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AUTOMATION OF MAKING INNOVATIVE DECISIONS IN DEVELOPMENT OF CITY INFRASTRUCTURE

Abstract: An automated method for evaluating expert questionnaires proposed, in which the questionnaire considered as a linguo-numerical model of the city infrastructure object under study, which makes it possible to present it in a form convenient for automated processing in decision support systems (DSS) based on the proposed procedures.

Keywords: innovative development, decision-making, belongs function, fuzzy estimates, rating scale.

Introduction

One of the main tasks of innovative development of the city's infrastructure is to increase the efficiency of innovative solutions. An innovative solution is a creative act aimed at eliminating problematic issues that have arisen in the development of the city's infrastructure. At the same time, we highlight General and particular innovative solutions [1,2]. General innovative solutions (strategic level) cover all production and financial and economic activities of the city, as well as its further innovative development. Private innovative solutions (tactical level) relate to any individual objects of the city and affect current issues of an operational nature [3,4]. In any case decision-making complicated by a large number of uncertain and contradictory factors. Research shows that decision makers without additional analytical support tend to use simplified and sometimes contradictory decision-making rules. In this case, the most effective tool for making a potentially better decision is decision support systems (DSS) [5,13]. Today, the development and effective management of urban facilities is unthinkable without the development and application of DSS. The complexity of making innovative decisions determined by the transience of changes in urban infrastructure, the presence of a large number of uncertainties in information, and the inability to build a reliable forecast of urban infrastructure development over a long period time. Therefore, decision-making is often impossible without the use of DSS and expert assessments.

Statement of the problem research

One of the main issues in the development of the DSS to implement the process of interviewing experts and further automated processing of their opinions by the DSS, or, using production rules, to look for a potentially better solution to the DSS itself. In both the first and second cases, the effectiveness of innovative decision determined by the constructive content of expert requests (questions). The quality of innovative solutions depends on how the expert questionnaire compiled (formed). Despite the widespread use of the survey method, the scientific basis of the survey not sufficiently developed for their practical use [5,13]. Below we propose a method in which a questionnaire designed to obtain expert assessments that characterize the expert's (or the DSS itself) responses to the questions posed in it considered as a linguo-numerical model and constructed as a block structure from system-wide positions.

Problem solution

Despite the widespread use of known survey methods (PARK, ORCLASS, etc.) they have significant limitations [5,7-10] designed to solve problems of a choice of 3 or 5 alternatives; use verbal evaluations; provide the choice of the best of a group of given alternatives only by pairwise comparison.

The "PFPA" method proposed in this article (**P**rocedures **F**or **P**rocessing **A**lternatives) is characterized by the fact that it is used for automated criteria-based evaluation of alternatives, and for each criterion, the entire set of alternatives is evaluated at once. In addition, this method provides that the expert sets ratings both on the linguistic rating scale and on the quantitative scale using the membership functions [7,8].

The main procedures of the method include:

Procedure 1. Building a system of hypotheses-bases and hypotheses-consequences.

Before applying the proposed procedure for this stage, it assumed that the analyst has formed a primary set of alternatives. We proceed from the assumption (the main hypothesis or the base hypothesis) that the primary set of alternatives is the solution to the problem situation. The main purpose of the survey (expert evaluation) is to prove this hypothesis. It is customary to distinguish between two types of hypotheses: hypotheses-grounds and hypotheses-consequences. Hypothesis-the base is the original theoretical assumptions. The proof of the basis hypothesis carried out through the proof of the consequence hypotheses. The base hypothesis must considered from different points of view, i.e. there must be a second level of the base hypothesis, from which the consequence hypotheses can then derived. Thus, the base hypothesis Z is determined, for which the second-level base hypotheses $Z_1, Z_2, \ldots, Z_n$ are identified. Further, for each hypothesis-basis Z_i, hypotheses-consequences of z_{i1}, z_{i2},..., z_{im} are derived. The set of second-level hypotheses $\{Z_i\}$ corresponds to the set of criteria K, and the set of hypotheses-consequences $\{z_{ij}\}$ corresponds to the set of criteria values.

Procedure 2. Formation of quantitative and linguistic scales of criteria for evaluating alternatives.

For each hypothesis-basis of the second level Z_i, a quantitative or linguistic scale of measurement of the hypothesis-consequence $\{z_{ij}\}$ must constructed, which determines the expert's responses of a quantitative or qualitative nature (an example of a linguistic scale shown in fig.1. The quantitative scales characterized by the unit of measurement and its range of variation [7].

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very low → low → average → high → very high

Figure 1. Example of sequence of linguistic assessments

Procedure 3. Drawing up the structure and filling out the questionnaire.

In the proposed procedure, the search for the optimal level of complexity of the questionnaire carried out heuristically in two stages:

At the first stage, the most informative questions that characterize the object of research selected, a scale of information content ratings selected, and an example of its $i$correspond to the structure of the considered object, allow only a single interpretation of the questions contained in it and the ability to give answers in a quantitative format. As a mathematical tool for forming the representation of question-answer relations, it proposed to apply the logic of first-order predicates [6]. In General, the question described by the formula:

$$(?\,x_1, \dots, x_n)G(A'', X, R) \quad (1)$$

where A'', R, X – set of terms of the form:

- $A'' = \{a_l | a_l\}$ – predicate constants that define alternative responses ($l = 1, \dots, s$); s – a number of alternative answers to the question;
- $R = \{r_k | r_k\}$- predicate constants that define input responses in open-ended question ($k = 1, \dots, q$); q – a number of answers to an open question to be entered;
- $X = \{x_i | x_i\}$- predicate variables ($i = 1, \dots, n$); n – a number of predicate variables;
- G - a propositional form containing sets of predicate constants and variables.

At the second stage, due to the different scales can used in the same questionnaire for evaluating different questions, the questionnaire questions grouped into groups corresponding to the accepted rating scales. As a result, the questionnaire is a hierarchical system of questions. The first group includes specific questions, the answers to which contain a quantitative assessment. The second group includes General questions, the answers for which contain an assessment of priority. The third group includes General questions that require a short "Yes-no" answer. The fourth group includes questions that require a verbal (qualitative) response in a detailed form. They can be divided into two groups: questions whose answers contain information about the object, and questions that require arguments for and against the thesis contained in them. This construction of the questionnaire is very convenient for automating the process of processing them in the DSS. Next, to create a questionnaire, we form blocks of questions. Each program question corresponds to a block of questions. The cluster is composed of atomic questions. Hypotheses-bases transformed into program questions: Q_1, Q_2 ... Q_n and hypotheses – consequences $z_{i1}, z_{i2}, \dots, z_{im}$ in atomic questions $q_{i1}, q_{i2}, \dots, q_{im}$ of block Q_i. Then each question closed in the form can be presented in tabular form. In the rows of the table (alternatives $a_i \in A$ are written, and in the columns of the table – the values $V_{ij} = \{v_{i1}, \dots, v_{ik}\}$ of the linguistic scale. An example of filling in a linguistic template for a tabular question shown in table 1.

Table 1.

Linguistic representation of a tabular question

Question q_{ij}					
Measurement / Alternatives	**Linquistic scale**				
	v_{i1} **very good**	v_{i2} **good**	v_{i3} **middle**	v_{i4} **bad**	v_{i5} **very bad**
a_1	∨				
…					
a_n			∨		

After drawing up the questionnaire, experts interviewed. Experts evaluate alternatives for each question in the questionnaire. The expert puts a mark next to the value of the quantitative or linguistic scale (column), which, in his opinion, more accurately assesses the alternative, otherwise leaves an empty space. Since decision-making indicators have different physical nature, it is necessary to bring them to a single selected scale.

Procedure 4. Normalization of criteria for evaluating alternatives.

Let the features that form alternatives to A_i contain both numerical (quantitative) and linguistic (qualitative) variables. In this case, each variable assigned a membership function. At the same time, we will use the universal scale [0,1] to evaluate preferences. In other words, for the set $x \in [0,1]$ and the membership function $\mu: x \to [0,1]$, the fuzzy set is defined as

$$\tilde{A} = \{(x, \mu_A(x)) | x \in X\} \quad (2)$$

The membership function (2) quantitatively grades the membership of elements of the set of the alternatives A, defined by $x \in A$ to the fuzzy set $\tilde{A}$ with the normalized variables $\tilde{x}$. A value of 0 means that the element does not belong to a fuzzy set, and 1 means that the element is fully described by this set. Among the most well-known and used belong functions, the most convenient and universal for the variables under consideration are the triangular functions shown in Fig.2 and Fig. 3[6,7]:

a) for the max-min preference scale A_i alternatives

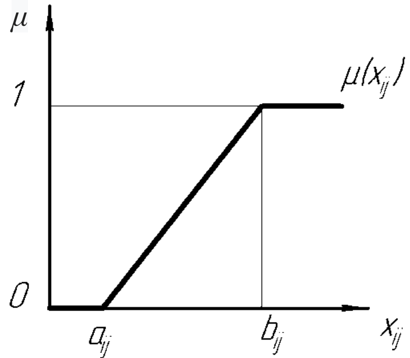

Figure 2. Increasing belongs function

The following analytical expression corresponds to this graphic (fig.2):

$$\mu(x_{ij}) = \begin{cases} 0, \text{если } x \le a_{ij}; \\ \frac{x_{ij}-a_{ij}}{b_{ij}-a_{ij}}, \text{если } a_{ij} < x < b_{ij}; \\ 1, \text{если } x \ge b_{ij}, \end{cases} \quad (3)$$

where $a_{ij} = x_{min_{ij}}$; $b_{ij} = x_{max_{ij}}$.

b) for the min-max preference scale A_i alternatives

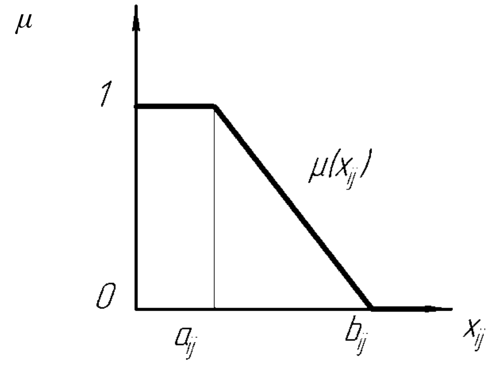

Figure 3. Falling belongs function

The following analytical expression corresponds to this graphic (fig.3):

$$\mu(x_{ij}) = \begin{cases} 1, \text{если } x_{ij} \le a_{ij}; \\ \frac{b_{ij} - x_{ij}}{a_{ij} - b_{ij}}, \text{если } a_{ij} < x_{ij} < b_{ij}; \\ 0, \text{если } x_{ij} \ge b_{ij}, \end{cases} \quad (4)$$

where $a_{ij} = x_{min_{ij}}$; $b_{ij} = x_{max_{ij}}$.

Normalization of estimates of the compared alternatives is based on formulas (3) and (4) as follows:

− for all quantitative estimates, the max and min values of the variable under consideration are found;

− for all linguistic (qualitative) assessments, the maximum and minimum numbers are determined.

Procedure 5. Automated evaluation of alternatives.

The values of alternative ratings on the nominal scale according to formulas (3) and (4) formed as:

$$\text{vij}' = \mu(\text{ij}), \quad (5)$$

where i - the number of the alternative, and j - the index of the value of the quantitative or linguistic scale. Then the sum of ratings for the s-th alternative can calculated by adding the sum of ratings for each j-th question, which are summed for all questions of the i-th block and for all blocks of the questionnaire:

$$r_S = \sum_{S=1}^{n} \sum_{i=1}^{m} \sum_{j=1}^{k} v_{ij}^{'} . \quad (6)$$

As a result, we can automatically generate for the initial set of alternatives A a set of their ranks $R = \{r_1, r_2, \dots, r_n\}$ ordered in descending order to determine the PBA (potentially the best alternative) according to the Condorcet principle [9,10]. The final choice of the best solution is left to the decision-maker (DM). If it is necessary to take into account the importance of a particular criterion (question), it is necessary to enter weight coefficients in formula (6), which can determined by one of the known methods of expert assessments [11,12]. Practical use of this method has shown that its results are identical to the known methods PARK, ORCLASS, etc., but the complexity of the decision-making process of the proposed method is significantly lower.

Example. Optimal choice of construction site for a mega-market.

The expert group proposed the following criteria: price, population density in 1 km radius, presence of competitors, infrastructure connections, the number of places for car Parking, accessibility of the site by public transport and visibility Megastore with the nearest major street. Preliminary analysis has shown that there are four possible places to build a mega-market (alternatives var. 1-var.4). Expert ratings listed in the table.

Table 2.

Expert ratings

x_{ij}	**Alternative** / **Variables**	**var.1.**	**var.2.**	**var.3.**	**var.4.**
x_{1j}	The number of places for car Parking, max	400	300	250	150
x_{2j}	Presence of the competitors, min	1(few)	5 (many)	3(average)	5(many)
x_{3j}	Population density in 1 km radius, max	200	4500	6000	7000
x_{4j}	The cost of the placement, million UAH, min	6	16	12	20
x_{5j}	The flow of public transport, max	1(low)	3(average)	5(high)	7(very high)
x_{6j}	Main street visibility, max	5 (good)	5(good)	3(average)	1(bad)
x_{7j}	Infrastructure, max	3(average)	3(average)	5(good)	7(very good)

Further, using the automated procedure of the "PFPA" method, we get the following estimates of var alternative 1-4, respectively: 3.99; 3.165; 4.13; 3.33. Thus, a potentially better alternative (PBA) is the var. 3.and var. 1. The final decision made by DM.

Conclusion

The activities of urban facilities characterized by a large number of vague restrictions, incompleteness and inaccuracy of source data, and a variety of goals and sub-goals. Therefore, it is advisable to use questionnaires based on a combination of numerical and linguistic scales when constructing the DSS. This article suggested a new method of forming and processing questionnaires of PFPA, in which, based on a system analysis, the questionnaire considered as a linguo-numerical model of the research object. That allows us to determine the optimal composition and level of complexity of the questionnaire on the proposed procedures and present it in a form convenient for automated processing in the DSS.

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