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APPROACH FOR USE OF INTELLIGENT TRANSPORT SYSTEMS FOR URBAN TRIP CHOICE

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In the present article an approach for driver's decision-making system in model construction is proposed. The possible alternatives for the selection of the driving route during the pre-trip and on-trip stages are considered. The issue of complex criterion construction for path selection on the basis of individual preferences is set. The calculation example of obtaining the complex metrics by applying resulting multiplicative index is given.

Keywords: *Intelligent Transport Systems (ITS), Decision-Making Support Systems, Path Choice Selection, Index Complexing*

1. Introduction

Due to the permanent increase of vehicles' quantities in the urban environment there appear new problems as well as continue to grow rapidly some existing problems of the city traffic mobility. For the larger cities and mega cities one of the most significant points is regarded to be an issue of the urban road system throughput shortage. Major causes are the initial defects of topological design leading to insufficient amount of lanes in the backbone streets and highways, limited number of possibilities for expansion of the existing street network and construction of additional transport infrastructure elements, absence of well-planned implemented parking systems, lack of free space that could be potentially used in order to extend road width, and so forth. The contribution to the urban transport system productivity decrease and presence of road jams is made by problems relevant to the quality of road covering. Alongside it is necessary to stress the fact of existing irrationality in available road space use.

Urban infrastructure methods of throughput increase mainly refer to a class of long-term decisions, though in some cases it cannot be implemented because of high map covering building density. Classic ways of road regulation appear to be sometimes insufficient for the complex traffic management tasks. Therefore intelligent transport systems (ITS)-based management and control methods gain the enormous popularity nowadays. Driver information assistance and road navigation modules are regarded to be the components of the urban transport control systems [1].

Taking into account the extreme congestion of a city road system, car drivers face the routine necessity in carrying out a driving route choice. As a road congestion background has dynamic origin and is connected to traffic flux depending on time of a season, day of week, hour, weather conditions, factor of road incidents, public events and so forth, the path choice is relevant to the amount and quality of information possessed by driver. Road navigation decisions could be made as prior to the beginning of motion (pre-trip choice), and directly during the driving process (on-trip choice). Driver decision-making substantially depends on occurrence of new information regarding the route preferences and current driving objectives, as well as on rapid changes of driving conditions.

Introduction of the decision-making support system (DMSS), regarding a driving route choice proves to be extremely useful as a supplementary tool for the urban traffic management needs and would become popular as an information service among the car drivers, who are acting as decision-makers (DM).

2. Construction of decision-making support model for the navigation demand of DM

For the development of corresponding DMSS on driving route choice we shall initially construct the conceptual model and we shall formulate the general requirements posed to the system.

The DMSS functional outcome is the suggested route till the chosen final destination point. The mandatory required initial data are considered to be the source vehicle location point and a selected driving destination point.

In order to provide the best driving route for DM a shortest path selection method is used. Solving the given problem the directed graph is constructed, displaying the physical topology of road system. As a road segments characteristic the values of metrics are placed on constructed graph arches.

All methods of the shortest path selection are based on metrics. The metric represents the measure quality estimation of a separate road network site. In other words, the metrics are applied as criteria of a route selection. The least value of the metrics is the best measure quality estimation. The single driving route metrics will consist of the sum of metrics of all sites of the road network included in the given route. Metrics can be simple (for example, the total way distance, class of the road, presence of paid travel roads, the information on driving regulations or restrictions, and so forth), or complex when preliminary metrics complexion technique should be applied for the reception of the typical complex metrics based on a simple ones. An example of the typical complex metrics is the route throughput index, which is formed going from the lane quantity on the separate sites of the route, permitted driving velocity and the quality of a road covering. Metrics values can vary in a wide range.

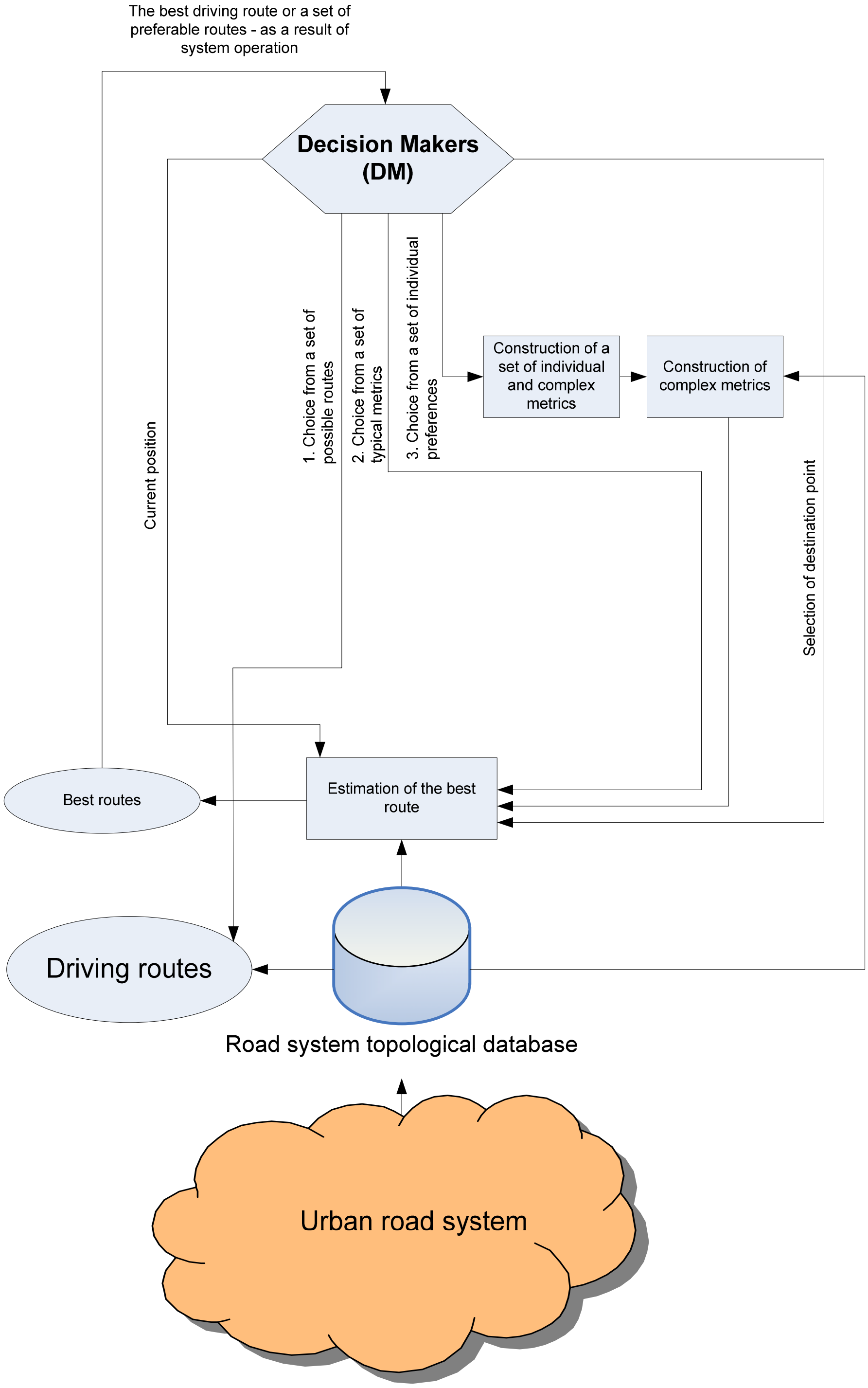

Figure 1. *The decision-making support illustration for the driving route choice*

We shall consider the most trustworthy scripts of routing path selection for the user interaction with driving navigating system.

1. Route selection

Route choice from the set of accessible driving routes:

$$R = \{R_1, R_2, ..., R_n\} .$$

It is the most frequent case of using the considered choice model in order to find the required route before the start of the trip. Proceeded decision-making alternative refers to the preliminary navigating choice (pre-trip choice) approaches category, in terms of restrictions presence $L = \{L_1(t), ..., L_m(t)\}$, caused by determined factors (scheduled public events, road construction works, etc.) and stochastic factors (failures, weather conditions, etc.), limiting a set of accessible routes.

2. A choice of the metrics

Choice of the typical metrics with the subsequent automatic detection of the best route on the basis of the shortest path finding algorithms:

$$M = \{M_1, M_2, ..., M_k\} \to R^* = \{R^*_1, R^*_2, ..., R^*_k\},$$

$$R^* \subseteq R .$$

In the considered case, the DM chooses destination and makes a typical metrics choice on which he wants to determine the best path, from the viewpoint of taken criterion. In the simplest case, the total route length may be considered as a path choice criterion; however a similar route choice may not be an optimum if to calculate spent time for driving.

The choice of the typical metrics can be carried out as at a preliminary stage right before the beginning of motion (pre-trip choice), and as an advantage of path reselection during the driving process (on-trip choice).

3. A choice based on individual preferences of DM.

This alternative is a choice from a set of preferences, with the subsequent expression of the complex metrics and automatic definition of the best driving route:

$$P = \{P_1, P_2, ..., P_m\} \to M^* = \{M^*_1, M^*_2, ..., M^*_j\} \to R^* = \{R^*_1, R^*_2, ..., R^*_j\} .$$

R^* – the best route;

M^* – the complex metrics.

The system operation mode, based on DM preferences can be either applied to the preliminary route choice (pre-trip choice), as well as to the rapid route selection during driving process (on-trip choice).

The additional factors for making a choice of the final interaction form with system are the DM characteristics such as sex, age, level of education, driving experience, and so forth.

3. Complex metrics construction problem

The last of the considered alternatives is most widespread in the real life practice. Thus, the choice of the user set of preferences results in necessity of the multi-criterial choice problem solution for which 3 groups of methods [2], generally, can be applied:

1. A method of the core parameter;
2. A method of a resulting parameter;
3. Lexicographic methods.

The method of the core parameter is based on transition of all quality parameters, with the exception of homogeneous, named the core parameter, in the category of restrictions such as inequalities and equalities. There are several shortcomings that are peculiar to this method:

- In most cases there are no sufficient background to consider any certain parameter as a core quality index, and all others as secondary.
- For quality parameters transited to the category of restrictions, it is hard enough to determine its allowable values.

The method of a resulting parameter is based on construction of the generalized parameter by intuitive evaluation of separate quality parameters impact on resulting quality of functions, performed by system. Evaluation of such influence is given by a group of experts, who are having the experience of similar systems development.

The most popular among resulting quality parameters are regarded additive, multiplicative and max/min parameters.

The additive quality parameter represents the sum of the weighed normalized individual parameters and looks like as follows:

$$Q = \sum_{j=1}^{m} \omega_j \overline{q_j}\,, \tag{1}$$

where $\overline{q_i}$ – the normalized value of the j[th] parameter; ω_j – weight factor for the j[th] parameter, having the bigger value, depending on its influence on system quality; $\sum_{j=1}^{m} \omega_j = 1; \omega_j > 0; j = \overline{1,m}$.

The main shortcoming of the additive index is that its use can lead to the mutual indemnification of the separate individual parameters. It means that reduction of one parameter up to zero value can be compensated by the increase of another parameter. For the partial solution of this problem there are put special limitations on the minimal values of individual parameters, and its weight factors.

The multiplicative quality parameter is constructed by multiplication of individual parameters taking into account their weight factors and looks like:

$$Q = \prod_{j=1}^{m} \overline{q_j}^{\,\omega_j}\,, \tag{2}$$

where $\overline{q_j}$ and ω_j have the same meaning, as in additive parameter.

The most essential difference of a multiplicative parameter from additive is rooted in a principle of a fair absolute concession on individual parameters for the additive index, while multiplicative parameter is based on the principle of a fair relative concession. The fairness rule is considered for the compromise when the total level of relative reduction in one or several parameters does not exceed a total level of relative increase in other parameters.

The max/min quality parameter. In some cases the considered kinds of the target function is difficult enough for proving and applying. In such cases the possible probable simple problem solution is application of max/min parameter. The rule for choosing an optimum system S_0 in this case looks like:

$\max\limits_{S=M_S} \min\limits_{1\le j\le m} \{\overline{q_1}(S),...,\overline{q_j}(S),...,\overline{q_m}(S)\}$, if weight factors of individual parameters are absent;

$\max\limits_{S=M_S} \min\limits_{1\le j\le m} \{\overline{q_1}^{\,\omega_1}(S),...,\overline{q_1}^{\,\omega_{j1}}(S),...,\overline{q_1}^{\,\omega_m}(S)\}$, if weight factors are determined.

The max/min quality parameter provides the best (the largest) value of the worst (the least) individual quality parameters.

The lexicographic method assumes presence of parameters ordered a priori on importance, for example $q_1(S) > q_2(S) > ... > q_m(S)$. The method requires preliminary allocation of alternatives set with the best evaluation on the most important parameter. If such alternative occurs to be unique it is considered the best; if there are several alternatives, there are selected and allocated from a subset those that are having the best values on the second parameter, etc.

In order to extend the set of proceeded alternatives and improvement of solution quality there can be appointed the concession on the set of parameters, within which limits the alternatives are considered as equivalents.

Both in classical, and in fuzzy statement the choice of the multi-criterial problem solution method is determined by the form of expert information presentation on parameters preference or its importance. The most suitable for the choice of the best driving route in terms of DMSS organization is regarded to be use of a resulting parameter method based on multiplicative convolution.

Generally, gaining a resulting parameter of final metrics is performed using the algorithm shown on Fig. 2.

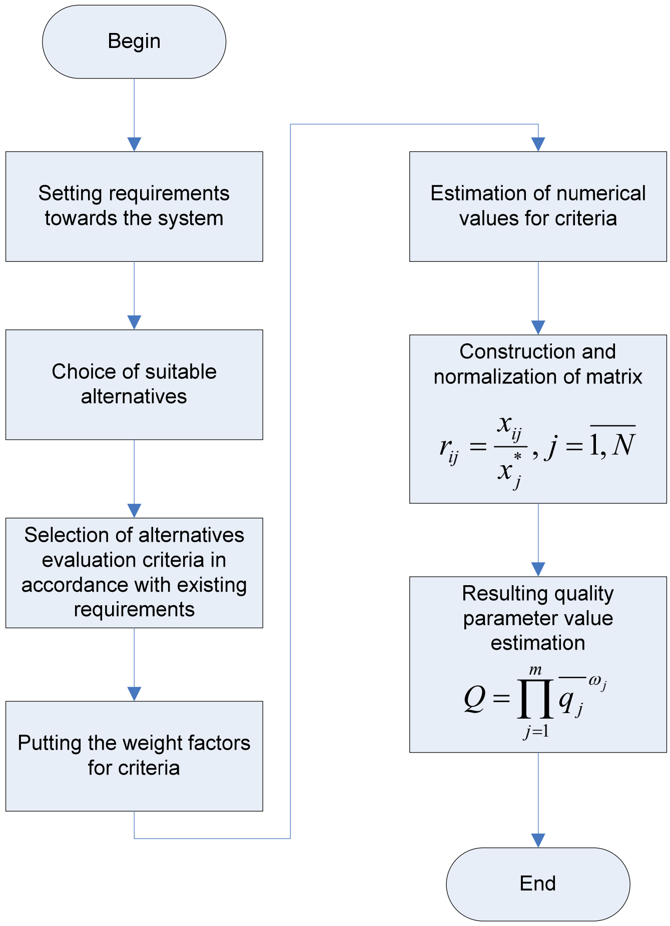

Figure 2. *Resulting parameter construction algorithm*

4. An example of the complex metrics calculation

Let's consider an example of obtaining the values of complex metrics. Values of DM individual criteria for the choice of driving route are presented in Tab. 1. As an example of individual metrics parameters have been selected the distance, the information on road congestions and presence of attractors. Values of the listed metrics are specified for a set of separate sites of a road system Link1–Link5. Experts appoint the weight factor for each of individual metrics, which is taken into account during the calculation of a final complex parameter.

Table 1. A set of the component metrics for construction of the link complex metrics

Weight factor	**0,35**	**0,4**	**0,25**
	Distance, *q1*	**Congestion information, *q2***	**Presence of attractors, *q3***
Link1	1	5	1
Link2	2	10	2
Link3	3	30	3
Link4	1	40	4
Link5	0,5	20	5

In order to gain a multiplicative quality parameter it is necessary to use an identical measurements scale for all elements in a decision-making matrix. For these purposes the normalization procedure should be carried out, i.e. reduction of all values of each column to a uniform kind, having divided all elements of each column in matrix by the largest value in the given column:

$$r_{ij} = \frac{x_{ij}}{x_j^*}, j = \overline{1, N}. \quad (3)$$

Exception is made for those parameters where the smaller value means the best characteristic. For example, in case of cost indexes, low cost of a route, is meaning obviously its preference. For the specified attributes, normalization procedure will look like as follows:

$$r_{ij} = \frac{x_{ij}^{\min}}{x_{ij}}, j = \overline{1, N}. \quad (4)$$

Results of normalization on the basis of (3) and (4), are resulted in Tab. 2.

Table 2. The table of the normalized metrics

Link	Distance	Congestion information	Presence of attractors
Link1	0,3	1	0,125
Link2	0,15	0,5	0,25
Link3	0,1	0,167	0,375
Link4	0,3	0,125	0,5
Link5	0,6	0,25	0,625

The result of the multiplicative method (shown on Fig. 2) application, according to the resulting parameter construction algorithm will give the following set of complex metrics (see Tab. 3):

Table 3. Values of the complex metrics

Link	Resulting complex metrics parameter
Link1	0,39
Link2	0,276
Link3	0,171
Link4	0,24
Link5	0,427

The obtained values of the complex metrics parameter are intended for use as criterion of the shortest path choice for the alternative of DM preferences complexion in DMSS. In the shown calculation example, the best value of the complex metrics among the given sites of the road system possesses Link3, where value of a resulting parameter is the least.

5. Conclusions

The DMSS and ITS navigation components application is not capable to change the structure of transport flows nor the road system utilization in a definite way, but has an essential impact on behaviour of certain groups of DM. It causes the certain complexities in the evaluation of efficiency for similar management and control systems application.

The given navigating service of a driving route choice is one of the main components of a modern urban traffic control system. The approach to construction of DMSS for the driving route selection, based on metrics parameters complexion method is offered in the present research work. It is made to reach the objective of information supply increase for DM.

The decision-making support model and possible methods of the complex metrics construction are described. The offered decision-making support model provides the multi-alternative choice dependent on individual preferences of DM.

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