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# Selection of adequate site location during early stages of construction project management: A multi-criteria decision analysis approach

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**Abstract.** In the management of construction projects special attention should be given to the planning as the most important phase of decision-making process. Quality decision-making based on adequate and comprehensive collaboration of all involved stakeholders is crucial in project's early stages. Fundamental reasons for existence of this problem arise from: specific conditions of construction industry (final products are inseparable from the location i.e. location has a strong influence of building design and its structural characteristics as well as technology which will be used during construction), investors' desires and attitudes, and influence of socio-economic and environment aspects. Considering all mentioned reasons one can conclude that selection of adequate construction site location for future investment is complex, low structured and multi-criteria problem. To take into account all the dimensions, the proposed model for selection of adequate site location is devised. The model is based on AHP (for designing the decision-making hierarchy) and PROMETHEE (for pairwise comparison of investment locations) methods. As a result of mixing basis feature of both methods, operational synergies can be achieved in multi-criteria decision analysis. Such gives the decision-maker a sense of assurance, knowing that if the procedure proposed by the presented model has been followed, it will lead to a rational decision, carefully and systematically thought out.

## 1. Introduction

The management of construction projects requires knowledge of modern management as well as an understanding of all construction processes throughout its life cycle. Such projects have a specific set of objectives and constraints in a predetermined set of scope, cost, time, and quality as well as stakeholders' satisfaction. There are potential conflicts between the stated objectives, which could be resolved at the start of the project. How well the project goals and objectives will be reached and how the different requirements will be fulfilled depend on the decisions made during the project's life cycle.

Management of construction projects is also based on detail decision analysis as the decisions are crucial in reaching the project objectives. As the decisions are made based on assumptions regarding for future outcomes, they are coated with a level of uncertainty. Therefore, decision-making can be seen as a critical success factor in construction project management i.e. decisions drive construction projects from beginning till the end.



The main objective is to present a model for selection of adequate site location which is based on AHP (for designing the decision-making hierarchy) and PROMETHEE (for pairwise comparison of investment locations) methods. The aim of this paper is to define and implement a multi-stakeholder management procedure during the early stages of the decision-making process in order to achieve consensus in the goal hierarchy structure and criteria weights.

The paper is structured as follows: Firstly, the research background is introduced. Secondly, the methodology used in this research is presented. Thirdly, the results of the proposed model are presented and discussed. Finally, the conclusions are drawn with regard to the examined locations and proposed model.

## 2. Research Background

In the management of construction projects, special attention should be given to the planning as the most important phase of decision-making process and construction project management. The stakeholders' ability to influence the final characteristics and the project's costs is the highest at the beginning and gets progressively lower as the project continues while the cost of changes and correcting errors generally increases as the project continues. Such can be resolved by applying basic project management knowledge and competencies in the form of common project management process groups (initiation, planning, execution, monitoring and control, and closure). According to PMI [1], project management processes, which are used on most projects most of the time, are grouped into ten knowledge areas, taking into consideration integration, scope, time, cost, quality, human resources, communications, risk, procurement, and stakeholder management of a project.

Fundamental reasons for the existence of the selection of an adequate site location during the early stages of construction project management arise from: specific conditions of the construction industry (final products are inseparable from the location i.e. location has a strong influence of building design and its structural characteristics as well as the technology which will be used during construction), investors' desires and attitudes, and influence of socio-economic and environment aspects. Considering all reasons mentioned, one can conclude that the selection of an adequate construction site location for future investment is not only a complex, low structured and multi-criteria problem but also a group decision-making problems.

In such complex environments, the use of management information systems and multi-criteria decision analysis (MCDA) is essential. Therefore, various decision support concepts have been devised to help decision-makers in order to improve urban areas, where it includes urban road infrastructure in planning and development stages [2] as well as maintenance stages [2, 3], managing the overall value management of entire urban area [4], or general planning of investment projects in construction management [5]. The MCDA approach has been applied in planning and managing private investment construction projects (such as the problem of selecting the best investment project [5] or selecting optimal constructions site [6]) and public investment construction projects (such as the problem of selecting the best investment project from public portfolio [7, 8]). There are a large number of attributes which shape the entire urban area as well as a single plot i.e. future construction site. A survey [9] has provided a valuable insight that not all attributes which define urban area, i.e. indicators, are equally important, and the difference between key and marginal ones is about 40% [10]. Therefore, by taking into account the differences between the indicators' importance, the decision-makers can make significant savings during the early stages of construction project management. During early stages it is of great importance to focus on indicators oriented towards economic efficiency of the project especially if it's an infrastructure projects [11].

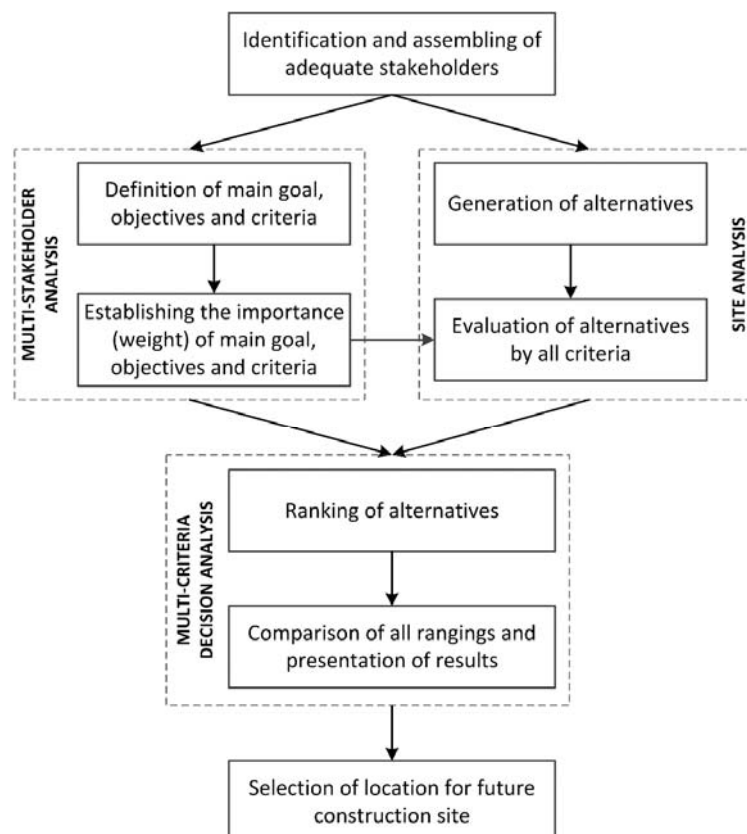
Most multi-criteria group decision-making methods were developed for group decision within an organizational/business context (for an overview, see [12]). In this context, the aim is to get a common view on the problem in a homogeneous group. The assumption is that the group is homogenous, even if different group members have opposite views, because they have the same overall goal (see 3.2.) i.e. the hierarchical goal structure is created. Macharis et al. [13, 14] developed a new methodology, called the multi-actor multi-criteria analysis (MAMCA), in which the stakeholders are involved as their points of view are explicitly taken into account without being asked to converge directly to a consensus. As the

context of this research is to evaluate under a solid hierarchical goal structure, the stakeholders will be considered as a homogeneous group.

### 3. Methodology

#### 3.1. Establishing the model for selection of adequate site location

The proposed model for selection of adequate site location consists of several processes as shown in Figure 1. The implementation of these processes begins with the identification and assembling of adequate stakeholders, resulting in the list of stakeholders, which is then followed by two process groups: multi-stakeholder analysis and site analysis. The multi-stakeholder analysis process groups consist of two processes. Throughout this process, the goal is to determine a single hierarchical goal structure (together with the importance/weight) as the compromise view i.e. attitude of all involved stakeholders in the decision making process (described in 3.2.). For this reason, the process is based on the AHP [15] premise. The site analysis process results with several alternatives i.e. site locations, which are evaluated according to previously determined criteria (the last decomposition level of hierarchical goal structure). After the goals, objectives and criteria have been defined, their weights determined, and the alternatives evaluated accordingly, the next step is to apply one of the outranking methods in order to rank them. Here, the PROMETHEE II method [16] is used for obtaining a full ranking, resulting in rank-list of observed site locations. This rank-list provides the decision maker with the basis for making a decision, especially when it is graphically presented.



**Figure 1.** Model for selection of an adequate site location.

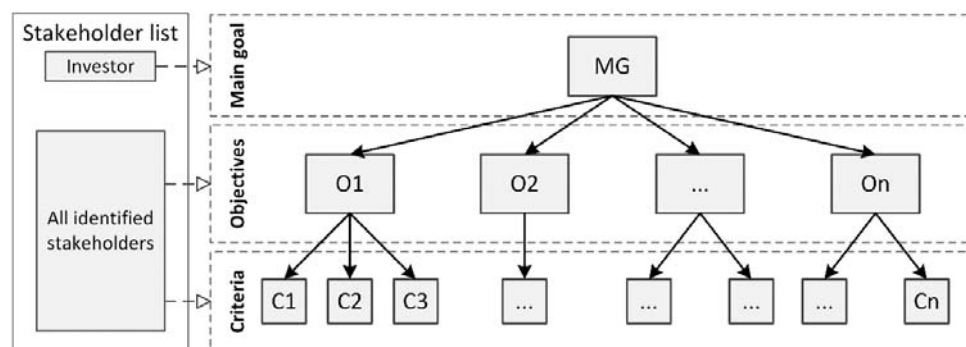
The proposed model is based on the idea of combining PROMETHEE and AHP [17] whose synergy effect is most evident during the decision-making hierarchy setup (setting up the goals, objectives and criteria), and is used for solving various multi-criteria problems [3-8]. Creating operational synergies by

strengthening PROMETHEE with ideas of AHP gives the proposed model the robustness and consistency in the decision-making process.

### 3.2. Multi-stakeholder management during early stages of construction project management

The stakeholder management is the most important part of construction project management as their influence is direct and can result in changes of the projects' scope, cost, time and quality, which can result in project failure. Therefore, proactive stakeholder management during the early stages of the construction project is of crucial importance. In order to gather all stakeholders and their attitudes, the hierarchical goal structure procedure (Figure 2) is proposed.

Establishing a hierarchical goal structure begins by defining the main goal (MG) and then follows with its decomposition to objectives (O) and criteria (C). Such is done by previously identified stakeholders. As they are all important to the project outcomes in different ways, they have different desires and attitudes. Therefore, the investor solely determines the MG which leads to objectives and criteria level in whose breakdown all the stakeholders are involved. The general idea is to create a list of criteria which can be precisely described and quantitatively or qualitatively measured. In order to achieve a consensus in the goal hierarchy structure, all stakeholders are involved in a panel discussion, thus forming a "goal wish list". This is an iterative process which ends when all stakeholders are in agreement.



**Figure 2.** Hierarchical goal structure procedure.

After the hierarchical goal structure is made, it is necessary to determine importance i.e. assign weights. Criteria must be weighted as they are not all equally important. Weighting is performed by the same procedure as previously described. The goal is to achieve a consensus among all weights.

## 4. Results and Discussion

The described model for the selection of an adequate site location has been tested on the public housing project in Primorje-Gorski Kotar County (North-West part of the Republic of Croatia). For five potential site locations, the main goal was to identify the best one for a future construction project.

The result of the previously described hierarchical goal structure procedure is presented in Table 1 the form of criteria and their short descriptions and evaluation techniques. Such is done by previously identified stakeholders which are grouped into four expert groups: city government (group consists of city mayor, his staff, and other city representatives), real estate agents and market experts (group consists of experts from several respectable real estate agencies), technical and economic experts (group consists of civil engineering, urban development, and experts from University of Rijeka).

Figure 3 shows all the parameters in the form of a decision matrix. It presents the internal limitations of the method, particularly the measurement units and the scoring of each location according to the given criteria as well as the assigned weights. The direction of preference (minimum or maximum) as well as preference function is also shown in Figure 3. Such is necessary to form a complex preference relation to emphasize that this outranking relation among two pairs, i.e. alternatives, is based on many criteria and that it is founded on generalizing those criteria, thus generating a complex preference relation.

**Table 1.** Criteria with short description, evaluation technique, and preference.

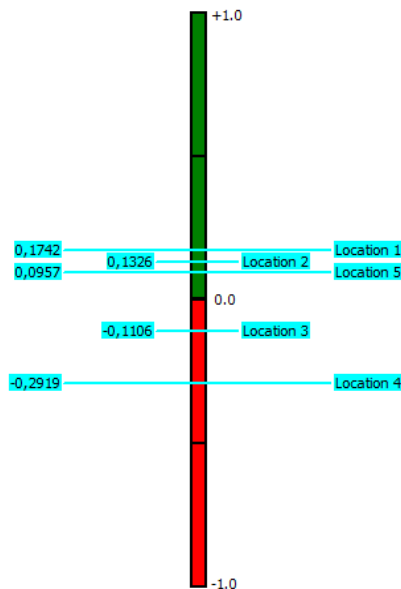
Criteria label	Criteria name	Short description of criteria and evaluation technique	Preference (Min/Max)
C1	Constructability	Constructability related to excavation and foundation works; Expert assessment – grading 1 (worst) to 10 (best)	Max
C2	Time required for construction	Expected duration of construction according to bill of quantities and dynamic plan – months	Min
C3	Time required to obtain building permits	Expert assessment of expected duration – months	Min
C4	Topography	Expert assessment of neighbourhood topography of the site area - grading 1 (significant relief) to 10 (level ground)	Max
C5	Zoning / Land use	Expert assessment of current and projected zoning and land use should be compatible with the use of the site for building - grading 1 (worst) to 3 (best)	Max
C6	Construction costs	Construction costs of the building; Expressed in €/m <sup>2</sup>	Min
C7	Costs of land acquisition	The amount includes the cost of land acquisition and other related costs; Expressed in €/m <sup>2</sup>	Min
C8	Utility contribution costs	The amount includes the utility contribution costs and other related costs; Expressed in 1.000 €	Min
C9	Amount of investment	The amount includes the costs of preparation of project documentation, construction costs, costs of land acquisition and other costs; Expressed in 100.000 €	Min
C10	The attractiveness of the location	Expert assessment that takes into account attractiveness of the building for future users according to its use and location; Expert assessment - grading 1 (worst) to 10 (best)	Max
C11	Probability of selling property	Expert assessment probability of selling property - grading 1 (low) to 5 (high)	Max
C12	The quality of utility infrastructure	Expert assessment that takes into account the existence and quality of all types of utility infrastructure (water supply system, sewage system, electrical system, waste management system, snowploughing services, etc.); Expert assessment - grading 1 (worst) to 10 (best)	Max
C13	Effect on the underground waters (site drainage)	Sites with good drainage are easier to develop and maintain. Expert assessment on drainage on site area	Min
C14	Effect on the surface waters (proximity to natural hazards)	Expert assessment based on natural features and the historical occurrence of earthquakes, avalanches/landslides, volcanic activity as well as health and safety hazards such as bluffs/steep cliffs, bodies of water and sewage/garbage disposal areas - grading 1 (low) to 5 (very high)	Min
C15	Landscape and visual impacts	Expert assessment of site surroundings such as vegetation, topography, views and surroundings - grading 1 (worst) to 10 (best)	Max
C16	Nearness to public facilities	Distances to major landmark such as shopping centre, bus stand, railway station, airport, schools, medical facilities, police and fire protection, parks and playgrounds; Expert assessment - grading 1 (worst) to 10 (best)	Max
C17	Vandal proof	Expert assessment of vandalism in surrounding area - grading 1 (low) to 5 (very high)	Min

Site selection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit
Cluster/Group	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
<b>Preferences</b>																			
Mn/Max	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Weight	7,50	9,00	3,00	4,50	6,00	6,00	6,00	6,00	8,00	8,00	6,00	6,00	4,50	4,50	6,00	4,50	6,00	6,00	4,50
Preference Fn.	Linear	Linear	Linear	Usual	V-shape	V-shape	V-shape	V-shape	Linear	Linear	Linear	Linear	Usual	Usual	Linear	Usual	Linear	Linear	Usual
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
-Q: Indifference	1,36	1,83	0,20	n/a	n/a	n/a	n/a	n/a	€ 50,00	€ 20,19	n/a	n/a	n/a	n/a	1,00	n/a	1,00	1,00	n/a
-P: Preference	3,76	5,03	0,55	n/a	1,00	€ 150,00	€ 65,00	€ 14,075,77	€ 54,41	3,00	n/a	n/a	n/a	3,00	n/a	2,00	2,00	2,00	n/a
-S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
<b>Statistics</b>																			
<b>Evaluations</b>																			
Location 1	9,00	14,00	1,00	7,00	3,00	€ 150,00	€ 150,00	€ 38,720,00	€ 178,50	9,00	very high	9,00	low	9,00	low	8,00	8,00	8,00	low
Location 2	8,00	16,00	1,50	8,00	3,00	€ 820,00	€ 120,00	€ 38,720,00	€ 153,20	7,00	very high	9,00	very low	9,00	low	7,00	7,00	7,00	moderate
Location 3	6,00	12,00	0,75	4,00	2,00	€ 600,00	€ 65,00	€ 21,256,00	€ 106,80	4,00	low	5,00	moderate	5,00	moderate	7,00	6,00	6,00	moderate
Location 4	4,00	18,00	1,25	6,00	2,00	€ 700,00	€ 80,00	€ 30,976,00	€ 125,50	4,00	moderate	7,00	low	7,00	moderate	6,00	6,00	6,00	high
Location 5	6,00	12,00	1,25	5,00	1,00	€ 700,00	€ 80,00	€ 30,976,00	€ 125,50	6,00	high	7,00	very low	7,00	low	8,00	8,00	8,00	moderate

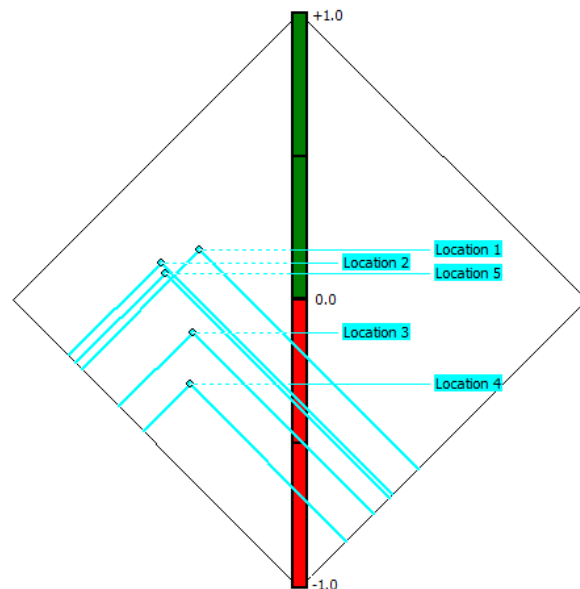
Figure 3. Decision matrix – input for conducting PROMETHEE II.

After defining, the goals, setting the criteria, and weighting them, the alternatives, i.e. locations, can be ranked. To rank them, the PROMETHEE II method is used, resulting in the complete ranking of all alternatives, i.e. locations (Figure 4). Results are based on the net flow Phi where the green half of the scale corresponds to positive Phi scores and the red half to negative scores. As the alternative is higher on the scale, it becomes better than the others and vice versa.

Alternative graphical representation of net flow Phi results is shown in PROMETHEE DIAMOND (Figure 5) as sometimes the different insight in results is needed. Their complete ranking is visible as well as their relative relations.



**Figure 4.** Results of PROMETHEE II.



**Figure 5.** Results of PROMETHEE DIAMOND.

In this case, the ranking results are clearly visible (Figure 4), and one can see that the alternative “Location 1” is the best one among these analyzed and compared five locations. The best alternative is closely followed by the second and third one. When the graphical presentation of results is not clear, the decision-maker should check their numerical values in net flow Phi. This method outputs information as a rank-list of reviewed locations (Figure 4 and Figure 5), providing the decision-maker a detail insight in priority as well as in quality of considered construction site locations with the basis to make decision and implement the solution.

## 5. Conclusions

The presented model is valuable because it improves consistency of decision-making in a group environment by overcoming problems which occur in solving poorly structured problems such as the selection of an adequate site location. The model ensures satisfaction of all stakeholders who are involved in the project, and their opinions are embedded in the final decision. This provides satisfaction to all stakeholders as the final result is rationally, systematically and carefully analyzed, and it is based on group compromise.

The advantage of the presented model is that it is easy to implement it into another site selection problem in a new environment and/or with new stakeholders. Even if such changes occur, the decision-maker can be sure that if the model is followed and the procedure remains consistent, the decision will be rational and pragmatically based on a group compromise. The advantage of such an approach to decision-making lies in the fact that even if it comes to a change in the structure of decision-makers, the decision-making procedure itself remains consistent.



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## References

- [1] PMI 2013 *A Guide to the Project Management Body of Knowledge (PMBOK guide)* Newtown Square p 589
- [2] Jajac N 2010 *Decision support system for development and maintenance of urban road infrastructure* (doctoral dissertation) Split: Faculty of Economics p 342
- [3] Jajac N, Knezić S and Marović, I 2009 Decision support system to urban infrastructure maintenance management *Organization, Technology & Management in Construction* **1** 72-79
- [4] Marović I, Završki I and Jajac N 2015 Ranking zones model – a multicriterial approach to the spatial management of urban areas *Croatian Operational Research Review* **6** 91-103
- [5] Jajac N, Bilić I and Mladineo M 2012 Application of multicriteria methods to planning of investment projects in the field of civil engineering *Croatian Operational Research Review* **3** 113-124
- [6] Jajac N, Bilić I and Alduk A 2013 Decision support concept to management of construction projects – problem of construction site selection *Croatian Operational Research Review* **4** 235-246
- [7] Marović I, Car-Pušić D and Hrvatin Z 2014 Establishing a model to evaluate public administration projects *e-GFOS* **5** 56-66
- [8] Car-Pušić D, Marović I, Gudac I and Medvedec D 2015 Prioritization of public investment projects: Case study of GSC portfolio *Proc. 34<sup>th</sup> Int. Conf. on Organizational Science Development* March 25-27 2015 Portorož Slovenia
- [9] Hanak T, Marović I and Pavlović S 2014 Preliminary identification of residential environment assessment indicators for sustainable modelling of urban areas *International Journal for Engineering Modelling* **27** 61-68
- [10] Marović I and Hanak T 2013 Identification of indicator influence in residential environment assessment *Proceedings of the Faculty of Civil Engineering in Rijeka* **16** 113-127
- [11] Korytarova J, Hromadka V, Vitkova E and Kozumplikova L 2014 Economic efficiency of large-scale infrastructure projects in the Czech Republic *Proc. 2<sup>nd</sup> Int. Conf. on Traffic and Transport Engineering* November 27-28 2014 Belgrade Serbia
- [12] Alvarez-Carillo PA, Duarte A and Leyva-Lopez JC 2010 A group multicriteria decision support system for ranking a finite set of alternatives *The 24<sup>th</sup> European Conf. on Operational Research – EURO 24* July 11-14 2010 Lisbon Portugal
- [13] Macharis C, de Witte A and Ampe J 2010 The multi-actor, multi-criteria analysis methodology (MAMCA) for the evaluation of transport projects: theory and practice *Journal of Advanced Transportation* **43** 183-202
- [14] Macharis C, Turcksin L and Lebeau K 2012 Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: state of use *Decision Support Systems* **54** 610-620
- [15] Saaty TL 1980 *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation* New York: McGraw-Hill
- [16] Brans J-P, Vincke Ph and Mareschal B 1986 How to select and how to rank projects: The PROMETHEE method *European Journal of Operational Research* **24** 228-238
- [17] Macharis C, Springael J, De Brucker K and Verbeke A 2004 PROMETHEE and AHP: The design of operational synergies in multicriteria analysis. Strengthening PROMETHEE with ideas of AHP *European Journal of Operational Research* **153** 307-317