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Which of DEA or AHP can best be employed to measure efficiency of projects?

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Abstract: This paper compares Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) approaches for monitoring projects, in order to determine their performance in terms of economic, environmental and social organizational goals. This work is founded on an existing methodology to select and monitor projects based on DEA, and discusses modifications and additions arising from using AHP. The proposal is applied to a real case. The results indicate that AHP constitutes an insightful approach in situations requiring a modelling of managerial preferences regarding the relative importance of organizational goals.

Key words: Analytic Hierarchy Process, Project Management, Sustainability, Data Envelopment Analysis.

1. Introduction

Consumers and regulators exert continuous pressure on firms to innovate in ways that will reduce their impact on the natural environment (Yalabik and Fairchild, 2011). Porter argues that ‘for profit’ companies are well suited to solve social problems while at the same time serving their shareholder’s interest to maximize investor returns (Porter and Kramer, 2011). Executives face the challenge of balancing sustainability related to the whole strategic priorities. This requires an effective project portfolio management that is supportive of sustainability driven strategies.

In this paper we consider the problem of assessing projects so that they provide maximum value and minimize environmental and social impacts. The main challenges are evaluating projects that support different goals, some of them provide benefits that cannot be measured in monetary terms, and prioritize them together with the existing company´s portfolio. In a previous work (Sánchez, 2014) an approach that integrates sustainability into project management is proposed. Data Envelopment Analysis is used for selection and monitoring of projects.

DEA is widely recognized as an effective means of evaluating the relative efficiency of a group of homogeneous decision making units which produce multiple outputs by using multiple inputs. However, there are some drawbacks. Managers need to assess projects considering different scenarios due to uncertainty. Joro and Viitala (2004) note that all inputs and outputs may not be equally relevant to the organizations analyzed and their stakeholders. And hence, it is useful to assign preferences to organizational goals or costs. However, by using DEA goals are modeled as having the same preference. Another issue with DEA is the homogeneity assumption where all DMUs are required to undertake the same processes, they should use the same inputs to produce the same outputs, and it is required that they operate within the same environment (Mar, 2009). Then, a very large unit is deemed efficient because there are no other units with similar production levels (Madlener *et al.*, 2006). As a consequence, DEA would prevent direct efficiency comparisons between small and large projects.

In particular, this research addresses the project monitoring problem through the integration of AHP into the project management framework presented in the work of Sánchez (2014). The method is based on a multi-criteria decision making technique that allows incorporating preferences among criteria. Hence, the research question becomes 'which of DEA or AHP can best be employed to measure efficiency of projects and are decisions derived from DEA and AHP consistent?' In order to answer this research question we describe how to develop an AHP-based model to monitor projects. The proposal is applied to a case study and results are compared with rankings produced by DEA.

This work is organized in the following sections. Section 2 introduces background concepts such as DEA and AHP. Section 3 describes the AHP model and discusses issues such as how to model costs and benefits. Section 4 describes the results obtained when using the different methods. Section 5 concludes with general findings on the applicability and consistency of the methodologies.

2. Theoretical background

2.1. Data Envelopment Analysis

DEA, first proposed by Charnes (Charnes *et al.*, 1978), is a non-parametric technique used to measure the efficiency of Decision Making Units (DMUs). Each DMU is seen as being engaged in a transformation process, in which, some inputs (resources) are used to try to produce some outputs (goods or services). In management contexts, DEA serves as a tool for control and evaluation of past accomplishments as well as a tool to aid in planning future activities (Banker *et al.*, 1984; Cook and Seiford, 2009). DEA models return an efficient projection point of operation on the frontier for each inefficient DMU, thus identifying the DMUs that can be used as performance benchmarks for the DMUs that are operating inefficiently.

There are some limitations regarding the application of DEA as described in Section 1. Another issue of using DEA as a benchmarking tool is that it may provide inappropriate benchmark DMUs for inefficient DMUs when the inputs (or outputs) are derived from two distinct objectives (Camanho and Dyson, 1999; Shimshak *et al.*, 2009; Chang and Yang, 2010). For instance, when quality outputs and operating outputs are directly mixed together for executing DEA. DMUs with low quality outputs (or low operating outputs) can be recognized as benchmark DMUs. This happens because DEA is linear-programming-based technique for evaluating efficiency of each DMU by selecting the most beneficial weights for inputs and outputs; once the outputs are sufficiently high, the low outputs of another one may be ignored due to zero weights.

2.2. Analytic Hierarchy Process

The AHP allows decision makers to model a complex problem in a hierarchical structure showing the relationships of the goal, objectives (criteria), sub-objectives, and alternatives (Saaty, 1997). After arranging the problem in a hierarchical fashion, the decision-maker makes subjective assessments with respect to the relative importance of each of the criteria, and indicates the preference of each alternative with respect to each of the criteria. Comparison matrices are used for pairwise comparisons between the sub-criteria with respect to its parent node, and each pair of alternatives with respect to each sub-criterion. These comparisons may be taken from actual measurements or from a scale that reflects the relative strength of preference, relevance or probability. Given n criteria and m alternatives, n matrices of order $m \times m$ and order $n \times n$ should be built, which makes that AHP is a non-scalable method. Once judgments have been entered for each part of the model, the information is synthesized to rank the alternatives in relation to the overall goal.

2.3. AHP and Project Management

Kumar (2004) developed a model based on AHP for project selection. The criteria are structured using a pre-defined list of organizational, technical, strategic and financial factors. Pairwise comparisons of factors reflect the importance of each of them. Candidate projects are evaluated using a grading scale with five elements. In Kendrick and Saaty (2007) the authors propose a four-step process to define a portfolio. A hierarchy of business drivers is defined. Projects are rated against criteria and the priority of each project is represented as a measure of its relative value toward the stated goals and objectives of the organization. The ratings are derived through pairwise comparisons. Finally, optimization techniques are use to define the portfolio that maximizes value for cost based on business rules. The portfolio value measures the overall aggregated priority of all the projects that are funded.

In Bible and Bivins (2011) the authors provide a project selection method based on the AHP. The objectives hierarchy in the evaluation model is a representation of the strategic plan. An alignment matrix shows which candidate projects support which objectives from the strategic plan (but not how much or how well). To produce accurate priorities for the alternatives (candidate projects) with respect to the objectives they support, alternatives can be evaluated using pairwise comparisons, or by using absolute measurement scales. Pairwise comparisons can be cumbersome and time consuming. Absolute measurement scales are based on a point scale with assigned intensity levels for each point. Synthesized results of the evaluation provide the relative priorities of the candidate projects with respect to achieving a goal. The list of prioritized projects is used as the input to derive a portfolio using an optimization algorithm (the combination of projects that provides the greatest benefit for the budget level).

2.4. Project Management Framework

The methodology comprises four steps: (1) cover stakeholders' concerns by means of stakeholder analysis; (2) define a Strategy Map and a Balanced Scorecard; (3) conduct sustainability analysis; and (4) perform a global optimization of projects (Sánchez, 2014). The full description of the framework exceeds the goals and scope of this paper. In what follows, a brief description of the main steps is provided.

The tasks involved in stakeholder analysis include identifying stakeholders and their interests. As a result of the analysis, stakeholders' interests are translated into goals, and a Balanced Scorecard (BSC) (Kaplan and Norton, 2004) is drawn. The BSC is structured using four perspectives: Triple Bottom Line, Stakeholders, the Internal Process and Learning and Growth. The Triple Bottom Line perspective includes economic, environmental and social value goals. The Stakeholders perspective balances the interests of all stakeholders. To meet stakeholders' expectations, the Internal Process perspective defines goals for processes. Finally, the Learning and Growth perspective includes goals related with the skills, culture and technology necessary for its employees to do the required work. For each goal, key performance indicators (KPIs) are described. Then, actions plans and projects are defined. The Strategy Map links together several domains and elements of the strategy in the four key perspectives.

The technique used to assess the environmental impact of projects depends on the characteristics of the project (e.g. production or service project).

The portfolio selection is formulated as a DEA problem where DMUs represent portfolios; inputs represent initial investments, development, operational and disposal costs, and socio-environmental impacts derived from sustainability analysis; outputs represent the estimated contribution of portfolios to each goal. In this way, DEA results provide a ranking of portfolios based on the simultaneous analysis of eco-impacts and contribution to organizational goals. Similarly, project monitoring is represented as a DEA problem where each project defines two DMUs: one DMU represents the ongoing projects and input and output data are given by incurred costs and by realized value, or updated cost forecasts and value if the project is not closed. The other DMU represents the planned project and input and output data are given by initial estimated expenditures and expected value contribution. Ideally, DMUs representing planned projects would define the efficient frontier and would be the reference set for ongoing projects.

3. Portfolio selection and project monitoring based on AHP

The aim of this section is to describe how to perform the portfolio selection and project tracking task using AHP. The proposal is aimed to be used instead of DEA. The multi-criteria analysis should include criteria to represent goals defined in the BSC, and economic, environmental, and social costs that arise of project implementation. AHP has been adapted to perform a benefit/cost analysis. In its more general form, two AHP hierarchies are used for the same set of alternatives, one for benefits and the other for costs (Azis, 1990; Saaty and Ozdemir, 2003). After synthesis of information, the benefits' priorities are then compared to the costs' priorities to see which option has the highest ratio. A final ranking is calculated using the following expression (Saaty and Ozdemir, 2003):

$$A_i = B_i \cdot \left(\tfrac{1}{C_i} \big/ R_{max} \right) \quad (1)$$

where A_i represents alternative i, B_i are the benefits of alternative A_i, C_i are the costs of alternative A_i, and R_{max} represents the maximum of $1/C_i$, $1 \leq i \leq n$, where n is the number of alternatives.

3.1. Portfolio Selection

3.1.1. Benefit Hierarchy

Criteria representing benefits are derived from goals defined in the BSC. These criteria are structured in a benefit hierarchy. Each perspective in the BSC defines a branch in the hierarchy, and goals and subgoals provide criteria and sub-criteria. Finally, KPIs are represented at the preliminary final level of the hierarchy. Alternatives are given by candidate portfolios (see Figure 1) and are presented at the final level of the hierarchy.

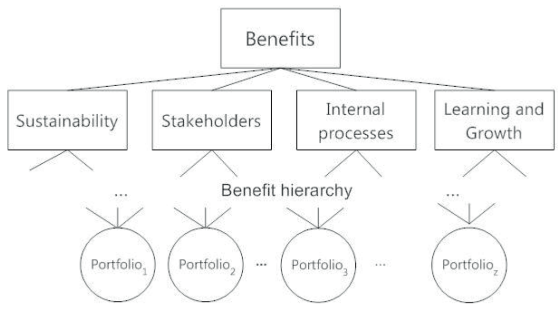

Figure 1. Benefit hierarchy template for Portfolio Selection.

Once the hierarchy has been stated, the relative preference of each criterion is defined by performing pairwise comparisons. For the higher part of the hierarchy, the evaluation of the importance of the criteria and sub-criteria refers to management concerns. Judgments will be expressed by managers of different areas (e.g. project management, financial, marketing) according to their requirements.

In the case of alternatives, assessment does not consider preferences but the evaluation is based on the forecasted contribution toward each KPI if the portfolio is funded. A portfolio is composed of projects and the portfolio contribution to a KPI is given by the maximum project contribution. Assume there are z candidate portfolios. Let $P=\{P_i, 1 \le i \le z\}$ be the set of portfolios. Let $P_i=\{p_k^i, 1 \le k \le n_i\}$ denote the projects in portfolio P_i where n_i is the number of projects and $1 \le i \le z$. The contribution of project p_k^i to each criterion is denoted by

$$B_k^i=\{b_{kj}^i, 1 \le j \le w\} \tag{2}$$

where w is the number of criteria. Hence, the contribution of portfolio P_i to each criterion is described by

$$B^i=\{b^i_{max,j}, 1 \le j \le w\} \tag{3}$$

where $b^i_{max,j}$ represents the maximum of $b^i_{k,j}$, $1 \le k \le n_i$. If a portfolio does not contribute to improve a particular KPI, then the current value of the KPI is used in the analysis.

Then, alternatives assessment is performed using raw data. Priorities can be derived from data as well as from pairwise comparisons (Forman, 2001) assuming a linear or inverse linear relationship is deemed to be reasonable. Simple arithmetic is adequate to derive the priorities by adding up each alternative data value, and dividing by the total to normalize such that the priorities add up to one. Similarly, inverse relationships can be calculated when a higher data value is less desirable.

3.1.2. Cost Hierarchy

Criteria representing costs are derived from economic and financial analysis developed for each candidate project in the portfolio. Additionally, environmental costs defined during the sustainability analysis step provide criteria and data. The relative preference of each cost is performed using pairwise comparisons. Alternatives assessment is performed using raw data (see Figure 2).

The portfolio cost measures the overall aggregated cost of all projects. More formally, the costs of project p_k^i is denoted by

$$C_k^i=\{c_{kj}^i, 1 \le j \le q\} \tag{4}$$

where q is the number of cost categories. Hence, the cost of portfolio P_i is described by

$$C^i=\left\{c_j^i=\sum_{k=1}^{v_i} c_{kj}^i, 1 \le j \le q\right\} \tag{5}$$

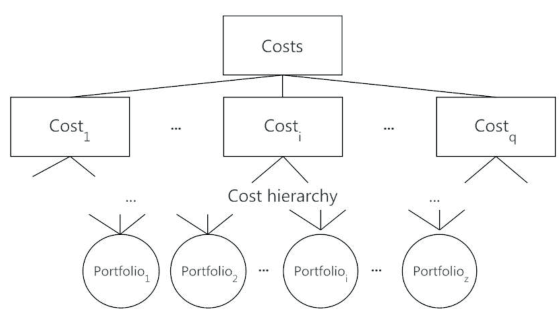

Figure 2. Cost hierarchy template for Portfolio Selection.

3.2. Project Monitoring

3.2.1. Benefit Hierarchy

The benefit hierarchy defined during portfolio selection is updated according to changes in the

BSC. Hence, some goals and KPIs may be added and others may be eliminated. Alternatives are given by new proposals and ongoing projects (see Figure 3) and are presented at the final level of the hierarchy.

If there is a change in the hierarchy defined during portfolio selection, then it is necessary to perform pairwise comparisons to calculate the relative preference of each criterion.

In the case of alternatives, assessment is based on each alternative (project) contribution to each criterion. Alternatives assessment is performed by specifying the forecasted value for each key measure if the project is implemented. If a project does not contribute to improve a particular KPI, then the current value of the KPI is used in the analysis. During project development, measures will remain unchanged, but once a project is completed, projects will deliver benefits and measures will be updated accordingly.

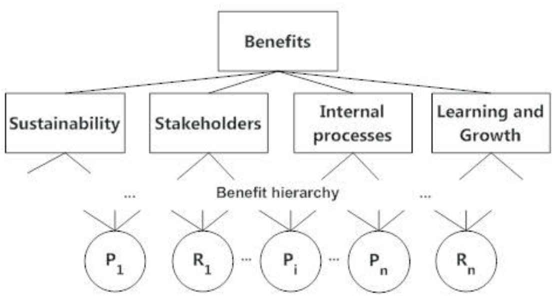

Figure 3. Benefit hierarchy template for project monitoring.

For the lower level of the hierarchy (the level of the alternatives) the evaluation considers numerical information updated at the control point of interest. In this way, KPIs' values recorded in the BSC can be directly used and time-consuming pairwise comparisons are avoided.

3.2.2. Cost Hierarchy

The approach to define the cost hierarchy is similar to the one used during portfolio selection. Criteria representing costs are derived from economic, environmental and social analysis developed for each project in the funded portfolio. The relative preference of each cost is performed using pairwise comparisons. Alternatives assessment is performed using raw data (see Figure 4).

4. Application Case

Alas Ingenieria is a small information technology company located in Bahía Blanca (Argentina) since 1991. The company provides advanced solutions for engineering and information management for industrial plants. They also provide support to develop, implement and integrate applications. Currently the company is organized under two segments –software products and services. The owner announced intent to explore options to promote growth, efficiency and improve the company´s social responsibility image. After performing a stakeholders' analysis (whose description is out of the scope of this paper), a Strategy Map (see Figure 5) and a BSC are defined. In what follows, the results of project monitoring are described. The funded portfolio is composed of projects described in Table 1.

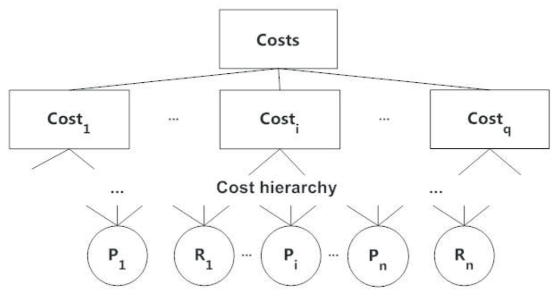

Figure 4. Cost hierarchy template for Project Monitoring.

4.1. Criteria and Sub-criteria Definition

The benefit hierarchy reflects the information provided by the BSC, *i.e.* perspectives; goals and KPIs (see Figure 6 and Figure 7). The cost impact categories which are particularly significant for this study are energy consumption, paper use and economic (initial costs and total cost of ownership). The cost hierarchy is structured using these categories (Figure 8).

4.2. Alternatives definition

Alternatives are given by projects included in Table 1. For each project, two alternatives are defined:

a) Alternative P_i, $1 \le i \le 18$, represents a project as planned.

b) Alternative R_i, $1 \le i \le 18$, represents the project´s status at a control point.

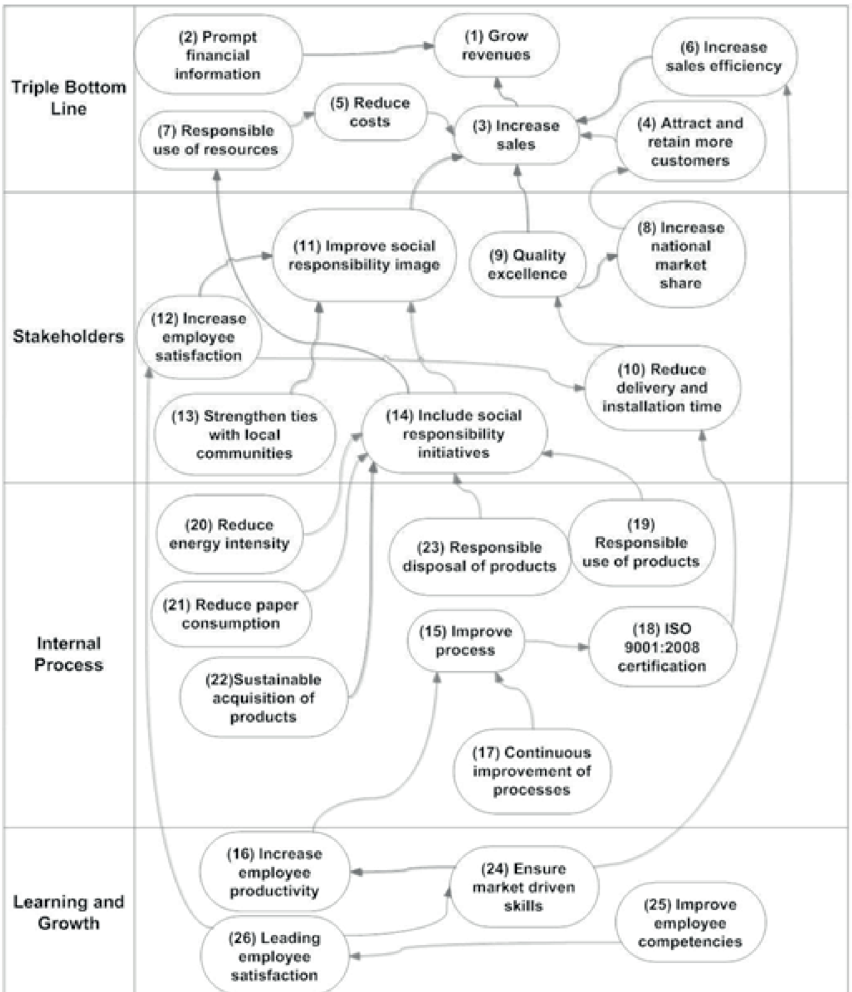

Figure 5. Strategy Map (partial view).

Table 1. Projects and supported goals in the Strategy Map.

Projects	Goals in the Strategy Map
Process map definition	9 - 10 - 15 - 18
Equipment repair and donation	13 - 23
Train employees	12 - 16 - 17 - 25
Process control	17
ISO 9001:2008 certification	18
Account information processing for financial analysis	1 - 18
Cost analysis	1 - 18
Train customers about responsible use of products	19
Upgrade appliances and electronics	20
Train employees about energy efficiency	20
Paper less initiative	21
Sustainable acquisition of products	22
Responsibly disposal of batteries	23
Paper recycling	23
Develop employee discount programs	12 - 26
Conduct employee performance evaluation	16
Financial software module deployment	2
CRM software module deployment	3 - 4 - 6 - 8

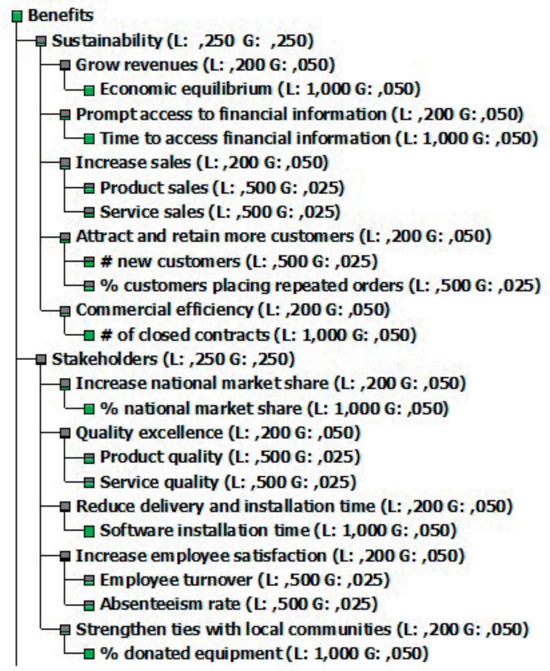

Figure 6. Benefit hierarchy.

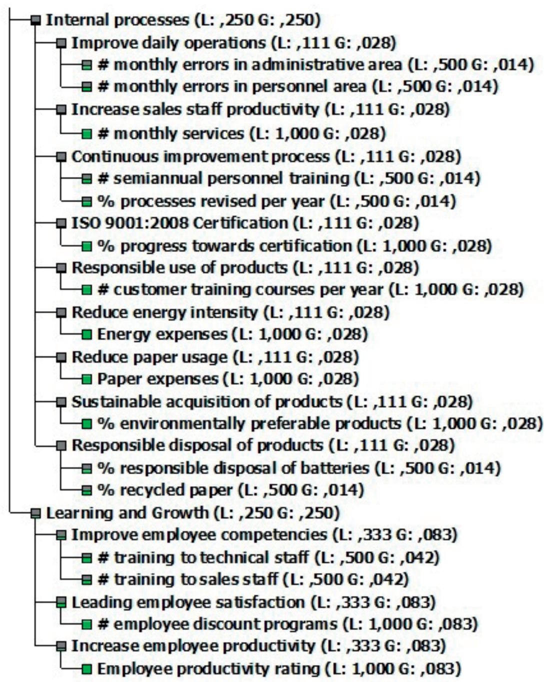

Figure 7. Benefit hierarchy (continuation).

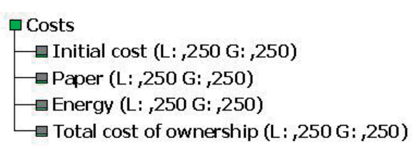

Figure 8. Cost hierarchy.

4.3. Criteria, sub-criteria and alternatives definition

In this case, the same relative preference was given to all criteria. In this way, AHP and DEA results are derived from the same scenario. The Benefits and Costs Hierarchy show global and local priorities for each criteria and sub-criteria. For example, criteria Triple Bottom Line, Stakeholders, Internal Process and Learning and Growth have the same priority with respect to the global goal (25%). Alternatives assessment at control *t* point is performed using data updated to that instant of time.

4.4. Synthesis Results

Once that all judgments had been defined, numerical evaluations are computed using Expert Choice® software. Table 3 (Appendix I) includes results of benefits, costs, and an integrated score. The final score that integrates benefits and costs is calculated using expression (1) (see Section 3).

In order to give an interpretation to AHP priorities, recall that data used to assess alternatives P_i belong from project plans; while data used to assess alternative R_i at control point t ($1 \leq i \leq 18$), belong from data updated at this control point. Hence, the aim of AHP step is analyzing each pair P_i, R_i, and finding out if priorities are different. For example, if P_i score is greater than R_i score, then it may be that benefits have not been realized yet, or that R_i spending has been more than planned.

Table 4 (Appendix II) includes an interpretation of AHP synthesis. It can be seen that resulting priorities reflect the status of projects. The worst score is for project 5 because its costs are much higher than the rest of the projects. Alternative P_1 has a low priority since forecasted cost is quite high. Projects 17 and 18 show a low priority because the score based on cost information is relatively bigger than others (see Table 3 in Appendix I).

4.5. DEA *versus* AHP

This section is devoted to compare and discuss AHP and DEA results. Since score numbers are not comparable in absolute terms, the aim is to find out if decisions derived from AHP results are consistent with decisions derived from AHP scores. In other words, for each pair P_i, R_i it is discussed if AHP scores are consistent with DEA ones.

Table 2 summarizes results and Table 5 (Appendix III) includes DEA scores. In general, they support the

Table 2. Summary of AHP and DEA scores comparison for each pair P_i, R_i.

Projects	AHP and DEA scores for P_i, R_i
Process map definition	Even though DEA finds both P1 and R1 efficient, P1 score is better than R1. On the other hand, AHP computes a better score for R1. The current status is that almost all benefits have been realized and the spending is much less than planned. AHP results are consistent with this. DEA finds P7 as a reference set of R1, then R1 is not compared with P1.
Equipment repair and donation	Both DEA and AHP give a better score to P2. However, DEA provides a bigger difference between P2 and R2. P2 is the reference set of R2. In fact, the total budget was spent and full benefits are expected in the future. DEA better highlights the situation.
Train employees	Similar remarks as for project 2.
Process control	Similar remarks as for project 2.
ISO 9001:2008 certification	Consistent.
Account information processing for financial analysis	Consistent.
Cost analysis	Consistent.
Train customers about responsible use of products	Consistent.
Upgrade appliances and electronics	Consistent.
Train employees about energy efficiency	Consistent.
Paper less initiative	There is a slight difference between P11 and R11 AHP scores while DEA scores are equal. However, it is doubtful that the decimal points are relevant. So it may be concluded that scores are consistent.
Sustainable acquisition of products	Consistent.
Responsibly disposal of batteries	Consistent.
Paper recycling	Consistent.
Develop employee discount programs	DEA finds P15 inefficient and R15 efficient. AHP provides the same score. The current scenario is that R15 provided more benefits than planned with the estimated budget. Then, DEA reflects the situation while AHP does not.
Conduct employee performance evaluation	Consistent.
Financial software module deployment	Consistent.
CRM software module deployment	Consistent.

same decisions based in AHP. It can be concluded that DEA scores are more precise with respect to the current progress of projects. DEA scores may not be realistic when the reference set of a project R_i is P_j, $i \neq j$ (see remarks about project 1 in Table 2).

Discrepancies in AHP and DEA rankings are not surprising since techniques are different. For example, DEA gives an outstanding rank for R5 (number 5). The score of P5 is smaller than R5´s score, and R5 is P5´s reference set. In other words, P5 is punished because it is compared to R5. In addition, there are no other units with similar production levels so R5 is deemed as efficient. This result arises because of the specialization problem that is a known drawback of DEA. By using AHP, the ranking of P5 (18) is also worse than R5´s rank (17), but the difference is not so large. To summarize, while the comparison of AHP and DEA scores are consistent for pairs P_i,R_i, rankings do not provide useful information because they compare all projects and management decisions should be based on the score analysis of pairs P_i,R_i.

5. Conclusions

This work describes how to use AHP as an aid in project management. The proposal is grounded on an existing project management framework to select and monitor projects based on DEA, and discusses modifications and additions arising from using AHP.

The main components of the AHP model is a benefit hierarchy that structures goals represented in a BSC, and a cost hierarchy that includes costs derived from economic, environmental and social impacts derived from project development. Criteria and sub-criteria assessment is realized doing pairwise comparisons. For the case of alternatives, the evaluation considers raw data.

The use of AHP allows overcoming some limitations of DEA. The first is the introduction of preferences. The possibility of assigning preferences to criteria allows considering different scenarios and performing what-if analysis. Scenario analysis is often a requirement when selecting projects since uncertainty in many factors such market development, cost variance, among many others. In particular, when project selection takes into account economic, environmental and social dimensions, reasoning about the impact of each dimension enhances the analysis. The second limitation of DEA is the homogeneity assumption where all DMUs are required to have comparable production levels. Since AHP does not require alternatives to be similar, projects of different size may be compared. In addition, AHP does not make assumptions about the number of alternatives. In DEA, it is desirable that the number of DMUs exceeds the number of inputs and outputs several times. Finally, AHP allows multiple decision makers to give judgments. While this option was not used in the work, it may be relevant since it favors inclusive approaches that allow the participation of multiple actors.

On the other hand, AHP has some disadvantages. Sometimes, it is not advisable to derive priorities directly from hard data because preferences are often not linearly related to data. For instance, if with respect to initial cost, alternative A is two times more preferable than B, then A may not be twice as preferable as B. How to systematically derive rating scales from raw data is a potential direction for research.

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Appendix I. AHP Synthesis Results

Table 3. Detail of AHP results.

Projects (alternatives)	Benefits	Costs	Integral Score
P1: Process map definition	0.026	0.054	0.00048148
P2: Equipment repair and donation	0.029	0.001	0.029
P3: Train employees	0.028	0.013	0.00215385
P4: Process control	0.028	0.001	0.028
P5: ISO 9001:2008 certification	0.029	0.455	6.3736×10^{-5}
P6: Account information processing for financial analysis	0.027	0.001	0.027
P7: Cost analysis	0.028	0.001	0.028
P8: Train customers about responsible use of products	0.028	0.053	0.0005283
P9: Upgrade appliances and electronics	0.027	0.001	0.027
P10: Train employees about energy efficiency	0.027	0.001	0.027
P11: Paper less initiative	0.027	0.015	0.0018
P12: Sustainable acquisition of products	0.029	0.001	0.029
P13: Responsibly disposal of batteries	0.028	0.001	0.028
P14: Paper recycling	0.027	0.001	0.027
P15: Develop employee discount programs	0.029	0.018	0.00161111
P16: Conduct employee performance evaluation	0.03	0.008	0.00375
P17: Financial software module deployment	0.025	0.033	0.00075758
P18: CRM software module deployment	0.03	0.03	0.001
R1: Process map definition	0.027	0.023	0.00117391
R2: Equipment repair and donation	0.028	0.001	0.028
R3: Train employees	0.027	0.001	0.027
R4: Process control	0.028	0.001	0.028
R5: ISO 9001:2008 certification	0.028	0.18	0.00015556
R6: Account information processing for financial analysis	0.027	0.001	0.027
R7: Cost analysis	0.028	0.001	0.028
R8: Train customers about responsible use of products	0.028	0.018	0.00155556
R9: Upgrade appliances and electronics	0.027	0.001	0.027
R10: Train employees about energy efficiency	0.027	0.001	0.027
R11: Paper less initiative	0.027	0.013	0.00207692
R12: Sustainable acquisition of products	0.028	0.001	0.028
R13: Responsible disposal of batteries	0.028	0.001	0.028
R14: Paper recycling	0.028	0.001	0.028
R15: Develop employee discount programs	0.029	0.018	0.00161111
R16: Conduct employee performance evaluation	0.028	0.008	0.0035
R17: Financial software module deployment	0.025	0.033	0.00075758
R18: CRM software module deployment	0.028	0.03	0.00093333

Appendix II. Project Monitoring based on AHP

Table 4. Project Monitoring results based on AHP.

Projects	Decision	Alternative	Score	Comments
Process map definition	Continue	P1	0.00048	In progress. Achievement of some benefits. Costs less than planned.
		R1	0.0018	
Equipment repair and donation	Continue	P2	0.029	Full benefits expected on the final period. Total budget spent.
		R2	0.028	
Train employees	Continue	P3	0.002154	In progress. Some benefits expected on the final period, others benefits expected in the long-term. Costs less than planned.
		R3	0.027	
Process control	Continue	P4	0.028	In progress. Some benefits expected on the final period, others benefits expected in the long-term. Costs less than planned.
		R4	0.028	
ISO 9001:2008 certification	Continue	P5	6.37363×10^{-5}	In progress. Achievement of some benefits. Costs less than planned.
		R5	0.00016	
Account information processing for financial analysis	Completed	P6	0.027	Deliverables fully accomplished. On budget.
		R6	0.027	
Cost analysis	Completed	P7	0.028	Deliverables fully accomplished. On budget.
		R7	0.028	
Train customers about responsible use of products	Continue	P8	0.00053	In progress. Achievement of some benefits. Costs less than planned.
		R8	0.0016	
Upgrade appliances and electronics	Completed	P9	0.027	Deliverables fully accomplished. On budget.
		R9	0.027	
Train employees about energy efficiency	Completed	P10	0.027	Deliverables fully accomplished. On budget.
		R10	0.027	
Paper less initiative	Continue	P11	0.0018	In progress. Achievement of some benefits. Costs less than planned.
		R11	0.0021	
Sustainable acquisition of products	Continue	P12	0.029	In progress. Achievement of some benefits. Costs less than planned.
		R12	0.028	
Responsible disposal of batteries	Continue	P13	0.028	In progress. Achievement of some benefits. Costs less than planned.
		R13	0.028	
Paper recycling	Continue	P14	0.027	In progress. Achievement of all benefits. Costs less than planned.
		R14	0.028	
Develop employee discount programs	Continue	P15	0.0016	In progress. Achievement of some benefits. On budget.
		R15	0.0016	
Conduct employee performance evaluation	Continue	P16	0.00375	In progress. Achievement of some benefits. On budget.
		R16	0.0035	
Financial software module deployment	Completed	P17	0.00076	Deliverables fully accomplished. On budget.
		R17	0.00076	
CRM software module deployment	Continue	P18	0.001	In progress. Achievement of some benefits. On budget.
		R18	0.00093	

Appendix III. Project Monitoring based on DEA

Table 5. Project Monitoring scores based on DEA.

DMU	Score	DMU	Score	DMU	Score
P1	1.03	P7	1.00	P13	1.02
R1	1.00	R7	1.00	R13	1.03
P2	1.01	P8	1.00	P14	1.00
R2	0.38	R8	1.02	R14	1.03
P3	1.06	P9	0.77	P15	0.76
R3	1.00	R9	0.77	R15	1.02
P4	1.02	P10	1.00	P16	1.02
R4	0.35	R10	1.00	R16	0.82
P5	1.01	P11	0.76	P17	0.17
R5	1.03	R11	0.76	R17	0.17
P6	1.00	P12	1.01	P18	1.05
R6	1.00	R12	1.02	R18	0.31