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Review of PROMETHEE method in transportation

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Abstract
In recent decades, decision support system has been constantly growing in the field of transportation planning. PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) method is an efficient decision-making support deployed in case of a finite number of criteria. It provides a partial ranking through PROMETHEE I and a complete ranking with PROMETHEE II. This outranking methodology is characterized by the elimination of scale effects between criteria and managing incomparability with the comprehensive ranking. However, PROMETHEE does not provide guidance to assign weights to criteria and assumes that decision makers are able to allocate weights. This review presents an overview of PROMETHEE models applied in transportation and points out the found gaps in literature.

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1. Introduction

The complexity of decision-making process depends on the number of criteria and alternatives considered in the evaluation. However, there are some techniques that support decision makers in choosing optimal solutions. Multi Criteria Decision Aid (MCDA) methods provide a wide range of techniques to solve complex problems, thus, it has been significantly used in different fields. Analytical Hierarchy Process (AHP), Techniques for Order preference by Similarity to Ideal Solution (TOPSIS), Multi Attribute Utility Theory (MAUT) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) are popular MCDA methods that rank alternatives depending on decision makers' preferences. Evidently, a good or a bad MCDA method does not exist, each has its advantages, and the choice depends only on the nature of the problem to be solved (Tsamboulas, 2007).

The family of PROMETHEE (Prefernce Ranking Organization METHod for enrichment evaluation) is an outranking method that aims at the evaluation of criteria in a qualitative and quantitative way, it is characterized by three pillars: the enrichment of the preference structure involving different preference functions, the enrichment of the dominance relation between alternatives for each criterion, and the decision aiding after the partial and complete ranking. Six major preference functions can be used depending on criteria characteristics (Brans et al., 1986), these preference functions withdraw criteria scaling effect which is one of the main advantages of this method. Decision makers can define the type of preference function and the thresholds values for each criterion from their perspectives, the overall evaluation is computed in the stage of the comprehensive net flow Φ.

This paper highlights PROMETHEE's (I&II) applications in transportation, as well as its contributions to cope with its drawbacks and come up with new models to improve public transportation service quality in future research.

In the next section 2, a comprehensive literature review is discussed. PROMETHEE method is presented in section 3, while discussion and conclusions in sections 4 and 5.

2. Literature review

Decision support models consider several criteria to determine the optimum solution, outranking methods such as PROMETHEE and ELECTRE are also used to support decision makers in solving complex problems through simple procedures. PROMETHEE was first developed by Brans in 1982 and then extended by Vencke and Brans in 1985. So far, there exist six extensions of PROMETHEE (Arcidiacono and Greco, 2018). PROMETHEE I and II provide respectively the partial and the comprehensive ranking, PROMETHEE III defines a complete interval ranking through the allocation of an interval to each alternative, PROMETHEE IV is specifically dealing with a continuous infinity of alternatives, PROMETHEE V is used in the case of grouped alternatives for clustering and segmentation, PROMETHEE VI handles the case of interval weights assigned to criteria instead of an exact value.

PROMETHEE has been combined with different weighing methods such as AHP and Entropy, for the aim of coping with criteria's weights allocation and strengthening the model, (Macharis et al., 2004) (Balali et al., 2014). Moreover, (Fernández-Castro and Jiménez, 2005), constructed a consensual model by deploying PROMETHEE I, II, III and V to evaluate 12 alternatives according to five criteria while PROMETHEE V was utilized to determine constraints to take into consideration in applying PROMETHEE II. However, to serve transport policy makers, (Balali et al., 2014) outrank structural systems, construction method and materials to build a Kashkhan bridge in Iran, preference functions and criteria's weights were chosen and evaluated by experts. The authors of (Turcksin et al., 2011) used the Analytical Hierarchy Process method to assign weights based on pairwise comparison between criteria, and PROMETHEE to outrank the appropriate policy scenario from three potential scenarios. (Brans and Mareschal, 1994), deployed PROMETHEE (I& II) to rank potential sites in Europe for a North American Company based on five criteria, PROMETHEE V was applied by adding six constraints to outrank the appropriate distribution centers that improve network's performance and minimize transportation activities between sites. (Elevli and Demirci, 2004) deployed PROMETHEE method for the selection of the suitable firm areas for new distribution centers for a company in Belgium, five underground ore transport system of a Turkish mine have been outranked with respect to six predefined criteria using PROMETHEE I and II.

Concerning the mobility and road safety, a study has been held to evaluate the performance of elderly drivers and outrank them using PROMETHEE as a MCDA approach with composite indicators, because of the direct impact of drivers on the transportation and the ratio of traffic accidents (Babaee et al., 2015). PROMETHEE suffers from rank reversal drawback, which is the possibility of changing alternatives ranking in case of adding or deleting a criterion or an action, (Ishizaka and Resce, 2020) avoided this problem by using Best-Worst method. Furthermore, this approach reduces the number of pairwise comparison between actions and minimize the efforts made by evaluators.

Group PROMETHEE decision making models enable problems evaluation by a group of decision makers, it is a consensual concept that takes into consideration different perspectives, for the aim of developing a compromise ranking..(Macharis et al., 1998), highlighted the first contribution in the literature in group decision making using (Group Decision Support System) GDSS-PROMETHEE method, the aggregation of different opinions has been introduced with two approaches. The first is aggregating the arithmetic mean of the computed net flows for each alternative $\phi(a_i)$, $i = 1, \dots, n,$ (n is number of alternatives). The second approach is constructing a global evaluation matrix of alternatives and decision makers and compute new net flows of the global ranking, this approach serves in defining a compromise in the case of diverse evaluations of decision makers Furthermore. Fuzzy PROMETHEE also results beneficial outcomes in building group decision support models. it involves several decision makers' opinions in order to aggregate divergent judgements, fuzzy values define the vagueness of evaluations between decision makers (Lolli et al., 2016).

Geometric Analysis for Interactive Aid (GAIA) plane is a useful graphical tool that transform ordinal values to graphical output for decision-making problems, it shows the interaction between criteria, alternatives, and decision axis, this latter indicates the direction of optimum solution. The alternatives in the same side and close to the decision axis have good ranking and present optimum solutions. in GAIA plane conflicting criteria are pointing in opposite directions, while the ones having similar preferences are in same direction (Gunawardena et al., 2015). Decision makers can make modifications on criteria's weights and get immediately the results of the new ranking of PROMETHEE II by using the feature of the walking weight (Brans and Mareschal, 1994). It also defines stability intervals in which the ranking stays the same as long as the values did not exceed interval bounds. Sensitivity analysis is crucial to understanding the impact of changing weights on complete ranking (Anagnostopoulos et al., 2003; Wang and Yang, 2006; Kabir and Sumi, 2015).

3. Method description

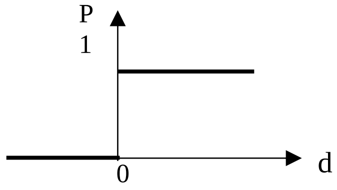
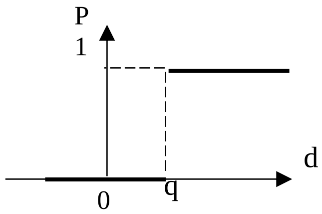
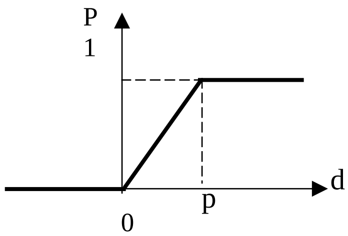
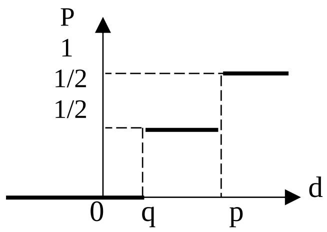
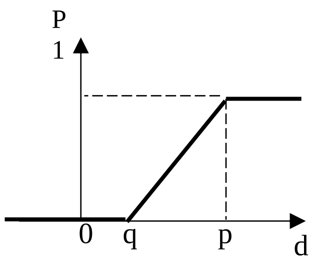
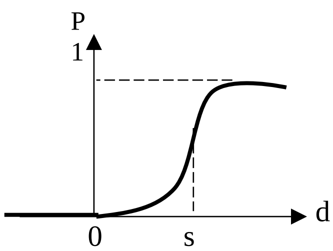
3.1. PROMETHEE Method

Decision makers choose MCDA methods in function of the nature of the problem, the outranking PROMETHEE method provides a practical procedure to evaluate complex problems, through the partial and comprehensive ranking. PROMETHEE method does not guide evaluators to assign weight to criteria, it assumes that decision makers are able to weigh the criteria(Wang and Yang, 2006). For the aim to strength the model, combining PROMETHEE with weighing methods is recommended such as AHP, Entropy, SMART weighing and Simos procedure.

PROMETHEE requires defining preference function of each criterion, the choice between six preference functions depends on the decision maker, who has to define the preference or the indifference thresholds. (Table 1) shows preference functions characteristics.

Let $G = \{g1, .. gj \dots, gm\}$ be a set of m criteria;
$j = 1, \dots \dots m$; $A = \{a1, .. ai \dots, an\}$ is the set of n alternatives; $i = 1, \dots . n$
$g_1(a_1)$ is the evaluation of the alternative a_1 according to criterion g_1

Table 1. PROMETHEE preference functions

Preference function	Definition	Parameters
	Type I: Usual Criterion $P(d) = \begin{cases} 0 \text{ if } & d \leq 0 \\ 1 \text{ if } & d > 0 \end{cases}$	--
	Type II: U-shape criterion $P(d) = \begin{cases} 0 \text{ if } & d \leq q \\ 1 \text{ if } & d > q \end{cases}$	q
	Type III: V-shape criterion $P(d) = \begin{cases} 0 & \text{if } \quad d \leq 0 \\ d/p & \text{if } \quad 0 < d \leq p \\ 1 & \text{if } \quad d > p \end{cases}$	p
	Type IV: Level criterion $P(d) = \begin{cases} 0 & \text{if } \quad d \leq q \\ 1/2 & \text{if } \quad q < d \leq p \\ 1 & \text{if } \quad d > p \end{cases}$	p,q
	Type V: V-shape with indifference preference $P(d) = \begin{cases} 0 & \text{if } \quad d \leq q \\ \frac{d-q}{p-q} & \text{if } \quad q < d \leq p \\ 1 & \text{if } \quad d > p \end{cases}$	p,q
	Type VI: Gaussian criterion $P(d) = \begin{cases} 0 & \text{if } \quad d \leq 0 \\ 1 - e^{\frac{-d^2}{2s^2}} & d > 0 \end{cases}$	s

The pairwise comparison between alternatives is necessary to outrank the alternatives, the amplitude of deviation between two alternatives is computed as follows:

$$dj(ai, ai') = gj(ai) - gj(ai') \quad (1)$$

The preference between two alternatives:
In the case of maximized criterion

$$Pj(ai, ai') = Fj[dj(ai, ai')] \quad (2)$$

In the case of minimized criterion

$$Pj(ai, ai') = Fj[-dj(ai, ai')] \quad (3)$$

The preference value P belongs to [0,1]

$$0 \leq P(ai, ai') \leq 1 \; ; \; \forall \; ai, ai' \in A \quad (4)$$

3.1.1. PROMETHEE I

PROMETHEE (I) comes up with partial ranking by determining the leaving and the entering flows φ+ and φ-. Given positive weights to m defined criteria (w_1,…..w_m) such that $\sum_{j=1}^{m} wj = 1$.
The comprehensive preference of a_i over $a_{i'}$ is computed as follows:

$$\pi(ai, ai') = \sum_{j=1}^{m} Pj(ai, ai') * wj \quad (5)$$

The positive flow

$$\varphi^{+}(ai) = \frac{1}{n-1} \sum_{ai' \epsilon A-\{ai\}} \pi(ai, ai') \quad (6)$$

The negative flow

$$\varphi^{-}(ai) = \frac{1}{n-1} \sum_{ai' \epsilon A-\{ai\}} \pi(ai', ai) \quad (7)$$

The leaving flow φ+ and entering flow φ- allow partial ranking of the alternatives without any loss of information. The Preference (P), Indifference (I) and Incomparability (R) relations are assessed if and only if the followed equations are verified:
ai is preferred over ai' ($aiP^{I}ai'$)

$$\begin{aligned} &\varphi^{+}(ai) > \varphi^{+}(ai') \; and \; \varphi^{-}(ai) < \varphi^{-}(ai') \text{ or} \\ &\varphi^{+}(ai) > \varphi^{+}(ai') \; and \; \varphi^{-}(ai) = \varphi^{-}(ai') \text{ or} \\ &\varphi^{+}(ai) = \varphi^{+}(ai') \quad and \; \varphi^{-}(ai) < \varphi^{-}(ai') \end{aligned} \quad (8)$$

ai and ai' are indifferent ($aiI^{I}ai'$)

$$\varphi^{+}(ai) = \varphi^{+}(ai') \; and \; \varphi^{-}(ai) = \varphi^{-}(ai') \quad (9)$$

ai and ai' are incomparable ($aiR^{I}ai'$)

$$\begin{aligned} &\varphi^{+}(ai) > \varphi^{+}(ai') \; and \; \varphi^{-}(ai) > \varphi^{-}(ai') \text{ or} \\ &\varphi^{+}(ai) < \varphi^{+}(ai') \; and \; \varphi^{-}(ai) < \varphi^{-}(ai') \end{aligned} \quad (10)$$

3.1.2. PROMETHEE II

The comprehensive ranking is important in the case of detecting incomparability between criteria, it equals the difference between leaving and entering flow.

$$\Phi\,(ai) = \varphi^{+}(ai) - \varphi^{-}(ai) \quad (11)$$

The higher the net flow ϕ(ai), the better the alternative is performing. Only two relations between alternatives are concluded for the comprehensive flow, which are preference and indifference relations.
ai is preferred ai' ($aiP^{II}ai'$)

$$\Phi(ai) > \Phi(ai') \quad (12)$$

ai and ai' are indifferent ($aiI^{II}ai'$)

$$\Phi(ai) = \Phi(ai') \quad (13)$$

The value of the net flow belongs to [-1,1] interval and the sum of the net flows computed in a problem equals to 0, because the amount of entering flows is the same as the leaving flows.

$$-1 \leq \Phi(ai) \leq 1 \quad (14)$$

3.1.3. GAIA Plane

Geometric Analysis fo Interaction Aid (GAIA) allows the visualization of the cardinal solution and eases the understanding of interaction between criteria. the attributes in the same direction have the same performance and the alternatives (criteria) pointing in opposite directions are called conflicting alternatives (criteria). The decision axis shows the direction of optimum solution of the problem, the attributes in the same direction and length with this axis have good performance (Dağdeviren, 2008; Bagherikahvarin and De Smet, 2017). Results are evaluated with sensitivity analysis. By changing criteria's weights the direction of decision axis may change while alternatives and criteria keep the same position (Kabir and Sumi, 2014; Ishizaka et al., 2020).

4. Discussion

Making decisions is a very frequent activity which could be easy to make with limited number of attributes. However, by increasing the number of criteria and alternatives, building a consensual model to find the best solution becomes necessary. PROMETHEE has advantages to solve complex problems, it is very known with its specific characteristics and clearness, it requires only important information that is easy to determine by evaluators, this is the reason behind its development in different domains. PROMETHEE is a beneficial method because of its major strong points in eliminating scaling effects between criteria and its simplicity for mathematical calculations outranking alternatives. However, it omits guidance to define weights to criteria considering that decision makers can assign weights, in addition of rank reversal problems in the case of adding new criteria or alternatives to the model, in addition, interaction and mutual influence between criteria are not ensured in PROMETHEE as long as the complexity to get a clear vision in case of a huge number of criteria (Brans and De Smet, 2016). These disadvantages can be overcome by constructing hybrid models to strength PROMETHEE; such as creating hierarchical structures for criteria vis-à-vis alternatives, and involve Choquet Integral to study mutual influence between criteria for robust results (Arcidiacono and Greco, 2018). After reviewing the literature and pointing out the gaps, it is important to highlight that PROMETHEE models were not applied in public transportation problems and the assessment of the service quality of transportation modes. However, other MCDA methods such as AHP, TOPSIS were used to evaluate public transportation and supply quality to construct a support system to identify the most significant attributes from the perspective of citizens and stakeholders (Alkharabsheh, Moslem and Duleba, 2019; Moslem et al., 2019). Nowadays governments' strategies aim to encourage non-users of public transport to switch from using private transport to shared modes for environmental, financial and traffic congestion reasons (Bilişik et al., 2013; Hensher, Ho and Reck, 2021; Zuo et al., 2018), besides the success of public transport that is measured by the ability to attract high number of passengers and meeting their expectations (Shen, Xiao and Wang, 2016; van Lierop and El-Geneidy, 2016).

5. Conclusion

This paper presents an overview of significant contributions in literature related to the application of PROMETHEE method in transportation. To the best of our knowledge, PROMETHEE has not been deployed in the evaluation and the assesemnt of public transport network. This exclusion presents a large number of potential researches which can bring advantages of solutions to improve public transportation, especially, service quality that impacts citizens behavior toward public transports.

Shedding light on PROMETHEE applications in transportation field only, can be considered as limitation of this paper. However, the application of this method in other fields have proven significant results and MCDA method stretghning.

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PROMETHEE 方法在运输中的应用

關鍵詞
义卖
MCDA
GAIA 飞机
运输

摘要
近几十年来，决策支持系统在运输计划领域一直在不断发展。 PROMETHEE（用于富裕度评估的偏好排名组织方法）方法是一种有效的决策支持，在有限数量的条件下易于部署，它通过 PROMETHEE I 提供了部分排名，并通过 PROMETHEE II 提供了完整排名。 这种排名方法的特点是消除了标准之间的规模效应，并通过综合排名来管理不可比性。 但是，PROMETHEE 不提供指导为标准分配权重，并且假定决策者能够分配权重。 这篇综述可以概述在运输中应用的 PROMETHEE 模型，并指出在文献中发现的空白。