11th International DAAAM Baltic Conference
"INDUSTRIAL ENGINEERING"
20-22 April 2016, Tallinn, Estonia

DELPHI METHOD APPLICATION FOR ENGINEERING

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Abstract: *The authors had the idea to try to use the Delphi method for generating and evaluating projects of roofing. For this purpose questionnaires were prepared and three rounds of investigation were carried out, in which participated 30 experts as the respondents for roof installation projects evaluation. For the research a set of the parameters and sub-parameters to be assessed was selected. This set was formed as the basis from collected and summarized data by the paper's authors. The practice has shown that the Delphi method in engineering field organizers must to have a very good knowledge in the field of survey and to provide the greatest set of the possible parameters as possible. It was found that there is a large difference of the experts' opinion what the parameters should be a priority. In order to evaluate objectively and to select the best roof design, the options have to rely on few experts' opinion and then it is good to use their average evaluation as a basis for possible options selection.*

Key words: Delphi method, decision support system, roofing, engineering

1. INTRODUCTION

For modern engineering activities it is required to develop methods that would enable to generate possible solutions and to select the best appropriate set for the consumer and producer. Delphi method can be used to assess a number of views of the experts from various fields. The authors had the idea to try to use the Delphi method for generating and evaluating projects of roofing.

The goal of the work: to provide a research of the Delphi method application possibilities in the engineering field of the roof installation when for roofing modelling the complex Decision Support System (DSS) can be used.

The subject of research: the Delphi method application for the complex DSS roofing projects evaluation system creation.

2. PROBLEM STATEMENTS

According to the authors, the modern engineering activity must to be related to the DSS application in various fields.

The DSS objective and purpose is to collect, analyse, and visualize the data and processes, after they are submitted for the experts and building customer assessment.

We are looking for purposeful engineering analysis and for the methods to managing creative effort of designing. The analysis must be supported by the evaluation criteria system. To create this evaluation criteria system it is necessary to make study of the evaluation subject, to found option that are important for the customers, engineers designers, builders, and other interested groups of influence.

According to S. Rahman et al. (2012) [1] and A. Spanaki et al. (2011) [2] it can be said, that the work to improve information systems in the field of construction can have a great outcome.

To improve the roofing projects evaluation by the experts the Delphi method was selected. According to A. Marchais-Roubelat and F. Roubelat (2011) [3] the Delphi method is important to give access to specific forms of knowledge and this knowledge may be

characterized according to the type of knowledge sought after, its status, its temporality, and its field of use and the risk of bias that may affect it. The aim is to obtain advice regarding the action to be made within the scope of an aid to decision-making.

In the H. Konu (2015) [4] study the Delphi was implemented in order to develop services by involving the customers in the process. Customer ideas and opinions are used in new product and service development even though it has sometimes been found challenging e.g. by criticising that customers do not necessarily know what they want. Two Delphi rounds were used. The first round was used to collect new ideas for different purposes in new service development and these ideas were then analysed and thematic products/product themes were formed by using narrative analysis. During the second round in the comments related to the thematic products, alternative forms or products were suggested.

According to Đ. T. N. Quyên (2014) [5] the Delhi method stages consist of the Pre-Delphi construction of potential indicators, panel selection and recruitment, data collection and analysis. Data collection and analysis was of three rounds. In Round 1, proposed set of indicators was discussed, in Round 2, experts were asked to rate the level of importance of the indicators using the scale from 0 to 4. Coefficient of Quartile Variation (CQV) was used to measure the level of consensus among ratings and Coefficient of variation (CV = σ/μ) was used to measure the extent to which indicators in a factor vary in weights, in Round 3, the interviews with experts were transcribed, and thematic analysis was applied to analyse the data.

According to L. Yu and K. K. Lai (2011) [6] multi-person multi-criteria group decision making model is composed of six main procedures: to construct the group decision making environment, to select different decision criteria for decision alternative evaluation, to formulate various decision alternatives, to use criteria weight determination methods to determine criteria weights, to give different decision results for every alternative, to aggregate different decision results into a group consensus in terms of the maximum agreement principle. The aggregated group consensus value can be used as a final measurement for the final decision-making purpose.

According to the B. E. Ribeiro and M. A. Quintanilla (2015) [7], participants of Delphi method found it difficult to assess variables and support their opinion in the absence of evidence, and making judgements under briefly described scenarios; the questionnaire was considered to be long and include complex questions, making participation in the survey rather time-demanding; the design of the survey did not allow space for a debate on the positive aspects of the subject.

V. Varho et al. (2016) [8] analysed the preferred and probable future of the small-scale renewable energy in Finland development. They formed the basis for scenario construction. The data analysis was mainly performed with cluster analysis. The statistical analyses were done using IBM SPSS Statistics 21 software. The clustering method uses the dissimilarities or distances between objects when forming the clusters. A hierarchical tree diagram, called a dendrogram on SPSS, showed the linkage points.

In the article of Y. Tang et al. (2014) [9], it was attempted to present a framework to evaluate and compare various technologies among the six links of the solar cells industrial chain. The Delphi method and Analytic Hierarchy Process (AHP) were used to determine the priority and ranks of the target technologies.

According to S. J. Barnes and J. Mattsson (2016) [10] the first phase of a future study would be to build on the current factors to develop an event set that can be used to construct dynamic scenarios. Such dynamic scenarios can be used via a Delphi study to determine the strongest “if then”

relationships between events that might foster either good or bad outcomes, identifying the events that have the strongest negative and positive interactions in bringing about a degree of collaborative consumption (ranging from nothing to everything). By focusing upon very specific subsets, such as cars, we may be able to create a series of specific models that lead to the best understanding for reaching a more comprehensive approach to collaborative consumption.

According to J. Cho and J. Lee (2013) [11] the results of the FAHP method indicated that marketability is predominant criterion for the commercialization of technology products. In particular, market potential, customer needs, profitability, and market competition factors seem to have distinctively higher importance, indicating that they are the key factors for commercializing technology for new products.

According to C. Okoli and S. D. Pawlowski (2004) [12] a Delphi study does not depend on a statistical sample that attempts to be representative of any population. It is a group decision mechanism requiring qualified experts who have deep understanding of the issues. Therefore, one of the most critical requirements is the selection of qualified experts.

J. Curiel-Esparza and J. Canto-Perello (2013) [13] paper presented a methodology based on AHP and Delphi processes for the selection of utilities placement techniques in which the intangibles are also assessed to avoid short-sighted urban underground planning.

3. APPLICATION AREA

The main application area for the research results is engineering activity. The research involved Lithuanian experts of various field to participate in the Delphi method for DSS system elements development and roof installation projects evaluation. The results of the investigation can be useful for DSS in engineering field development and worldwide in generally.

4. RESEARCH COURSE

As the first step the aim of the research was formulated. At the second step the research of the Delphi method application case took place. Third step involved the analysis and evaluation of the obtained data by using an average value method, correlation regression analysis, Kendall's coefficient of concordance and after the analysis adequate conclusions were stated.

5. METHOD USED

The authors had the idea to try to use the Delphi method for generating and evaluating projects of roofing. For this purpose questionnaires were prepared and three rounds of investigation were carried out, in which participated 30 experts as the respondents for roof installation projects evaluation:

1. During the first round of investigation the respondents were asked about the set of parameters and sub-parameters for evaluation and about its evaluation expediency. For this purpose, professionals who are engaged in the design work, roofing installation project owners, and other people who have ideas on the subject, were interviewed.
2. During the second round of investigation the respondents were asked to determine the weights of the parameters for different categories of the projects. Roof installation project categories were divided into the extremes (for very important persons (VIP)), protected by the state, expensive, mid-price, low-cost items, and other types of roof installation projects.
3. During the third round of investigation the respondents were interviewed and the priority positions of the parameters were determined, which was done according to the importance for the successful implementation of roof installation projects and customer satisfaction (respondents

were asked to identify an order sequence number from 1 to 11). The questionnaire was developed in order to harmonize the opinions of the experts. The results were processed using Kendall concordance coefficient.

Kendall's coefficient of concordance KW was calculated as:

$$KW = \frac{12(\sum_{i=1}^{n}(\sum_{k=1}^{m} r_{i,k} - \frac{1}{n}\sum_{i=1}^{n}(\sum_{k=1}^{m} r_{i,k}))^2)}{m^2(n^3 - n)}; (1)$$

where $r_{i,k}$ is given the rank for the object *i* by the judge number k, n – the total number of the objects, and m – the total number of the judges. If the KW is 1, all the survey respondents have assigned the same rank sequence to the list of concerns. If KW is 0, then there is no overall trend of agreement among the respondents.

Estimation of the separate parameters for each possible alternative of the roof installation projects can be accomplished by the formula, converting them into 0 – 100 points system from the 1 – 5 points system:

$$F_{hj} = 100\left(\frac{V_{hj} - \min_F}{\max_F - \min_F}\right); \quad (2)$$

where V_{hj} – evaluation of j parameter for the h project (average points assigned by the experts from 1 to 5), $\max_F$ –maximum points for V_{hj} parameter evaluation (in our case 5 points), $\min_F$ –minimum points for V_{hj} parameter evaluation (in our case 1 point).

The total evaluation for each of the possible roof installation project can be done as a weighted average of the separate parameters evaluated by the experts (the 0 – 100 points system):

$$A_h = \frac{\sum_j W_{hj} F_{hj}}{\sum_j W_{hj}}; \quad (3)$$

where W_{hj} – is the weight of j parameter for the h project (weight of the parameter is positive and common for all valued projects of the selected type of the roof and was assigned as average of 30 respondents answers presented from 1 to 5 points).

6. RESULTS

For the research a set of the parameters and sub-parameters to be assessed was selected. This set was formed as the basis from collected and summarized data by the paper's authors. The field study showed that for solving roof engineering problems the respondents offered only a few additions to the authors proposed parameters and sub-parameters set.

Nevertheless, it was found that in general the average evaluation points of the individual parameters of individual types of projects, evaluated by the experts in various stages of investigation, were correlated. In this regard, in order to evaluate objectively and to select the best roof design, the options have to rely on few experts' opinion and then it is good to use their average evaluation as a basis for possible options selection.

After the analysis of received data and application of the Kendall concordance coefficient calculation methodology it was found that there is a large difference of the experts' opinion what the parameters should be a priority. The concordance rate of 0.14 was obtained when the maximum value is 1.

During Delphi method investigation, roof installation project categories were divided into the extremes, protected by the state, expensive, mid-price, low-cost items, and other types of roof installation projects. The weights (W_{hj}) of the parameters were obtained very different for all of the selected type of the roof installation project categories.

The most differently estimated average values of the parameters weights are presented in the Table 1.

For the individual projects assessment it is necessary, to evaluate in the Table 1 presented parameters, plus estimated project price (Ph) in €, and the compliance with the norms and standards.

Parameters	The weight of parameter for the roof installation projects (W_{hj})	
	Expensive roof installation projects	Low-cost (cheap) roof installation projects
Parameter of geometric properties (j=1)	4,23	3,47
Parameter of aesthetic properties (j=2)	4,5	2,3
Parameter of physical properties (j=3)	4,27	2,97
Parameter of ecological properties (j=4)	3,7	1,87
Parameter of economic properties (j=5)	4,07	4,03
Parameter of durability properties (j=6)	4,27	3,1
Parameter of efficiency properties (j=7)	4	2,8
Parameter of safety properties (j=8)	4,37	3,7
Parameter of warranty for the roof (j=9)	4,2	3,3

Table 1. The average weights of the parameters

After Delphi method results implementation in the DSS, the customer of the roof installation project can view a variety of appropriate options, which have been already evaluated by the experts, and to decide which one to choose. If none of the proposed options satisfies the customer, then the new stage for potential new options generating and evaluation can be implemented.

7. CONCLUSIONS

After examination of the thematic problem of this article the following conclusion were stated:

1. The Delphi method in engineering field organizers must to have a very good knowledge in the field of survey and to provide the greatest set of the possible parameters.
2. The relevance and importance of the surveyed parameters can be evaluated by the experts, but practice showed that the number of the new proposals about parameters set from the experts was limited. Experts only suggest possible additional valuable set of the parameters that will be evaluated in the next round according the Delphi method.
3. After the analysis of received data and application of the Kendall concordance coefficient calculation methodology it was found that there is a large difference of the experts' opinion what the parameters should be a priority. The concordance rate of 0.14 was obtained when the maximum value is 1 (the minimum value is 0).
4. The average evaluation points of the individual parameters of individual types of the projects, evaluated by the experts in various stages of investigation, were correlated. In this regard, in order to evaluate objectively and to select the best roof design, the options have to rely on few experts' opinion and then it is good to use their average evaluation as a basis for possible options selection.
5. Delphi method opens up new possibilities for the development and evaluation of the engineering solutions, but this method requires special knowledge and survey data processing takes quite a

long time, in our case it took two months.
6. Further expert evaluation, after it was established and weighed set of the valuable parameters, can be done by invited three or more experts, to obtain the average ratings.

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