
Measuring the efficiency of outsourcing: an illustrative case study from the aerospace industry

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Abstract. Outsourcing is related to the action which an organization deals with its suppliers through a kind of business contract where a specific activity or service has been hired to be made. The outsourcing of some activities has become a common practice in the industry, nowadays. It reduces costs, significantly, in the production process and, at the same time, adds some values to the business organization. However it is necessary to measure the performance of these activities. Data Envelopment Analysis (DEA) is a non-parametric method useful to measure comparative performance. It has a wide range of applications measuring comparative efficiency. The Analytic Hierarchy Process (AHP) is a multiple criteria decision-making method that uses hierarchic structures to represent a decision problem and then develops priorities for the alternatives based on the decision-maker's judgments. This paper presents an integrated application based on DEA and AHP to evaluate the efficiency of subcontracted companies in a Brazilian aerospace factory.

Key-words. Aerospace Industry, Efficiency and Performance Analysis, Outsourcing, DEA, AHP.

1 Introduction

Outsourcing is an updating subject in many companies nowadays and it has become an option to reduce costs and to improve the productivity in the production process. The decision to outsource is often made in the interest of lowering firm costs, redirecting or conserving energy directed at the competencies of a particular business, or to make more efficient use of worldwide labour, capital, technology and resources.

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By this way it is necessary to develop a process to control the activities that will be outsourced. An evaluation of the productivity and efficiency of these companies becomes necessary to get the results reached by each company and with these data take some management decisions related to the outsourcing process and its costs. To evaluate this efficiency value some criteria need to be considered by the decision-maker once the objective of this study is to estimate the efficiency of outsourced companies based on the decision-maker's judgments and then develops priorities for the alternatives. In this paper an integrated application of DEA with AHP will be made to determine the efficiency of outsourced companies in the aerospace industry.

A comparative table with all outsourced companies (*Decision Making Unit or DMUs*) will be elaborated according to the inputs and outputs related to spare parts technical publication process. There are 8 outsourced companies to be evaluated. The input in this process is represented by the activities subcontracted or even the package that will be send to these subcontracted companies. This package comes from every modification that happens in the aircraft and that will represent an updating of spare parts technical publications. In this case the input means the quantity of technical documents that will be released by project department. A quantity of figures in the aircraft spare parts technical publications will be necessary to be revised or even created in function of those modifications released by the project and engineering departments. Beyond the elaboration of new or revised figures to be introduced in the spare parts technical publications, the updating of part list in the data bank becomes necessary once this information will be used to all operators to plan their spare parts logistic and aircraft maintenance to keep their fleet flying every time. The output of this process will be represented by the quantity of figures done and incorporated in the spare parts technical publications and at the same time if this activity will be delivered on time or not by each outsourced company.

This paper is organized in a review of theoretical considerations related to DEA and the efficiency concept and also a revision of AHP. In the next section the case study will be shown in details with a description of outsourcing process in the aerospace factory regarding to spare parts technical publications process and the application of DEA integrated with AHP. The results of this application will be shown with some comments and after this section a conclusion of these results will be made with possible future possibilities to continue this study.

2 Theoretical considerations

2.1 Data Envelopment Analysis

DEA is a methodology for measuring the relative efficiencies of a set of decision making units (DMUs) that use multiple inputs to produce multiple outputs [2]. DEA was initially developed by Charnes et al for a case of school evaluation [3]. DEA is also defined as a linear programming method to compute DMUs comparative efficiencies [5]. In this case the DMUs relative efficiency is defined as the ratio of the weighted sum of its outputs to the weighted sum of its inputs [6]. In

DEA is possible to consider n DMUs each consuming m inputs and producing p outputs where \mathbf{X} and \mathbf{Y} are matrices, consisting of nonnegative elements, containing the observed input and output measures for the DMUs [6]. Usually there are multiples inputs and outputs, so it is necessary to form a unique virtual output and a unique virtual input, for the observed DMU p . By using linear programming (LP) [4], we can find the weights that maximize the ratio output per input through the model showed in Figure 1 [4]:

$$\begin{aligned} \text{Max } \alpha_0 &= \sum_{r=1}^s \mu_r y_{r0} \\ \text{s.t. } \sum_{i=1}^m v_i x_{i0} &= 1, \\ -\sum_{i=1}^m v_i x_{ij} + \sum_{r=1}^s \mu_r y_{rj} &\leq 0, \quad j = 1, \dots, n, \\ v_i &\geq 0, \quad i = 1, \dots, m, \\ \mu_r &\geq 0, \quad r = 1, \dots, s. \end{aligned}$$

Figure 1. Equation of CCR model [4]

The CCR model was chosen for this purpose once all outsourced companies have similar scales of operation [5]. In other words, the scale effects for each company are irrelevant. An important point to be mentioned is that it is necessary to choose the orientation of DEA model. In this case study the output oriented model was chosen once it attempts to maximize outputs while using no more than the observed amount of any input [3]. For this model it is necessary to exchange the numerator and the denominator and to minimize the objective function [3].

2.2 Analytic Hierarchy Process

The AHP is a multiple criteria decision-making method that uses hierarchic structures to represent a decision problem and then develops priorities for the alternatives based on the decision-maker's judgments [8]. In general, the multiple criteria methods can be classified as weighting methods, outranking methods, goal and reference point methods and value function methods [7]. AHP uses redundant judgments for checking consistency, and this can exponentially increase the number of judgments [7]. Analytic focus of rating method enables decision-makers to evaluate a large number of alternatives easily. In this method an element is compared against an ideal property and generally, only the final alternatives of choice are absolutely measured [7]. It is used a linear scale from 1 to 9 (Fundamental Scale) in the judgements [8]. In this paper the AHP was applied to determine the weighted sums of scaled indicators. The weighted sums of scaled indicators reached with AHP will determine the criterion values which will be the input and output values for DEA application. This integration of both methodologies has been proposed trying to incorporate preference information of decision-maker in the final result of efficiency.

3 The application in the aerospace industry

The aerospace industry has some particular process that differs from other kind of industries and the process of spare parts technical publications is one of these particularities.

Generally an aircraft manufacturer used to produce different models of aircraft and for each of these models it is necessary to support all these aircrafts during a long period. The aerospace industry follows the procedures and standards from IATA (*International Air Transport Association*) which elaborated important international standards such as ATA 100 , ATA 200, SPEC 2000 and SPEC 2200. All those standards were elaborated by operators, regulatory agencies, manufacturers, and others important government authorities around the world.

By this way there is a great importance regarding to safety and quality in the aerospace industry. As many others industries the resource of outsourcing was adopted by many of manufactures around the world although always following the roles and standards based on ATA 100 and SPECs 2000/2200. As a result of this development the resource of outsourcing has started to be applied in the spare parts technical publications because it was necessary to increase productivity and at the same time to improve the efficiency in all the technical team of spare parts engineering in function of the increasing in modifications related to new models of aircrafts that were being developed. So it was necessary to elaborate a process to control the activities of outsourced companies. As consequence it was proposed the employment of DEA integrated with AHP once it can result in a good tool to control and to take some efficiency values of these subcontracted companies with the possibility to incorporate the decision-maker preferences according to the criteria adopted to this case study.

It is necessary to define a set of criteria, which are sufficient to characterize the process of outsourcing of spare parts technical publications. The criteria should be relevant to the decision-maker once he/she should emphasize different aspects of outsourced companies performance. Also it is important to use multiple criteria in the evaluation, because it is extremely difficult if not impossible to find a way to aggregate the criteria into one criterion [6]. These criteria were defined by a group of specialists of spare parts technical publications team that used their experience and monthly reports related to all technical documents worked by these subcontracted companies. According to this group of specialists and their carefully analysis to define a set of criteria which are sufficient enough to characterize the process of outsourcing of spare parts technical publications the above criteria were defined:

- Quality (C1)
- Time (C2)
- Cost (C3)
- Quantity of technical documents released by project (C4)

For these criteria it is necessary to introduce some indicators which can be employed to make the criteria suitable for evaluation. These indicators are concrete in the sense that we can somehow more or less objectively measure alternatives

with them [6]. It is also interesting to create some indicators to some criteria once they contain enough information about the values of the criteria. The indicators were proposed below to all criteria except for the fourth criterion.

(a) Criterion: Quality (C_1)

- Illustration,
- Part List and
- Number of Questions

(b) Criterion: Time (C_2)

- Delivered,
- New and
- Assembly

(C) Criterion: Cost (C_3)

- Internal,
- External and
- Tools

Carrying out a systematic and quantitative evaluation of these companies, it is important to introduce the scales for the criteria according to the indicators allocated to each criterion [6]. In order to aggregate values to the indicators it is necessary to quantify them with appropriate tool and for this case study the AHP was chosen once it will be used to determine the weighted sums for each indicator. The results which will be obtained with AHP for each criterion will be applied to determine the efficiency of production process with DEA. These values will be the inputs and outputs to determine the efficiency of these companies with DEA.

5 Results and Comments

The first step in this analysis was to determine the weighted sums for scaled indicators [6]. The values for these judgements were obtained with a group of specialists that attributed values to indicators for each criterion. For this purpose it was used the AHP and Table 1 presents the judgements according to explanation in section 2.2.

Criterion C_1				
	Illustration	Part List	Questions	Weight
Illustration	1.0	0.33	0.2	0.10
Part List	3.0	1	0.33	0.26
Questions	5.0	3.0	1.0	0.64

Criterion C ₂				
	Delivered	New	Assembly	Weight
Delivered	1.0	3.0	3.0	0.59
New	0.33	1.0	3.0	0.28
Assembly	0.33	0.33	1.0	0.13
Criterion C ₃				
	Internal	External	Tools	Weight
Internal	1.0	3.0	2.0	0.54
External	0.33	1.0	3.0	0.30
Tools	0.5	0.33	1.0	0.16

Table 1. Weighted sums of scaled indicators

Criteria C₁ is the quality of spare parts technical publications. This quality can be measured by illustrations created or revised for each outsourced company, or even by the quantity of questions received per month by operators and also by the revision of parts list which needs to show exactly all the parts numbers and the relation of interchangeability between parts. The other criteria C₂ is represented for the time that these companies used to deliver the package of activities send to them. The indicators in this case mean the time spend for each company to deliver a package of activities to a new aircraft (in this case a program that it is still being developed), to a delivered aircraft or to an assembly aircraft. The cost of each outsourced company is represented by criteria C₃ which indicators are the external costs, internal costs and the costs with specific tools as softwares and systems. Criteria C₄ is the input of the process. This input was measured by the quantity of technical documents released by project and engineering departments which reflects modifications in the aircrafts. The other step for this evaluation was to determine the values for the criteria. A group of five specialists were asked to scale all indicators in a range where the lower value is zero and the higher value is one. The weighted sums for each indicators was used to determine the final value for each criterion [6] and Table 2 gives the result of this analysis.

	OUTPUTS												INPUT	
	Illustration	Part List	Questions	C ₁	delivered	new	assembly	C ₂	Internal	External	Tools	C ₃	C ₄	
Weights	0.10	0.26	0.64		0.59	0.28	0.13		0.54	0.30	0.16			
A	0.60	0.80	0.70	72	0.60	0.90	0.90	72	0.60	0.40	0.40	51	90	
B	0.70	0.80	0.60	66	0.70	0.50	0.80	66	0.50	0.30	0.30	50	85	
C	0.90	0.70	0.80	78	0.90	0.80	0.70	85	0.90	1.00	0.80	73	75	
D	1.00	0.90	0.80	85	0.70	0.90	1.00	80	1.00	0.90	0.80	94	60	
E	0.70	0.70	0.70	70	1.00	0.80	0.90	93	0.50	0.40	0.40	78	72	
F	0.80	0.90	0.70	76	0.80	0.70	0.70	76	0.60	0.30	0.30	44	80	
G	1.00	0.80	0.90	88	0.80	0.70	0.70	76	0.80	0.70	0.90	71	70	
H	0.70	1.00	1.00	97	1.00	0.80	0.80	92	0.80	0.90	1.00	91	65	

Table 2. Criterion values as the weighted sums of scaled indicators

The criterion values for each alternative will be used to evaluate the production efficiency for these outsourced companies with DEA and in this application of DEA the outputs are represented by criteria C_1 , C_2 and C_3 while the input is represented by criteria C_4 . The results for efficiency evaluation with DEA can be viewed in the Table 3.

DMU	Efficiency
A	0.57
B	0.55
C	0.80
D	1.00
E	0.91
F	0.67
G	0.84
H	1.00

Table 3.Efficiency scores of DEA

The results of DEA evaluation were elaborated with the software FSDA – Free Software for Decision Analysis [1]. Observing the results of Table 4 is possible to note that the DMUs D and H are efficient with standard efficiency while the others are not so efficient as DMUs D and H. In this paper an efficiency analysis of 8 outsourced companies was performed considering the values obtained with AHP analysis to indicators chosen according to decision-maker's preference. Other possibilities to develop this study case can be performed applying other decision making tools although the results obtained here tried to approach the preference of the decision-maker to establish the efficiency of these outsourced companies.

6 Conclusion

In this paper an integrated application of DEA and AHP in the aerospace industry was showed. This application was done with outsourcing process of aircrafts spare parts technical publications and how this application could help the decision-maker to evaluate the efficiency of the outsourced companies considering criteria and alternatives related to this outsourcing process. Those criteria and indicators were chosen by a group of specialist that deal with the spare parts technical publications process which were considered relevant to affect the final results of this production process and also its efficiency and productivity.

Through the application of AHP was possible to scale these indicators in weighed sums and define which one was considered the most important to the process according to the range of values that were attributed to each indicator by the decision-maker. An other evaluation was done to determine the criteria values of alternatives in each criterion. These results were used to determine the

efficiency of each alternative related to criteria that were scaled by the decision-maker applying DEA. For this application the criteria of quality, time (deadline) and cost were considered the outputs for DEA while the quantity of technical documents released by project department related to modifications in the product was considered the input for DEA evaluation.

As a result for DEA evaluation DMUs D and H were considered efficient for output orientation model what means these DMUs used to maximize outputs while using no more than the observed amount of any input. According to this result a proposal to improve the efficiency of others outsourced companies will be elaborated considering the criteria defined by the decision-maker. The results of efficiency for DMUs D and H will be used as a benchmarking for others DMUs and at the same time all the values reached with measured parameters will be considered to improve the performance of these outsourced companies.

7 References

- [1] ANGULO-MEZA, L., BIONDI NETO, L., SOARES DE MELLO, J.C.C.B., GOMES, E.G., COELHO, P.H.G. "FSDA – Free Software for Decision Analysis (SLAD – Software Livre de Apoio a Decisão): a software package for data envelopment analysis models". Congreso Latino Iberoamericano de Investigación de Operaciones y Sistemas, La Habana – Cuba, 2004.
- [2] KAO, C. Interval efficiency measures in data envelopment analysis with imprecise data, *European Journal of Operational Research* 174 (2006) 1087–1099
- [3] CHARNES, A., COOPER, W.W., RHODES, E. Measuring the efficiency of decision making units. *European Journal of Operational Research* 2, 429–444, 1978.
- [4] JAHANSHAHLOO, G.R. Finding strong defining hyperplanes of Production Possibility Set, *European Journal of Operational Research* 177 (2007) 42–54
- [5] SOARES DE MELLO, J. C. C. B. Engineering Post-Graduate Programmes: A Quality And Productivity Analysis, *Studies in Educational Evaluation* 32 (2006) 136-152
- [6] KORHONEN, P., TAINIO, R., WALLENIOUS, J. Value efficiency analysis of academic research *European Journal of Operational Research* 130 (2001) 121±132
- [7] ERTAY, T., RUAN, D., TUZKAYA, U. R. Integrating data envelopment analysis and analytic hierarchy for the facility layout design in manufacturing systems *Information Sciences* 176 (2006) 237–262
- [8] SAATY, T. L., *The Analytic Hierarchy Process*, McGraw-Hill, New York, 1980.