TECHNOLOGY SELECTION: A MULTIOBJECTIVE APPROACH

Ardeshir Ahmadi, IHU University,Tehran, Iran
Ardeshir79@yahoo.com

ABSTRACT

The best monorail technology is selected from five alternatives based on seven characteristics. The requirements are considered as the elements of the idea point, and the decision matrix elements are normalized by computing their relative discrepancies from the ideal values. Distance based methods are applied with three different weighted distances. All methods give the same solution, so it can be recommended for implementation.

INTRODUCTION

Technology selection is one of the most important problems for industrial firms. Each technology variant has its own specifications, which have to satisfy the particular needs of the customer. There is usually no technology alternative which meets the requirements exactly, so the alternative with the smallest overall discrepancy between its specifications and the customer's requirements is selected. We can consider this problem as a multiobjective optimization problem when minimizing the discrepancy between each specification and its target value gives the objective functions.

There are many different solution concepts and methods for solving multiobjective programming problems including sequential optimization, ε-constraints, weighting, direction and distance based methods to mention only the most frequently used algorithms. The target values of the different requirements can be considered as the components of the ideal point and the overall discrepancy between the target values and the specifications of the different technology variants is the distance between the ideal point and the alternatives. Therefore distance based methods are the most appropriate methods for such problems. A comprehensive summary of solving multiobjective optimization problems including distance based methods is given for example in Szidarovszky et al. (1986) [1].

In this paper the selection of the most appropriate monorail technology is considered for the city of Qom, Iran. Five technology variants are available to choose from. Distance based methods will be applied to solve this selection problem. Section 2 will summarize the mathematical methodology and Section 3 will outline the particular case study and present the solution. Section 4 concludes the paper.

MATHEMATICAL BACKGROUND

Assume there are *m* alternatives to select from, each of them is characterized by *n* criteria. If a_{ij} denotes the evaluation of alternative *i* with respect to criterion *j*, then this decision problem can be described by the decision matrix (Table 1), in which the rows correspond to the alternatives and the columns to the criteria. Alternative *i* is therefore characterized by an evaluation vector $\underline{a}_i = (a_{i1}, a_{i2,...,}$ $a_{in})^T$. Let a_j^* (*j*=1, 2, …, *n*) denote the ideal (or target) value of criteria *j*, then vector $\underline{a}^* = (a_1^*, a_2^*,...,$ $a_n^*)$ is the ideal point, and the objective is to find the alternative which has the closest evaluation vector to the ideal point.

Table 1. Decision Matrix

Alternatives	Criteria			
	1	2	…	n
1	a_{11}	a_{12}	…	a_{1n}
2	a_{21}	a_{22}	…	a_{2n}
.	.	.	…	.
.	.	.	…	.
.	.	.	…	.
m	a_{m1}	a_{m1}	…	a_{mn}
Ideal values	a_1^*	a_2^*	…	a_n^*
Weights	w_1	w_2	…	w_n

The actual method clearly depends on the definition of the distance between vectors $\underline{a}_i$ and $\underline{a}^*$. If $p \geq 1$ is a given parameter, then the Minkowski distance is defined as

$$\rho_p(\underline{a}_i, \underline{a}^*) = \left\{ \sum_{j=1}^{n} w_j \mid a_j^* - a_{ij} \mid^p \right\}^{\frac{1}{p}}, \tag{1}$$

where w_j is the importance weight of criteria *j*. In practical applications *p*=1, 2 or ∞ is usually selected. The case of *p*=1 corresponds to the possibility of complete compensation between the criteria, $p=\infty$ to no compensation at all, and *p*=2 is used if there are only partial compensation.

The criteria usually represent different characteristics, which are measured in different units, and in addition, their orders of magnitude are usually different. Therefore the criterion with the largest order of magnitude dominates the right hand side of (1). In order to avoid this problem, the evaluation numbers are usually normalized. One way of doing it the introduction of utility functions for all criteria, when $u_j(a_{ij})$ represents the satisfaction level of the value a_{ij} for criteria *j*. These utility functions are normalized into the unit interval [0, 1]. If no utility function is available, then a single normalizing rule

$$\bar{a}_{ij} = \left| \frac{a_i^* - a_{ij}}{a_i^*} \right| \tag{2}$$

is applied, and the $\bar{a}_{ij}$ values replace the original evaluation numbers a_{ij} in the decision matrix. In the special cases of *p*=1, 2 or ∞, we have to minimize the following objective functions:

$$\sum_{j=1}^{n} w_j \left| \bar{a}_{ij} \right|, \tag{3}$$

$$\left\{ \sum_{j=1}^{n} w_j \left| \bar{a}_{ij} \right|^2 \right\}^{\frac{1}{2}} \tag{4}$$

and

$$\max_j \{ w_j \left| \bar{a}_{ij} \right| \} \tag{5}$$

In many applications the geometric distance is selected, and in this case the distance

$$\prod_{j=1}^{n} \left| \bar{a}_{ij} \right|^{w_j} \tag{6}$$

is minimized. Since this distance does not satisfy the usual requirements of distances and it gives minimal value if only one criterion gives the ideal value, regardless of the values of the other criteria, in our case study we will not consider it.

MONORAIL TECHNOLOGY SELECTION

There are five technology variants to choose from: a Japanese (*J*), a German (*G*), a Korean (*K*) and two Chinese alternatives (C_1 and C_2). The German version is a hanging technology with relatively small carrying capacity, and the others are all straddle technologies. The requirements by the Urban Railway Company are based on seven characteristics: length (*L*), width (*W*) and height (*H*) of each car, smallest radius (*R*) a train can turn, passenger capacity (*C*), maximal speed (*S*) and maximal acceleration (*A*). The specifications of the five candidate technologies and the requirements are given in Table 2. There were other characteristics under consideration, but all technology variants meet the related requirements, so they are not considered in our analysis.

Table 2. Specifications and Requirements

Characteristics	*J*	*G*	*K*	C_1	C_2	Requirements
L(*m*)	61	52	54	70	60	52
W(*m*)	3	3.08	2.90	2.90	2.98	2.9
H(*m*)	5.3	5.36	5.176	5.3	5.3	5.6
R(*m*)	100	80	100	60	100	65
C (passenger)	765	207	650	664	784	800
S km/*h*	80	100	60	80	70	80
$A\ km/h^2$	82	88	83	84	84	83

The characteristics are measured in different units, so they cannot be compared directly to each other. The requirements are considered as the components of the ideal point, and in order to have unitless and so comparable elements in the decision matrix the relative discrepancies from the ideal values replace the physical data. Notice that larger speed than the required maximal speed and larger acceleration than the maximal acceleration both meet the requirements, so no discrepancy is considered in these cases. The normalized decision matrix is presented in Table 3, where the last

Table 3. Normalized Decision Matrix

Characteristics	*J*	*G*	*K*	C_1	C_2	Weights
L	0.173	0	0.038	0.346	0.154	6
W	0.034	0.062	0	0	0.028	8
H	0.054	0.043	0.076	0.054	0.054	9
R	0.538	0.231	0.538	0	0.538	15
C	0.055	0.741	0.188	0.170	0.0175	30
S	0	0	0.250	0	0.125	12
A	0.012	0	0	0	0	20

column shows the importance weights of the different characteristics. In the normalized decision matrix the ideal point has zero coordinates, since zero relative discrepancy is the best possible value. We applied objective functions (3), (4) and (5) to solve the technology selection problem. The results are shown in Table 4.

Table 4. Numerical Results

Method	*J*	*G*	*K*	C_1	C_2
(3)	11.756	26.578	17.622	7.662	11.729
(4)	4.650	17.320	6.213	1.612	4.713

(5)	8.07	22.23	8.07	5.10	8.07

The C_1 technology variant shows the smallest weighted average discrepancy by all of the above three methods, so clearly it is the best technology, so it is recommended to the city to implement.

CONCLUSIONS

The best monorail technology was selected from five alternatives based on seven characteristics. Distance based methods were applied with three different distances, where the relative discrepancies from the requirements were the normalized elements of the decision matrix. Three particular weighted distances were used, and in all cases the Chinese technology (C_1) showed the best overall match with the requirements, so it can be recommended for implementation.

REFERENCES

[1] Szidarovszky, F., Gershon, F. M. & Duckstein, L. Techniques of Multiobjective Decision Making in Systems Management. Elsevier, Amsterdam, 1986.