# Possibilities of eliminating ineffective alternatives in the multi-criteria selection of counterparties for horizontal cooperation

*Gennady* Brodetskiy[1], *Victoria* Gerami[1], and *Denis* Gusev[1*]

[1]National Research University Higher School of Economics, Russia

**Abstract.** The report presents an approach to the filtration of alternatives when choosing a counterparty for horizontal cooperation based on multiple criteria. Filtration procedures precede the optimization procedures for multi-criteria decisions. The filtration is based on the theory of binary relations and preserves only alternatives-majorants in relation to a strict order according to a given criterion. Presented approach eliminates ineffective alternatives without significant quality degradation of the resulting choice. These procedures are implemented in a numerical example for the following generalized selection criteria: scalar; ideal point; geometric mean.

## 1 Introduction

The development of a new management ideology in Russia is related to the “Fourth stage of the digital revolution” when the principles of the digital economy are laid in the basis of business processes. It will ensure effective interaction of economic entities, as well as optimization of business processes. It will also allow updating the information systems in order to implement the synthesis of technological platform and infrastructure for the digital economy of urban agglomerations. In the design of such developments, a special role should be assigned to modeling and optimization of business processes in supply chains, taking into account the specifics of their transport support, in particular, on the so-called "last mile to the consumer". This also requires optimal cooperation with local transport counterparties for appropriate level of service [2] in conditions of urban agglomerations.

The actual problem of urban agglomeration’s development is the effective organization of horizontal cooperation [1] in the delivery of goods including selection the best counterparty based on multiple criteria. At this stage, one has to face the need to take into account many different competing target indicators (costs, level of service, environmental and social indicators, etc., called “partial criteria’ in theory of choice). In practice this generally requires formalization of multi-criteria problem taking into consideration a large number of alternative solutions. In such situations, procedures for eliminating ineffective alternatives can be of significant help. So new approaches to their formal filtration become important part of multi-criteria decision making.

* Corresponding author: gussev79@mail.ru

# 2 Proposed approach to filtration of alternatives based on a discrete set of decisions

In common global practice multi-criteria problem solution implements the MCDM methodology (multiple criteria decision making). In the case of multi-criteria problems based on a discrete set of decisions, special subsection of this methodology is used - MADM (multiattribute decision making) according to [4]. The types of counterparty selection problems in horizontal cooperation [3] determine the following feature. The analyzed set of alternative solutions in the format of such problems, as a rule, will be discrete. In other words, it will be necessary to choose the best solution among a finite number of analyzed alternatives. When solving multi-criteria problems of this type, one can use the tabular form of presentation of the initial data when setting the problem on a discrete set of solutions. The format of such a presentation is proposed in Table 1.

**Table 1.** Format of input data for multi-criteria problems on a discrete set of solutions.

| **Alter-natives** | **Partial criteria** | | | | | **Selection criterion indicator** |
|---|---|---|---|---|---|---|
| | $C_1$ | … | $C_j$ | … | $C_n$ | |
| $A_1$ | $a_{11}$ | … | $a_{1j}$ | … | $a_{1n}$ | $F_1$ |
| ... | … | … | … | … | … | … |
| $A_i$ | $a_{i1}$ | … | $a_{ij}$ | … | $a_{in}$ | $F_i$ |
| ... | … | … | … | … | … | … |
| $A_m$ | $a_{m1}$ | … | $a_{mj}$ | … | $a_{mn}$ | $F_m$ |
| UT | $u_1$ | … | $u_j$ | … | $u_n$ | |

The table 1 shows that the $i-th$ row of such a matrix contains a set of indicators $a_{i1}$, ..., $a_{ij}$, ... $a_{in}$ for the alternative $A_i$ according to the given partial criteria ($C_1$, ... , $C_j$ , ... , $C_n$ ). In the additional column of such a table, special indicators of the selection criterion ($F_i$ - for alternative $A_i$) are calculated. This requires the implementation of a special sequence of procedures when using a particular selection criterion.

This report proposes an approach to formalizing the appropriate procedure for eliminating ineffective alternatives, which will facilitate the selection of the optimal alternative from a given set of solutions. The filtering procedures for alternatives can be formalized on the basis of the theory of binary relations. Namely, we suggest the use of the relation of strict order and majorants [6]. We present here a simplified and convenient approach that will be used to identify alternatives that are majorants at least according to one of the partial criteria under consideration. The approach is called majority filtration and consists of the following steps.

1. Find the coordinates of a *utopian point* (UT) with the best values for each particular criterion. UT is formalized in table 1 and has following coordinates: $u_1$, …, $u_j$, … $u_n$.

2. For each partial criterion, mark the alternative, for which the value of the particular criterion coincides with the corresponding coordinate of the UT.

3. The marked alternatives are majorants, and only they remain for the implementation of the procedures for further analysis to select the best solution (other alternatives should be considered as ineffective and eliminated).

In other words, with the specified majority filtering procedures, only those alternatives remain that are the best for at least one particular criterion. In practice such restriction may be helpful for *the decision maker* (DM) to obtain formal explanation why some counterparties are not selected.

## 3 Numerical example

Let us consider numerical example of the problem of counterparty selection when it is required to analyze 30 alternatives noted as $A_1$-$A_{30}$ in table 2. Each alternative is a counterparty, which can be chosen for the horizontal cooperation. Only one best alternative needs to be selected by DM taking into consideration the following partial criteria to be maximized (so we note this problem as $C_j \rightarrow$ max, j = 1..4):

$C_1$ – the expected savings caused by cooperation, millions of rubles;
$C_2$ – average % of deliveries in time;
$C_3$ – average % of order fulfillment;
$C_4$ – average % of deliveries without a problem.

**Table 2.** Indicators of partial criteria and marked alternatives-majorants, problem Cj → max.

| Alter-natives | Partial criteria | | | | Alter-natives | Partial criteria | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
| $A_1$ | 8 | 84 | 79 | 97 | $A_{16}$ | 8 | 93 | 88 | 97 |
| $A_2$ | 8 | 83 | 93 | 97 | $A_{17}$ | 8 | 84 | 94 | 96 |
| **$A_3$** | 8 | 93 | 87 | **98** | $A_{18}$ | 8 | 82 | 93 | 97 |
| $A_4$ | 6 | 93 | 92 | 96 | $A_{19}$ | 8 | 93 | 94 | 97 |
| $A_5$ | 9 | 79 | 84 | 97 | $A_{20}$ | 8 | 92 | 97 | 97 |
| $A_6$ | 8 | 83 | 89 | 95 | $A_{21}$ | 8 | 84 | 88 | 97 |
| $A_7$ | 9 | 84 | 79 | 95 | $A_{22}$ | 8 | 85 | 93 | 94 |
| $A_8$ | 9 | 83 | 80 | 97 | $A_{23}$ | 7 | 86 | 94 | 90 |
| **$A_9$** | 7 | **94** | **98** | **98** | $A_{24}$ | 8 | 84 | 91 | 97 |
| $A_{10}$ | 5 | 94 | 93 | 96 | $A_{25}$ | 6 | 87 | 93 | 95 |
| $A_{11}$ | 8 | 92 | 94 | 96 | **$A_{26}$** | 8 | **94** | 94 | 93 |
| $A_{12}$ | 6 | 94 | 93 | 97 | $A_{27}$ | 8 | 82 | 93 | 95 |
| $A_{13}$ | 5 | 93 | 92 | 97 | **$A_{28}$** | **10** | 80 | 88 | 92 |
| $A_{14}$ | 9 | 83 | 84 | 97 | $A_{29}$ | 8 | 87 | 95 | 96 |
| $A_{15}$ | 8 | 84 | 89 | 95 | $A_{30}$ | 8 | 86 | 92 | 95 |

Initial estimates of the analyzed alternatives are presented in Table 2. According to the theory of multi-criteria choice [4], ensuring the quality of decisions made under many criteria requires preliminary implementation of procedures for identifying alternatives that are not

Pareto optimal. It is easy to verify that all considered in Table. 2 alternatives are Pareto optimal.

While analyzing initial data in the table. 2 we find the coordinates of the corresponding UT, which coordinates will be (10; 94; 98; 98). Now let us mark those alternatives for which the values of the particular criteria coincide with the coordinates of the UT. They are easily found and highlighted in Table 2:

for the partial criterion $C_1$ - alternative $A_{28}$;

for the partial criterion $C_2$ - alternative $A_9$;

for the partial criterion $C_3$ - alternative $A_9$;

for the partial criterion $C_4$ - alternatives $A_3$ and $A_9$.

In practice it means that only these candidates for horizontal cooperation are allowed for further consideration. In other words, filtered alternatives have best indicators at least by one particular criterion. The marked alternatives are majorants and all others alternatives should be eliminated. All remaining alternatives are given in table 3.

As you can see in table 3, there has been a significant reduction of the alternatives that remain for the further consideration.

**Table 3.** Alternatives after majority filtration.

| **Alternatives** | **Partial criteria** | | | |
|---|---|---|---|---|
| | **$C_1$** | **$C_2$** | **$C_3$** | **$C_4$** |
| $A_3$ | 8 | 93 | 87 | 98 |
| $A_9$ | 7 | 94 | 98 | 98 |
| $A_{26}$ | 8 | 94 | 94 | 93 |
| $A_{28}$ | 10 | 80 | 88 | 92 |

Let us note that the indicator of the first partial criterion has a value estimate in table 3 but indicators of the other partial criteria are measured as a percentage. In order to avoid the impact of the "phenomena of inadequate choice" [5], it is necessary to use one of the approaches, which will make it possible to correctly use arithmetic operations in the implementation of procedures for a particular selection criterion. At the same time, the approach often used in practice involves the use of generalized data [5], which will be demonstrated below.

The transition to generalized data will require the implementation of the following procedure: it will be necessary to divide each initially given indicator of the alternative by the UT. By the way coordinates of UT are the same because filtration procedure keeps all alternatives with at least one coordinate which is equal to corresponding coordinate of UT. We also note generalized partial criteria as $K_j$, j = 1..4. This is convenient to distinguish initial problem ($C_j \rightarrow$ max) and the generalized one ($K_j \rightarrow$ max).

**Table 4.** Transition to generalized data, problem Kj → max.

| **Alternatives** | **Generalized indicators of partial criteria** | | | |
|---|---|---|---|---|
| | **$K_1$** | **$K_2$** | **$K_3$** | **$K_4$** |
| $A_3$ | 0,80 | 0,99 | 0,89 | 1,00 |
| $A_9$ | 0,70 | 1,00 | 1,00 | 1,00 |
| $A_{26}$ | 0,80 | 1,00 | 0,96 | 0,95 |
| $A_{28}$ | 1,00 | 0,85 | 0,90 | 0,94 |

Now we implement sequence of the optimization procedures according to the following selection criteria: generalized scalar criterion; generalized *ideal point* criterion (IT); generalized geometric mean criterion.

The *generalized scalar selection criterion* provides for the summation of the corresponding generalized indicators of particular criteria for each alternative. In this case, the best would be the alternative with the highest indicator of the selection criterion, which, of course, corresponds to the format of the problem of maximizing all particular criteria.

In addition, we note that the *ideal point criterion* requires finding the smallest distance (in the space of values of particular criteria) from each analyzed alternative to the UT. The alternative with the smallest indicator of the specified distance (among those which are analyzed) is called *the ideal point* (IT). IT is accepted as the best alternative according to this criterion. The distance is equal to the square root of the expression, which is obtained by summing the squares of the differences between each indicator of the considered alternative and the corresponding YT coordinate.

Selection according to the *generalized criterion of the geometric mean* is easy to implement. From the name of this selection criterion, it is clear that it characterizes a multiplicative approach to choosing the best alternative. In this case, it is provided for the determination of the geometric mean value for the analyzed line elements as an indicator of the selection criterion. When maximizing partial criteria, the best one should be recognized as the alternative with the highest such indicator.

Accordingly, the calculation of the corresponding procedures of generalized selection criteria is omitted here. The optimization results for these three selection criteria are shown in table 5.

**Table 5.** Optimization results based on generalized selection criteria.

| **Alternatives** | **Generalized partial criteria** | | | | **Indicators of generalized selection criteria** | | |
|---|---|---|---|---|---|---|---|
| | | | | | **Scalar** | **IT** | **Geometric mean** |
| | **K1** | **K2** | **K3** | **K4** | | | |
| A3 | 0,80 | 0,99 | 0,89 | 1,00 | 3,677 | 0,230 | 0,916 |
| A9 | 0,70 | 1,00 | 1,00 | 1,00 | 3,700 | 0,300 | 0,915 |
| A26 | 0,80 | 1,00 | 0,96 | 0,95 | 3,708 | 0,210 | 0,924 |
| A28 | 1,00 | 0,85 | 0,90 | 0,94 | 3,688 | 0,191 | 0,920 |

Table 5 shows that according to the generalized scalar selection criterion $A_{26}$ is the best alternative. We can easily see it in corresponding column where 3,708 is highlighted. According to the generalized criterion of the geometric mean alternative $A_{26}$ is also chosen, since it has the highest indicator and it is also highlighted in Table 5. At the same time, alternative A28 is located at the smallest distance to UT (in the space of partial criteria), therefore it should be chosen as the best according to the IT criterion.

## 4 Conclusion

In some situations, the proposed approach to filtration significantly reduces the number of the alternatives considered. Such reduction may affect quality of solutions. In presented numerical example (according to the selection criteria implemented) the results are same whether we use filtration procedures or not. That is why eliminated alternatives can be considered ineffective. It is important to note that the result may depend on structure of initial data and optimization sequences of selection criteria. In some cases, the eliminated alternative may still seem to be reasonable for DM and its elimination can have negative impact on quality of resulting solutions. According to the theory of multi-criteria decision making, any Pareto optimal alternative can be chosen. Therefore, we emphasize that such a filtration procedure, of course, must be consistent with the DM’s preferences. The possibilities of practical application of the respective scientific results undoubtedly emphasize the importance of optimizing the choice of a counterparty for horizontal cooperation when managing transport supply in urban agglomerations.

## References

1. M. Bengtsson, S. Kock, *Cooperation and competition in relationships between competitors in business networks*, The Journal of Business and Industrial Marketing, **14(3)**, pp. 178-194 (1999)
2. F.C.A.M Cruijssen, Horizontal cooperation in transport and logistics, (CentER, Tilburg, 2006).
3. J.S. Raue, A. Wieland, *The interplay of different types of governance in horizontal cooperations*, The International Journal of Logistics Management, **26(2)**, pp. 401–423 (2015)
4. G.-H. Tzeng, J.-J. Huang, Multiple Attribute Decision Making: Methods and Applications, (CRC Press, 2011)
5. G.L. Brodetskiy, D.A. Gusev, Effective methods of multicriteria optimization of transport supply: elimination of “Phenomena of inadequate choice”, Intern. Conf on Information technology and innovation in transport, pp. 76-81 (2020)
6. M. Aizerman, F. Aleskerov, *Theory of Choice*, (Elsevier, Amsterdam, 1995)