A multicriteria decision method to evaluate local transport service

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Abstract. This paper deals with the use of multiple criteria decision methods to evaluate a number of bus routes operating in the territory of Florence, on the basis of a set of variables describing the effectiveness level of the service.
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1 Introduction

In Italy, legislative decree n. 422/1997 vested regional governments with the responsibility for programming and financing expenditure decisions. The Authority also expressed its preference for a less frequent recourse to the use of public franchise for local transport services in favour of a system of licenses or permits.

Under this law, a partial liberalization of the local public transport market and the renewing of fleet occurred. A number of new companies were born to manage lines pertaining to railway and road transportation.

According to these regulations, the vested organization (Region government) must be provided of a support tool in defining the organizational architecture of the local transport system. Moreover, the regulation of competition allows for achieving greater overall system efficiency, by offering an integrated service (tariff integration included) where multimodality can help in optimizing the use of the system. Hence, at first, it is necessary to set the commercial value of the running programme which is able to satisfy transport demand, on the basis of actual operative conditions.

According to the legislative decree n. 422/1997, in several phase concerning both planning and management of local public transport, it becomes necessary to make evaluations on only a part of the programmed service like the market value of a single transit line, for example, a bus route. In this respect, the paper presents the results of a statistical analysis aimed to provide a performance evaluation of the bus routes operating in the urban and suburban area of Florence.

At the first step, we considered a set of variables describing the level of effectiveness of the services. From the use of the multicriteria decision methods PROMETHEE II (**P**reference **R**anking **O**rganization **METH**od for

Enrichment **E**valuations), it is possible to derive an ordinal indicator for the bus routes. Outranking methods like PROMETHEE are decision support systems but they have also been used to rank alternatives in other kinds of problems. For example, they were used to evaluate the importance of a number of service attributes for the measurement of customer satisfaction [Franceschini and Rossetto, 1997]. In addition, PROMETHEE II is relatively simple in the involvement of criteria importance (weights) and in the computational procedure.

At the second step, we will briefly discuss the possibility to use the ordinal indicator provided by the PROMETHEE with a productivity index (Km./costs) to obtain an overall performance measure of a bus route.

The paper is structured as follows. In the next paragraph, we briefly describe the PROMETHEE approach, an outranking method for multicriteria decision problems. Finally, in the last two paragraphs, the empirical analysis is presented and discussed.

2 PROMETHEE decision methods

Some of the widely developed methods in the field of decision theory include utility theory, outranking methods and the Analytical Hierarchy Process [Gupta and Berger, 1994], [Roy, 1990]. Within these schools of thought there are many alternative approaches which correspond to different classes of problems, or different solution requirements. It is difficult to see how any one of these theories might become the best one, as each has its own advantages and disadvantages.

In this paper, we consider the outranking methods. These methods split the alternatives according to an A *is at least as good as* B hypothesis, and then explore the concordance and discordance using a decision algorithm.

A well known outranking method, that is also very intuitive and easy to use, is PROMETHEE, originally developed by Brans and Vincke [Brans and Vincke, 1985]. PROMETHEE allows a direct use of the data in a simple multicriteria table. Instead of having to perform a large number of comparisons, the decision-maker has to define his own scales of measure (without limitation), to indicate his priorities and his preferences for every criterion (by focusing on value, without having to worry about the method of calculation).

Let us consider two potential alternative A and B, and one evaluation criteria $f(.)$. Each single evaluation is expressed by $f(A), f(B)$ and gives a real number. This criterion may have to be minimized or maximized.

In order to rank the two alternatives, PROMETHEE requests additional information. For the criterion, a specific preference function must be defined. For example, we assume that the preference function *P(A,B)* is such that:

$$P(A,B) = \begin{cases} 0 & if \;\; f(A) \leq f(B) \\ p(f(A) - f(B)) & if \;\; f(A) > f(B) \end{cases} \tag{1}$$

where $P(A,B)$ depends on the difference $f(A)-f(B)$. $p(.)$ is a function such that: if it is zero, A and B are indifferent choices; if it is close to zero, there is a weak preference for A; if it is close to 1, there is a strong preference for A; if the preference function is 1, there is a strict preference for A.

A wide used shape for a preference function is the linear form like, for example:

$$p(x) = \begin{cases} 1 & if \quad x > m \\ x/m & if \quad x \leq m \end{cases} \tag{2}$$

and $x = (f(A)-f(B)) \geq 0, m > 0$.

According with (2), the decision maker progressively prefers A over B for increasing differences $f(A)-f(B)$. The intensity of the preference progressively grows; when $x > m$ there is strict preference for A.

If there are k criteria and therefore k preference functions $p_i(A,B),\ i = 1,...,k$, different weights can be attached to different decision criteria. Such weights represent the importance of the different criteria in decision making.

These weights are used to derive the *outranking* index $\pi(A,B)$ of A over B, which is:

$$\pi(A,B) = \frac{\sum_{i=1}^{k} w_i p_i(A,B)}{\sum_{i=1}^{k} w_i} \tag{3}$$

This index provides a measure of the preference for A on B over all the criteria. As $0 \leq p_i(A,B) \leq 1$, expression (3) will assume values between 0 and 1.

In the case of n alternatives, PROMETHEE method calculates positive and negative preference flows for each alternative. The positive flow of A expresses how much the alternative A is dominating the others; the negative flow expresses how much it is dominated by the other ones. Positive and negative flows for the alternative A are expressed by the following formulas:

$$\phi^+(A) = \sum_b \pi(A,b) \tag{4}$$

$$\phi^-(A) = \sum_b \pi(b,A) \tag{5}$$

where the summation is over b, that is over the alternatives different from A. $\phi^+(A)$ expresses how much A outranks the other alternatives; $\phi^-(A)$ expresses how much the other alternatives outrank A.

The version labelled PROMETHEE II provides a complete ranking of the alternatives on the basis of the net flow:

$$\phi(A) = \phi^+(A) - \phi^-(A) \tag{6}$$

Therefore, we have:

- A outranks B iff $\phi(A) > \phi(B)$
- A and B are indifferent alternatives iff $\phi(A) = \phi(B)$

3 The case study: public transport in Florence

In this paragraph we describe the data used for the analysis and the main features of the Florence public transport system with special reference to ATAF (Azienda Trasporti Area Fiorentina) that is the main service provider.

Public transport in Florence in almost exclusively based on a system of bus routes.

ATAF operates with about 450 buses producing more than 18 million kilometers a year over a total route length of 450 km and serving a population of more than 580,000 units (inhabitants in the Municipality of Florence and other municipalities). Since 2001, some of the original ATAF suburban bus routes have been transferred to a new company (LI.NEA).

The percentage of regular users of ATAF service is about 40% of the served population. Of these, 67.2% are women and only 39.1% are occupied. The total population of bus users is characterized by a large presence of not-occupied individuals. For most of these, bus is the only transportation mean to move within the Florentine territory.

In 2000, a form of ticket integration was introduced for several of transportation providers (ATAF and other bus services, railways). Anyway, the use of train or non ATAF providers within the territory around Florence is rare. There is not an actual intermodal transport as the various transport modes are not efficiently integrated to provide a user-friendly service.

Data for the empirical analysis are derived from three sources.

- *ATAF database.* It provides the most important data related with the structure of the organization, the planned routes and terminals, the network system.
- *ATAF customer satisfaction survey.* It is a yearly CATI survey on the total served population (i.e. the inhabitants of the Municipality of Florence and of the other Municipalities served by ATAF), carried out to monitor mobility behavior. This data source provides information about the importance of some items describing the effectiveness of the service (i.e. the weights for the PROMETHEE analysis).
- *Interview of ATAF management staff.* This source provides information about the weights for the PROMETHEE analysis, from the managers' point of view.

4 The case study: results of the empirical analysis

In this section we describe variables, criteria and preference functions used for ranking a number of bus routes operating in the territory of Florence. We considered 16 bus routes, that resulted the most used (in 2002) from the ATAF customer survey. Moreover, in our analysis, we considered a total of 9 criteria, that cover some features of the transport service. Table 1 describes the data recorded for each route and the related optimality direction. The values related to each of the 16 bus transit lines are derived from internal agency data.

Criteria	Description	Users weights	ATAF weights
C1 min	Network length/N. stops	0.100	0.101
C2 max	N. bus shelters/N. stops	0.100	0.087
C3 max	N. stops with schedule information /N. stops	0.075	0.130
C4 max	N. of produced runs/N. planned runs	0.050	0.072
C5 max	Speed (Km/h)	0.125	0.116
C6 max	N. served municipalities/N. municip.s in the network	0.100	0.087
C7 max	Pollution limitations 0/3)	0.100	0.130
C8 max	Importance for tourism (ordinal 0/3)	0.100	0.130
C9 max	Number of passengers	0.250	0.145

Table 1. Criteria for the decision and related scaled weights

Table 1 shows the weight system adopted. Specifically, we considered two types of weights.

- ATAF weights: they are obtained through an interview to ATAF managers.
- Users' weights: for C1-C8, they are derived from the customer satisfaction survey described above; for C9, ATAF weight is attributed also to users.

We computed the mean of the evaluations (attributed by the respondents on a 10 points scale) about the importance of a number of services characteristics [Zeithaml *et al.*, 1990]. The weights have been proportionally scaled to sum up 1.

The PROMETHEE method also requires the specification of a preference function. In this application we adopted the linear form of the following type:

$$p(x) = \begin{cases} 0 & if \quad x \leq 0 \\ x/R & if \quad x > 0 \end{cases} \tag{7}$$

where R is the variation range of the criterium variable and x is expressed according to the maximization or minimization orientation of the criterion. Note that x/R gives a standardized value as requested by the function $p(x)$ in formula (2).

Before applying PROMETHEE method,we have conducted a principal component analysis (PCA) on the variables involved in the decision problem (Table 1). This analysis is useful to investigate the presence of any conflicting character of the criteria [Brans and Mareschal*et al.*, 1994]. To facilitate the interpretation of PCA results, the sign of C1 (which is *'min'* oriented) has been changed to negative.

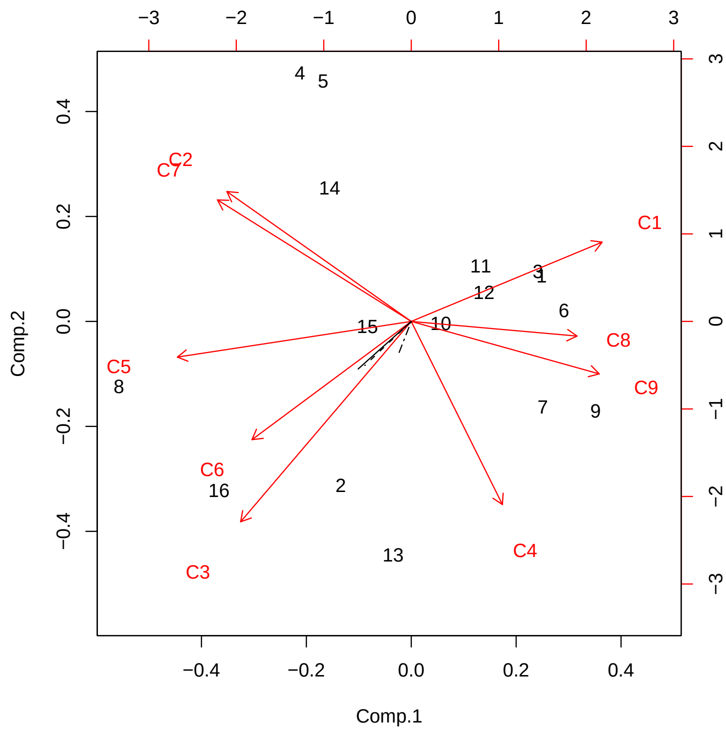

Fig. 1. Biplot from the PCA on criteria data (correlation matrix)

Figure 1 provides an approximate representation of the information related to this problem, because only 60% of the variance is reproduced by the first two principal components [Brans and Mareschal*et al.*, 1994]. We can see that some criteria (lines with arrows)are oriented in the opposite direction. That is the case, for example, of: C1 *vs* C6 and C3, C2 *vs* C7, C5 *vs* C8 and C9. Some cases are easy to be understood. The opposition of C5 against C8 and C9 is determined by the fact that bus routes serving the center of Florence are characterized by a strong importance for tourism (C8), are generally crowded (C9) and travel at a lower speed (C5). Viceversa occurs for buses travelling in suburban areas. The numbers in the figure label the 16 bus routes.

In a situation like the one represented in the biplot, the results of a multicriteria decision method could be quite sensitive to the weight system. Figure 1 shows also the projection of weights (dot-dash line: users weights, dashed line: equal weights, solid line: ATAF weights; the last two are partially overlayed). In the case of a decision problem, one should look at the alternatives located in the direction of the weights [Brans and Mareschal*et al.*, 1994].

In the case investigated in the paper, the projection of weights can give an approximate idea (because only 60% of variance is absorbed by the two components) of the compromise resulting in the ranking process and can allow a comparison among different systems of weights. We can see, for example, that Ataf and users weights are oriented almost in the same direction.

Table 2 contains the rank of the 16 bus routes, obtained through the application of PROMETHEE II method with, respectively: equal weights, users' weights and ATAF weights.

Table 2 contains also a label indicating the type of bus transit line: R means *radial* route, that links the center of the town with suburban sites; L indicates *longitudinal* suburban bus route, that links opposite suburban sites (for example, West-East, North-South, etc.). The radial routes are placed, on the average, at better rank position than longitudinal routes (mean rank larger than 9 *vs.* 7 of the longitudinal transit lines).

Though the presence of some conflicting character among the 9 criteria, the ranking obtained through different weights are similar. In fact, the rank correlation coefficient is 0.85, 0.88, 0.91 respectively for equal weights *vs* users' weights rankings, equal weights *vs* ATAF weights rankings, ATAF weights *vs* users' weights rankings.

Bus		Ranks			PCA	
lines	Type	Equal weights	Users weights	ATAF weights	Scores	Rank
1	L	10	9	10	0.5792	11
2	L	9	12	9	0,1447	9
3	L	13	13	13	1,2099	13
4	L	11	11	11	0,4738	10
5	R	12	10	12	-0,1094	8
6	L	14	14	14	1,6911	15
7	L	5	2	5	-0,4845	6
8	R	4	6	4	-1,8037	2
9	L	7	5	6	-0,6073	5
10	L	15	16	16	1,4800	14
11	R	16	15	15	1,9793	16
12	L	3	1	3	-1,3787	4
13	R	8	7	7	-0,4356	7
14	R	2	3	2	-1,5765	3
15	R	6	8	8	1,0921	12
16	R	1	4	1	-2,2546	1

L: longitudinal R: radial

Table 2. Results of PROMETHEE II method and subsequent PCA

In order to estimate the market value of a bus route, the effectiveness measure obtained through the PROMETHEE method is not sufficient because also economic features must be considered. In this respect, we have investigated the relationship between PROMETHEE ranks and the productivity indicator Km/costs, that is available for each bus route. If we consider PROMETHEE ranks as a quantitative variable and by using a negative sign for the variable km/costs (so that it is oriented in the same direction of PROMETHEE ranks), the correlation is 0.716. In this case, a scalar performance measure could be obtained through PCA. The first component absorbs more than 90% of variance and can summarize the effectiveness and productivity indicators. Table 2 shows the scores and the related ranks obtained from PCA.

5 Concluding remarks

The customer and user oriented approach requires the monitoring and measure of service's effectiveness. In this paper, effectiveness of bus routes operating in the territory of Florence is based on information derived from a customer satisfaction survey and internal agency data. A multicriteria decision approach (the PROMETHEE outranking method) has been used to derive a rank ordering of the different bus routes.

This ranking, together with a measure of productivity, has been used to provide a measure of overall performance for the bus routes. Of course, the use of PCA is only a compromise solution.

The empirical analysis here carried out shows a possible use of customer survey data and internal data in order to estimate the market value of the service. In particular, the PROMETHEE method could be a way to synthesize indicators of different nature and importance.

References

[Brans and Mareschal*et al.*, 1994]Brans J.P., B. Mareschal (1994), "PROMCALC & GAIA: A new decision support system for multicriteria decision aid", *Decision Support Systems*, 12, 297-310.

[Brans and Vincke, 1985]Brans J.P., P. Vincke (1985), "A preference ranking organization method: the Promethee method for multiple criteria decision making", *Management Science*, 31.6, 647-656.

[Franceschini and Rossetto, 1997]Franceschini F., S. Rossetto (1997), "La valutazione e il controllo in linea della qualita' dei servizi", *De Qualitate*, 1, 43-57.

[Gupta and Berger, 1994]Gupta S.S., J.O. Berger (1994), *Statistical decision theory and related topics*, Springer Verlag.

[Mareschal, 1988]Mareschal B. (1988), *Weight stability interval in multicriterion decision making*, the MIT Press.

[Roy, 1990]Roy, B. (1990), "Decision Aid and Decision Making", *European Journal of Operaitonal Research*, 45, 324-331.

[Zeithaml *et al.*, 1990]Zeithaml V.A., A.Parasuraman, L.L.Berry (1990), *Delivering Quality Service - Balancing Customer Perceptions and Expectations*, The Free Press.