Andrea Furková
Marian Reiff

MULTIPLE SELECTIONS OF ALTERNATIVES UNDER CONSTRAINTS: CASE STUDY OF THE SLOVAK RETAIL MARKET[1]

Abstract: *This paper is given over to an attractiveness assessment of the retail chains operating in Slovakia. Selected multi-attribute decision-making methods are used to analyse customer preferences utilising various criteria. Most of the time retail chains operating in Bratislava City region have been chosen as variants. The application of the PROMETHEE II method has provided us with a complete ranking of the retail chains analyzed and as a consequence of these results, we were able to define customer preferences. Having these results in hand, we proceed to making multiple selections of retail chains under constraints. We decided to employ the PROMETHEE V methodology and binary linear programming model formulation to solve this problem. The main goal of this paper is to exploit the multiple selections of retail chains as support tool for decision making concerning retail chains selection and evaluation from customers' and suppliers' point of view.*

Keywords: *retail attractiveness, optimisation under constraints, PROMETHEE II, PROMETHEE V.*

JEL : C 6, M 2, M 3

Introduction

In Slovakia, grocery retailing is mainly operated by international companies as well as a relatively small number of national supermarket chains. The Slovak grocery retail market is characteristic of its relatively small market size. The increasing concentration of retail outlets is dominated by a small number of mainly internationally controlled brands. It is possible to observe changes in food retailing internationally, as retailers seek to achieve better economies of scale and asset

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utilisation in order to provide consumers with a better service. Consumers consider a range of factors when purchasing food and grocery products [1]; for example, store location, product range and quality, queuing time, opening hours and access to parking. For stores such as supermarkets, price plays an important part in this mix. Numerous approaches have been used to measure service quality and determine consumer store choice behaviour. For example, analysis of grocery stores location reflecting consumer behaviour in the Bratislava Region are conducted in [8], [10], [11]. The evaluation and modelling of customer preferences and service satisfaction have received increased attention in marketing (consumer behaviour) and management science (decision analysis) [5]. Research in these two disciplines is closely related, and different preference models and measurement techniques can be applied to predict consumer preferences and marketing trends. In this paper, we focus on the application of chosen multicriteria decision-making methods in customer preferences and service satisfaction analyses. The first part of our analysis is aimed at assessing the attractiveness of retail stores operating in Slovakia in 2011. We have used the PROMETHEE II method as our methodological tool. With the results acquired, we proceed to the main goal of this paper, i.e. discussing multiple selections of retail chains under constraints. We employ PROMETHEE V methodology and binary linear programming model for our formulations. We make constraint assumptions concerning advertising effectiveness, market share of sales and the numbers of chosen retail stores.

The essential methodological basis for our empirical analysis is discussed briefly in the next part of this paper.

1 Multi-attribute Decision-making Methods

Multicriteria decision-making problems can be divided into certain main groups according to the definition of the feasible set of alternatives. The first is the case when we have a finite number of criteria, but the number of feasible alternatives is infinite (the alternatives being determined by the system of the requirements constraints). These problems belong to the field of multiple criteria optimisation. On the other hand, the type of problem, when the number of criteria and alternatives is finite, and the alternatives are explicitly given, are called multi-attribute decision-making problems (MDMP). The theory of MDMP is very well-established, and the possibilities of real applications (evaluation of investment alternatives, evaluation of the credibility of bank clients, the rating of companies, consumer goods evaluation and many others) are very large. We know relatively many different methods e.g. PROMETHEE, ELECTRE, WSA, TOPSIS (see e.g. [2], [7], [12]).

The multi-attribute decision-making problem is usually defined by a criterion matrix as shown below:

$$\begin{array}{c c} & \begin{array}{cccc} Y_1 & Y_2 & \dots & Y_k \end{array} \\ \begin{array}{c} X_1 \\ X_2 \\ \vdots \\ X_n \end{array} & \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1k} \\ y_{21} & y_{22} & \dots & y_{2k} \\ \vdots & & \ddots & \\ y_{n1} & y_{n2} & \dots & y_{nk} \end{bmatrix} \end{array} \tag{1}$$

where $X_1, X_2, ..., X_n$ is the set of n alternatives,
$Y_1, Y_2, .., Y_k$ is the set of k criterions,
y_{ij} is the criterion value of the alternative X_i, i=1,2,...,n, j=1,2,...,k.

In the matrix, each column belongs to a criterion and each row describes the performance of an alternative, i.e. each element of the matrix y_{ij} is a single numerical value representing the performance of alternative i on criterion j. The essential part of the multi-attribute decision-making problem is setting the type of the criteria (minimization or maximization) and assigning weights to the criteria. The weight w_i reflects the relative importance of the criteria and is assumed to be positive. The weights of the criteria are usually determined on a subjective basis. They represent the opinion of a single decision-maker or synthesize the opinions of a group of experts using a group decision technique as well. The main goal of the multi-attribute decision-making techniques can be complete or partial ranking of alternatives.

Multi-attribute decision-making methods are based either on the Multi-attribute Utility Theory or Outranking Methods [3], [12]. In this paper, we focus on outranking methods. These methods are based on pair-wise outranking assessments and, having determined for each pair of alternatives whether one alternative outranks another, these pair-wise outranking assessments can be combined into a partial or a complete ranking. The most popular families of the outranking method are ELECTRE, TOPISIS or PROMETHEE. In this paper, PROMETHEE II and V are used for our analysis of customers' preferences and also a customers´ preferences model under constraints is presented. The PROMETHEE methods used in our analysis will be briefly outlined in the following section.

The implementation of the PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) method requires knowledge of the criterion matrix *(1)*, weights of the criteria and preference functions of criteria with their parameters for measuring the strength of the preference of the pairs of alternatives with respect to the given criterion. The PROMETHEE method can provide a partial ranking of alternatives (PROMETHEE I) or complete alternative rankings (PROMETHEE II, III). The procedure of the PROMETHEE II method can be summarized as follows. First, the alternatives are compared in pairs for each criterion. The preference for the alternative is expressed by a number from the interval [0,1] (0 for no preference or indifference and 1 for strict preference). The preference function F_i relating the difference in performance to preference is selected by the decision-maker (for more details see e.g. [3], [11]). Next, a multicriteria preference index is formed for each pair of alternatives as a weighted average of the corresponding preferences for each criterion. The index $\pi(X_i, X_j)$ expresses the preference of alternative X_i over alternative X_j considering all criteria and can be defined as:

$$\pi\left(X_i, X_j\right)=\frac{\sum_{i=1}^{k} w_i F_i\left(X_i, X_j\right)}{\sum_{i=1}^{k} w_i} \tag{2}$$

In order to rank the alternatives, the following precedence flows are defined:

Positive outranking flow:

$$\phi^{+}\left(X_i\right)=\frac{1}{n-1}\sum_{j=1}^{k} \pi\left(X_i, X_j\right) \tag{3}$$

Negative outranking flow:

$$\phi^{-}\left(X_i\right)=\frac{1}{n-1}\sum_{j=1}^{k} \pi\left(X_j, X_i\right) \tag{4}$$

The positive outranking flow expresses how much each alternative outranks all the others. The higher the positive outranking flow, the better the alternative and it represents the power of this alternative. The negative outranking flow expresses how much each alternative is outranked by all the others. The smaller the negative flow, the better the alternative, and it represents the weakness of this alternative. The PROMETHEE II method provides a complete ranking of the alternatives according to the net outranking flow which is defined as follows:

$$\phi\left(X_i\right)=\phi^{+}\left(X_i\right)-\phi^{-}\left(X_i\right) \tag{5}$$

All alternatives are now comparable, the alternative with the highest $\phi(X_i)$ can be considered as the best one. The PROMETHEE I method offers a partial ranking based on the comparison of the positive and negative outranking flows (for more details see e.g. [3], [7], [12]).

The PROMETHEE II method is appropriate to select one alternative or when a ranking of alternatives is required. However, in some applications it is necessary to find an optimal selection of several alternatives, given a set of constraints. The PROMETHEE V method extends the PROMETHEE II method to this selection problem, i.e. optimization under constraints. The objective is to maximise the total net outranking flow value of the selected alternatives, at the same time being feasible to the constraints. Binary variables are introduced to represent whether an alternative is selected or not, and integer programming techniques are applied to solve the optimization problem [3], [4].

The PROMETHEE V method procedure can be summarized as follows:

Let $\{X_i, i = 1,2,... n\}$
be the set of possible alternatives and let us associate the following variables to them:

$$x_i = \begin{cases} 1 & \text{if } X_i \text{ is selected,} \\ 0 & \text{if not.} \end{cases} \tag{6}$$

The next two following steps are necessary:

STEP 1: The multicriteria problem is first considered without constraints. The PROMETHEE II ranking is obtained and computed net flows are used in the next step of the procedure.

STEP 2: The following model of linear programming is then considered in order to take into account the additional constraints:

$$\begin{aligned} & \max \left\{ \sum_{i=1}^{n} \phi(X_i) x_i \right\} \\ & \sum_{i=1}^{n} \lambda_{p,i}\, x_i \sim \beta_p \qquad p = 1,2,...,P \\ & x_i \in \{0,1\} \qquad i = 1,2,...,n \end{aligned} \tag{7}$$

where ~ holds for =, ≥ or ≤. The coefficients of the objective function *(7)* are the net outranking flows. The higher the net flow is the better for the alternative. The constraints of this model can include such constraints as, e.g. budget, return, marketing, etc., and they can be related either to all alternatives or to some clusters [4]. After having solved the formulated binary linear programming model, we obtain an alternative or a subset of alternatives satisfying the constraints and providing as much net flow as possible.

2 Empirical Results

The purpose of this paper is to employ multi-attribute decision-making methods in customer preferences and service satisfaction analyses. The PROMETHEE II method discussed above is used to analyse customers´ preferences via different criteria most common retail chains operating in Slovakia in 2011 were chosen as variants. Analysed data are based on customer questionnaires carried out in the Bratislava Region by the Faculty of Commerce (University of Economics in Bratislava) in 2011 [12] and more information about sample can be found in [9]. The variants chosen were the retail chains Albert, Billa, Kaufland, Jednota, and Tesco – Express. The data set has an aggregated form of branches' data from the chosen retail stores. These supermarkets cover about 98% of market share in this region (we dismissed and excluded from our analysis large hypermarkets due to the different sizes of these premises).) Six criteria

(y_1 – y_6) were chosen to express customer preferences and are defined as follows:

- Purchase time of customers – average weekly time spent on purchases in supermarkets (y_1).
- Visits to the supermarkets – customers' willingness to travel to supermarkets by car or by bus – the share of customers willing to travel to the supermarket (y_2).
- Dissatisfaction with the supermarkets – different factors such as prices, lack of service, product range, product quality, purity, opening hours, parking, etc. – the share of customers wishing to improve something (y_3).
- Improvements recorded by customers – the share of customers who recently recorded some improvements in the supermarkets (y_4).
- Advertising – the effectiveness of leaflets – 5-point scale, 1 to 5 points being awarded according to the leaflets' influence – from high to low (y_5).
- Market share of sales – the share of customers according to the questionnaire (y_6).

Tab. 1

Input Data Set

Alternatives	Criteria					
	y_1	y_2	y_3	y_4	y_5	y_6
Albert	127,0968	0,7419	0,7097	0,4839	2,5806	1,7857
Billa	95,9698	0,7350	0,6500	0,4050	3,0850	34,6774
Kaufland	108,1162	0,7305	0,5988	0,4012	2,9581	9,6198
Lidl	106,4020	0,6800	0,6050	0,3300	2,7650	18,0300
Jednota	105,3500	0,7150	0,6750	0,3650	3,1550	31,1060
Tesco – expres	129,3750	0,6250	0,4583	0,2500	3,7500	2,8226
Type of criteria	max	max	min	max	min	max
Preference function	3-linear	2-quasi	1-gener	2-quasi	2-quasi	5-indif
q		0,05		0,04	5	10
p	30					15

Source: customer questionnaire carried out in the Bratislava region by the Faculty of Commerce (University of Economics in Bratislava) in 2011 and own settings

The criteria values are listed in Tab. 1 (Input Data Set). We supposed the same importance of all criteria and all calculations originating from SANNA (System for Analysis of Alternative) [8]. The PROMETHEE II method is based on the principle of evaluating alternatives based on preference relations. The selected preference functions of criteria, with their parameters (preference thresholds – p and indifference thresholds – q) for measuring the strength of preference of the pairs of alternatives with respect to the given criterion, are also given in Tab. 1. Six different types of preference function (see [3], [7]) are proposed in the original PROMETHEE definition. In our analysis, we chose four different types of preference functions for our criteria. Based on this information, and according to our formula *(2)*, multicriteria preference indices were calculated (see Tab. 2). Following the net flow values (see Tab. 2) calculated according to our formulas *(3)*, *(4)* and *(5),* we obtained a complete ranking of retail chains (see Tab. 2).

Tab. 2

Multicriteria preference indices, outranking flows and ranks of alternatives

	Albert	Billa	Kauf-land	Lidl	Jednota	Tesco – expres	$\varphi^+(y^i)$	$\varphi(y^i)$	Alterna-tive rank
Albert	0,00000	0,33333	0,27211	0,44830	0,28748	0,33333	**0,33491**	**0,06572**	**3.**
Billa	0,33333	0,00000	0,16667	0,50000	0,33333	0,50000	**0,36667**	**0,13116**	**1.**
Kaufland	0,16667	0,23415	0,00000	0,50952	0,18203	0,33333	**0,28514**	**0,10710**	**2.**
Lidl	0,33333	0,22462	0,00000	0,00000	0,17251	0,50000	**0,24609**	**-0,12484**	**5.**
Jednota	0,33333	0,05211	0,16667	0,10253	0,00000	0,50000	**0,23093**	**-0,02417**	**4.**
Tesco – expres	0,17932	0,33333	0,28477	0,29429	0,30014	0,00000	**0,27837**	**-0,15496**	**6.**
$\varphi^-(y^i)$	0,26920	0,23551	0,17804	0,37093	0,25510	0,43333			

Source: own

The results of PROMETHEE II are a starting point for the main part of our study, i.e., as a formulation of a binary linear programming model following the PROMETHEE V method. Let us consider the situation when a potential retail investor is about to offer their regional products to existing retail chains. Due to the fact that these regional products are widely in demand, all retail chains are agreeable to cooperating and selling these products. However, our retail investor also has three additional requirements:

- Advertising effectiveness – as a potential retail investor would like to advertise their products in chosen retail chains' leaflets, it is required that the total effectiveness of the chains´ leaflets must be higher than 9 points.
- Market share of sales – it is required that the total number of market share of sales must be higher than 20%.
- Number of retail chains – according to marketing and financial analyses, the retail investor defined that the chosen number of retail chains cannot exceed three.

To make a decision concerning proper retail chain selection, we employ the PROMETHEE V method which enables us to take into account the results of PROMETHEE II (preference ranking of chains) and, at the same time, to take into account defined constraints. The calculated net outranking flows (from Tab. 2) are used as inputs in the objection function of the binary linear programming model formulated in *(7)*. Three constraints of this model are formulated based on defined retail investor requirements and the binary variables represent the retail chains. The model of binary linear programming can be formulated as follows:

$$\max f(\mathbf{x}) = 0{,}06572\,x_1 + 0{,}13116\,x_2 + 0{,}10710\,x_3 - 0{,}12484\,x_4 - 0{,}02417\,x_5 - 0{,}15496\,x_6$$
$$2{,}5806\,x_1 + 3{,}0850\,x_2 + 2{,}9581\,x_3 + 2{,}7650\,x_4 + 3{,}1550\,x_5 + 3{,}7500\,x_6 \geq 9$$
$$1{,}78573\,x_1 + 4{,}6774\,x_2 + 9{,}61981\,x_3 + 8{,}03003\,x_4 + 1{,}1060\,x_5 + 2{,}8226\,x_6 \geq 20$$
$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 \leq 3$$
$$x_i \in \{0;1\} \quad i = 1,2,3,4,5,6$$

The optimal solution and optimal objection function values are:

$$\mathbf{x}^* = (0;1;1;0;1;0) \qquad f(\mathbf{x}^*) = 0{,}21408$$

If retail investors take into consideration the results of the PROMETHEE V method, it is optimal to cooperate with these retail chains: Billa – x_2, Kaufland- x_3 and Jednota – x_5 and this choice respects all the given constraints.

Conclusions

The purpose of this paper was to extend the application of multi-attribute decision-making methods (PROMETHEE II and PROMETHEE V) to customer preferences and service satisfaction analyses. The application of the PROMETHEE II method has provided us with a complete ranking of the retail chains analysed and, as a consequence of these results, we were able to define customer preferences. However, our main aim was to use the PROMETHEE V procedure for a multiple selection of alternatives under constraints. Formulating and solving binary linear programming models following the PROMETHEE V method, we illustrated the problem of retail chain selection under constraints concerning advertising effectiveness, market share of sales and the number of retail chains chosen. The total net outranking flow values were maximised as an objective function.

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