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# Learning the public preferences for living environment characteristics: the experimental approach

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## 1 ABSTRACT

The goal of the research presented in this paper is to propose, test, document and evaluate the application of preference models in the field of urban planning and design. The preference models simulate the human decision making in various hypothetical situations.

The preference model used in the research is created in experimental way by using the conjoint analysis. It is demonstrated how the complex characteristics of the environment can be transformed into operational form that can be consequently used for preference analysis and modelling. The preference model assembly phases are demonstrated.

Once the preference model is created, it provides with the predictions of preferences for alternative scenarios (combinations of environment characteristics) and other information that supports the interpretation of the factors influencing the identified preferences. The paper presents concrete outputs that can be directly applied to everyday practice of urban planners and designers.

With the help of conjoint analysis several preference models are constructed that represent the preference structure of individual respondents or groups of respondents. The preference structures of various groups of respondents are compared and significant differences are identified.

It is also demonstrated how the preference model can serve as a planning support system for simulation of inhabitants' responses to proposed changes in the urban environment. For those purposes the outputs of the preference models are projected onto real environment characteristics represented by GIS model. Areas of Prague have been selected as cases.

The effective use of preference models is encouraged by the use of information technology that offers many advantages including the experimental stimulation of respondents, data collection and analysis. At the end of the paper the implications for further research are presented.

## 2 INTRODUCTION

Preference model simulates human evaluation of various hypothetical situations. Any imaginable characteristic of urban environment can serve as an input into the model. The paper presents the experimental approach to preference analysis: the conjoint analysis is used to distil the preferences out of respondent's evaluation and the preference model provides with predictions of preferences for alternative scenarios. In this way the effects of various urban environment aspects on human behaviour can be explored:

- accessibility of facilities, services and workplaces and their relative localization [24, 10]
- density, amount and accessibility of open spaces in the urban environment [3, 4, 5, 10, 16, 17]
- quality and diversity of services [24]
- fit of urban environment for chosen leisure activity of its habitants [1]
- factors influencing the mobility of habitants and their choice of transportation mode [11]
- effects of social environment [18]
- effects of various land-uses adjacencies [10, 17, 7, 11]
- effects of environmental stress factors [14]
- visual qualities of urban environment [15]

The public preferences for living environment are the main focus of this research. It is assumed that the habitants' preferences have the major impact on the choice of living environment. The examined characteristics are adjacency, accessibility and land uses.


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## 3 PREFERENCE ANALYSIS APPROACHES, METHODS AND PRINCIPLES

Two general approaches are used for preference measurement: "Revealed preferences" methods and "Stated preferences" methods. The revealed preferences are derived from data or an observation of human behaviour in a real environment. Prices of land, data on habitants' migration in urban environment and other socio-economic data can serve as the sources of data [11]

The Stated preferences experimentally stimulate the subject by means of hypothetical scenarios.

The paper describes the use of "Conjoint analysis" to derive the model of preferences in experimental way.

First the evaluated object is represented by finite number of characteristics [14, 11]. Each characteristic is in turn explicitly defined by finite number of states (Conjoint analysis belongs to "Discrete choice methods"). Description entering the method is therefore abstract and formal and consists of attributes and their states. By combination of attribute states we receive large, but finite set of all possible alternative scenarios that is called "Experimental Set of Data" (ESD).

Scenario is carefully and purposely given description of certain object or environment that can be real or purely hypothetical. The scenarios can represent a physical object as well as a mental construct. For example it is possible to test the preferences to not yet existing objects or environments.

The scenarios are used for stimulation of the subject and as an element to which the evaluations are attributed. The CA belongs to decompositional methods as it automatically breaks the evaluation of whole scenarios down to its constitutive elements: individual attributes and their states [14]. Decomposed values are referred to as partial preferences or partial utilities.

Partial preferences enter the preference model as its parameters. The task of the preference model is to recompose the partial preferences into preferences of the whole scenario. Decomposition of global preferences to partial preferences and their consequent recomposition is modelled assuming certain principals of human evaluation and mental processes of decision: the additive and the multiplicative models represent two main alternatives [14, 11].

## 4 THE PREFERENCE MODEL ASSEMBLY PHASES

The preference model assembly phases are demonstrated step by step.

### 4.1 The choice of the critical characteristics

Extensive literature exploration was completed to identify the attributes of the environment that are important for the habitants' choice of the living environment. Only the characteristics that are expected to involve the choice of a subject and/or that are relevant for the research objective were chosen.

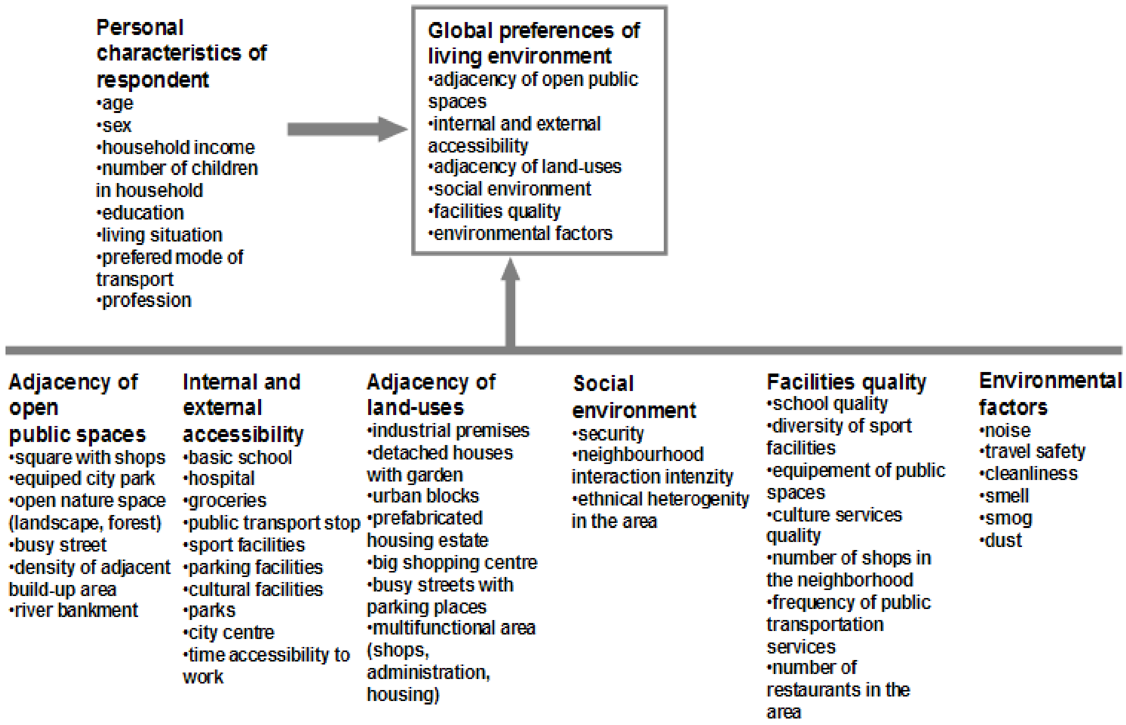


Figure 1: The hierarchical model of the attributes critical for evaluation and choice of living environment

The method of preference analysis has some limits concerning the number of characteristics that can be evaluated in one application of the method. The number of characteristics (size of ESD) that can be concurrently evaluated is limited by maximum number of scenarios that can be evaluated by one subject. The limiting factor is the subject fatigue during the evaluation procedure. It is strongly recommended that the number of evaluation acts in one procedure does not exceed the number of 30 [14].

Not only the number of scenarios, but also its complexity (number of attributes in one scenario) must respect the respondents' cognitive capacity. The size of scenario should not exceed the number of 15 attributes given that each attribute has no more than 10 states. The optimal size of scenarios is 7 attributes, each with 3 states.

It is obvious that the limits of the method are in contrast to the complexity of the phenomena that we intend to study. In this case the complexity of the environment description is managed by dividing the environment characteristics into themes that are commonly accepted. The ESD takes form of hierarchical structure. This enables to build a partial preference model for each theme separately and finally to integrate the partial preference models and to assemble them into single preference model [14].

### 4.2 The attribute states definition

Seven attributes were included into the preference model presented. The attributes where not defined with regards to the theme but rather with the intention to test various forms of environment characteristics description. The intention was to involve the categorical as well as continuous variables into the experiment.

In the case of categorical variables each category represents some discreet state of real environment characteristics. The categories presented to the subject should correspond to the subject's perception of the characteristics.

The characteristics that have continuous character must be defined by several discreet states. Because only some of the values of the characteristics can be selected to be presented to the respondents, it is important to select the values that best describe the respondents' perception of the characteristics. However the subjective perception does not always simply correspond to objective states of perceived characteristic. For example the relation between the proximity and preference is not always monotonous, but it can rather include a threshold, which the increasing preference suddenly starts to decrease. If this is the case, there should be at least 3 attribute states defined: 2 states defining the outlying values and one or more states should indicate the points of expected change of the preference trend [14, 11].

In the experiment questions the categorical variables were used for description of three types of objects adjacencies: urban park, open landscape and busy street. There are three types of proximity zones defined with regards to the respondents' dwelling:

- „Vista zone" represents topological adjacency of object/activity/use to subject's dwelling. To this type of adjacency strong visual effects are related.
- "Local-displacement zone" represents the space of walking distance. It is assumed that objects, activities and uses in this zone have a strong social and psychological effects stemming out of the intensive social interaction, personal contacts, the sense of belongingness and identity.
- "Enlarged-displacement zone" represents the space outside of "Vista" and "Enlarged-displacement" space. The Enlarged-displacement space is characterized as a space of extended mobility, where movement in this space is contingent on the use of transport technology. Our use and knowledge of this space depends on the mode of transport. It is consequently discontinuous, fragmented. The habitant's emotional attachment to this space is weaker.

Additionally, categorical attribute "character of adjacent residential buildings" describes three distinctive types of residential buildings in the experiment: detached houses with garden, compact blocks of flats and prefabricated panel housing estate.

The experiment includes two continuous characteristics: time accessibility of a shop and public transport stop by walking and time accessibility of the city centre by any mode of transport.

| Name of attribute | Attribute state |
|---|---|
| the proximity of an urban park with facilities (benches, children and sport playgrounds)<br>the proximity of an open countryside (forest, meadows)<br>the proximity of a busy road (600 cars in one hour) | the object is adjacent and visible from your dwelling<br>the object is located in the walking distance (less than 5 minutes)<br>the object is located beyond the walking distance |
| the pedestrian accessibility of a shop with the basic range of goods in minutes<br>the walking accessibility of public transport stop (bus, tram) in minutes | 3 minutes<br>7 minutes<br>15 minutes |
| the accessibility of city centre by any transportation means in minutes | 15 minutes<br>30 minutes<br>45 minutes |
| the type of adjacent residential buildings | detached houses with garden<br>compact residential blocks with inner courtyards<br>panel housing estate without clean distinction between public and private/semi-public open space |

Table 1: Attribute states description

### 4.3 The assembly of scenarios

The attributes defined are combined into scenarios. In the experiment the fractional factorial design was used to create the set of scenarios (ESD). Fractional factorial design is based on fraction of all attribute states combinations. The selection of a subset of combinations is possible only under the condition of preserving the orthogonality of ESD: the states of attributes being varied with the same frequency across all the presented scenarios. Only in this way the preferences attributed to each scenario can be decomposed to individual states of attributes.

The advantage of using only relatively small number of scenarios (32) is that scenarios can be evaluated be single respondent during one session. That enables the researcher to build preference model for each respondent.

The weakness of the fractional design is that only main affects can be estimated while higher-order (interaction) effects are ignored.

### 4.4 The stimulation of the respondents and evaluation of scenarios

The scenarios in this experiment are presented in textual form. The main reason of using the textual form is that attributes are too abstract to be presented in visual form. (There are some convincing attempts to use visual stimulation of respondent in the "Green space" project [25]).

The subject can attribute the preferences to scenarios in three ways [14, 11]: ranking, rating or discreet choice. While discreet choice most closely imitates the way of decision-making in real life, the combination of ranking and rating was used in this experiment mainly because of the efficiency of both techniques (minimum number of evaluation acts in one evaluative session) [11].

### 4.5 The choice and formal definition of preference model

The additive or multiplicative rule represents two hypotheses about the way human beings compose the overall preferences and decisions from the partial preferences referring to individual characteristics of their environment.

The additive model assumes that any attribute state of low preference can be compensated by another attribute state of high preference. The multiplicative model assumes that compensations are impossible because the partial preference of one attribute state is dependent on the presence or absence of another attribute. Therefore the individual attributes cannot be each other substitutes [14, 11].

For this experiment the additive model was chosen. The formal notation of additive model that uses the categorical attributes is:

$$Y\mathrm{i} = \beta 0 + \beta \mathrm{i}1 * A\mathrm{i}1 + \beta \mathrm{i}2 * A\mathrm{i}2 + \ldots + \beta \mathrm{iy} * A\mathrm{iy}$$

where $Y\mathrm{i}$ means global preference to i-th scenario that is composed of attribute i having attribute states *1..y*: $A\mathrm{i}1$ .. $A\mathrm{iy}$ with partial preferences (utilities) of each attribute state $\beta\mathrm{i}1$ .. $\beta\mathrm{iy}$.

### 4.6 The application of information technology

One of the goals was to exploit all opportunities that the new information technology offers. To attain the goal, the virtual laboratory was to created that enables to elicit the evaluation out of respondent being anywhere in the world at whatever time and to reward respondents' participation with immediate (on fly) presentation of the preference models based on his/her evaluation. The intention was not only to collect data from a respondent, but to attract the respondent to the topic and the method of the research itself. It could be one way the information technology could help people to be aware of some seldom perceived aspects of their interaction with the environment.

Advantages of the use of ICT are:

- smooth data distribution and collection;
- attractive graphic stimulation;
- immediate feedback given to the user;

The use of ICT is accompanied with the following disadvantages:

- respondents can pretend fake identity and consequently degrade the results of experiment [12];
- non-uniform access to internet across the population.

Visually attractive, user-friendly, easily accessible and highly interactive web application was created.

The application enables evaluation of scenarios, creation and presentation of preference model. The Java applet technology was used to create client interface, but it was recently changed into html pages on client side and Java Servlet Pages on server side. Data persistence is maintained by database server MySQL server 4.1. The statistical toolkit: „Michael Thomas Flanagan´s Java Library" was used for the creation of the preference model, JFreeChart library was used for rendering the charts. Whole application was assembled and debugged in the development environment NetBeans 4.1. All used technology is distributed under GNU licence (General Public Licence). The only professional software used was the package of statistical tools: is SPSS 12.0.1. [22].

# 5 THE PREFERENCE MODEL FROM THE USER POINT OF VIEW

## 5.1 Getting the information on respondent

The respondent first inputs his/her personal characteristics later used for the creation of group preference models that represent the preferences of selected respondents only.

The respondent states his/her age, sex, personal status, number of children in household, monthly household income rank, size of city inhabited, type of residential building inhabited and most frequently used transportation means for local movement. The respondent is not requested to uncover his/her real identity.

## 5.2 Instructing the respondent

The personal data questionnaire is followed by two instruction pages informing the respondent about the goals of the experiment and steps of the procedure. Three types of adjacency (Vista space and Local / Enlarged displacement space) are explained and illustrated on the example of several distinct aerial photos of urban tissue. The aim is to sensitize the respondent to the scale of each type of adjacency.

## 5.3 The elicitation of respondent's preferences

The evaluation procedure lasts about 20 minutes. The respondent evaluates each of the presented scenarios on the scale <0; 100>. Whenever the respondent presses the "sort" button, the program automatically sorts the scenarios according to the scores attributed. This combination of rating and ranking enables the respondent to fine-tune the evaluation by comparing the most similarly evaluated scenarios side by side.


Figure 2: The evaluation panel eliciting the respondent's preferences

When the respondent feels comfortable with own evaluation of scenarios, he/she submits the evaluation and the program redirects the respondent to the interfaces that provide the interaction with preference models.

## 5.4 The interaction with the preference model

The application offers three main user interfaces, each designed for learning other aspects of the preference models: Compare, Analyze, and Project.

### 5.4.1 Interface "Compare"

Two default preference models were created: the general preference model that represents the preferences of all respondents taking part in the research and the personal model presents preferences of an individual respondent. Further, a respondent can create a number of group preference models that represent the preferences of selected respondents.

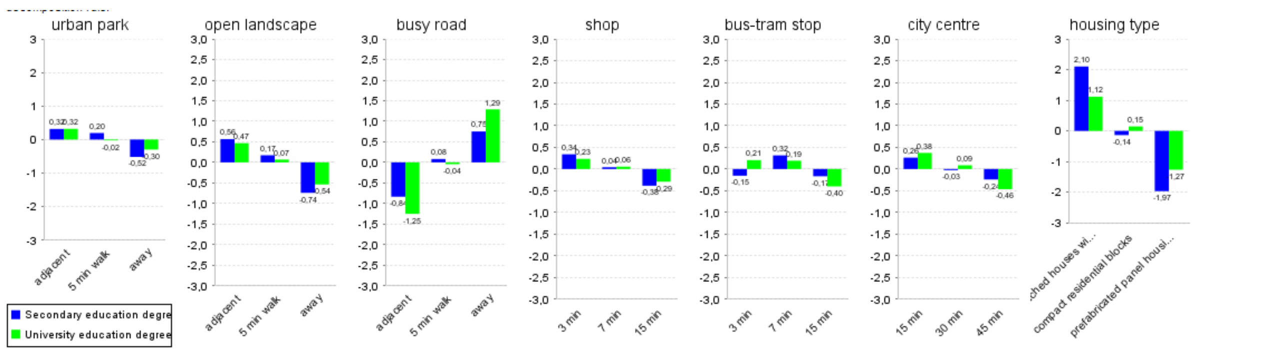


Figure 3: The comparison of partial preferences of two selected preference models representing the respondents with the secondary education degree and with the college or university education degree.

The interface 'Compare' enables side-by-side visualization of the selected model parameters. For a respondent it is possible to compare the differences between the partial preferences of two chosen preference models.

Apart from the partial preferences the interface offers the comparison of importance that each attribute had for a respondent or group of respondents when evaluating the scenarios.

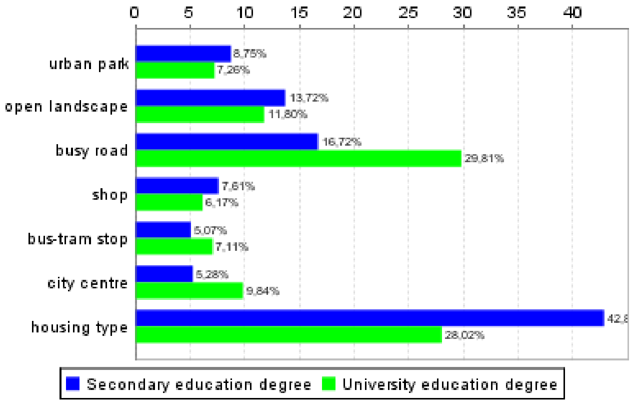


Figure 4: The comparison of attribute importance of two preference models representing the respondents with the secondary education degree and with the college or university education degree.

The interface 'Compare' presents other two important model parameters: the intercept of regression line and the coefficient of determination.

The intercept of regression line represents the average evaluation of all scenarios. Intercept is relatively low when the respondents were rather displeased by offered scenarios during the evaluation. The value of the intercept has no impact on the value of partial preferences for individual attribute states presented above. Therefore the partial preferences are comparable across all preference models.

The coefficient of determination shows how big portion of total preference variability is explained by the preference model. The coefficient of determination represents the quality of the preference model; it is high when the respondent's evaluation was consistent. A low value of the coefficient of determination usually indicates the respondent's fatigue during the evaluation procedure or a premature interruption of evaluation procedure.

Each preference model represents the preferences of particular group of respondents. The interface 'Compare' offers description of respondents using the personal characteristics that each respondent entered at the start of evaluating procedure. Following graphs describe the characteristics of selected respondent groups.

### 5.4.2 Interface "Analyze"

Interface 'Analyze' provides with a tool for deeper analysis of the characteristics of respondent groups' evaluations. Respondents are sorted into groups according to their personal characteristics; charts present the parameters of each group evaluation.

First box chart presents the distribution of partial preferences that each group of respondents expresses for the selected attribute. Each box shows how much one of the respondent's group prefers one of the state an attribute. The partial preferences can be read on the vertical axis.

The second box chart shows the distribution of the attribute importance for each group of respondents.

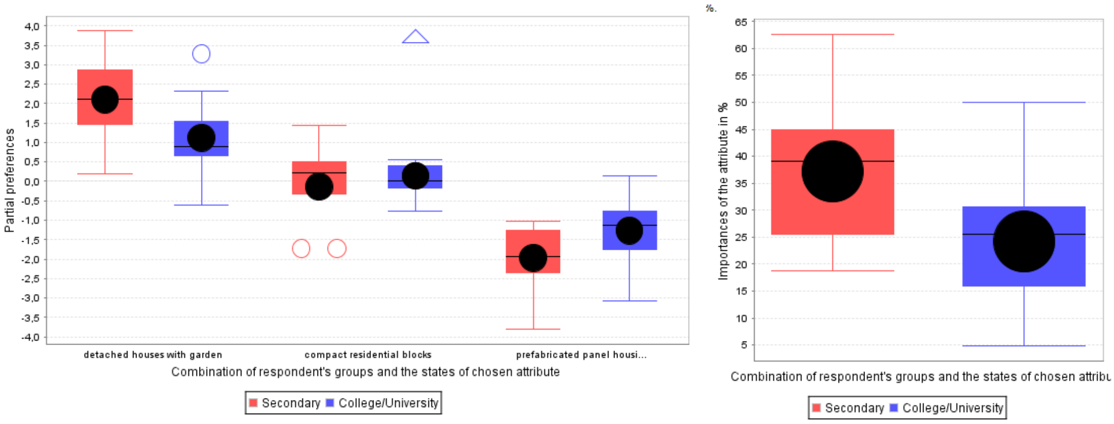


Figure 6: Distribution of partial preferences and the importance of chosen attribute for two groups of respondents: with the secondary education degree and with the college or university education degree.

### 5.4.3 Interface "Project"

The preference models can be used to evaluate any real or imaginary environment. Several areas in Prague were used as the cases. Each case area was described with the use of the attributes of a selected preference model. The spatial analysis was employed for the creation of raster layers representing the characteristics to be evaluated by the preference model. Each raster layer is evaluated by selected preference model and resulting value-map is created.

The pictures bellow shows the evaluation of Dejvice-Vokovice-Střešovice area (3,6 x 2,5 km). Blue and red colours scale from low (0 points) to high (up to 9 points) evaluation. There are differences noticeable in the negatively evaluated areas adjacent to the capacity roads (blue strips), red-yellow spots covering the areas of highly prestigious garden suburbs and blue spots covering the areas of housing estates built up in the post-war period. Public transport stops and shops are distributed in the area quite evenly and as such they do not have a strong impact on the evaluation. These factors may, however, play significant role in some other, more peripheral parts of Prague.

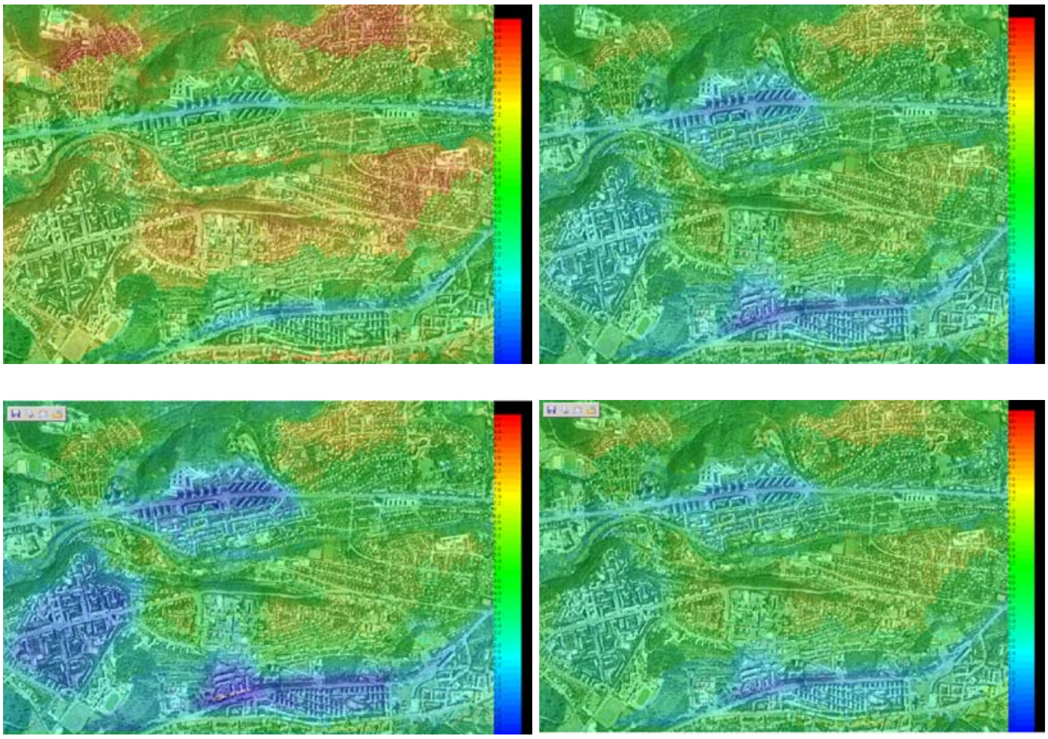

Figure 7: The evaluation of the same area by four different preference models: personal, general preference models and two Groups' models: one is representing the respondents with the secondary education degree and another one respondents with the college or university education degree.

The preference models created to represent the preferences of various groups of respondents have something in common. Majority of them express low preferences for areas adjacent to busy road and post-war housing estates. On the other hand they highly valuate the adjacency to open landscape and low density housing areas. While the conclusions are trivial and just verify the common sense, it should be stressed that the added value of preference models consists in their ability to uncover much more subtle phenomena. They give us information on the marginal changes of preferences as the function of the change of one or more environmental factors or respondents' personal characteristics.

The interface 'Project' enables to assess the comparative attractiveness of different areas too. The projection is also useful for the evaluation of the areas that we do not know or we are not able to evaluate using the common sense. It is the case of more abstract characteristics of the areas such as accessibility of services and transportation infrastructure.

Each presented interface has its own purpose. Interfaces 'Compare' and 'Analyze' are useful for the study of respondents' preference structures, while the interface 'Project' is more useful for the geographical analysis of different areas.

## 6 THE OUTPUTS OF PREFERENCE MODELS AND THEIR USE

Even though the experiment is not yet finished and there is still more respondents needed to reach the sample balanced in terms of equal distribution of respondents' personal characteristics, the preliminary conclusions have been done with the intention to demonstrate what kind of information it is possible to get out of the analysis.

### 6.1 Partial preferences

The partial preferences (utilities) for each state of the attributes with regard to the importance of particular attribute are the most important outputs of the analyses. The partial preferences represent the positive or negative contribution that each state of the attribute has for the evaluation of whole scenarios. The preliminary results of the experiment indicate the following conclusions:

- The adjacency of open landscape brings much bigger benefit than the adjacency of urban park. The benefit relies to large extend on a direct adjacency. By removing a park or open landscape out of visual connection to the walking distance, it looses much of its value.
- The negative effects of busy road adjacency (direct visual connection) are so important that they can be compensated for only by joint effects of direct adjacency of urban park and open landscape.
- There are differences in the preferences of the time accessibility of a shop with the basic range of goods and a public transport stop. The highest partial preference for the accessibility of a shop is 3 minutes and with the increasing accessibility the preference diminishes. A public transport stop has the highest partial preference in 7 minute time accessibility. With decreasing or increasing time accessibility for the "peak" value the preferences diminish. In this case the curve of preference is not in direct proportion with the objective amount of the characteristics; therefore it would be reasonable to extend the number of attribute states presented to respondents and to test the exact distribution of partial preferences.
- As expected, the partial preferences for time accessibility of city centre diminish with the increasing distance of the city centre in linear manner. It would be interesting to test the preferences for direct adjacency of a city centre. We could assume an existence of negative effects coming form the high-density and intensive use of public space that would slow down the marginal increase of partial preferences of the increasing city centre accessibility.
- The partial preferences of the housing estate adjacency proved to be the most negative of all the attributes. The preferences of compact residential blocks are slightly positive and the preferences of detached houses with garden show the most positive partial preferences of all the attributes. The respondents with university degree have less strong positive or negative preferences to the respective

types of residential environments than the respondents' having attained the secondary education degree only.

- Apart from the level of attained education also the factor of the size of the city in which respondent lives influences the partial preferences of 3 minutes accessibility of public transport stop. Bigger is the city size, higher are the partial preferences of close proximity of public transport stop.

### 6.2 Compensatory or noncompensatory preference structures

The experiment uses the additive model that assumes the compensatory nature of respondent's preference structure. It is assumed that respondents can compensate for an attribute state of low preference with another attribute state of high preference. Under this assumption the preference model can indicate the mutual compensations (trade-offs) between the attributes which would indicate how big change of one characteristic would compensate the change of another characteristic. It is possible to identify very different combinations of attribute states that will be indifferent with respect to the respondent's evaluation. The impact of one change compared to the impact of other change on the respondent's preferences can be calculated. Such information can be very useful for estimation of public acceptance of various changes in the environment. Using the price as one environmental variable enables us to evaluate the compensations also in monetary terms.

The assumption of the compensatory preference structure is very strong and does not reflect the complex interference between the effects of several attributes when taking joint effect. There are indications that many characteristics of the environment function in this way. The joint effects of environmental characteristics are called interaction effects. The interaction effects identified are for example the perception of safety and the preferences for urban parks. In case of public transport it is very possible to identify the interaction effect between the time accessibility of public transport stop and the frequency of the transport service, total time of transport, comfort and safety of the transport. Interaction effects also could be expected between the density of built-up area and the preferences of public open spaces.

The measurement of the interaction effects requires collecting much more information than in the case of main effects measurement. Therefore it is usually impossible to constitute the preference structure on the individual base. This factor was decisive for the selection of the additive model for the experiment as the goal was to create the preference model that would represent the preference structure of individual respondents.

### 6.3 Attribute importance

The importance of attributes indicates the respondents' sensitivity to the respective environmental effects. When evaluating the scenarios, a respondent is required to evaluate simultaneously large number of information. When the number of information exceeds the cognitive capacity of a respondent, the selective approach to the evaluation of the scenarios is applied, when only some of the attributes are employed as the criteria of the scenario evaluation and other - less important - attributes are used only if there are some resources left for fine-tuning of the evaluation. The selective strategy is perfectly valid even for real life situations. This is the strength of decompositional methods where the whole scenarios are evaluated.

The experiment revealed that the most important criteria for the scenario evaluation are the type of adjacent residential buildings (30,59%) and the proximity of a busy road (25,12%). The attributes of average importance are the proximity of open countryside (11,72%) and the accessibility of city centre (10,60%). At this moment we can only speculate whether the low importance of the accessibility of an urban park is caused by having the attribute of open landscape as the substitute for the urban park.

The experiment indicates that each group of respondents applies different strategic selection of evaluative criteria.

### 6.4 Validity of experiment outputs

The validity of the preference measurement is usually measured using the "hold-out" that are evaluated by a respondent but not used for derivation of partial preferences. Instead they are used to compare the predictions of the preference model with the evaluation of the respondents to assess the validity of the model. This experiment does not use the "hold-out" scenarios because of already high number of scenarios in single evaluative session. Instead the subjective evaluation of personal preference model by respondents was introduced. Each respondent when being confronted with her/his personal preference model was asked the following question:

“Does your personal preference model fit to your preferences as you reflect them?”

The answers were scaled between the 1 – agree completely and 7 – does not agree at all. The respondents indicated strong agreement with the preference model that was presented to them. The mean of the answers was 2,73 (standard deviation was 0,88).

## 7 CONCLUSION AND IMPLICATIONS FOR FURTHER RESEARCH

The partial results already indicate what could be the expected outcomes of the experiment. To confirm the partial results much more respondents is needed. Today’s 32 respondents must be multiplied at least ten times. At present the results are valid only on the level of individual respondent.

So far the method of preference analysis and simulation proved to be valid and useful. For further development and application of the method the following ideas are proposed:

- use other, less subjective techniques of preference model validity measurement, for example the „hold-out“ scenarios;
- test the reliability of the measurement by test-retest procedure;
- create more robust preference model that would include most of the attributes presented in the hierarchical model of the attributes (see figure 1).
- precise the spatial model, more precise spatial model would enable valid evaluation of the small scale areas.
- test the correlation between the preferences projected into the spatial model and other indicators of area attraction, for example the land prices or the price of rent.
- use the types of models that would enable an evaluation of the interactive effects. The disadvantage of this change would be the loss of the opportunity to evaluate the preferences on the individual bases.

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