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MULTICRITERIA DECISION MAKING APPLIED TO PROJECT OUTSOURCING.

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ABSTRACT
Outsourcing a part (or the totality) of a business, process or project, implies, in a certain way, losing control over the outsourced item, and transferring this control to the selected source, outside the company. This may have a significant effect over two important areas of competence, such as quality and delivery. Another consequence linked to process or project outsourcing, may be the fact of losing the know-how over the outsourced part in a medium-long term period of time and, consequently, increasing the business dependency on the selected third party company
Objectives: through the use of the Analytic Hierarchy Process (AHP) [1], it is intended to develop a mathematical model and computer tools, that would help to take the right outsourcing decisions over the project (or parts of it) under evaluation.
Methods: the first step in the AHP is to build a hierarchy tree, by decomposing the goal (project outsourcing) into its constituent parts (fundamental criteria). Next, a relative weight should be assigned to each one. Finally, after the relevant information is collected, the model should be fed with it.
Results and conclusions: relative scores for each choice would be computed within each leaf of the hierarchy tree; synthesized through the model, and shall yield, finally, a composite score for each choice at every tier, as well as an overall one. Depending on this score, the part, or the project would have a measure that would help to make the right outsourcing decision.

Keywords: outsourcing, AHP (Analytic Hierarchy Process), decision-making.

1 INTRODUCTION
This paper evolves between two main topics that have attracted the efforts and interest of many organizations and industries, on the past two decades, all around the world; as are Project Outsourcing and Decision Making. Regarding the latest, the work has been developed through the use of a multi-criteria analysis process, envisioned by Thomas L. Saaty, and published by himself on 1980, in the book named "Analytic Hierarchy Process" (AHP)[1]. The goal of this article is to apply this multi-criteria decision making methodology, to the field of project outsource management. By the end of the paper, it should be understood what are the risks of a wrong project outsourcing strategy, and what is the criteria to take into account when facing such a dilemma. The methodology, decision elements and process should help to decide what part of a project should be outsourced, or should not. It may be used, as well, to compare projects when needing to know which of them is more suitable to get done in house, or outside the company, by a third party. The scope is to apply the AHP methodology to a general kind of project. This may be used, afterwards, as a starting point for more specific applications, depending on the industry, services or institution sector where the outsourcing strategy should be developed.
The consequences of inconvenient, improper or wrong outsourcing decisions, have led companies to lose competitiveness in the market place, miss customers and even get forced to move away from some business or markets. The decision of moving outside part of a project, a business, or a complete service, is as strategically complex, critical and important, as deciding to hire more engineering workforce, or on what new technology should the investment go. In several cases, it has been required

a high level of effort and money to recover back to the original competitive status; and in some occasions it seems that these decisions are taken more from guts, or past experiences, rather than from facts; as it should be done after performing a thorough analysis of the different choices and a careful prioritization of all of them.
These realities are the igniters of the present paper: the need to develop a decision making methodology that could take into account multiple types of criteria, from very different nature and characteristics; being some times quantitative and others qualitative, that would facilitate the decision making process and would provide a work frame where the outsourcing criteria would be structured; a relative priority would be given to every criteria in order to set their importance towards achieving the final objective (project outsourcing); and a math model and tools would be provided to facilitate, guide and back-up, the decision making process.

2 PROJECT OUTSOURCING

Outsourcing part, or the totality, of a project or service, is the business process that a company or institution uses to move part of the resources occupied on non-core activities, to external companies or third parties, through a contract. In this sense, many different models of outsourcing may be implemented: from hiring contractors (in this case, the customer will commit to provide space, hardware and IT services), to outsourcing the complete process (both, headcount and facilities).
The "core competences" concept was developed in the business management field, and introduced first time on 1990 by C.K. Prahalad y Gary Hamel [2]. As it was described there, core competency is "an area of specialized expertise that is the result of harmonizing complex streams of technology and work activity."
Another way to define what is a core competency of a business is really to find what are the key value and advantages that differentiate any company from the competition. This is, to answer the question: "why a customer would prefer my products (or services) rather than the ones from my competitors?". There may not be a single answer: price, post/pre-sales service, quality, or all together. On the other hand, every one should be aware of the risks linked to outsourcing (covered in point 2.1.).
It is important to keep in mind that outsourcing, by itself, does not mean saving costs. The automatically associated term, delocalization (very popular on the 90's), implies also a transfer of work jobs to other geographies, through the use of local agents that would facilitate the transfer process, or directly installing bases in those foreign countries where hand labour is less expensive, or where there exists a real tax advantage that would help the business profit line. Although outsourcing by itself might not save costs unless it is linked to delocalization; being able to outsource non core competencies would allow any organization to focus on core activities, becoming more competitive and having more chances to win in the market place.
Deeping a bit more on the concept by itself, outsourcing is defined as the management, or execution, of any business function by a third party, or external service supplier. The outsourcing company will need to transfer part of the operational or administrative work outside, in a way that the external company may operate and complete the expected work, far away from the day-to-day business reality of the outsourcing company, and its own final customers. Although outsourcing implies a high degree of bi-directional exchange of information, a great effort on coordination, and confidence among both parties, it is supposed that in a mid/long term should be of flawless execution for the outsourcing company.
The suppliers offering outsourcing services often insist on the need of delegation. Outsourcing implies by itself the delegation of corporate responsibilities to manage a part of a business or a project. Theoretically, this portion should not be critical to the day-to-day company function, but actually, it may be. Many companies are now offering specialized outsourcing services in the fields of IT, human resources, assets management, reprography and security services, financial and accounting. In some cases, the after sales support to direct customers is also being outsourced; even the engineering design or manufacturing activities. Outsourcing seems to do not have an end or a ceiling. But it has some risks, as explained in point 2.1.

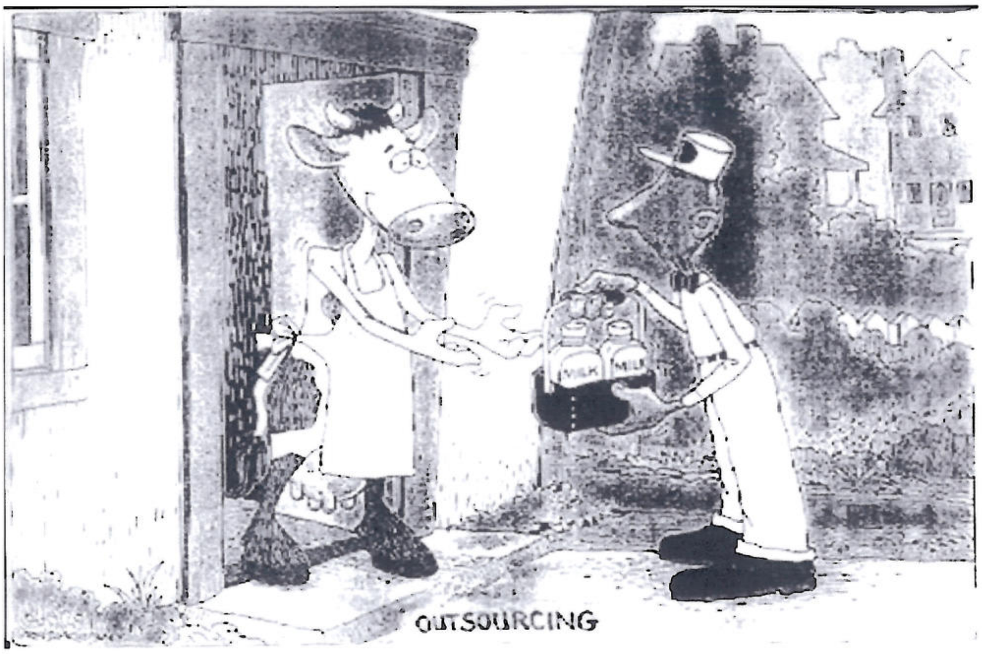

Figure 1. Outsourcing

2.1 Consequences of outsourcing

The consequences of improper, inconvenient or wrong outsourcing decisions may have a critical effect on companies all around the world. Let's take a look to Figure 1: a cow buying goods to a milkman. It may sound funny, but humans do so. When having a baby, mothers decide if they'll breast-feed their children or if they'll buy milk powder. This is a pure outsourcing decision that may illustrate the dark face of outsourcing, as it means loosing control over whatever is outsourced; having limited influence (or not at all) over the final quality of the product; and loosing in a mid/long term period of time, the capacity to produce or generate IP on that outsourced process or part of the project; thus is depending more and more on the third party company to run own business. These is why it is so important to complement outsourcing strategies with continuous benchmarking exercises, supplier evaluation methods or audits, and writing and signing good specifications and contracts.

Let's illustrate the above with a couple of real examples: on one side, we can take the decision made by one of the top three computer makers [3] to stop routing some customer-support requests, previously outsourced to a call centre in India, after customers complained about the quality of service; and bring the process back to the US [4]. A company spokesman said "Customers weren't satisfied with the level of support they were receiving, so we're moving some calls around to make sure they don't feel that way anymore". This is a clear example of decreasing the level of quality on the outsourced part, and thus, deciding to bring the process back in-house.

On the other hand, we can take a Formula 1 case to illustrate the loose of control and knowledge, thus becoming dependent on a third party. A company bases their competitive advantage on car aerodynamics and speed, and focuses all the available know-how to make cars faster and win races. They outsource an important part of the prototypes, as it is the engine but this supplier company announced they would not be selling engines anymore to the first company, thus they needed to run benchmark exercises, and hurry up to close a contract with another engine maker, as they did not want to get away from the business.

In summary, outsourcing has important trade-offs to make, as loose of control over the outsourced, little (or not) influence over the quality of the output, or loosing the know how (no more IP generation) and consequently depending on the third party supplier to run the own business.

3 THE ANALYTIC HIERARCHY PROCESS

In this point of the paper, the multi-criteria decision-making process developed by Thomas L. Saaty [1][5] will be presented as the state of the art methodology for complex decision-making. It will be included, as well, a summary of the different feedback and concerns it has received from the scientific community. In this regard, it should be highlighted the work published by José Luis Zanazzi on 2003 [7] with title: "Anomalies and survival in Saaty's decision making method", that will be covered on point 3.2.

3.1 Synthesis of the Analytical Hierarchy Process (AHP)

Developed by Thomas L. Saaty, [1], AHP offers an effective approach to complex decision making problems. It does so through a methodology that helps to define what are the basic decision elements, giving them a relative weight and facilitating the analysis of the gathered data for every criterion; accelerating and improving, in this way, the quality of the decision.

It must be remarked that through the use of the AHP, one may capture evaluation measures of very different nature, from objective (quantitative), to subjective (qualitative); providing a useful methodology to give relative priorities among them; checking the consistency of the decisions and the suggestions provided, reducing, in this way, the risk of having a partial view in the decision making process.

Through the combination of the AHP with rigorous team work, organizations may minimize common decision making errors, such as lack of focus, poor planning, seldom participation of the people having the knowledge on the decisions, or lack of leadership. Distractions that may make any management team to take improper or wrong decisions that would cost large investments to get fixed.

In order to apply the AHP, the first step is to break-down the final objective in its constituent parts, progressing from the general to the specific. In its simplest form, this structure comprises an objective, criteria and alternative levels down. Every criterion should be divided in a lower level of criterions, until an appropriate level of detail is achieved; keeping in mind that, the more number of criterions included, the less relatively important they'll be.

This cascade of criterions is known as the hierarchy tree, and it is organized by levels. On level 1 there is the objective; on level 2, the fundamental criteria towards that objective; on level 3, the sub-criteria corresponding to every fundamental criterion; and in this way, all the levels down until the last level, where the decision elements are.

The next step is to assign a relative weight to each one of them. Every criterion will have a local priority (immediate) as well as a global one. The sum of the entire criterion below a parent criteria (immediate superior), on every layer of the hierarchy tree, must be equal to 1. Their global priority will show, then, their relative weight in the total model.

Something that should be highlighted is the way of assigning weights on the AHP. This is, in order to compare two elements, **a** and **b**, where **a** is preferred in front of **b**, the degree of preference must be qualified based on the guidelines shown on Table 1

*Table 1. Relative scores for two given decision elements, **a** and **b**. Source T. Saaty [6]*

Intensity of importance	Definition	Explanation
1	Equal Importance	**a** is equally important as **b**
2	Weak	
3	Moderate Importance	Experience and judgment slightly favour **a** in front of **b**
4	Moderate plus	
5	Strong Importance	Experience and judgment strongly favour **a** in front of **b**
6	Strong plus	
7	Very strong or demonstrated importance	Activity **a** is favoured very strongly over **b**
8	Very, very strong	
9	Extreme Importance	The evidence favouring **a** over **b** is of the highest possible order of affirmation.
Reciprocals of above	If activity **a** has one of the above nonzero numbers assigned to it when compared to **b**, then **b** has the reciprocal value when compared to **a**	
Rational numbers	Ratios arising from the scale	If consistency were to be forced by obtaining **n** numerical values to span the matrix

The final step is to feed the model with the information gathered. The different weights must always be considered in relative terms, never as an absolute figure, comparing one option to the rest. The

relative scores for every election are computed within every hierarchy level and synthesized through the model, giving as a result a composed score for every election on every layer, as well as a general score.
In a very practical and operative way, and as the consequence of the different comparisons done using the references on Table 1, it is obtained, for every criterion, a matrix **A** as the one shown in Figure 2.

		With		
		a	b	c
Comparing	a	1	3	½
	b	1/3	1	1/8
	c	2	8	1

*Figure 2. Example: three elements (**a**, **b** and **c**) comparison matrix (**A**)*

On Figure 2, for example element **c** is twice more important than **a**; while **a** is three times more important than b. Every one of these matrixes can be, later on, synthesized to obtain the weight of the different elements. Effectively, if the vector containing the different weights (**Wi**) is defined as:

$$W = [w1,\ w2,\ ....\ ,\ wn\ ]$$

It can be verified that:

$$A\ W = \rho\ W$$

And thus, ρ is the eigenvalue of **A**, while **W** is **A**'s associated eigenvector. In this way, the eigenvector associated to every matrix is the one porting the weights of every decision element. This assumption is solidly proved. In effect, if all the judgments made by the owners of the decisions are transitive, then every score may be understood as the division among the weights of the elements compared. Thus:

$$ai,j = wi\ /\ wj$$

And under these conditions, can be verified that:

$$A\ W = \begin{vmatrix} w1/w1 & w1/w2 & \dots & w1/wn \\ w2/w1 & w2/w2 & \dots & w2/wn \\ \dots & \dots & \dots & \dots \\ wn/w1 & wn/w2 & \dots & wn/wn \end{vmatrix} \begin{vmatrix} w1 \\ w2 \\ \dots \\ Wn \end{vmatrix} = n\ W$$

And so, the matrix eigenvalue equals the compared decision elements.
In the reality, the judgments are rarely transitive (one may like 2 times more bananas than apples; and two times more apples than watermelons; but not necessarily like 4 times more bananas than watermelons), thus the above equation may not meet these cases. Nevertheless, if **A** is a symmetric matrix and defined positive, then exists a unique eigenvalue meeting the condition **ρ > n.**
The intransitivity nature of judgments is known as inconsistency, and a way to measure general inconsistencies of a matrix is given by the following formula:

$$CI = (\ \rho - n\ )\ /\ (\ n - 1)$$

To be able to translate the inconsistency level to a standard 1-100 scale, Thomas L. Saaty determined by simulation, the expected inconsistencies on matrixes built in a random way. If **CIA** is the measure of a matrix like those, then the consistency ratio (**CR**) is:

$$CR = CI\ /\ CIA$$

In general, if CR is less than 10%, then the inconsistency is considered as acceptable. Otherwise the judgments should be reviewed and the work re-done.

3.2 Some critics on the AHP method, weakest points and possible improvements:

Jose Luis Sanáis [7], on its work titled "Anomalies and survival in Saaty's decision making method", analyzes and encloses, through an epistemological view, the discussion set around the multi-criteria decision making method explained in point 3.1. Sanáis highlights that during the past years, a good number of scientists have dedicated a considerable amount of effort to detect defects on Saaty's process and to develop possible improvements. With this respect, the paper makes a thorough analysis of the discrepancies found and explains from a scientist philosophical point of view, the reasons why the AHP as generated such a level of discussion and the motivations to keep it on use, regardless of those. The critics have mainly centred on these four topics:

- Decision process hierarchy tree.
- Preferences evaluation.
- Matrix normalization.
- Range reversion.

Follows a description of the main concerns, and the proposed solutions or workarounds, in every case.

▪ ***Decision process Hierarchy tree:*** there are two sources of concerns on this topic. On one side, there is the possibility of having an incomplete hierarchy tree, thus the weighting of the different criteria might be, some how, biased or distorted, not meeting reality. About this, the author of the AHP suggests that the person or team in charge of taking the decision, should design carefully the hierarchy structure, and ensure its completion before starting the task of assigning relative weights. And in this regard, suggests the use of different powerful techniques, as brainstorming sessions with as many diverse individuals as possible, to make sure all the decision elements are taken into consideration. he second source of concerns relates with the fact that there may be differences on the quality and the quantity of the information available for each one of the decision elements. Again, Saaty highlights that in this case the issue is data availability, and the problem will always lead to wrong decision making, independently of the method or process applied.

▪ ***Preferences evaluation:*** Saaty's multi-criteria decision making process requires paired comparisons among all the alternative criteria, evaluating the preferences with the use of a scale (Table 1) that goes from 1 (equal importance of criteria **a** vs criteria **b**) to 9 (extreme preference of criteria **a** vs **b**). The concern, in this case, is about the working model of the human brain, pointing out the natural way of doing comparisons is global and not local; even more, there are references to common errors made when having to take local decisions (paired) without knowing the global context (i.e., one may prefer chicken to beef, but at the end of the day, be a vegetarian person). Thomas L. Saaty organized an investigation on this field, and managed several experiments in order to certify the goodness of the process, that are gathered in several publications (1994) and in his book published on 1995 "Decision making for leaders" [5]. Supporting Saaty in this regard, Watson & Freeling in 1983 [8], showed that several experiments done on the psychometric field, did not reveal there was a clear advantage among local or global comparisons. As an improvement to the preferences evaluation, Saaty proposes on 1977 and 1978 the use of fuzzy logic to represent the unavoidable errors of the observations. Additionally, suggests the acceptance of a certain level of measurement errors, that should be kept under control through the use of the consistency checking, and if it is not within the acceptance limits, re-do and improve the judgements. On the other hand, it has also received some critics, the scope of the proposed evaluation scale (from 1 to 9), and some scientists have suggested to open it in order to increase resolution. Others have some concerns on the time that needs to be spend to make all the paired comparisons when there is a big number of elements in play. Takeda in 1987 [9] elaborates some proposals to reduce the quantity of comparisons without affecting the final result.

▪ ***Matrix normalization:*** the AHP normalizes the preferences matrixes to transform the evaluation of preferences in a range of numbers going from 0 to 1, through the use of the matrix eigenvector. This can be done because the matrixes are defined as symmetric and positives, thus only one eigenvalue is allowed. If the judgements that form the preference matrixes are perfectly consistent, then the eigenvector reproduces the judgements accurately. But in the case of inconsistencies, the normalized values get distorted and become difficult to understand. Some scientists as Belton and Wendell (1985) have proposed to use several iterations of the eigenvector; this is, to apply several matrix normalizations until achieving the stability of the judgements.

▪ ***Range reversion:*** On 1983, Belton & Gear [10] suggested that the AHP has some problems to meet the irrelevant alternatives axiom. This is, the relative importance of a pair of alternatives, changes when an independent third new one is evaluated. Saaty argues in 1994 [5] the fundamental condition of this behaviour, and demonstrates, through simulation, that it may happen in a small percentage of applications (less than 8%).

4 AHP APPLIED TO PROJECT OUTSOURCING

The previous sections of this paper have covered the concepts of project outsourcing and the multi-criteria decision making process, together with their risks and improvement opportunities. At this point they'll be both integrated to create a single view and a frame work to take outsourcing decisions. Let's keep in mind that every project is, by itself, a complete universe of options, constrains, priorities and values that need to be evaluated and decided almost on a case by case basis. Thus there may not be a "one size fits all" kind of model. But there are some basic criteria that everyone should take into account when deciding what parts of a project may be subject of outsourcing. The application of the AHP method can help triggering the right discussions, provide a tool to analyze data, and support with numbers the outsourcing decision.

4.1 The hierarchy tree

As it was highlighted on section 3, the first step in the AHP is to build a hierarchy tree, by decomposing the goal (project outsourcing) into its constituent parts (fundamental criteria). The construction of the tree can be done following different techniques: from organizing brainstorming sessions with diverse individuals within the organization; to the use of past experiences. To build the following one, it was used a mix of both techniques, starting with a first draft based on past experience from outsourced projects, and enriching and refining the decision elements through brainstorming sessions with diverse team members of different organizations, industries and institutions. The resulting hierarchy tree is shown on Figure 3.

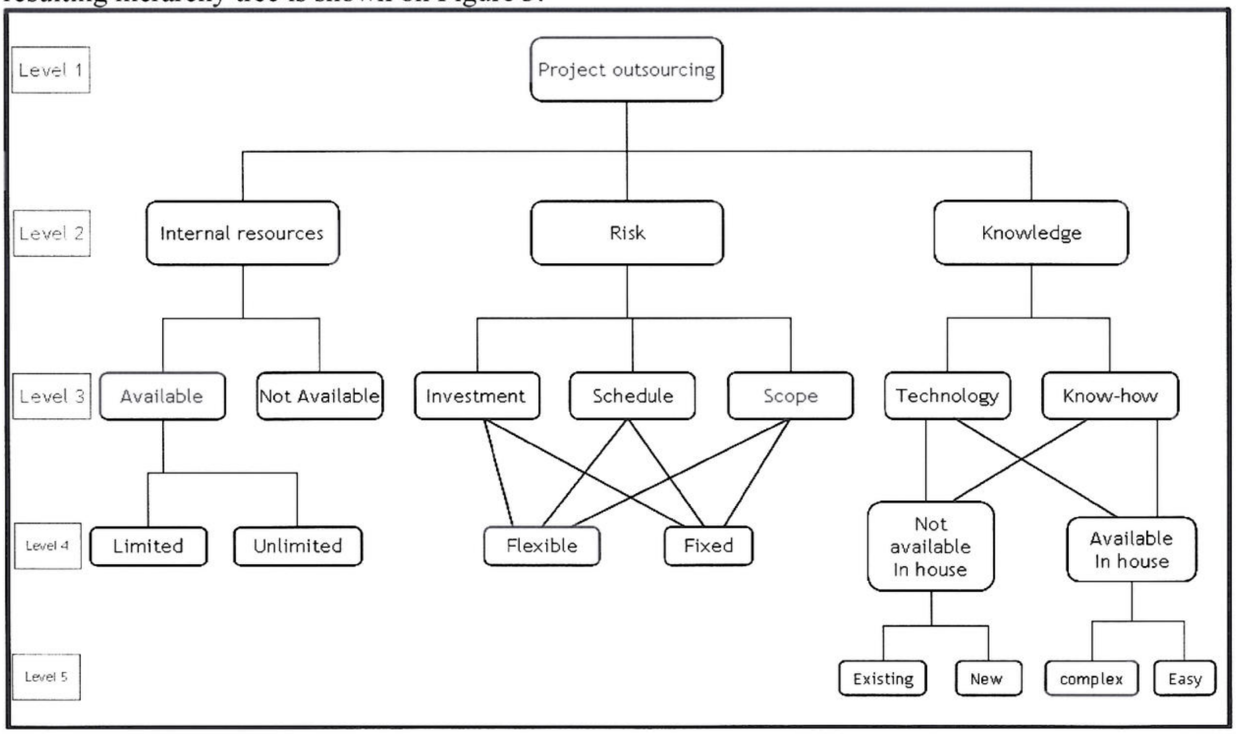

Figure 3. Hierarchy Tree for generic Project Outsourcing

On level one, the final objective is stated: Project Outsourcing. On level 2, the fundamental criteria are shown: internal resources availability, project risk and existing knowledge within the organization. These are broken down up to level 4 and 5, where the decision elements are reflected.

▪ ***Level 2. Fundamental criteria:*** In order to build the second layer of the hierarchy tree, there is a fundamental assumption that has been done regarding the healthiness of the project itself, from a business point of view. In this case, it is to be assumed that some basic financial analysis has been done, and it has been decided that the project is financially viable, and the business is willing to allocate resources and money to make it happen. So, the decision to take in this case is what parts (or the totality) of the project should be outsourced and what parts should be done in-house.
Three fundamental criteria have been identified, in this case: Internal resources, Risk and Knowledge.
Internal resources: people and tools needed to produce the part of the project under question. This should take also into account, the skills needed to do the work.
Risk: the probability of success, or failure, of the project, defined by how flexible or fixed are in the project, terms as scope, schedule and investment.
Knowledge: having available the knowledge needed to produce the part of the project under question. This is, to define WHAT (technology) and HOW (know-how) should be completed that portion of the project. Let's illustrate this with the example of a PC maker.
A core component of any PC is the CPU. The computer maker should decide WHAT CPU to be used in order to achieve the final computer specifications (technology) and also should know HOW the CPU should work to be able to integrate it within the PC architecture and achieve the final performance (know-how). Any way, both aspects (technology and know how) may be purchased from outside or built in-house.

▪ ***Level 3, 4 and 5. Decision elements:*** In this third level of the hierarchy tree, the above criteria are expanded into more specific categories, in this case, if either the technology or the know-how are already available or not in-house; and exploding those concepts down to level 5, the decision elements can be found for each one of the options. Regarding the availability of internal resources, one should question if these are unlimited (not a very probable case) or not. About the scope, schedule and investment, the question should be on the degree of flexibility the business would allow, in the totality, and on every part of the project. And, last but not least, if the technology/know-how is not available in house, one should ask whether it exists in the market already (or very soon) or not. If the technology/know-how is available in house, it should be questioned if it is complex or easy. The higher the complexity, the more difficult will be to specify, and thus, to explain a third party how or what to do, thus less susceptible to be outsourced. Back to the PC-CPU example, 10 years ago, it was more the second option (design and produce the CPU in-house). Nowadays, no PC manufacturer would think on competing against the two biggest microprocessor manufacturers. What might have been a tough outsourcing decision in the past, has a no-brain answer today.

4.1 Relative Weighting

The next step in the process is to assign a relative weight to each one of the criteria. Every one of them will have a local priority (immediate, obtained through pair comparisons of the elements below a common parent criterion and provided by the matrix eigenvector, as explained on point 3.1 - page 4, as well as a global one (this is, the product of the local priority times the global priority of each one of the parent criterions above). The global priority of the decision elements will show, then, their relative weight in the total model. In this way, Figure 4 shows the paired comparisons among all the criteria in the hierarchy tree –first four columns-, the calculation on the relative weights given by each one of the matrixes eigenvectors –middle four columns-, as well as the verification of the consistency of the judgements –last two columns-. The process to build the first four columns of Figure 4 (Decision Matrixes) has been outlined on page 4; point 3.1.
The way of calculating the middle four columns (eigenvector and eigenvalue) has been explained on page 5, and there are a few plug-inns for excel that facilitates the operations, as well as linear algebra programs that automatically make the calculations. The local priorities equal the normalized eigenvector values; while the global ones are obtained through the product of every local priority times the global priority of the parent criteria.
Finally, at the end of the section 3.1, on page 5, it is highlighted how to perform the calculation of the last two columns of figure 4, to check the consistency of the judgements. Local and global weights resulting from these calculations (first two from the middle four columns) are summarized on Figure 5.

Level 2 Criteria matrix

Project outsourcing

1.000	Int Resources	Risk	Knowledge
Int Resources	1	1/3	1/5
Risk	3	1	1/3
Knowledge	5	3	1

Priorities	
Local	Global
0.105	0.105
0.258	0.258
0.637	0.637

Consistency of judgements			
eigvl	eigenvect	CI	0.019
3.039	0.105	CR	0.019
	0.258	CIA	1.000
	0.637		

Level 3 Criteria matrix

Int. Resources

0.105	Available	Not Available
Available	1	1/9
Not Available	9	1

Priorities	
Local	Global
0.100	0.010
0.900	0.094

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.100	CR	0.000
	0.900	CIA	1.000

Risk

0.258	Investment	Schedule	Scope
Investment	1	1/5	1/3
Schedule	5	1	3
Scope	3	1/3	1

Priorities	
Local	Global
0.105	0.027
0.637	0.165
0.258	0.067

Consistency of judgements			
eigvl	eigenvect	CI	0.019
3.039	0.105	CR	0.019
	0.637	CIA	1.000
	0.258		

Knowledge

0.637	Technology	Know-how
Technology	1	3
Know-how	1/3	1

Priorities	
Local	Global
0.750	0.478
0.250	0.159

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.750	CR	0.000
	0.250	CIA	1.000

Level 4 Decision elements matrix I

Int. Resources Available

0.010	Limited	Unlimited
Limited	1	5
Unlimited	1/5	1

Priorities	
Local	Global
0.833	0.009
0.167	0.002

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.833	CR	0.000
	0.167	CIA	1.000

Investment

0.027	Flexible	Fixed
Flexible	1	1/5
Fixed	5	1

Priorities	
Local	Global
0.167	0.005
0.833	0.023

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.167	CR	0.000
	0.833	CIA	1.000

Schedule

0.165	Flexible	Fixed
Flexible	1	5
Fixed	1/5	1

Priorities	
Local	Global
0.833	0.137
0.167	0.027

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.833	CR	0.000
	0.167	CIA	1.000

Scope

0.067	Flexible	Fixed
Flexible	1	1/3
Fixed	3	1

Priorities	
Local	Global
0.250	0.017
0.750	0.050

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.250	CR	0.000
	0.750	CIA	1.000

Technology

0.478	NA IH	Available IH
NA IH	1	9
Available IH	1/9	1

Priorities	
Local	Global
0.900	0.430
0.100	0.048

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.900	CR	0.000
	0.100	CIA	1.000

Know-How

0.159	NA IH	Available IH
NA IH	1	5
Available IH	1/5	1

Priorities	
Local	Global
0.833	0.133
0.167	0.027

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.833	CR	0.000
	0.167	CIA	1.000

Level 5 Decision elements matrix II

Technology Not Available IH

0.430	Existing	New
Existing	1	9
New	1/9	1

Priorities	
Local	Global
0.900	0.387
0.100	0.043

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.900	CR	0.000
	0.100	CIA	1.000

Technology Available IH

0.048	Complex	Easy
Complex	1	1/5
Easy	5	1

Priorities	
Local	Global
0.167	0.008
0.833	0.040

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.167	CR	0.000
	0.833	CIA	1.000

Know-How Not Available IH

0.133	Existing	New
Existing	1	7
New	1/7	1

Priorities	
Local	Global
0.875	0.116
0.125	0.017

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.875	CR	0.000
	0.125	CIA	1.000

Know-How Available IH

0.027	Complex	Easy
Complex	1	1/5
Easy	5	1

Priorities	
Local	Global
0.167	0.004
0.833	0.022

Consistency of judgements			
eigvl	eigenvect	CI	0.000
2.000	0.167	CR	0.000
	0.833	CIA	1.000

Figure 4. Project Outsourcing, paired comparisons, priorities and consistency of judgment

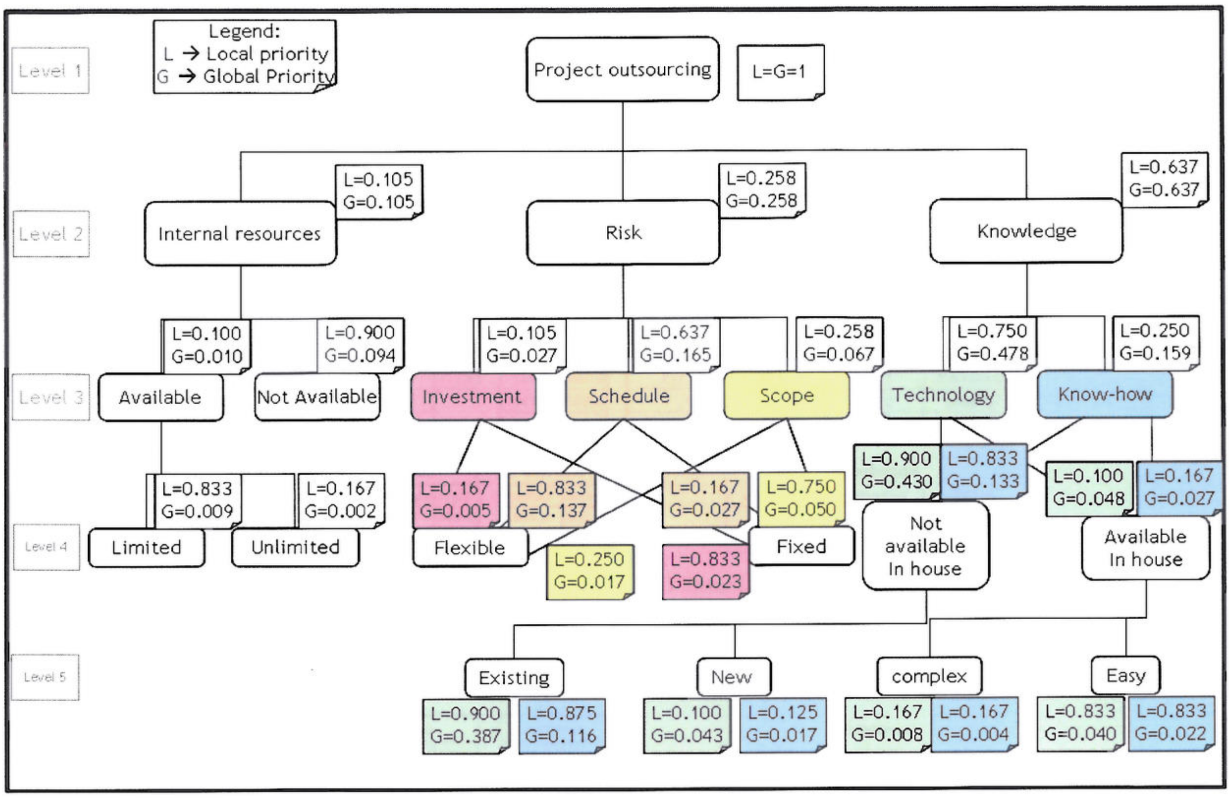

Figure 5. Hierarchy tree with local and global priorities

Now, the project should be split in parts, and every part compared against every decision element on the hierarchy tree shown in Figure 5, taking in account their global priority. Once the data is input into the model, the parts of the project receiving a higher score, will be the ones that are more likely to be outsourced, while the parts getting the lower numbers, should be the ones to keep in-house

5 RESULTS

Let's use a real project application to illustrate the behavior of the decision model. In this example, a technology company needs to design and manufacture a new Printer. This project, called A for instance, may be split, at a high level and in the seek of simplicity, in the following six parts:

- Mechanical parts and systems specification and architecture [ME].
- Electrical parts/Electronics and systems specification and architecture [EE].
- Printing systems (print heads, and ink containers) specification and architecture [EE].
- Firmware and software needed to make the printer work and become usable [FW/SW].
- Integration tests and qualification [T&I].
- Assembly and production processes [Mfg].

In the real project, the printer was an extension of a product designed in the past by the same company. That product was already in production and it had been successfully sold in the market place for more than 4 years. The main project value proposition was changing the size (shortening the printer and reducing the foot-print), implementing better print modes and rolling new printing drivers.
Now, each one of the project parts would need to be compared against the decision elements in a 6x6 matrix, and weighted by pairs from 1 to 9 (according to Table 1). The eigenvalue of the matrix will be used to check the consistency of the judgments (and if inconsistency ratio is >10% the judgments should be revised). The normalized matrix eigenvector will provide the local priorities, and the product of every local priority with the global ones will give the global weights of every part of the project. All this process calculation is shown on Figure 6.
The sum of all the global weights will give the final score by project part. Keep in mind these are all relative scores, thus, the higher the number of the part, the most convenient to be outsourced. This last step is summarized on Table 2.

Example Project A

Know-How Available IH — easy

0.022	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.254	0.0056	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0025	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0011	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0011	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0027		
Mfg	3	5	5	5	3	1		0.415	0.0092		

Know-How Available IH — complex

0.004	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	5	5	5	3	3	6.271	0.401	0.0018	CI	CR
EE	1/5	1	1	1	1/3	1/7		0.053	0.0002	0.054	0.054
PS	1/5	1	1	1	1/3	1/7		0.053	0.0002	CIA	
FW/SW	1/5	1	1	1	1/3	1/7		0.053	0.0002	1.000	
T&I	1/3	3	3	3	1	1		0.168	0.0007		
Mfg	1/3	7	7	7	1	1		0.270	0.0012		

Know-How Not Available IH — New

0.017	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	1	1	1	3	7	6.007	0.223	0.0037	CI	CR
EE	1	1	1	1	3	7		0.223	0.0037	0.001	0.001
PS	1	1	1	1	3	7		0.223	0.0037	CIA	
FW/SW	1	1	1	1	3	7		0.223	0.0037	1.000	
T&I	1/3	1/3	1/3	1/3	1	3		0.078	0.0013		
Mfg	1/7	1/7	1/7	1/7	1/3	1		0.031	0.0005		

Know-How Not Available IH — Existing

0.116	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	5	5	5	3	3	6.271	0.401	0.0466	CI	CR
EE	1/5	1	1	1	1/3	1/7		0.047	0.0054	0.054	0.054
PS	1/5	1	1	1	1/3	1/7		0.047	0.0054	CIA	
FW/SW	1/5	1	1	1	1/3	1/7		0.047	0.0054	1.000	
T&I	1/3	3	3	3	1	1		0.146	0.0170		
Mfg	1/3	7	7	7	1	1		0.235	0.0273		

Technology Available IH — easy

0.040	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.254	0.0101	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0044	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0020	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0020	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0048		
Mfg	3	5	5	5	3	1		0.415	0.0165		

Technology Available IH — Complex

0.008	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	5	5	5	3	3	6.271	0.401	0.0032	CI	CR
EE	1/5	1	1	1	1/3	1/7		0.053	0.0004	0.054	0.054
PS	1/5	1	1	1	1/3	1/7		0.053	0.0004	CIA	
FW/SW	1/5	1	1	1	1/3	1/7		0.053	0.0004	1.000	
T&I	1/3	3	3	3	1	1		0.168	0.0013		
Mfg	1/3	7	7	7	1	1		0.270	0.0022		

Technology Not Available IH — new

0.043	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	1	1	1	3	7	6.007	0.223	0.0096	CI	CR
EE	1	1	1	1	3	7		0.223	0.0096	0.001	0.001
PS	1	1	1	1	3	7		0.223	0.0096	CIA	
FW/SW	1	1	1	1	3	7		0.223	0.0096	1.000	
T&I	1/3	1/3	1/3	1/3	1	3		0.078	0.0033		
Mfg	1/7	1/7	1/7	1/7	1/3	1		0.031	0.0013		

Technology Not Available IH — existing

0.187	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	5	5	5	3	3	6.271	0.401	0.1554	CI	CR
EE	1/5	1	1	1	1/3	1/7		0.053	0.0207	0.054	0.054
PS	1/5	1	1	1	1/3	1/7		0.053	0.0207	CIA	
FW/SW	1/5	1	1	1	1/3	1/7		0.053	0.0207	1.000	
T&I	1/3	3	3	3	1	1		0.168	0.0650		
Mfg	1/3	7	7	7	1	1		0.270	0.1046		

Scope — Fixed

0.050	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	1	1	1	3	7	6.007	0.256	0.0990	CI	CR
EE	1	1	1	1	3	7		0.256	0.0990	0.001	0.001
PS	1	1	1	1	3	7		0.256	0.0990	CIA	
FW/SW	1	1	1	1	3	7		0.256	0.0990	1.000	
T&I	1/3	1/3	1/3	1/3	1	3		0.089	0.0345		
Mfg	1/7	1/7	1/7	1/7	1/3	1		0.035	0.0136		

Scope — Flexible

0.017	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.255	0.0986	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0434	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0469		
Mfg	3	5	5	5	3	1		0.417	0.1613		

Schedule — Fixed

0.027	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	1	1	1	3	7	6.007	0.256	0.0990	CI	CR
EE	1	1	1	1	3	7		0.256	0.0990	0.001	0.001
PS	1	1	1	1	3	7		0.256	0.0990	CIA	
FW/SW	1	1	1	1	3	7		0.256	0.0990	1.000	
T&I	1/3	1/3	1/3	1/3	1	3		0.089	0.0345		
Mfg	1/7	1/7	1/7	1/7	1/3	1		0.035	0.0136		

Schedule — Flexible

0.137	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.255	0.0986	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0434	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0469		
Mfg	3	5	5	5	3	1		0.417	0.1613		

Investment — Fixed

0.023	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	1	1	1	3	7	6.007	0.256	0.0990	CI	CR
EE	1	1	1	1	3	7		0.256	0.0990	0.001	0.001
PS	1	1	1	1	3	7		0.256	0.0990	CIA	
FW/SW	1	1	1	1	3	7		0.256	0.0990	1.000	
T&I	1/3	1/3	1/3	1/3	1	3		0.089	0.0345		
Mfg	1/7	1/7	1/7	1/7	1/3	1		0.035	0.0136		

Investment — Flexible

0.005	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.255	0.0986	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0434	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0469		
Mfg	3	5	5	5	3	1		0.417	0.1613		

Int. Resources Available — Unlimited

0.002	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.255	0.0986	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0434	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0469		
Mfg	3	5	5	5	3	1		0.417	0.1613		

Int. Resources Available — Limited

0.009	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	3	1/3	6.249	0.255	0.0986	CI	CR
EE	1/3	1	3	3	1	1/5		0.112	0.0434	0.050	0.050
PS	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	CIA	
FW/SW	1/5	1/3	1	1	1/3	1/5		0.050	0.0193	1.000	
T&I	1/3	1	3	3	1	1/3		0.121	0.0469		
Mfg	3	5	5	5	3	1		0.417	0.1613		

Int. Resources — Not available

0.094	ME	EE	PS	FW/SW	T&I	Mfg	Eigen Val	Eigenvector	Global priori	Consistency of judgements	
ME	1	3	5	5	1/3	1/5	6.278	0.124	0.0482	CI	CR
EE	1/3	1	3	3	1/5	1/7		0.063	0.0244	0.056	0.056
PS	1/5	1/3	1	1	1/7	1/9		0.030	0.0116	CIA	
FW/SW	1/5	1/3	1	1	1/7	1/9		0.030	0.0116	1.000	
T&I	3	5	7	7	1	1/3		0.238	0.0921		
Mfg	5	7	9	9	3	1		0.439	0.1700		

Figure 6. Example: Project A, outsourcing strategy evaluation.

Table 2. Relative weights for every part of Project A (Design and mfg of a new PC)

	Know-Hov	Know-Hov	Know-Hov	Know-Hov	Technolo	Technolo	Technol	Technolo	Scope	Scope	Schedule	Schedule	Investmen	Investmer	Int. Resou	Int. Resou	Int. Resou	SUM
ME	0.0056	0.0018	0.0037	0.0466	0.0101	0.0032	0.0096	0.1554	0.0990	0.0986	0.0990	0.0986	0.0990	0.0986	0.0986	0.0986	0.0482	1.0743
EE	0.0025	0.0002	0.0037	0.0054	0.0044	0.0004	0.0096	0.0207	0.0990	0.0434	0.0990	0.0434	0.0990	0.0434	0.0434	0.0434	0.0244	0.5854
PS	0.0011	0.0002	0.0037	0.0054	0.0020	0.0004	0.0096	0.0207	0.0990	0.0193	0.0990	0.0193	0.0990	0.0193	0.0193	0.0193	0.0116	0.4483
FW/SW	0.0011	0.0002	0.0037	0.0054	0.0020	0.0004	0.0096	0.0207	0.0990	0.0193	0.0990	0.0193	0.0990	0.0193	0.0193	0.0193	0.0116	0.4483
T&I	0.0027	0.0007	0.0013	0.0170	0.0048	0.0013	0.0033	0.0650	0.0345	0.0469	0.0345	0.0469	0.0345	0.0469	0.0469	0.0469	0.0921	0.5261
Mfg	0.0092	0.0012	0.0005	0.0273	0.0165	0.0022	0.0013	0.1046	0.0136	0.1613	0.0136	0.1613	0.0136	0.1613	0.1613	0.1613	0.1700	1.1801

According to Table 2, the parts of the project that should be outsourced are (in this order) the "Manufacturing" (all the assembly and production process) –global score 1.1801- and the ME –global score 1.0743-. The ones that should be done in-house are (in order) the PS –global score 0.4483- and the FW/SW –global score 0.4483-. Finally, the testing & integration –global score 0.5261-, and the EE design are some how in between, and probably a case by case study should be done on each part design and/or integration test in order to take the right outsourcing decision.

6 CONCLUSIONS

Through the AHP it has been developed a decision making model, process and tools that can be used as a frame work to set up the outsourcing strategy for any project, keeping in mind that every one will be, by itself, a complete universe of options, constrains, priorities and values that need to be evaluated and decided almost on a case by case basis. For new applications of the method, the hierarchy tree should be reviewed, questioned and, if needed, complemented with new additional criteria, and thus, revised the relative weights of the paired comparisons. But there are some basic criteria and guidelines that everyone should take into account when deciding what parts of a project may be subject of outsourcing and what others not. The application of this method can help triggering the right discussions, provide a tool to analyze the data, and support with numbers the outsourcing decision.

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