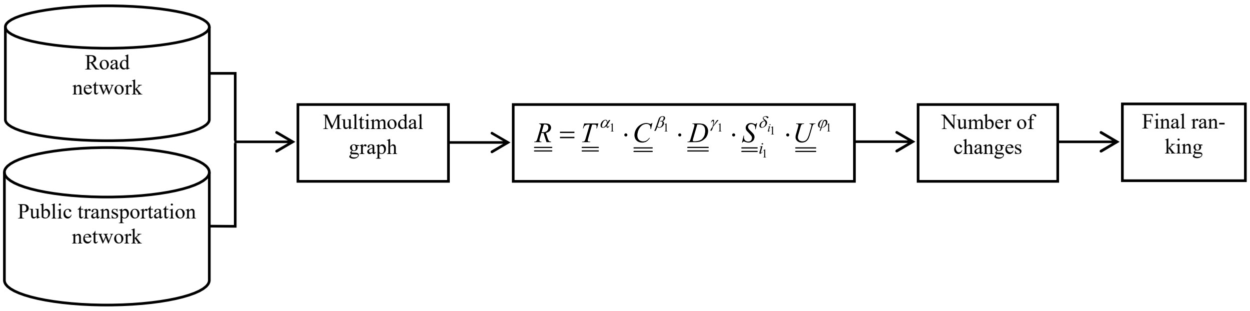

Fig. 4. Multimodal graph concept (KATONA G., ET AL. 2016)

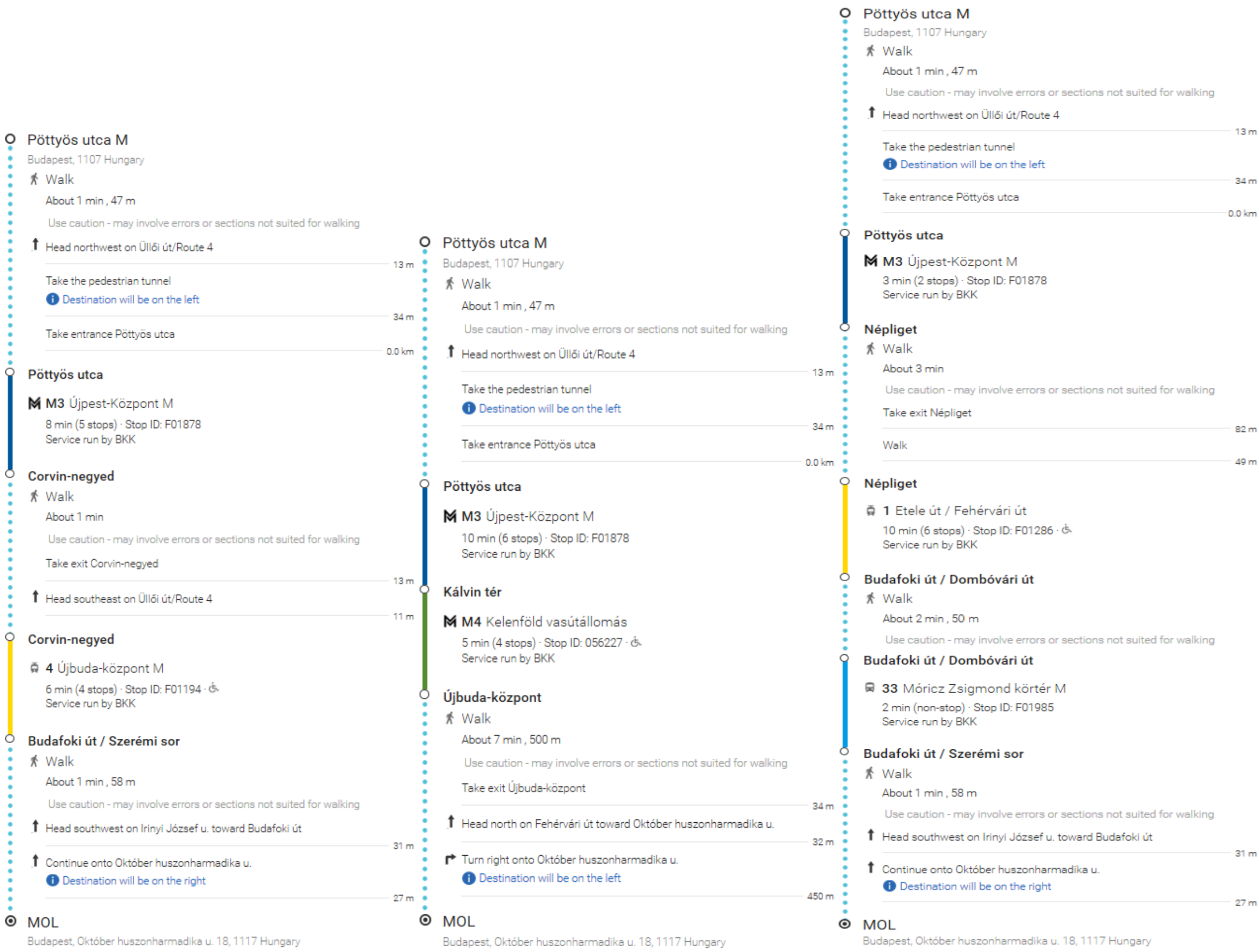

Fig. 5. The high capacity connections

In this model (Fig. 4) the $\underline{\underline{C}}$ and $\underline{\underline{S}}_i$ is chosen to be $\underline{\underline{1}}$ and their importance is to be zero, while these data were not available. The φ_1 is chosen to be 1 to help the examination of the sensitivity analysis. The α_1 is chosen for only to this sensitivity analysis to be 0.75 and γ_1 to be 0.25. During the choosing process the work of Marcus Friedrich (FRIEDRICH M. 1994) and the Gravity model (HÖGBERG P. 1976, PTV AG, 2014) was taken into account. In this case, the concrete values are not as important as the aim is the examination of the connection between the user habits and the route planning results.

In the next step the Eq. (1) equation can be calculated based on the total resilience results.

The Ant Colony algorithm is a heuristic method and the tau value is based on this process, therefore $\underline{\underline{\tau}} = \underline{\underline{1}}$ to avoid the influence of the heuristic characteristic. The value of beta was chosen to be 0.05 considering the earlier results (KATONA G. ET AL. 2015), presented in the following (3) equation.

$$P_{ij}=\begin{cases}\dfrac{(1)^{\alpha}\cdot(\eta_{ij})^{\beta}}{\sum\limits_{u\notin M_k}(1)^{\alpha}\cdot(\eta_{ij})^{\beta}} & if \quad j\notin M_k\\ 0 & if \quad j\in M_k\end{cases}=$$

$$=\begin{cases}\dfrac{\left(R_{ij}^{-1}\right)^{0.05}}{\sum\limits_{u\notin M_k}\left(R_{ij}^{-1}\right)^{0.05}} & if \quad j\notin M_k\\ 0 & if \quad j\in M_k\end{cases} \tag{3}$$

4. Analysis and discussion

4.1. Sensitivity analysis

A sensitivity analysis was made to determine the effect of the $\underline{\underline{U}}$ to the $\underline{\underline{P}}$. In the absence of real data the $\underline{\underline{U}}$ matrix is filled in with randomly generated values. This can be used to the sensitivity analysis where only the effect of the changes is important not the specific value. To evaluate this the user habit matrix value is modified between the stops designated F01493 and F01465. This is symbolically can be written: $U_{F01493,F01465}$. The identifier of the stops is indicated by “F” and a generated number, which is corresponds the BKK’s GTFS data. The values of the $U_{F01493,F01465}$ – which were the input of the sensitivity analysis - are stated in the table below (Table 1).

Table 1. Input for the sensitivity analysis

1st case	$U^1_{F01493,F01465}$	0.8
2nd case	$U^2_{F01493,F01465}$	0.9
3rd case	$U^3_{F01493,F01465}$	1
4th case	$U^4_{F01493,F01465}$	1.1
5th case	$U^5_{F01493,F01465}$	1.2

In every case the probability matrix was recalculated according to the (3) equation. This is presented in the (4) equation, where z identifies the cases of the sensitivity analysis.

As a starting node the stop with F01465 identifier is represented as a line in the path choosing probability matrix. The calculated results are graphically presented in Fig. 6 in connection with the inputs of the sensitivity analyses. With the evaluation of the data it is possible to say the results follow a direct proportionality.

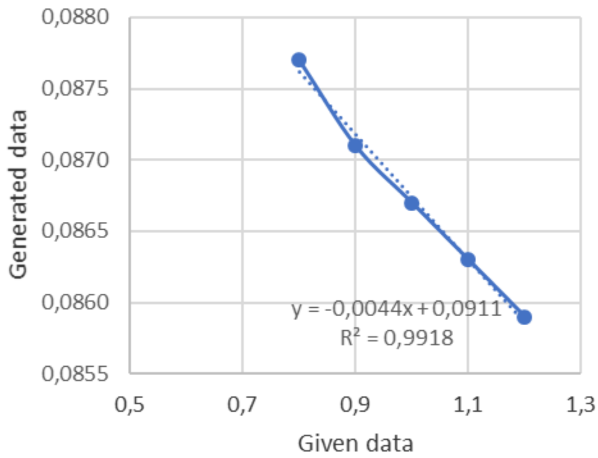

Fig. 6. Relationship between the given and the generated data

The correlation coefficient is indicated with R, and it is equal to approximate 99%, that indicates an excellent linear reliability. On this basis the path choosing probability can be easily scalable.

The result of the five cases (Fig. 7) is demonstrated as a column that is a transposed line of the path choosing probability matrix $\left(P^z_{F01493}\right)^T$. The examined results $\left(U^z_{F01493,F01465}\right)$ are marked with red. According to the (4) equation all the values in the line $\left(P^z_{F01493}\right)$ are influenced by the sensitivity analyses. In this examination only the $P^z_{F01493,F01465}$ reaches the perceptible order of magnitude

At the bottom (Fig. 7) the percentage indicates a relative deviation from the third case $\left(U_{F01493,F01465}=1\right)$.

4.2. Survey

A preliminary survey was made to explore the wishes of the users. On this basis the questionnaire was not representative. It could be fulfilled if the attendant had internet connection. Regarding to this, the survey is shared via Facebook and e-mail. Considered this the evaluation of the received 146 answers can be done. Higher education (university and college) and the capital of Hungary (Budapest) is over represented in the data.

The model which was presented in the 0 paragraph is influenced by the user habits. This is not effected by the user modification reasons, although based on a survey a perception can be made to support the algorithm adaptation to an individual user with the user habit matrix modification.

$$P^z_{F01493,F01465}=\frac{\left[\left(\underline{\underline{T}}^{0.75}_{F01493,F01465}\cdot\underline{\underline{D}}^{0.25}_{F01493,F01465}\cdot\underline{\underline{U}}^{z}_{F01493,F01465}\right)^{-1}\right]^{0.05}}{\sum\limits_{F01493}\left[\left(\underline{\underline{T}}^{0.75}_{F01493,F01465}\cdot\underline{\underline{D}}^{0.25}_{F01493,F01465}\cdot\underline{\underline{U}}^{z}_{F01493,F01465}\right)^{-1}\right]^{0.05}} \tag{4}$$

1st option	F01465
F01465	—
F01878	8,98E-02
F01493	8,77E-02
F01282	8,60E-02
F01252	8,44E-02
F01232	8,28E-02
F01188	8,21E-02
F01194	8,18E-02
F01378	8,14E-02
F01373	8,09E-02
F02224	8,07E-02
F01989	8,03E-02
MOL	7,99E-02
	101,12%

2nd option	F01465
F01465	—
F01878	8,98E-02
F01493	8,71E-02
F01282	8,60E-02
F01252	8,44E-02
F01232	8,28E-02
F01188	8,21E-02
F01194	8,18E-02
F01378	8,14E-02
F01373	8,09E-02
F02224	8,07E-02
F01989	8,03E-02
MOL	7,99E-02
	100,53%

3rd option	F01465
F01465	—
F01878	8,98E-02
F01493	8,67E-02
F01282	8,60E-02
F01252	8,44E-02
F01232	8,28E-02
F01188	8,21E-02
F01194	8,18E-02
F01378	8,14E-02
F01373	8,09E-02
F02224	8,07E-02
F01989	8,03E-02
MOL	7,99E-02
	100,00%

4th option	F01465
F01465	—
F01878	8,98E-02
F01493	8,63E-02
F01282	8,60E-02
F01252	8,44E-02
F01232	8,28E-02
F01188	8,21E-02
F01194	8,18E-02
F01378	8,14E-02
F01373	8,09E-02
F02224	8,07E-02
F01989	8,03E-02
MOL	7,99E-02
	99,52%

5th option	F01465
F01465	—
F01878	8,98E-02
F01493	8,59E-02
F01282	8,60E-02
F01252	8,44E-02
F01232	8,28E-02
F01188	8,21E-02
F01194	8,18E-02
F01378	8,14E-02
F01373	8,09E-02
F02224	8,07E-02
F01989	8,03E-02
MOL	7,99E-02
	99,09%

Fig. 7. The result of the sensitivity analysis

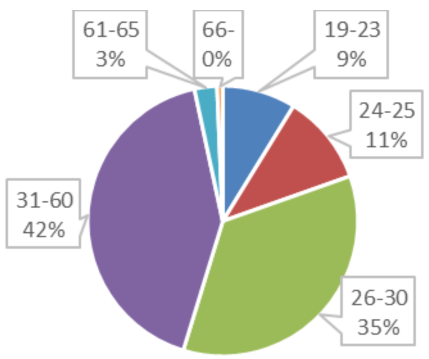

Fig. 8. Distribution of the age

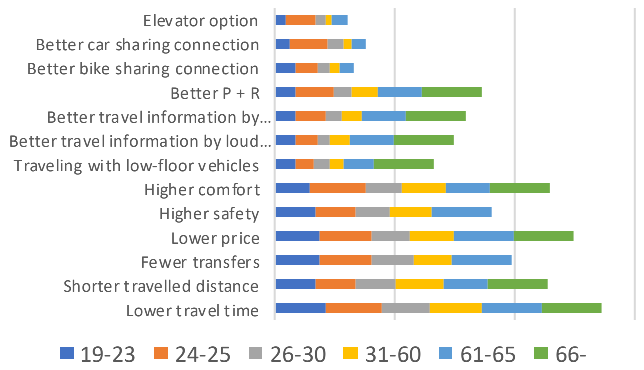

Fig. 9. Possible reason to choose a detour (alternative route)

Fig. 9 and Table 2 present some results of the survey. As a result, lower travel time is important in every age. The significance of shorter travelling distance and low-floor vehicles are getting more critical in higher age. Interesting results are, the elevator availability option and comfort are highly relevant between age 24 and 25. This may be examined in the future.

Table 2. Dataset of the detour choosing

	19-23 (%)	24-25 (%)	26-30 (%)	31-60 (%)	61-65 (%)	66- (%)
Lower travel time	83	94	79	87	100	100
Shorter travelled distance	67	69	65	79	75	100
Fewer transfers	75	88	67	64	100	0
Lower price	75	88	62	72	100	100
Higher safety	67	69	54	70	100	0
Higher comfort	58	94	60	72	75	100
Traveling with low-floor vehicles	33	31	25	26	50	100
Better travel information by loud speaker	33	38	21	31	75	100
Better travel information by screen	33	50	29	31	75	100
Better P + R	33	63	33	41	75	100
Better bike sharing connection	33	38	21	15	25	0
Better car sharing connection	25	63	25	15	25	0
Elevator option	17	50	17	11	25	0

These data (Fig. 9 and Table 2) can be combined with the stops properties and the user age. As a result the path choosing probability can be modified. In this process the result of the sensitivity analysis will be useful.

5. Conclusion

In this paper the multimodal graph was introduced especially from user habits point of view. The route planning method was the Ant Colony algorithm that generates a path choosing possibility matrix. The aim was to determine the effect of the user habits to these possibilities. Regarding to this a sensitivity analysis has been created. Moreover a preliminary survey has been made to detect the user wishes.

Based on this work it is possible to say the supplementation of the shortest path algorithm with user wishes is hardly recommended. And these results can be a good basis to the service providers in their network development. It is necessary to find a way to collect these wishes automatically. One possibility can be the data mining technique and the smart phone data.

This study is a part of a PhD work to set up a multimodal route planner. These results highly support this research. The next step will be to analyze the effect of the cost.

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用户习惯和多式联运计划

关键词
用户习惯
多式联运计划
蚁群算法

抽象
路线规划研究的结果由后勤和汽车行业监测。成本节约的经济方面是关注的焦点。最佳路线可能会节省时间或燃料。有效驾驶或最佳路线是实现经济目标的良好基础。此外，新型汽车解决方案的传播特别是在电动汽车的情况，优化对于有限的电池存储具有特殊的意义。此外，自主汽车发展不容忽视。因此，社会可以期待更安全的道路，更好的空间使用和有效的资源管理。然而，用户的要求是非常多样的，这是不可忽略的。支持这些目标，本文研究了多模式路由规划与用户需求之间的联系。检查的重点是灵敏度分析和调，以评估数据并支持用户习惯效应的设置到最终路线。