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Procedia Computer Science 00 (2019) 000–000

Procedia Computer Science

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CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies

Multicriteria analysis as a better tool for the selection of public projects alternatives

João Miranda[a,b], Anabela Tereso[c]*, José C. Teixeira[d]

[a]*Master in Engineering Project Management, University of Minho, 4800-058 Guimarães, Portugal*
[b]*Primaned Belgium, Uitbreidingstraat 84/3, 2600 Antwerpen-Berchem, Belgium*
[c]*Production and Systems Department/Centre ALGORITMI, University of Minho, Campus of Azurém, 4804-533, Guimarães, Portugal*
[d]*Civil Engineering Department, University of Minho, Campus of Azurém, 4804-533, Guimarães, Portugal*

Abstract

It is the duty of a State to stimulate nation's economy and social welfare, using their limited funds. This is the general purpose of the so-called public projects. The demand for these investments continues to increase, but not always they fulfil that purpose, quite the opposite. In the current economic context, it becomes urgent to revert this scenario. Often, this poor outcome can be traced to a wrong decision on the project to implement. This is possibly the decision with the greatest impact on the whole project lifecycle. Cost-Benefit Analysis (CBA) is still the dominant tool for project selection, but the increasing interest in intangible and non-monetized parameters, opened the door for other better fitting tools like Multicriteria Decision Analysis (MCDA). This paper presents a critical analysis on the traditional approaches to the selection of these projects, pointing out directions for governments and other public entities to make better and more informed decisions about the projects to implement.

Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN – International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: anabelat@dps.uminho.pt

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Keywords: Public investments; Value-driven project management; Project appraisal and selection; Multicriteria decision analysis

1. Introduction

Public investment projects are means to an end. They are instruments for change [1], actually, the preferred instrument of governments to carry out their strategies and deliver the change the society requires [2]. So, in global terms, an impressive number of large public projects has been implemented over the years across the world [1], [3]. But these projects hold a bad reputation [2], [4], as recurring news and even research point out projects that finished behind schedule or above budget [1].

Yet, something more critical is not usually discussed in public forums: a great number of projects do not deliver any benefits [1], [5]. These are the “flows of value that arise from a project”, perceived by the society [5]. And, often, lack of project value can be traced to a wrong decision on the project to implement.

This article demonstrates that the decision on the project or the concept to implement is possibly the decision with the greatest impact on the whole project lifecycle, which means that successfulness of this kind of initiatives is shaped from scratch. As such, it is also discussed the selection processes of the public investment projects, from the viewpoint of project management, namely the methods used to substantiate those processes, as these are paramount to ensure the right options are selected, so public funds are spent wisely and the common interest is preserved, as it is confirmed as well. Inspired by new trends in this field, the article further presents alternative and innovative ways to address and solve this problem, validated by existing and diversified literature and illustrated by a case study.

2. The importance of choosing the right project

Traditionally, the project management field is product-oriented, focusing on outputs and features [5]. A project is considered successful when features are delivered, according to specifications, on time and within budget [3], [4]; in other words, when the project was managed efficiently and the so-called “triple constraint” – scope, time and cost – is fulfilled. However, there is a growing conscience of the misleading nature of this approach, and many people in the field is shifting to a different one, focusing on outcomes [†] and benefits – i.e., a benefit-oriented approach [5]. With it and in simple terms, more important than the features is the difference that these features will make to the stakeholders.

If public investment projects are instruments of change [1] and part of strategies to provide social welfare and growth, success should be assessed with a wider strategic view, whereby a project is successful if [3]:

1. Expected benefits are delivered;
2. Long term relevance is assured, by aligning benefits to stakeholders’ needs and priorities;
3. Effects are sustainable throughout all project life.

According to Williams and Samset [4], accomplishing strategic success is far more determinant in large public investments than the operational success, defined by the “triple constraint”. If delays and cost overruns are a problem, a much larger one will occur if one of the abovementioned criteria is not met. In this case, the project failed to implement the expected change, not justifying then its purpose [4].

Then, success is determined, firstly, by the selection of the right projects. Many argue that, among all macro decisions on an investment, this is probably the most fundamental one, having higher influence over the course of the project and its outcome [4], [6]. By selecting and prioritizing the projects with greater benefits to society, properly aligned with strategic objectives, governments will safeguard public interest and enhance the probabilities to carry out successfully their strategies [5], [7].

A thorough appraisal of several previously identified alternatives is mandatory to ensure that the right project is chosen [8]. However, many times the project choice is made without proper bases [3], [6]. In those cases, efforts and resources are focused on a single option, while other possible better alternatives are not appraised or they are even ignored [9]. A pre-established solution quite often leads to absurd scenarios where the resulting conditions will be even worse than those prior to the project [4].

[†] Both outputs and outcomes are results of a project, but while output refers to the object or product and its features, outcome refers to the impact that product will have, that is, the benefits delivered.

Project selection is done during the preliminary stages of the project or the front-end. The front-end phase of a project comprises all the activities performed from the moment it is imagined until the final decision to implement [4]. This process can be described as follow:

1. The problem that the project aims to solve is completely defined and stakeholders are identified. Their priorities, requirements and needs are analysed and elicited [3];
2. Change initiative objectives and expected benefits to be delivered are determined, properly aligned with the governmental strategy and with those priorities, requirements and needs [3];
3. A wide range of possible opportunities for solving the problem is examined, with regards to the business case, technological concept, organizational structure and processes required to deliver the project [10];
4. Alternatives are screened and suppressed regarding their quality and feasibility until it is evident which is the best solution, that is, the alternative providing greatest value to the society [10];
5. The investment decision on this solution is ratified, the project can start to be planned and prepared [10].

3. Tools for project selection

Project selection is an iterative and highly complex process, as it happens with every decision making process, with multiple objectives and unpredictable results, observing several constraints [8]. Any chosen project should be the best solution as a whole and combine, the best way possible, the individual requirements of all stakeholders [11]. But, since alternatives present different performance levels, considering different decision parameters, the best solution is almost every time very difficult to find, as very rarely an alternative is the best in all parameters [8]. Decision making, i.e., project selection must be based on rational, objective and verifiable methods [7]. These must be able to appraise all project effects, to certify the projects are the best solutions to achieve the proposed objectives and that there is no better use for the resources needed [12].

Cost-Benefit Analysis (CBA) is the most prominent tool for project appraisal and selection, being used in most countries [13]. CBA balances project benefits against its costs. Scholars advocate that this is a tool to measure the project contribution for social growth and/or a mean to measure its economic efficiency [13], [14]. This tool is based on social welfare economics [11], [12], where projects should bring value and should help to improve the society welfare. CBA will verify projects value by assessing whether, after changes are implemented, those who win with the changes are enough to compensate those who lose [13]. By quantifying both costs and benefits, governments can assess which options give the best contribution to social growth [13], since they are able to judge the taxpayers willingness-to-pay or willingness-to-accept (to be compensated by the change). Each cost and benefit of the project, either direct or indirect, must be expressed in monetary terms [11], [13]. After calculating all costs and benefits, those can be aggregated into a single value‡, which will act as an indicator of the project net impact on social welfare [15]. If the benefits outweigh the costs, a project is worthy [13], [15]. The selection procedure of a public investment project has all the elements of a CBA, so most decision-makers agree to use it [14], [15]. Anemma et al. [16] state that it clearly demonstrates the economic efficiency of a project social impacts, producing in the end clear and evident results – made explicit by that indicator – which allows decision-makers to justify their decisions , thereby avoiding possible limitations of the decision-making system and external biases over it. However, the use of CBA within public investments is debatable [14], [16] and many experts suggest or advocate alternative tools as a complement or even as a replacement [17]. It is a tool mainly prepared to deal with economic parameters [13], [18], but unable to integrate multiple conflictive parameters of non-tangible nature, like equity and social justice [15]. These cannot be neglected but their monetization is at least arguable [16]. Sometimes, agents just ignore them, undermining the process credibility and consistency [15]. Another great deficiency of CBA is that restricts stakeholders' engagement [14]. Change initiatives like public projects should be a result of democratic procedures, where all opinions matter. However, calculations and assumptions of this tool are just understood by the analysts and some experts on the subject withdrawing relevance to stakeholders and their ability to discuss, criticize and intervene – they fall in a black box§ [17]. Taken together, all these limitations justify doubts about this tool adequacy to appraise public projects [16].

Given the increasing awareness around wider social non-monetized impacts with strategic value and the inability

‡ Common indicators are the Benefit-Cost Ratio, the Internal Rate of Return, the Net Present Value, etc.

§ Black box is a complex object or system which people just perceive the inputs and outputs, but not the process or mechanism in between.

of CBA to deal with them, evaluation processes have been gradually adapted [18]. Scientific research has shifted the focus to alternative or complementary instruments, able to properly balance those parameters of more qualitative and subjective nature, emerging over the last few years the Multicriteria Decision Analysis (MCDA) [15]. These approaches are suggested by several authors [16], [18], but also indicated in official documents, namely guidelines for project evaluation, like the Green Book, issued by United Kingdom Treasury, or the ones issued by the European Union [7], [12]. Therefore, it is not surprising that the number of processes using this kind of tools is increasing [13]. This analysis assumes that decision-makers strive to make rational decisions, i.e. to find solutions that maximize global satisfaction in a logical and structured way [8]. It comprises a set of flexible methods which allows detailed and integrated assessment of different options, by considering different points of view and preferences from different stakeholders [18], converting conflicting or incomparable objectives or criteria into a common dimension or metric, allowing the alternatives to be assessed [8]. After properly weighted, the aggregated value of the different impacts will produce an unique classification for the alternatives, allowing their comparison and, therefore, the selection of the best option [16]. In a multicriteria situation, rarely a solution is better than all others for all the criteria, so the solution must be a compromise between the different and contradictory requirements and priorities of all decision-makers. The obvious main benefit of MCDA, compared to CBA, is its ability to analyse non-monetized impacts and to frame both quantitative and qualitative parameters on a comparable metric [16]. Another key advantage is the importance given to the stakeholders and their opinions. They are the ones that define the objectives, criteria and their weights and even judge the relevance of each option, observing the assessment criteria [15]. This provides a democratic content to the decision, which will represent a compromise between the different views [13]. MCDA clearly avoids or mitigates the main deficiencies of CBA, but it also has some limitations, which should not be ignored in public investments [15]. As this analysis often relies on subjective assumptions and perspectives on qualitative assessment of impacts and assigning weights to the criteria, some authors contest the impartiality and transparency of the resulting solutions [13], [15]. Also, as in CBA, impacts derive from estimations that can also be arguable, which obviously can compromise the transparency of the process [16]. Still, altogether, it seems clear the greater suitability of multi-criteria analysis for the selection procedures of public investment projects [19].

4. Case study of a public investment

To illustrate a possible use of MCDA methods in public investments, the authors applied them to a real case scenario, within an academic study, which it is synthetized as follows. The case refers to the selection of the Oporto High-speed Trains Central Station, which would be part of the Portuguese high-speed railway network program (popularly known as the TGV). This was considered instrumental a few years ago, by former Portuguese governments, but suspended meanwhile due to the economic crisis. The goal was not to suggest merely the best location, but the full configuration concept, including the station corridors, tracks to be laid down, a new dedicated bridge, etc. This was a clear example of a large public investment, which decision needed to assess multiple and diversified impacts to the city and the nearest neighbourhoods, their inhabitants and possible users. This case was formerly presented in another scientific paper, by Mateus, Ferreira and Carreira [20], which were the consultants for the Portuguese High-speed Railway Network (RAVE). Their report and information were kindly provided for the academic study. Of course, all basic information is the same, namely the alternatives, the appraised criteria and related structure, the estimations of impacts and the client's judgements. All evaluation criteria were determined and broken down until the elementary criteria level[**], as follow: Decision goal, i.e. location and configuration; Criteria family; Evaluation criteria; Sub-criteria. The impacts were defined by the decision-makers, that is, RAVE representatives and estimated by specialized external entities (see Table 1). Any criterion which impact was the same for every alternative was ignored from the calculations since it could not contribute for differentiation.

The different alternatives identified can be visualized in Fig. 1: 1) two alternatives in Boavista (first picture on the left), only differing on the number of tracks in the station corridor (A, B); 2) underground station, underneath the existent train station of Devesas (second picture from the left), south to Porto (C); this location would share most of the configuration of Boavista alternatives, including the new bridge; c) expansion of Campanhã Station in Porto, comprising 3 possible paths and a new bridge, different than the previous alternatives; the first of these paths CI

[**] Lowest level of a criteria branch, that is, which is not dividable anymore and which can be described by a measurable impact

(middle picture) would require a long section of railway south to it, almost undefined at that stage; thus, this path was divided into 3 different scenarios (optimistic, intermediate, pessimistic), each representing a different alternative (D, E, F); d) the other two alternatives, CII (second from the right) and CIII (first from the right), would just move a few years later to the new bridge, and differ between them on the fact that CII would use a new tunnel south of the bridge, while CIII would just use existing tracks (G, H).

Table 1. Criteria breakdown structure and impacts

	CRITERIA	IMPACT DESCRIPTORS
1	Endogenous factors during construction	
1.1	Construction and expropriation costs	Present value of construction and expropriation costs
1.2	Construction Schedules	Construction schedule: (a) between Ribeira de Silvalde and the Central Porto Station; (b) between Ribeira de Silvalde and the Airport Station
1.3	Construction Risks	Geological and Geotechnical; Location; Affected Utilities
2	Endogenous factors during Operation	
2.1	Operation and Maintenance Costs	Present value of annual maintenance and operation costs
2.2	Demand	Increase of potential demand over the high speed service
2.3	Accessibility	With professional and non-professional purpose
2.4	Travel Time	Journey time: (a) between Aveiro Station and the Central Porto Station; (b) between Aveiro Station and the Airport Station
2.5	Users comfort	Intermodality with other transport means; Availability of Support Services
2.6	Operating Easiness	Railway tracks on the station
3	Exogenous factors during construction	
3.1	Earthworks	Volume of earthworks to be carried out Length of surface railway track
3.2	Noise	Length of tunnelled railway track crossing urban areas
3.3	Vibration	Length of tunnelled railway track crossing urban areas
3.4	Impact on Traffic	Area of primary roadways in urban areas crossed by surface railway track
3.5	Impact on Residential Activities	Population living in city blocks crossed by surface railway track
3.6	Impact on Economic Activities	Employees of companies located on the city blocks crossed by surface railway track
4	Exogenous factors during Operation	
4.1	Impact on Ecologically Sensitive Areas	Area of national ecological or agricultural park crossed by surface railway track
4.2	Impact on Architectural/Archaeological Heritage	Historical and cultural heritage: (a) architectural items within 50 m of the right-of-way; (b) archaeological items within 50m of the right-of-way
4.3	Noise	Length of surface railway track
4.4	Vibration	Length of tunnelled railway track crossing urban areas
4.5	Residential Relocations	Population to be relocated
4.6	Impact on Urban Planning	Urban impacts on: (a) urban landscape; (b) functional zoning; (c) urban regeneration; (d) planned public urban projects; (e) changes in land value; (f) land use planning
4.7	Impact on Traffic and Accessibility	Streets; City center; National roadway; Intermodality infraestructure

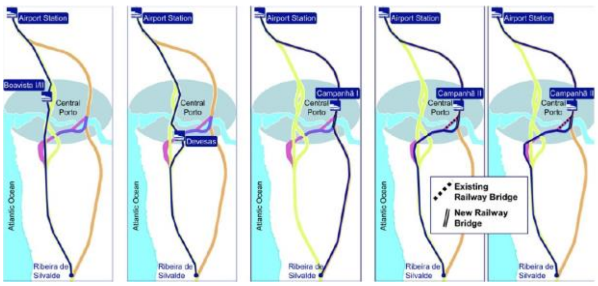

Fig. 1. Possible locations and configurations [20]

5. Application of AHP to the case study

In the original analysis, Value Theory, using value functions, complemented with the MACBETH method was used. In this study, an alternative analysis was performed, based on a different method from the same school, the Analytical Hierarchy Process (AHP). According to its creator, Thomas L. Saaty, “The Analytic Hierarchy Process (AHP) is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales” [21, p. 83]. AHP is one of the most popular MCDA methods around the world, that uses a hierarchical structure to aggregate the performance of alternatives, in the upward direction, where alternatives are classified by cardinal figures that represent their interest, i.e. their value [8]. Pairwise comparisons are done, using Saaty’s scale of 1 to 9 [21]. This method is very straightforward, intuitive and easy to apply [19]. As a result, the process is not so exhaustive as other methods [22], thus the choice for this method. However, it is not a flawless method, of course, so a few auxiliary procedures were added, to enhance the efficiency and reliability of the calculations.

One commonly pointed out flaw of AHP is the lack of consistency in the pairwise comparisons [22]. To mitigate this problem, a rule was established to harmonize the pairwise comparisons. Basically, the impacts were previously converted into the same scale of measure (linear scale of 0-10), where 10 meant the best performance level on that criterion and 0 an acceptability threshold. After the conversion, pairwise comparison matrices were build, with scoring based on the gap between converted performances, according to the Table 2.

Table 2. AHP scoring scale

AHP Scoring Scale	Performance gap
1	Less than 0.4 exclusive
2	Between 0.4 and 1.6 exclusive
3	Between 1.6 and 2.8 exclusive
…	…
9	Between 8.8 and 10

Having a threshold allows to define the worst possible performance level and to eliminate alternatives with inadmissible performance on some criteria, which is also a notable shortcoming of this method [19]. These thresholds were not present in the original analysis, which gave zero scores to the worst of the alternatives. However, with that procedure, there was a chance that good performances were being too much penalized. In AHP terms, this would mean that the best alternative would have an extreme importance relationship when compared to the worst one, which could not be the case. So, the creation of the thresholds helped to establish a fairer system of pairwise comparisons. Finally, the weights express the trade-off between criteria, so they should not be randomly assigned, as it happens several times, using the decision-makers' gut-feeling [23]. Instead of making a straight pairwise comparison between the criteria, priorities must be appraised observing the performance levels of each criteria. Another auxiliary procedure was then used to obtain the criteria weights. Fictitious alternatives were created, one per criterion. Using the real impacts, each of these alternatives takes the highest impact in one of the criteria (different in each case) and the lowest impact for all others. Pairwise comparisons are then made between these fictitious alternatives, using AHP matrices, where the decision-makers evaluate their relative interest. Table 3 shows a sample of this procedure.

Table 3. Calculation of the criteria priorities using fictitious alternatives

Criterion	Best	Worst
3.1	0.932	1.308
3.2	11.427	17.994
3.3	5.954	12.359
3.4	2380	3745
3.5	6105	7712
3.6	519	1784

Fictitious Alternatives	3.1	3.2	3.3	3.4	3.5	3.6
1	0.932	17.994	12.359	3745	7712	1784
2	1.308	11.427	12.359	3745	7712	1784
3	1.308	17.994	5.954	3745	7712	1784
4	1.308	17.994	12.359	2380	7712	1784
5	1.308	17.994	12.359	3745	6105	1784
6	1.308	17.994	12.359	3745	7712	519

	1	2	3	4	5	6	Sum	w_i	
1	1	5	6	2	4	1/2	18,50	0,2656	
2	1/5	1	2	1/4	1/2	1/6	4,12	0,0591	
3	1/6	1/2	1	1/5	1/2	1/7	2,51	0,0360	
4	1/2	4	5	1	4	1/3	14,83	0,2129	
5	1/4	2	2	1/4	1	1/5	5,70	0,0818	
6	2	6	7	3	5	1	24,00	0,3445	RC
							69,66	1,00	0,0388 Ok

Following the previously described steps, the analysis was then applied, scrolling upwards the hierarchy and using the referred auxiliary procedures. The aggregation continued until the top level, with the weights of the family criteria determined, making possible to calculate the global priorities of alternatives and, thus, to indicate the best possible alternative. Table 4 shows the final aggregation and ranking of alternatives.

Table 4. Global scoring of the alternatives

	CRITERIA FAMILY					
	1	2	3	4	*Score*	Ranking
A	0.0498	0.0684	0.1211	0.1349	**0.0669**	7º
B	0.0307	0.0662	0.1066	0.1349	**0.0621**	8º
C	0.1298	0.0792	0.1868	0.2214	**0.0903**	6º
D	0.1371	0.1518	0.1379	0.1035	**0.1485**	5º
E	0.1403	0.1588	0.1443	0.1043	**0.1547**	3º
F	0.1490	0.1686	0.1540	0.1067	**0.1642**	1º
G	0.1679	0.1492	0.0802	0.0993	**0.1510**	4º
H	0.1953	0.1578	0.0690	0.0951	**0.1623**	2º
	15.8%	**81.9%**	**0.3%**	**2.0%**		

6. Results and discussion

This study confirmed that Campanhã location is clearly the best location for the station, with all possible configurations being considerably better. The results are highly robust regarding the rankings between the locations as Devesas would only outrank the worst of the Campanhã options if one of the following unlikely scenarios occurs:

- Reduce more than 32% the weight of families 1 and 2, in favour of family 4;
- Increase 60% the estimates of option C, on families 1 and 2;
- Reduce 40% the estimates of option D, on families 1 and 2.

Regarding the possible configurations of Campanhã, the optimistic scenario of the first path (alternative F) is the best option, but by very slight margins towards the third path (alternative H).

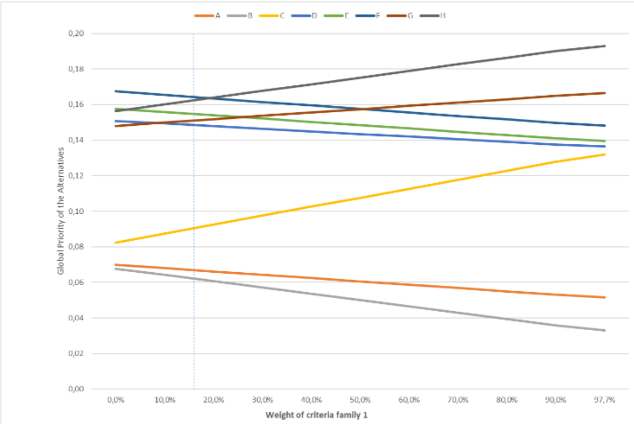

Fig. 2. Effect on global priorities changing criteria family 1 and 2 weights

Fig. 2 shows a graph with the evolution of the global priorities, changing the weight of the criteria family 1 in favour of family 2, the most important ones by far – more than 97.5 of total weight. The vertical bar indicates the current weights. As one can see, a very small increase on family 1 would change the order between alternatives F and H. More relevant changes, though, would be needed to change the order between F and G or between E and H. So, as with the original study, it is safe to indicate Campanhã as the preferred location. However, more rigorous analysis would be needed to decide about the best configuration.

7. Conclusions and future research

In the context of the public projects, CBA is by far the most popular tool for project selection and it is being used for a long time. However, Multicriteria Decision Analysis is emerging, gaining its own space and it is being used in many formal procedures. Substantial limitations can be pointed to the CBA, as indicated, namely the inability to properly integrate parameters of intangible nature and the inability to engage stakeholders. These limitations are avoided or mitigated by MCDA, depending on the method, proving their suitability within public investments.

With the case study shown, that was obvious: all kind of impacts were balanced, both tangible and non-tangible, all criteria, weights and impacts were determined and provided by the main stakeholders, and finally all calculations and results are clear and objective to all. Of course, some criticism can be pointed out to this simulation. Above all, this project was part of an instrumental program for Portugal, so it should have been appraised regarding the governmental strategy, as it was mentioned before. However, strategic alignment is not clear. The available data does not provide any information about the impacts being used as measures for some strategic target. On the other hand, the fact that different studies provided such similar results also testifies the reliability and robustness of these methods.

It is crucial to perform more studies in the selection of public investments, using MCDA, to demonstrate that this is really the most appropriate tool for this kind of procedures. Preferably, in the future, these analyses should consider the strategic alignment as well. And research, should not end with the project selection. Research should also be made on the way projects are controlled during their lifecycle to ensure they will really deliver value to society.

Acknowledgement

This work has been supported by FCT – *Fundação para a Ciência e Tecnologia* within the R&D Units Project Scope: UIDB/00319/2020

References

[1] B. Flyvbjerg, “What you should know about megaprojects and why: An overview,” *Proj. Manag. J.*, vol. 45, no. 2, pp. 6–19, 2014, doi: 10.1002/pmj.21409.

[2] A. T. Shiferaw and O. J. Klakegg, “Linking policies to projects: The key to identifying the right public investment projects,” *Proj. Manag. J.*, vol. 43, no. 4, pp. 14–26, Aug. 2012, doi: 10.1002/pmj.21279.

[3] A. T. Shiferaw, “Front-end project governance – Choice of project concept and decision-making – An international perspective,” Norwegian University of Science and Technology, 2013.

[4] T. Williams and K. Samset, “Issues in front-end decision making on projects,” *Proj. Manag. J.*, vol. 41, no. 2, pp. 38–49, Apr. 2010, doi: 10.1002/pmj.20160.

[5] Y. Y. Chih and O. Zwikael, “Project benefit management: A conceptual framework of target benefit formulation,” *Int. J. Proj. Manag.*, vol. 33, no. 2, pp. 352–362, 2015, doi: 10.1016/j.ijproman.2014.06.002.

[6] K. Samset and T. Christensen, “Ex ante project evaluation and the complexity of early decision- making,” 2015, doi: 10.1007/s11115-015-0326-y.

[7] European Commission, *Guide to Cost-Benefit Analysis of investment projects economic appraisal tool for cohesion policy 2014-2020*, no. December. 2014.

[8] J. Seppälä, L. Basson, and G. A. Norris, “Decision analysis frameworks for life-cycle impact assessment,” *J. Ind. Ecol.*, vol. 5, no. 4, pp. 45–68, 2002, doi: 10.1162/10881980160084033.

[9] K. Samset and T. Christensen, “Ex Ante Project Evaluation and the Complexity of Early Decision-Making,” *Public Organiz Rev*, vol. 17, 2017, doi: 10.1007/s11115-015-0326-y.

[10] S. Lucae, E. Rebentisch, and J. Oehmen, “Understanding the front-end of large-scale engineering programs,” *Procedia Comput. Sci.*, vol. 28, no. Cser, pp. 653–662, 2014, doi: 10.1016/j.procs.2014.03.079.

[11] L. D. Phillips and C. A. Bana e Costa, “Transparent prioritisation, budgeting and resource allocation with multi-criteria decision analysis and decision conferencing,” *Ann. Oper. Res.*, vol. 154, no. 1, pp. 51–68, 2007, doi: 10.1007/s10479-007-0183-3.

[12] HM Treasury, *Appraisal and evaluation in Central Government*, no. July. London, United Kingdom, 2011.

[13] D. Browne and L. Ryan, “Comparative analysis of evaluation techniques for transport policies,” *Environ. Impact Assess. Rev.*, vol. 31, no. 3, pp. 226–233, 2011, doi: 10.1016/j.eiar.2010.11.001.

[14] K. Nyborg, “Project evaluation with democratic decision-making: What does cost-benefit analysis really measure?,” *Ecol. Econ.*, vol. 106, pp. 124–131, 2014, doi: 10.1016/j.ecolecon.2014.07.009.

[15] N. Thomopoulos, S. Grant-Muller, and M. R. Tight, “Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology,” *Eval. Program Plann.*, vol. 32, no. 4, pp. 351–359, Nov. 2009, doi: 10.1016/j.evalprogplan.2009.06.013.

[16] J. A. Annema, N. Mouter, and J. Razaei, “Cost-Benefit Analysis (CBA), or Multi-Criteria Decision-Making (MCDM) or both: politicians’ perspective in transport policy appraisal,” *Transp. Res. Procedia*, vol. 10, pp. 788–797, 2015, doi: 10.1016/j.trpro.2015.09.032.

[17] P. Naess, “Cost-Benefit Analyses of transportation investments,” *J. Crit. Realis.*, vol. 5, no. 1, pp. 32–60, 2006, doi: 10.1558/jocr.v5i1.32.

[18] M. B. Barfod, K. B. Salling, and S. Leleur, “Composite decision support by combining cost-benefit and multi-criteria decision analysis,” *Decis. Support Syst.*, vol. 51, no. 1, pp. 167–175, 2011, doi: 10.1016/j.dss.2010.12.005.

[19] M. Cinelli, S. R. Coles, and K. Kirwan, “Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment,” *Ecol. Indic.*, vol. 46, pp. 138–148, 2014, doi: 10.1016/j.ecolind.2014.06.011.

[20] R. Mateus, J. A. Ferreira, and J. Carreira, “Multicriteria decision analysis (MCDA): Central Porto high-speed railway station,” *Eur. J. Oper. Res.*, vol. 187, no. 1, pp. 1–18, 2008, doi: 10.1016/j.ejor.2007.04.006.

[21] T. L. Saaty, “Decision making with the analytic hierarchy process,” *Int. J. Serv. Sci.*, vol. 1, no. 1, p. 83, 2008, doi: 10.1504/IJSSCI.2008.017590.

[22] M. Velasquez and P. T. Hester, “An Analysis of Multi-Criteria Decision Making Methods,” *Int. J. Oper. Res.*, vol. 10, no. 2, pp. 56–66, 2013.

[23] R. Mateus, J. A. Ferreira, and J. Carreira, “Full disclosure of tender evaluation models: Background and application in Portuguese public procurement,” *J. Purch. Supply Manag.*, vol. 16, no. 3, pp. 206–215, 2010, doi: 10.1016/j.pursup.2010.04.001.