A R C H I W U M   I N S T Y T U T U   I N Ż Y N I E R I I   L Ą D O W E J
Nr 1 ARCHIVES OF INSTITUTE OF CIVIL ENGINEERING 2007

APPLICATION OF MULTI-CRITERIA OPTIMIZATION METHODS IN CHOOSING MATERIAL SOLUTIONS FOR CONSTRUCTION OF FLEXIBLE STEEL CULVERTS

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Abstract

There are various ways to select material for construction of flexible culverts. Most of the driving force in this process is steered by life – time expectancy. At the same time there's another constraint which is culvert bearing capacity in time related to traffic loads and deterioration progress of culvert itself. Sometime there are considerations related to shape of a culvert with respect to its' hydrology efficiency. All theses parameters are correlated with cost of a culvert. In order to decide which set of parameters is optimal from the prospective of the culvert owner one should incorporate all mentioned parameters and apply a feasible tool to make a choice. Therefore we have a multi-criteria situation where we can apply a scientific method of optimization of choice through selecting options and giving criteria as well as weights for specific criteria. This paper will present a practical approach with use of chosen MCDMM [1] (multi-criteria decision making methods) in selection of flexible structures material.

Key words: flexible culverts, optimization, criteria, decision making, choice, material

1. INTRODUCTION

Generally, in order to make right decisions a substantial amount of knowledge or data is needed in most cases [2,3]. Rather than making decisions based on "gut feeling" or intuition one should apply clear reasoning supporting one's choice. The choice of material used for flexible corrugated steel culverts is based on several criteria:

1. cost of product
2. type of product
3. technical performance or serviceability (conditions of service)
4. life-time expectancy
5. bearing capacity

6. installation cost
7. time of assembly

Within each of the selected criteria several options can be considered and these are very much correlated with each other. For example cost of material is related to its bearing capacity and life-time expectancy through the thickness of steel wall and anti-corrossion protection [4]. Bearing capacity is conditioned to technical conditions of service (depth of cover, loads, etc.). Installation costs are dependant on time of assembly [5,6] and time of assembly is a function of labor consumption directly related to type of flexible structure (structural plates, pipe, shape) and many other factors [5]. As there are several criteria driving the decision making process it is important to apply an appropriate method which incorporates those and helps in making optimal decisions. There are number of multi-criteria-decision making methods that support decision makers in optimal choices, e.g. Electre, Entrophy Method, TOPSIS, they are very well described in many source e.g. [1]. Practical experience show that they can be implemented successfully in the area of buried flexible structures [5,7]. Hererinafter an example of application of TOPSIS method will be presented. The extend of a backfill zone is neglected in the analysis to simplify the picture however it is important to notice that it has a substantial influence on cost of construction.

2. DESCRIPTION OF DEPENDANCY OF CHOICE CRITERIA

As mentioned above the criteria considered in making optimal decisions in selecting material for flexible corrugated culverts are dependant one on another. Figure 1 presents the relations between identified criteria which helps to understand a "cause-effect" relation in making selected decisions. It is visible that some of the dependancies have feedback characteristics e.g. type of material vs. technical conditions of service or type of material vs. bearing capacity. The thick lines indicate most critical relations based on experience coming from daily practice. However it does not mean that those relations and criteria would be selected and prioritized by decision maker in every specific case. The blue lines indicate secondary consequences of considered criteria on other indirectly related criteria. Understanding of overall relations between criteria helps decision maker to adjust weights attributed to those criteria when building a model for selection of optimal decision in chosin material for flexible culvert. The choice can be a fundamental distinction between type of material in terms of corrosion protection system applied on the steel surface or among types of corrugations (or systems) of structures, as well as combination of those two choices.

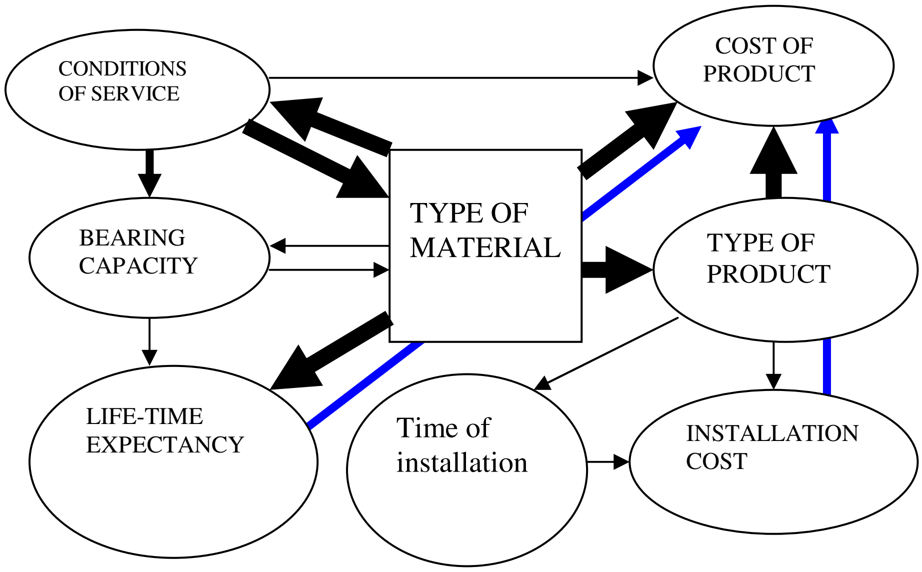

Figure 1. Relations between identified criteria of selection of flexible culvert connection

3. APPLICATION OF TOPSIS SOFTWARE FOR OPTIMAL DECISIONS IN CHOOSING MATERIAL FOR MULTIPLE CRITERIA

As discussed above TOPSIS software is one of tools used to help in making decisions for multi-criteria tasks. In the following example an effort of making optimal decision in chosing material for flexible culvert with different weights of criteria will be presented.

Example.

A designer considers what type of material to use to build a flexbile culvert. The culvert must comply with following technical restricions:

1. Diameter min. 2500 mm, length 15 m
2. Height of cover 0,6 m
3. Load class: A (according to Polish Standard)
4. Average aggressivness of water and abrasion level: slightly aggressive, low
5. Lifetime expectancy: 40 years

The material options he considers are:

1. W1. Galvanized corrugated steel pipe (1000 g/m2 zinc coating), 125*25 mm
2. W2. Galvanized corrugated steel plate structure (1000 g/m2), 200*55 mm
3. W3. Trench coated corrugated steel pipe (600 g/m2 + 300 μm of polymer coating) , 125*25mm

Figure 2. Examples of types of material discussed in the analysis

From statical calculations with a use of Swedish desing method [8] and calculations of lifetime based on [9] following results of thickness of the steel wall are obtained:

1. 3,5 mm
2. 3,0 mm
3. 2,0 mm

Direct costs for 3 considered solutions without costs of assembly:

1. 6200 [EUR]
2. 5700 [EUR]
3. 6800 [EUR]

Labor consumption of assembly [5] :

1. 6 [manh]
2. 33 [manh]
3. 6 [manh]

Time of assembly [5]:

1. 2 h
2. 10 h
3. 2 h

Total overhead daily costs related to traffic restriction costs (society costs) due to assembly duration:

1. 200 [EUR]
2. 2000 [EUR]
3. 200 [EUR]

Criteria:

A decision maker considers at first turn 3 criteria at weight ranked as below:

1. K1. Lowest direct cost, at weight w_1= 0,5.
2. K2. Shortest time of assembly, at weight w_2= 0,3.
3. K3. Lowest society costs, at weight w_4= 0,2.

By setting the highest weight for lowest cost of assembly a decision maker is prioritizing this criterion and it will be the optimization goal.

Subsequently a decision maker considers 3 criteria at different weights ranked as below, which means he has changed his priorities and he seeks optimal solution for lowest society cost as a goal of optimization:

4. K1. Lowest direct cost, at weight w_1= 0,1.
5. K2. Shortest time of assembly, at weight w_2= 0,3.
6. K3. Lowest society costs, at weight w_4= 0,6.

The higher value of w_i the more important criterion.

Model values for 3 options (W1, W2, W3) set at 3 criteria (K1, K2, K3) are presented in table 1.

Table 1. Values of criteria for different material solutions

	K1	K2	K3
W1	6200	2	200
W2	5700	10	2000
W3	6800	2	200

Results obtained from TOPSIS method with use of software developed at Poznan University of Technology in Poland. The first set of results are related to first optimization goal: lowest direct cost of assembly

Allocation of extreme solutions:

A1+=0,045 A1-=0,4956
A2+=0,057 A2-= 0,2887
A3+=0,01980 A3-=0,1980

where,
A_i+ is ideal solution,
A_i- is anti-ideal solution (negative solution).

Calculation of distance from extreme solutions:

L1+=0,4494	L1-=0,2917
L2+=0,2917	L2-=0,14965
L3+=0,087	L3-=0,5285

where,
L_i+ distance from ideal solution
L_i- distance from anti-ideal solution

Calculation of relative distance of specific solutions form the ideal solution K_i (the bigger K_i the better solution):

K_1= 0,3935
K_2= 0,606
K_3= 0,9837

Based on results a preference chain can be described as below:

W3>W2>W1.

It means that for a/m set criteria and assumptions for TOPSIS method option W3 is optimal in respect of goal function. The least optimal solution is W1.

By giving different values of weights of criteria i.e. lowest society cost as a goal of optimization following results are obtained:

K_1= 0,9921
K_2= 0,017
K_3= 0,9828

Based on results a preference chain can be described as below:

W1>W3>W2

It means that for a/m set criteria and assumptions for TOPSIS method option W1 is optimal in respect of goal function. The least optimal solution is W2.

Presented result are in line with another method for seeking best solutions in-terms of cost i.e. Least Cost Analysis [10].

4. CONCLUSIONS

Presented methodology of seeking optimal solutions for choice of flexible culvert material based on multi-criteria decision making show that the optimal solutions may vary depending on optimization goals. It is important to realize that sometimes optimization goals of contractor and customer may vary. For more complex tasks with increased number of evaluation criteria presented methodology may help to optimize decision making.

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ZASTOSOWANIE METOD OPTYMALIZACJI WIELOKRYTERIALNEJ DO WYBORU ROZWIĄZAŃ MATERIAŁOWYCH KONSTRUKCJI PODATNYCH Z BLACH FALISTYCH

Streszczenie

Istnieje wiele sposobów wyboru materiału do budowy konstrukcji z blach falistych. W większości przypadków kryterium wyboru jest ich żywotność. Kolejnym ograniczeniem jest nośność konstrukcji poddanej obciążeniami w okresie użytkowania oraz proces jego degradacji. Niekiedy rozważa się kształt konstrukcji w aspekcie jej zdolności hydraulicznych. Wszystkie te parametry związane są z kosztami konstrukcji z blach falistych. W celu oceny , który zestaw parametrów jest optymalny z punktu widzenia użytkownika konstrukcji z blach falistych, należy użyc je w analizie oraz zastosowań stosowne narzędzie w celu dokonania wyboru. W związku z tym pojawia się sytuacja, w której w obliczu wielu kryteriów doboru możemy zastosować naukową metodę optymalizacji wyboru uwzględniającej wagi przypisane poszczególnym kryteriom. Referat zaprezentuje praktyczne zastosowanie jednej z metod optymalizacji wielokryterialnej [1] przy wyborze materiału do budowy konstrukcji z blach falistych.

Słowa kluczowe: przepust podatny, optymalizacja, kryteria, podejmowanie decyzji, wybór, materiał