Selection of Segments to be Sourced from Low Cost Countries for a Global Industrial Equipment Manufacturer based on a Multi-Attribute Decision Support System

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Abstract. We introduce a complex decision-making problem, the prioritization of potential high-profit category segments to be sourced from low cost countries, where several conflicting criteria must be taken into account simultaneously to help focus the attention on developing low cost countries sourcing strategies for candidate segments, where potential savings are higher and risk is minimum. The GMAA system will be used for this purpose. It is a decision support system based on the Decision Analysis cycle that accounts for incomplete information concerning the inputs, where so-called decision-making with partial information plays a key role.

1 Introduction

Competitive pressures are forcing companies to reduce their overall costs, while delivering faster and more diverse product portfolios to be more responsive to customers and competitors. In response to these pressures, companies are increasingly taking advantage of the opportunity to source from low cost countries (LCC) to achieve significant savings and give their organizations a competitive advantage.

For a global industrial equipment manufacturer with material costs accounting for about 50% of the value of its final products, sourcing performance is crucial to Original Equipment Manufactured (OEM) competitiveness. OEM management identified a number of potential purchasing categories for which OEM's different divisions will coordinate their sourcing activities to reduce total cost and optimize the supplier base, achieving significant savings on this addressable expenditure. OEM's overall strategy was to seek high quality and service levels, while minimizing total cost of creating a cost-efficient production process.

Looking to drive more cost-effective and global supply chains, the procurement organization was leveraging the procurement function to identify low cost and potential reliable overseas sources of supply and rapidly prioritizing the effort in terms of

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Advances in Artificial Intelligence Theory
Research on Computing Science 16, 2005, pp. 3-12

high-profit category segments and LCC regions to gain a foothold in emerging markets. However, the sourcing function within the company faced specific constraints.

Even though multinational companies have been sourcing from LCC for many years, purchasing in these regions is often very risky, and a number of companies spend a lot of energy identifying and minimizing these risks (identifying reliable sources, political instability, currency risks, longer lead-times, more complex logistics, different/non-existent legal structures,…).

Typical incremental cost reductions of 15%-20% can be achieved by sourcing from LCC. Nonetheless, to move the supply source for some specific segment categories to these regions, these segments have to be proven to have a comprehensive risk assessment, balanced against potential for lower costs. Although benefits are compelling, they come with significant challenges.

While there is no single approach to entering the LCC market, the first critical step is to conduct a comprehensive category assessment and prioritization to determine opportunities for sourcing from LCC, allowing the company to assess LCC by priority segment and reduce the "time-to-benefit" realization of its LCC sourcing program.

For the purpose of determining the highest profit potential category segments to be sourced from LCC, a range of conflicting criteria were taken into account simultaneously to provide the most relevant information about other factors. Therefore, the promise of significant cost reductions is not the only consideration, and the country, industry and supplier risks will be key factors for application during the prioritization of the category segments. In this case, the responsible procurement organization has evolved into a formal decision process in which other strategic issues related to LCC sourcing activities were quantified and formally incorporated into the analysis, where the potential for lower costs was only one factor in the objectives of the purchaser.

We propose using the *Generic Multi-Attribute Analysis* (GMAA[1]) to deal with the above complex decision-making problem, [1,2]. The GMAA system is a PC-based decision support system based on the Decision Analysis (DA) cycle that accounts for incomplete information concerning the inputs, i.e., alternative performances, component utilities and objective weights. It uses an additive multiattribute utility model to evaluate the alternatives under consideration and includes different tools for performing co-called *decision-making with partial information* to take advantage of the imprecise inputs, see [3].

We have divided the paper, according to DA stages, into three sections. The first section deals with problem structuring, in which an objective hierarchy is built, attributes are established for the lowest-level objectives and the alternatives to be evaluated are identified, as are their performances in terms of the above attributes. Next, in the second section, stakeholder preferences are quantified, which implies assessing component utilities for the different attributes and the relative importance of objectives in the hierarchy by means of weights. The third section focuses on the evaluation of alternatives and sensitivity analysis. Finally, some conclusions are provided in the fourth section.

[1] http://www.dia.fi.upm.es/~ajimenez/GMAA

2 Problem Structuring

As mentioned above, the overall objective of this complex decision-making problem is to create a cost efficient production process by determining the most highest profit potential category segments to be sourced from LCC at the lowest risk. For this purpose, we have to take into account several conflicting objectives that were structured in an objective hierarchy as follows:

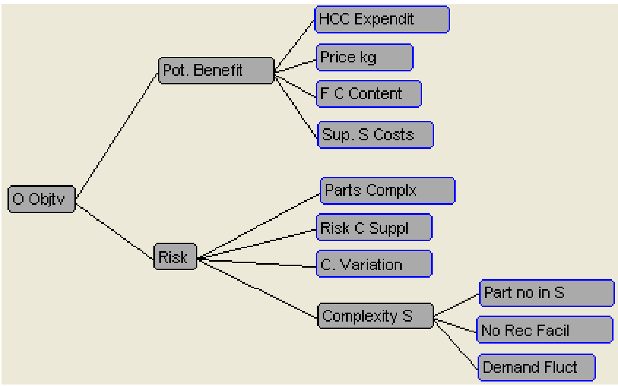

Fig. 1. Objectives hierarchy to create a cost efficient production process

The Overall Objective (O.Objtv) was split into two main sub-objectives: *Potential Benefits* (Pot. Benefit) and *Risks* (Risk). *Potential Benefits* were measured in terms of four sub-objectives. The *Total annual expenditure* (HCC Expendit) on all parts in the segment not sourced from LCC. The expenditure is an indicator of the potential volume with which we are dealing. The higher the expenditure is, the more room there is for savings. The *Price per kg* (Price kg) indicates the price regarding the value-added for the parts produced in high cost countries (HCC). The higher the HCC price/kg value-added represents high potential benefit. The *Factor cost content* (F C Content) is subject to comparison between HCC and LCC. Labor is the main factor cost to be taken into account. The higher the labor content is, the larger is the window for differences in cost between sourcing countries. High labor content represents potential high cost savings when sourcing from LCC. Finally, *Supplier switching costs* (Sup. S Costs) is the cost when switching from the current supplier set-up to a new supplier. The higher the switching cost, the lower the potential benefit. Tooling cost is the most important and most easily quantifiable switching cost to take into account. Other switching costs can be considered if known.

On the other hand, *Risks* is split into four sub-objectives. *Complexity of parts* (Complx Parts) represents part of the risk selecting a new supplier. Technical issues related to quality and material specification could be added to the assessment of the total complexity of parts in each segment. The higher the complexity, the higher the risk is. *Risk with current suppliers* (Risk C Suppl) quantifies the number of segments the supplier is supplying at that moment. Moving business in one segment from the current supplier to LCC will influence the supply of the other segments (price increasing, production stop, low performance, etc.). Therefore, the more segments supplied by one supplier, the higher the risk when moving to LCC.

The *Coefficient of variation* (C. Variation) tells us how homogeneous the price per kg of the parts in the segment is. The higher the coefficient of variation, the greater the risk, because there is more variation in the way the different parts of the segment are handled. Finally, *Complexity of segments* (Complexity S) represents supply chain issues in relation to the purchase of parts from a larger perspective. The *Number of parts within a segment* (Part no in S), the *Number of receiving facilities* for the parts in the segment (No Rec Facil) and *Demand fluctuation* (Demand Fluct) are the main quantifiable criteria to be taken into consideration. Table 1 shows the attribute names, units and ranges for the lowest-level objectives in the hierarchy.

Table 1. Attribute names, units and ranges

Attribute name	Units	Range
A1: HCC Expendit	Million euros	[0, 6]
A2: Price kg	Euros per kg	[0, 30]
A3: F C Content	% Labor Costs	[0, 100]
A4. Sup. S Costs	Discrete values	Low, Medium or High
A5: Parts Complx	Subjective Scale	[0,1]
A6: Risk C Suppl	Discrete values	1, 2, 3 or more segments
A7: C. Variation	% Variation	[0, 100]
A8: Part no in S	No. of parts	[0, 650]
A9: No Rec Facil	Discrete values	1, 2, 3-6, 7-8, 9 or more rec. facilities
A10: Demand Fluct	% Fluctuation	[0-100]

The following non-metallic product segments were identified: *SG1* (Polyurethane floor mats), *SG2* (Insulation parts), *SG3* (Fiberglass insulation & liner), *SG4* (Hydraulic hoses), *SG5* (Rubber mounts), *SG6* (Silicone hoses), *SG7* (Air hoses), *SG8* (Plastic injected ABS parts), *SG9* (Plastic injected ASA parts), *SG10* (Nylon Hydraulic tanks), *SG11* (Rotomoulded polyolefin plastic parts), *SG11* (Thermoformed ABS plastic parts), *SG12* (Thermoformed polyolefin plastic parts), *SG13* (InterWet ABS + polyurethane parts), *SG14* (Low compression molding composite parts), *SG15* (Reaction injection molding dicyclopentadiene parts), *SG16* (Reaction injection molding dicyclopentadiene hoods with metal inserts), *SG18* (Resin transfer molding injection molding composite parts) and *SG19* (Hand lay-up composite parts S).

Table 2 shows performances in terms of the attribute for the twenty segments under consideration.

Table 2. Non-metallic product segments and their performances

	A1	*A2*	*A3*	*A4*	*A5*	*A6*	*A7*	*A8*	*A9*	*A10*
SG1	1.73	3.8	26%	Low	0.33	2	23%	40	2	8%
SG2	1.07	8.4	21%	Low	0.92	2	76%	32	6	18%
SG3	0.72	14.7	29%	Low	0.85	6	57%	245	7	6%
SG4	1.20	13.7	21%	Low	0.54	4	50%	623	7	22%
SG5	1.53	18.7	22%	Medium	0.15	3	65%	80	8	13%

SG6	0.91	40	34%	Low	0.11	5	80%	43	5	11%
SG7	0.63	23	31%	Low	0.48	7	75%	54	9	9%
SG8	0.75	18	22%	High	0.47	1	15%	6	1	5%
SG9	0.65	7.4	17%	High	0.55	1	10%	45	8	13%
SG10	4.75	11.8	16%	High	0.11	1	16%	16	6	1%
SG11	5.10	12	47%	Medium	0.91	1	40%	48	9	14%
SG12	1.50	22.6	30%	Medium	0.89	4	63%	200	7	10%
SG13	0.95	8.7	33%	Medium	0.88	2	72%	25	7	1%
SG14	0.64	18.9	33%	Medium	0.12	3	39%	25	1	15%
SG15	1.49	8.2	28%	High	0.15	1	33%	36	7	3%
SG16	1.58	9.6	23%	High	0.47	1	20%	30	3	10%
SG17	2.49	22.1	28%	High	0.17	2	25%	30	6	10%
SG18	3.94	24.6	31%	High	0.19	1	47%	38	4	3%
SG19	2.30	14.1	35%	Medium	0.48	1	31%	12	2	1%

Note that although the above table includes precise values, uncertainty about some of them was taken into account by means of percentage deviations. Specifically, 5% and 3% deviations were introduced in *A2: Price kg* and *A3: F C Content*, respectively, for all the segments under consideration, except *SG2*, *SG8* and *SG9* with 10% and 7% deviations, respectively.

3 Preferences Quantification

Quantifying stakeholder preferences implies, on the one hand, assessing component utilities for the attributes under consideration that represent stakeholder preferences for the possible attribute values, and, on the other, eliciting objective weights that represent their relative importance throughout the hierarchy.

The GMAA system provides methods for quantifying preferences; see [1,2]. In both cases (component utilities and weight assessment) the stakeholders are allowed to provide imprecise information, leading to imprecise utilities and weights. Note that this makes the system suitable for group decision-making because individual conflicting views can be captured through value intervals.

The GMAA system was used to assess components utilities. Imprecise utilities for discrete values were provided for some attributes, while imprecise linear piecewise utility functions were assessed for others. Figure 2 shows the assessed imprecise linear piecewise utility function for *A1: HCC Expendit*, while Figure 3 shows the imprecise utilities provided for the three possible attribute values (1, 2 and 3 or more segments) in *A6: Risk C Suppl*.

A direct assignment and a method based on trade-offs were used to elicit objective weights representing their relative importance throughout the hierarchy, [4].

Remember that attribute weights for the decision, used in the additive multi-attribute model to evaluate alternatives, are assessed by multiplying the objective weights in the path from the *Overall Objective* to the respective attribute. Figure 4 shows the resulting attribute weights for the decision for the problem under consideration.

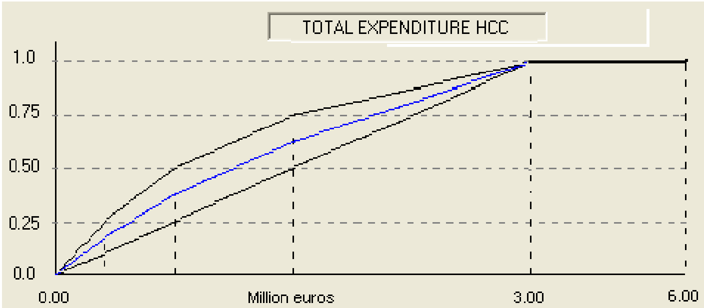

Fig. 2. Component utilities for *A1: HCC Expendit*

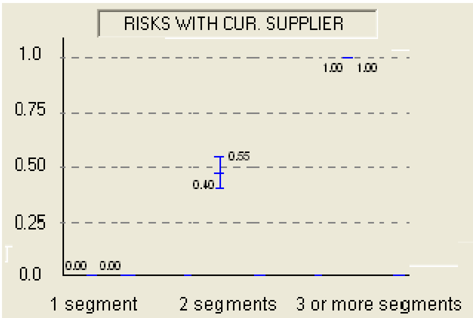

Fig. 3. Utilities for discrete attribute values in *A6: Risk C Suppl*

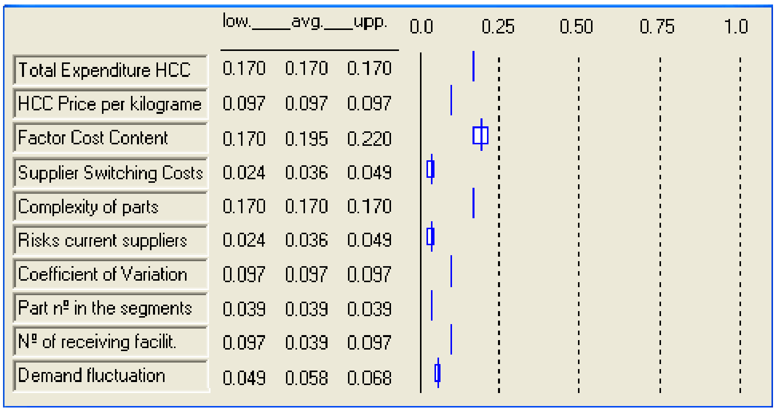

Fig. 4. Attribute weights for the decision

It is important to note that the two main sub-objectives, *Potential Benefits* and *Risks*, were initially equally important, i.e., their respective weights were 0.5, and the summation of the average decision-making weights for attributes stemming from either is 0.5.

4 Evaluation of Alternatives and Sensitivity Analysis

As mentioned earlier, an additive multi-attribute utility function was used to evaluate the segments under consideration. It takes the form

$$u(S^i) = \sum_{j=1}^{10} w_j u_j(x_j^i) \qquad (1)$$

where w_j is the *j-th* attribute decision-making weight, x_j^i is the performance of segment S^i for the *j-th* attribute and $u_j(x_j^i)$ is the component utility associated with the above segment performance. For the reasons described in [5,6], we consider (1) to be a valid approach.

As the system admits imprecision concerning component utilities and weights and uncertainty about segment performances, the above additive model was suitable for assessing the average overall utilities on which the ranking of segments is based, and minimum and maximum overall utilities that give further insight into the robustness of this ranking, see Figure 5.

Looking at Figure 5, *SG19*, *SG11*, *SG18* and SG*13* are the best ranked segments, with average overall utilities of 0.6963, 0.6835, 0.5877 and 0.5417, respectively; while *SG9*, *SG4* and *SG5* are the worst ranked segments, with average overall utilities of 0.3833, 0.3716 and 0.3213. Although *SG19* appears to be the most highly recommended segment, the overlapped utility intervals (ranking robustness) should be examined in a more detail through the sensitivity analysis (SA).

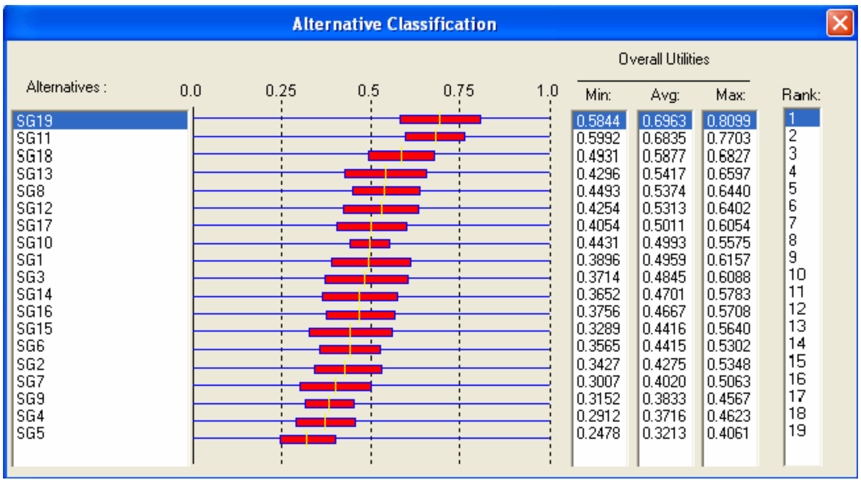

Fig. 5. Ranking of segments and overall utilities

The GMAA system allows users to select another objective to rank by. In our problem it could be very interesting to view the ranking of alternatives for the main sub-objectives, *Potential Benefits* and *Risks*, see Figure 6. Note that both objectives were equally important.

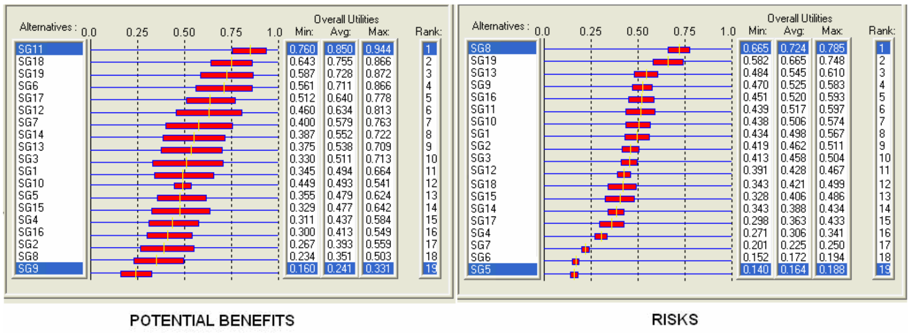

Fig. 6. Ranking of segments for *Potential Benefits* and *Risks*

Note that the best ranked segments for *Potential Benefits* are *SG11* and *SG18*, but they are ranked sixth and twelfth for *Risks*. On the other hand, *SG19* is ranked third and second for both objectives, respectively. Taking into account that *Potential Benefits* and *Risks* are equally important, this matches the ranking for the *Overall Objective*, in which *SG19* is the best ranked segment.

SA should be considered as a source of stimulation to make stakeholders think about the problem in more depth and can give further insight into the robustness of the recommendations. [3,7] introduce a framework for SA in multi-objective decision making.

The GMAA system includes several types of SA. First, non-dominated and potentially optimal alternatives (segments) can be assessed, [8]. In our problem, only three segments, *SG11*, *SG18* and *SG19*, are non-dominated and potentially optimal. Consequently, we should focus the analysis on these segments and discard the remainder because dominated segments can never be the optimal. Note that these were the best ranked segments.

We can also perform Monte Carlo simulation techniques for SA, [9], which allows simultaneous changes to attribute weights and generates results that can be easily analyzed statistically through box diagrams to provide more insights into the multi-attribute model recommendations.

The system selects the attribute weights at random within the respective normalized weight intervals in Figure 4 using a computer simulation program. Each combination of attribute weights is then used to assess a segment's ranking and, finally, the system computes several statistics about these rankings for each segment, like minimum, maximum, mean..., which are output by means of a multiple box plot, see Figure 7.

Looking at the box plots for *SG11*, *SG18* and *SG19*, we realize that they are always ranked second, third and first, respectively. Therefore, we can conclude that the segment category with the best tradeoff between potential benefit and risks to be sourced from LCC is *SG19: Hand lay-up composite parts*. However, we were not just interested in the best segment to be sourced from LCC, our aim was to identify a segment set with a good enough tradeoff between potential benefit and risk.

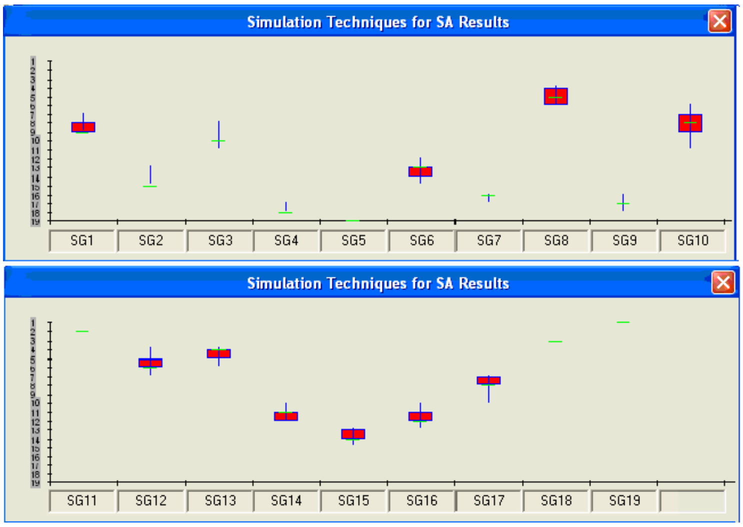

Fig. 7. Results of Monte Carlo simulation techniques

Taking into account the above segment's rankings and the results of SA, OEM management finally recommended the best ranked segments accounting for the 60% of the total expenditure of the non-metallic category segments to be sourced from LCC, see Figure 8.

Final recommended segments

Rank	Alternatives	Overall Utilities Min:	Overall Utilities Avg:	Overall Utilities Max:	Total Spend w/HCC	% spend	Cumm %
1	SG19	0.584421	0.696259	0.809945	2,30	6,78%	6,78%
2	SG11	0.599205	0.683484	0.770322	5,10	15,03%	21,81%
3	SG18	0.493066	0.587714	0.682714	3,94	11,61%	33,42%
4	SG13	0.429618	0.541691	0.659655	0,95	2,80%	36,22%
5	SG08	0.449297	0.537422	0.643996	0,75	2,21%	38,43%
6	SG12	0.425394	0.531276	0.640246	1,50	4,42%	42,85%
7	SG17	0.405360	0.501112	0.605404	2,49	7,34%	50,19%
8	SG10	0.443123	0.499324	0.557503	4,75	14,00%	64,19%
9	SG01	0.389639	0.495854	0.615723	1,73	5,10%	69,29%
10	SG03	0.371448	0.484540	0.608774	0,72	2,12%	71,41%
11	SG14	0.365216	0.470133	0.578293	0,64	1,89%	73,30%
12	SG16	0.375603	0.466701	0.570811	1,58	4,66%	77,95%
13	SG15	0.328941	0.441557	0.564017	1,49	4,39%	82,35%
14	SG06	0.356492	0.441473	0.530208	0,91	2,68%	85,03%
15	SG02	0.342685	0.427510	0.534785	1,07	3,15%	88,18%
16	SG07	0.300710	0.401960	0.506272	0,63	1,86%	90,04%
17	SG09	0.315248	0.383333	0.456682	0,65	1,92%	91,95%
18	SG04	0.291185	0.371589	0.462338	1,20	3,54%	95,49%
19	SG05	0.247849	0.321267	0.406146	1,53	4,51%	100,00%

Fig. 8. Finally recommended non-metallic product segments

Therefore, the company balances potential benefit and risk for category segments and, at the same time, handles the effort and costs to assess LCC attractiveness and conduct supplier identification and screening activities instead of just looking at savings.

6 Conclusions

In this paper, we have introduced a complex decision-making problem, the selection of non-metallic category segments by an original equipment manufacturer to be sourced from low cost countries taking into account conflicting criteria, potential benefit and the risks involved.

We have made provision for all the stages of the Decision Analysis cycle using the GMAA system, a user-friendly decision support system based on an additive multi-attribute utility model and that accounts for incomplete information about the problem parameters. We have achieved a final recommendation on the basis of the ranking of non-metallic category segments. Best ranked segments accounting for 60% of the total annual expenditure of parts in the segment not sourced from LCC are those to be recommended.

Acknowledgments

This paper was supported by the Spanish Ministry of Education and Science projects TSI2004-06801-C04-04 and MTM2004-21099-E.

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