A modified MCDM algorithm with cumulative entropy weights for selecting the winner of the tender

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ABSTRACT
The aim of this research is to evaluate the proposed bids using impartial and entropy weights in a multi-criteria decision-making model. We use matrix data for hypothetical bidding involving nine criteria, with the presence of four domestic and two foreign contractors. Then, using cumulative entropy function, we estimate the entropy weights and use it in a multi-criteria decision-making model. The criteria of experience and knowledge in the field, good history and satisfaction in previous projects, financial and support capabilities, localization of the contractor, having the experience at the site of the project, availability and readiness of equipment and machines, the adequacy of technical staff, the work quality system, the efficient management and appropriate management system, creativity and innovation in similar tasks are the input variables of the decision model. After analyzing them, the proposals are prioritized through a multi-criteria decision-making model. The research findings include Shannon entropy and cumulative entropy-based weights for evaluation criteria and after applying the specific weight for the proposed quotation, the utility rate of each contractor is calculated. The results show that the use of modified multi-dimensional decision-making method is more advantageous than traditional methods of evaluating bidding proposals in selecting the winner of a tender, and also using cumulative entropy weights in comparison with Shannon's leads to a more realistic choice of contractors.

KEYWORDS: MCDM, Entropy, Bidding, Quotation, Reliability.

MSC2010: 90B50, 91B06

FOR CITATION:
Matin A.O., Misagh F. A modified MCDM algorithm with cumulative entropy weights for selecting the winner of the tender. Strategic Decisions and Risk Management. 2019;10(1):46–51. DOI: 10.17747/2618-947X-2019-1-46-51.

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Модифицированный алгоритм MCDM с кумулятивными весами энтропии для выбора победителя тендерна

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АННОТАЦИЯ
Целью данного исследования является оценка предложений с использованием беспристрастных и энтропийных весов в многокритериальной модели принятия решений. Мы используем матричные данные для гипотетических торгов по девяти критериям при наличии четырех отечественных и двух иностранных подрядчиков. Затем, используя кумулятивную функцию энтропии, мы оцениваем веса энтропии и используем их в многокритериальной модели принятия решений. Критерии опыта и знаний в данной области, хорошая история и удовлетворенность предшествующими проектами, финансовые и вспомогательные возможности, адаптивность подрядчика, наличие опыта работы на месте реализации проекта, наличие и готовность оборудования и машин, адекватность технического персонала, система качества работы, эффективное управление и соответствующая система управления, творческий подход и инновации в аналогичных задачах являются входными переменными модели принятия решений. После анализа предложений рассчитывается коэффициент полезности каждого подрядчика. Результаты исследования включают энтропию Шеннона и совокупного веса на основе энтропии для критериев оценки. После применения конкретного веса для каждого предложения рассчитывается коэффициент полезности каждого подрядчика. Результаты показали, что использование модифицированного многокритериального метода принятия решений более эффективно, чем традиционные методы оценки тендерных предложений, а также использование совокупных весов энтропии по сравнению с результатами Шеннона для более реалистичного выбора подрядчиков.

КЛЮЧЕВЫЕ СЛОВА: MCDM, энтропия, торги, критерия, надежность.

ДЛЯ ЦИТИРОВАНИЯ:
Матин А.О., Миясг Ф. Модифицированный алгоритм MCDM с кумулятивными весами энтропии для выбора победителя тендерна. Стратегические решения и управление рисками. 2019. 10(1):46–51. DOI: 10.17747/2618-947X-2019-1-46-51.

1. INTRODUCTION
The evaluation of a bid is considered by the bidder, contractors and the evaluation committee of the proposal. Traditionally, the quote value is used as the indicator of the bidding process, which is not difficult to understand its simplicity. Experience has shown that the winners of the bidding may not have the ability to complete the assigned duties and leave the job halfway. In order to overcome this problem, it is essential that the contractors’ eligibility criteria be considered in the evaluation of the bidding process. In this paper, we present a modified multi-criteria decision-making model with impartial weights of information measures.

Traditionally, multivariate statistical methods are used to evaluate and rank the performances in the financial analysis (Dikosavlaki, Mavrotas, Papayannakis, 1992). These methods are not suitable, due to unrealistic assumptions and their dependence on a single performance criterion, for today’s dynamic business environment.

Data Envelopment Analysis (DEA) (Charnes, Cooper, Rhodes, 1978) has attracted much attention for evaluation and ranking. The evaluation of large commercial banks with multiple inputs and outputs is discussed in (Charnes, Cooper, Sun, et al., 1990) using DEA. It is also shown in (Shannon, 1948) that it can be used to compare various products of various sizes.

Some researchers believe that DEA is more efficient and useful in evaluating companies than common approaches (Smith, 1990). Nevertheless, the primary objective of data envelopment analysis is to identify the existence and abundance of inefficiency and the inactivity of companies and to rank their sub-aspects (Stewart, 1996). In addition, the selection of inputs and outputs that are included in the evaluation process is often confronted with problems (Boussofiane, Dyson, Thanassoulis, 1991).

Recently, multi-criteria analysis or decision making has been widely used in choosing, taking into account several criteria of evaluation, the optimal among available options as well as ranking them. With multi-dimensional characterizations of proposers in tenders, this method provides an efficient framework for comparing them with respect to their various abilities and anticipates their overall performance.

The entropy weights with modified TOPSIS are used to compare and rank companies in (Deng, Chung-Hsing, Robert, 2000). By applying entropy in the decision-making model, the effect of inherent auto-correlation of financial incorporate ranking is reduced. A risk measure based on entropy is introduced in (Yang,
Qiu, 2005) for generating generalized decision-making models. With that risk measure, they have succeeded in solving some problems that cannot be solved with classical models. A dynamic decision model has been introduced in (Wang, Zhan, 2012) for evaluating proposals at auctions, which used Shannon entropy as weights.

The entropy method for determination of weight considers adequately the information of values all the monitoring sections provided to balance the relationship among numerous evaluating factors. This weakens the bad effect of some abnormal values and makes the result of evaluation more accurate and reasonable.

Specific weights are usually recommended to be communicated to national and state organizations.

3. FINDINGS

In this section, we implement the modified multi-criteria decision-making method for a set of six hypothetical proposers. Necessary criteria for evaluation of technical and knowledge ability (the field, executive background), good record and satisfaction in previous work, financial and supportability, availability of ready-made equipment and maintenance, efficient and appropriate management, and the stability, reliability, and efficiency of the technical staff, creativity and innovation in similar work, localization of contractor and experience in the project location are considered for evaluating contractors. These criteria are indicated by the symbols C1, C2, C3, C4, C5, C6, and C7, respectively.

The score of each bidder is executed in accordance with the instructions issued by the government authorities and the bidding committee. In order to support the domestic economy against foreign contractors, in many countries participation between participants is made after a percentage deduction from the rates of foreign contractors. In this research, the foreign companies score is reduced by 10% and then the decision is made.

As pointed out at the end of (2-2), the national and state organizations may announce some specific weights to the criteria in the bidding process. These weights were included in Table 1. Table 2 presents the raw and standardized values of a hypothetical decision matrix. For each proposer, the raw score is in the first row and the standard values are in the last. The values in the table reflect a clear difference between proposals, then the amount of entropy decreases, while the entropy weight should be a large number. Therefore, it is logical to use instead of Hj the calculation weight.

In a problem of reviewing the proposals, the options or participants are already known to decide on them. After determining the criteria, it has to be clear how they will be used to determine the utility of each bidder for winning the tender. In practice, a matrix is formed consisting of proposers and criteria with proposals in rows and criteria in its columns. The decision maker enters in each cell of the matrix consistent numerical value for the quantitative criteria and their respective rank for the qualitative ones.

Each criterion has its own measurement scale and, therefore, it is impossible to compare them with each other. They should be measured in a way independent of the unit in order to be compared. To do this, normalisation method is used. After standardizing each criterion, their relative importance is determined relative to each other. In fact, we are looking to calculate the amount of information, which is estimated by entropy, in each criterion to solve the decision problem.

In the linear method of standardization, first, we reverse the values of each criterion and then divide each value of the column into its maximum. If all of them have a negative aspect, there is no need to calculate the inverse of each of the values, and it is possible (in addition to the previous method) to divide the value of each cell to the maximum value of the column and subtract the yield from one. In the case of reviewing bids, the criteria may be positive (profit) or negative (loss), which is in a non-descending ordered sample of size m, then the largest possible value for Hj is called the uncertainty or the degree of deviation for the j-th criterion, and at last, its entropy weight is obtained from (4).

Table 2 presents the raw and standardized values of a hypothetical decision matrix. For each proposer, the raw score is in the first row and the standard values are in the last. The values in the table reflect a clear difference between proposals, then the amount of entropy decreases, while the entropy weight should be a large number. Therefore, it is logical to use instead of Hj the calculation weight.

### 2.2. CUMULATIVE ENTROPY WEIGHTING

In this section, in analogy with Shannon entropy, empirical cumulative entropy is used to weight the criteria. First, we reverse the entropy estimator that was presented in (Misagh, 2016; Misagh, Yari, Farnoosh, 2011) and (Misagh, 2016; Misagh, Yari, Farnoosh, 2011) for generating generalized decision-making models.

Let Ψj be the maximum value of the j-th criterion to solve the decision problem. In this case, the desirability of each proposal will be increased.

### 2.3. MODIFIED DECISION-MAKING ALGORITHM

Table 2 presents the raw and standardized values of a hypothetical decision matrix. For each proposer, the raw score is in the first row and the standard values are in the last. The values in the table reflect a clear difference between proposals, then the amount of entropy decreases, while the entropy weight should be a large number. Therefore, it is logical to use instead of Hj the calculation weight.
Figure 1. Radar diagram for desirability of proposers

Table 3 Shannon entropy weights

| Entropy-based index | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|---------------------|----|----|----|----|----|----|----|----|----|
| Hf                 | 0.9947 | 0.9981 | 0.9966 | 0.9981 | 0.9989 | 0.9981 | 0.9980 | 0.9982 | 0.9959 |
| d                | 0.0053 | 0.0019 | 0.0034 | 0.0019 | 0.0011 | 0.0019 | 0.0018 | 0.0040 | 0.0057 |
| v0                 | 0.0865 | 0.031927 | 0.0579 | 0.0318 | 0.0314 | 0.0327 | 0.0314 | 0.6742 |

Table 4 Cumulative entropy weights

| Entropy-based index | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|---------------------|----|----|----|----|----|----|----|----|----|
| C0                 | 0.118 | 0.0899 | 0.127 | 0.060 | 0.059 | 0.060 | 0.128 | 0.078 | 0.241 |
| C0.1               | 0.156 | 0.0971 | 0.121 | 0.112 | 0.048 | 0.112 | 0.060 | 0.115 | 0.180 |
| C0.2               | 0.137 | 0.0931 | 0.124 | 0.066 | 0.053 | 0.096 | 0.094 | 0.097 | 0.211 |

Table 5 Final weights for bidding

| Weight | Entropy | I | II | III | IV | V | VI |
|--------|---------|---|----|----|----|---|----|
| C0.2   | Shannon | 0.2628 | 0.0613 | 0.1114 | 0.0611 | 0.0249 | 0.0408 | 0.0206 | 0.0208 | 0.4321 |
| C0.5   | Cumulative | 0.250 | 0.128 | 0.170 | 0.132 | 0.049 | 0.088 | 0.043 | 0.044 | 0.096 |

Table 6 Desirability of proposers

| Weight | Entropy | I | II | III | IV | V | VI |
|--------|---------|---|----|----|----|---|----|
| C0.2   | Shannon | 0.663 | 0.732 | 0.763 | 0.6 | 0.522 | 0.657 |
| C0.5   | Cumulative | 0.7196 | 0.6581 | 0.7148 | 0.6609 | 0.6607 | 0.7013 |

Note: Shannon entropy is a measure of uncertainty or unpredictability in a set of possible outcomes. It is commonly used in information theory and statistics to quantify the amount of information present in a message or a set of data. Shannon entropy is defined as the negative logarithm of the probability of the event, where the logarithm is taken to the base 2 (for information measured in bits).

In conclusion, the use of Shannon entropy in decision-making processes can provide valuable insights into the uncertainty and risk associated with different options. By assigning weights to each criterion based on Shannon entropy, decision-makers can make more informed and objective decisions. This approach can be particularly useful in complex situations where multiple factors need to be considered.

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