Bidder Multiple Criteria Assessment with Simos Method Use

Michal Krzeminski ¹, Tomasz Wojtkiewicz ²

¹ Warsaw University of Technology, Faculty of Civil Engineering, Al. Armii Ludowej 16, 00-637 Warsaw, Poland
² Military University of Technology, Faculty of Civil Engineering and Geodesy, ul. Gen. Sylwestra Kaliskiego 2, 00-908 Warsaw, Poland

m.krzeminski@il.pw.edu.pl

Abstract. The article presents two important issues. The first was to propose a set of evaluation criteria developed on the PMBOK standard. The authors chose the most appropriate five areas from among the nine highlighted and then on their basis proposed evaluation criteria. The second important element was the development of a method of assessment based on the Simosa method and assumptions of the Entropy method. This approach enabled the modification of the weighting vector in the case when, in one criterion, all variants had the same value assigned.

1. Introduction
Choosing the right contractor is critical to the success of the construction project. In the decision-making process very often we are guided by a multiple criteria assessment. Therefore, to perform this analysis, you must select the evaluation criteria, develop a weighting vector, and select a multi-criteria evaluation method. According to the authors, all these three elements are very important. There are many assessment methods such as the weighted sum method, entropy, Electre, AHP, PROMETHEE. In practice, the weighted sum method is used most often [6]. The reason for this is its simplicity and clarity. This method was chosen by the authors. The study focuses more on the first two elements. The PMBOK (Project Management Body of Knowledge) standards are widely known and used, so it was decided to build a set of assessment criteria precisely based on them. The weighting vector was created by using the Simosa method. In the authors’ opinion, this method allows to partly reduce subjectivity in developing weights vector.

2. Set of chosen criteria
In PMBOK there are nine main areas of knowledge. Project management knowledge areas are: integration, scope, time, cost, quality, human resources, communications, risk and procurement [8]. All of them are strictly dedicated to project management. For construction site management only five can be easily applied. Authors have chosen time, cost, quality, risk and procurement management [7]. On this base their created five criteria. First was time, in meaning the bidder who will give offer that will warranty shortest time of competition of the process. First criterion is measurable and there is no need for creation of assessment scale. Second is cost, is similar to the first in meaning of scale and goal, cheaper equal better. Third is quality, in this case is not as simple as in previous case, first the scale (from 1 to 5) it was assumed that when DM (Decision Maker) give five he recognizes this
company and from previous experience he can say that they can warranty good quality of their products. If assessment is one that means that there is now data about bidder or he doesn’t care about quality. Fourth criterion is risk. Risk is also strongly measurable \([1]\). Authors strongly believes that risk management is one of most important element of project management in construction process. Nowadays when we start using artificial intelligence more often we should collect as much data as we can. Assumed scale is simple binary scale, mark one if there is standardized quality system in company and zero if not. Last criteria is procurement. It should be said that company without supply base will always have problems with accomplishment of four previous criteria \([3]\). Scale is from 1 for 4 and DM decide, if mark is four that means that company is perfectly prepared to the given task \([4]\). What is interesting that if we give scale from 1 to 4 we don’t give space for DM to be undecided, he can’t put three and stay in the middle.

3. Entropy method in multi criteria assessment

The entropy is a thermodynamic parameter of the state of the system. However, in the statistical interpretation, it determines the degree of not ordering the harvest (or the degree of uniqueness). Polish language dictionary, in thermodynamics: the amount equal to the sum of the quotyons of the heat portion taken by the system in a reversible process. In theory of information: measure of indefiniteness, chaotic, degree of disorder. The Entropy method allows estimating the validity of the analysed criteria describing the options in question based on the discrepancies in each \([10]\). In theory, the information was first applied by Claude Shann and later refined by B. McMillana and L. Breiman. Based formula in entropy method is:

\[
E_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \cdot \ln p_{ij}
\]  

(1)

where:

- \( j \) - number of criterion,
- \( i \) - number od assessed variant (from 1 to \( n \)),
- \( p \) - assessment value.

It's easily to find that if all criteria will have the same value of assessment then entropy will equal 1. For weights vector modification we use volatility level \( z \) based on below formula:

\[
z_j = 1 - E_j
\]

(2)

Criteria weights vector is modified by using:

\[
w_j^0 = \frac{x_j}{\sum_{j=1}^{n} x_j} \frac{\tilde{w}_j}{\sum_{j=1}^{n} x_j \tilde{w}_j}
\]

(3)

where:

- \( \tilde{w}_j \) – weights establish by DM,
- \( w_j^0 \) – new weights.

4. Simos method in multi criteria assessment

The original Simos method based of the following three steps \([9]\). First step is that DM gives a set of cards with the name of one criterion and a set of white cards. How much white cards will be given is decision of DM. Next step is that the DM is asked to rank the cards. Cards should be ranked from most to less important, if two cards have the same importance they should be placed in the same line. Last step is to place white cards between cards witch names of criteria. Assumption is that if we put for
example 2 white cards between criteria A and B that means that A is three times more important form us. Base on this we can describe Siomos algorithm in four steps. First is creation of the rank. Create distance between criteria by using white cards. Step three is calculation of non-normalized weights and in last step we calculate normalized weights. Most important card should be placed on the bottom and less important on the top of the table. Below in figure 1 we can see example of use based on previously described criteria.

![Figure 1. Cards order according to Simos method](attachment:image.png)

Below table 1 shows results of calculations done with Simos method use.

| Cards number | Position | Non-normalized weights | Normalized weights |
|--------------|----------|-------------------------|-------------------|
| Procurement  | 1        | 1                       | 0.04              |
| White card   | 1        | 2                       | ...               |
| Quality      | 1        | 3                       | 3                 | 0.12              |
| White card   | 2        | 4;5                     | ...               |
| Risk         | 1        | 6                       | 6                 | 0.22              |
| White card   | 1        | 7                       | ...               |
| Time, Cost   | 2        | 8;9                     | 8.5               | 0.31              |

In the last line of the table we can find two criteria, Authors assumption was that this two criteria are equally important [2]. Time and cost criteria weight is equal 0.31 each.

5. The proposed evaluation procedure
Based on entropy method that allow for modification of weight vector new developed method was developed. Criteria will be choosing and describe in regular way. Based weight vector will be established with Simos method use. For assessment weight sum method was chosen. Modification became from idea of entropy method. For each criterion mark authors recommend to calculate standard deviation according to below formula:
4

\[ s = \sqrt{\frac{\sum_{i=1}^{n}(p_i - \bar{p})^2}{n-1}} \]  

(4)

If standard deviation equal zero authors propose to change weight of this criterion for zero. In opposite to entropy method weight of criteria will be calculated with Simos method but DM will change card of criterion for white card and proceed as follows.

6. Example of use

In table 2 authors collect information about three bidders that get their offers. Presented data is normalized and all criteria are in profit type [5].

Table 2. A slightly more complex table with a narrow caption

|                | Bidder 1 | Bidder 2 | Bidder 3 |
|----------------|----------|----------|----------|
| Time           | 0.83     | 0.87     | 1.00     |
| Cost           | 1.00     | 0.88     | 0.75     |
| Quality        | 0.40     | 0.60     | 0.60     |
| Risk           | 1.00     | 1.00     | 1.00     |
| Procurement    | 0.75     | 1.00     | 0.75     |

As we can find in table in risk criterion all bidder got same mark equal one. If we calculate result with weight sum method with weights value from previous chapter we can find result on below Hasse diagram.

Figure 2. Hasse diagram for based weight vector

New proposal is to modify weight vector. Authors proposal is that if calculated standard deviation for criterion equal zero weight of this criterion should also equal zero and weight vector should be modified with Simos method use. In our case we need to change risk card for white card. New order of cards is presented on figure 3 below.

Figure 3. Cards order according to Simos method with risk card eliminated
Below in table 3 we can find new calculated weight with Simos method use. As we can see the value of Procurement criterion weight doesn’t change. Value of Quality criterion weight rise for about 30 percent. And for time and cost quite similar.

Table 3. Criteria weight calculations with Simos method use

| Cards number | Position | Non-normalized | Normalized weights |
|--------------|----------|----------------|-------------------|
| Procurement  | 1        | 1              | 1                 | 0,04              |
| White card   | 1        | 2              | ...              | ...               |
| Quality      | 1        | 3              | 3                 | 0,16              |
| White card   | 2        | 4;5            | ...              | ...               |
| White (was Risk) | 1 | 6         | ...              | ...               |
| White card   | 1        | 7              | ...              | ...               |
| Time, Cost   | 2        | 8;9            | 8,5               | 0,40              |

Authors made their calculations with new criteria weights and as a result obtain little different Hasse diagram presented on figure 4.

![Figure 4. Hasse diagram for modified weight vector (Simos method)](image)

Hierarchy is different as authors suspect on the beginning. To compare obtained results another approach to weight vector modification has been taken under consideration. Quite popular is that if we eliminate something we should divide eliminated part equally to the rest. In our case we eliminate weight for risk which equal 0,22. Four other criteria stay so we should add to any of them 0,055. Author made their calculation once again and on figure 5 we can see the result

![Figure 5. Hasse diagram for modified weight vector (equality assumption)](image)

In below table 4 authors presents final assessment value that all bidder got in each analysed weight scenario.

Table 4. A slightly more complex table with a narrow caption

| Bidder | Non modified weight vector | Weight vector modified with Simos | Weight vector modified with equality assumption |
|--------|-----------------------------|----------------------------------|-----------------------------------------------|
| Bidder 1 | 87                          | 83                               | 81                                            |
| Bidder 2 | 88                          | 84                               | 83                                            |
| Bidder 3 | 86                          | 83                               | 82                                            |
7. Results and discussions
The three bidder evaluation was conducted using weighted sum method. For assessment has been used five criteria developed on the basis of PMBOK standards. Three various orders were obtained. Each time bidder number 2 was in the first place. The only modification was subordinated to the vector of weights. Given in table 4 point values showed that all the options (in this case bidders) received the similar number of points. It showed how important in this case, the vector of weights is. A small change can greatly affect the result, especially in the case that final decision is guided by Hasse diagram without point table consideration.

8. Conclusions
Presented in the article methodology can be useful in any procedures in which we are supposed to work with the multiple criteria assessment. A common assertion is that in the cases in which is used unmeasurable scale the result is doomed to a lack of objectivity. It is often argued that assessment has too large impact on the line-up by decision maker. The authors have shown that problems can arise at later stages. It is important, to formalize all steps in the analysis of several criteria. It is also necessary to focus on the correct description of the criteria with assessment scale. It is necessary to properly determine the vector of weights; the Simos method can be here very useful. You need to choose the right method for the evaluation of several criteria. Any changes should be clear and annotated. Based on the principles of the method of entropy assumes that you want to change the vector of weights in the case where all the evaluations of this criterion were equal. Authors show two ways of this modification, and it seems that, using the Simos method largely retains the original character vector of weights. As shown in the article, a small change of the weights vector can change the end line-up.

References
[1] H. Anysz, N. Ibadov, Neuro-fuzzy predictions of construction site completion dates, Technical Transactions vol. 6 pp 51-58, 2017.
[2] J. Figueiraa, B Roy, Determining the weights of criteria in the ELECTRE type methods with a revised Simos’ procedure, European Journal of Operational Research vol 139 pp. 317–326, 2017.
[3] N. Ibadov, Contractor selection for construction project, with the use of fuzzy preference relation, Procedia Engineering vol. 111 pp. 317-323, 2015.
[4] N. Ibadov, Determination of the risk factors impact on the construction projects implementation using fuzzy sets theory, Acta Physica Polonica A vol.130 pp 107-111, 2016.
[5] M. Kaftanowicz, M. Krzemiński, Multiple-criteria Analysis of Plasterboard Systems, Procedia Engineering vol 111, pp 364 – 370, 2015.
[6] M. Krzemiński, Comparison of Selected Multi-criteria Assessment Methods, AIP Conference Proceedings vol 1738 pp. 200004, 2016.
[7] M. Krzemiński, Chosen criteria of construction schedule evaluation, Procedia Engineering, vol 153, pp. 345 – 348, 2016.
[8] PMBOK® Guide – Sixth Edition, 2017.
[9] E. Siskos, N. Tsotsolas, Elicitation of criteria importance weights through the Simos method: A robustness concern, European Journal of Operational Research vol. 246 pp. 543–553, 2015.
[10] A. I. H. Syed, U. K. Mandal, Entropy based MCDM approach for Selection of material, National Level Conference on Engineering Problems and Application of mathematics pp.1-7, 2016.