Mapping verbal AHP scale to numerical scale for cloud computing strategy selection

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Abstract:

Analytic Hierarchy Process (AHP) is an established multi-criteria decision making method based on pairwise comparisons. Evaluations are given on a verbal scale and then converted into quantitative values for calculating the priorities of the criteria and alternatives. Several conversion scales have been proposed, which confuses the decision-maker. In order to select the best matching scale according to the mental representation of the verbal scale of each individual decision-maker, verbal scales are first used to compare alternatives with known measures, e.g. surface of figures. The best matching scale representing the real values is then selected. This AHP with individualised scales has been applied in a real case study to select cloud computing strategies.

Keywords: Analytical Hierarchy Process, Multiple criteria decision analysis, Pairwise comparisons, Scale Calibration, Cloud Computing

1. Introduction

AHP is one of the many methods available for solving multi-criteria decision problems [1]. It has been extensively used in practice as it can be testified by the multiple compilations of success stories [2-7]. In particular, applications in information management have been numerous, e.g. [8-11]. The

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cornerstone of AHP is the pairwise comparison, which permits the decision-maker to focus temporarily on only two alternatives or criteria at a time. The individual preference is expressed on a verbal scale and then converted into a numerical value to calculate priorities. Generally, the conversion table is decided a priori by the analyst without consulting the decision-maker. Most applications use the 1-9 linear scale (Table 1) or sometimes a shorter 1-5 scale, e.g. [12].

Intensity of importance	Definition
1	**Equal importance**
2	Weak
3	**Moderate importance**
4	Moderate plus
5	**Strong importance**
6	Strong plus
7	**Very strong or demonstrated importance**
8	Very, very strong
9	**Extreme importance**

Table 1: Scale of relative importance (according to Saaty [13, 14])

However, the 1-9 Saaty scale has been criticized because studies demonstrate that verbal expressions have different meaning to different persons [15] and may even be far to represent the reality [16]. Several other scales have been proposed (see section 2) but the question remains: which scale to choose? To overcome this problem, it has been suggested that individual scales need to be developed. Dong et al. [17] and Liang et al. [18] have proposed a method to calculate personalised scales that minimise the inconsistency of the matrix. These techniques are questionable because inconsistency in the pairwise matrix can have several origins in addition of the scale effect: error, lack of information, distracted or undecided user, etc. The research is quite poor in this area and only recently, two studies [19, 20] have proposed a more objective way to convert verbal scale into quantitative values for Fuzzy AHP and ANP. Both studies were based on two steps, where the first step mapped verbal scale with comparisons given by the decision-maker on alternatives with known measures and the second step is customised to the multicriteria method. In [19], in the first step, several questions on measurable values were asked. The same verbal judgements given by the decision–maker and its corresponding measurable value are grouped. In the second step, the triangular membership function is constructed as following: the lowest measure corresponds to the lower bound, the mean of the measureable values to the modal and the highest measure to the upper bound. [20] used also a two-steps method to correct any deviation in judgements. They asked to compare the dimension of two planets and looks at the deviation of the estimation to the real value. For example, the authors asked "comparing Earth to Mercury, which one is bigger and how much?". The correct answer is 12'756/4'879 = 2.6. The authors rounded this value to 3 (the reason of the rounding is not given) and then measured the distance to the answer provided by the decision-maker. For example, the decision-maker estimates that Mercury is 5 times bigger, the distance is 3-5 = -2. This distance (-2) is then added when the same evaluation (5) of the real problem is given in order to correct the deviation of judgement. This means that each time the decision-maker says 5, a 3 is registered.

In this paper, we also used a two-step method. We first asked to compare the surface of geometrical figures and as a result, the most suitable scale was selected for each participant. Then, the AHP with the most appropriate scale for each participant is applied to a case study in order to evaluate cloud storage strategies of an enterprise data storage company.

2. Scales in AHP

The linear (integer) scale was originally suggested by Saaty [13, 14]. The fact that it is the only scale used in the supporting software has probably influenced its use by default [21]. Harker and Vargas

[22] proposed the power and root scale, but specified that the choice of the scale is context dependent and the linear scale would often perform better. Lootsma [23] introduced the geometric scale. He argued that is the best way to represent equidistant stimuli, especially auditory. [24] pointed out that the integer scale one to nine yield local weights, which are unevenly dispersed, so that there is a lack of sensitivity when comparing elements, which are preferentially close to each other. Based on this observation, they proposed a balanced scale where the local weights are evenly dispersed between two alternatives over the weight range [0.1, 0.9]. [25] developed a balanced power scale, similar to the previous one but with balanced weights among three alternatives. Earlier Ma and Zheng [26] developed a scale, where the inverse elements x of the scale, i.e. $1/x$, are linear instead of the x in the Saaty scale. [27] proposed an asymptotic scale avoiding the boundary problem, e.g. if the decision-maker enters a_{ij} = 3 and a_{jk} = 4, s/he is forced to an intransitive relation when the upper limit of the scale is 9 and therefore cannot enter a_{ik} = 12. [28] proposed a logarithmic scale, which provides a fairer outcome for compromised solutions.

Scale type	Definition	Parameters
Linear [13]	$c = a \cdot x$	$a > 0$; $x = \{1, 2, \ldots, 9\}$
Power [22]	$c = x^a$	$a > 1$; $x = \{1, 2, \ldots, 9\}$
Geometric [23]	$c = a^{x-1}$	$a > 1$, often $\sqrt{2}$; $x = \{1, 2, \ldots, 9\}$ or $x = \{1, 1.5, \ldots, 4\}$ or other step
Logarithmic [28]	$c = \log_a(x+(a-1))$	$a > 1$; $x = \{1, 2, \ldots, 9\}$
Root square [22]	$c = \sqrt[a]{x}$	$a > 1$; $x = \{1, 2, \ldots, 9\}$
Asymptotical [29]	$c = \tanh^{-1}\left(\frac{\sqrt{3}(x-1)}{14}\right)$	$x = \{1, 2, \ldots, 9\}$
Inverse linear [26]	$c = 9/(10-x)$	$x = \{1, 2, \ldots, 9\}$
Balanced [24]	$c = w/(1-w)$	$w = \{0.5, 0.55, 0.6, \ldots, 0.9\}$
Balanced power scale [25]	$c = (\sqrt[n-1]{9})^{x-1}$	$x = \{1, 2, \ldots, n\}$

Table 2: Evaluation scales (extended from [30])

All scales have some proprieties but the real question, and probably the only one that counts, is: what is the scale in mind of the decision-maker? In order to map the verbal values with the best scale, we use a problem with known measurable values as explained in the next section.

3. Scale mapping

The scale mapping exercise is based on two phases. First, an experimental part captures the mental representation of the verbal scale on known alternatives. This part is similar to [19]. The second part is different. The best numerical scale representing the personal representation of the verbal scale is selected.

3.1. Experimental Procedure

The mapping of scale is performed through a comparison of measurable alternatives. In this case, we used geometrical figures as in [19, figure 2]. The participants were asked to compare their surface with the verbal scale given in [19, Table 2]. They were also informed that the figures were in an increasing order, so the questionnaire had only one scale direction [19, Table 3], e.g. A is necessarily smaller than B. The real measured pairwise comparisons of the figures are given in [19, Table 4]. Not all comparisons were asked to avoid overwhelming the participants. In total, 40 questions on the relative size of the figures were asked.

The consistency was measured with the formula proposed by Saaty [13]:

$$\text{CI} = \frac{\lambda_{\max} - n}{n-1}, \tag{1}$$

where n = dimension of the matrix

λ_{max} = maximal eigenvalue

If the CR, ratio of CI and RI (the average CI of 500 randomly filled matrices), is less than 10%, then the matrix can be considered as having an acceptable consistency.

CR = CI/CR, (2)

where CR is the consistency ratio

RI is the random index

It is to note that an RI must be calculated for each scale.

3.2. Scale selection

The verbal judgements given by the decision-maker are matched with the real values. For example, suppose that the decision-maker evaluates a ''strong/very strong'' difference between figures F-B, G-B, H-B and I-B. The real values of these four evaluations read [19, Table 4] (i.e. 3, 3.5, 4, 4.5) are entered into the matching table (Table 3). It can be deduced that the decision maker representation of ''strong/very strong'' is in average of 3.75. The same exercise is repeated for all the other comparisons.

Knowing the average value of the verbal scale representation of the decision-maker, we can search the best fitting scale. For this purpose, we select the scale from Table 2 that has the lowest Euclidian distance (3).

$$Euclid(Y,K) = \sqrt{\sum_{i=1}^{9}(y_i - k_i)^2} \quad (3)$$

where: y_i: average numerical representation of the decision-maker

k_i: the scale rating

For example, in Table 3 on the third row from the bottom, the balanced scale with an Euclidean distance of *Euclid (Y,K)* =

$$\sqrt{(1.16-1)^2+(1.16-1.22)^2+(1.44-1.50)^2+(1.71-1.86)^2+(2.45-2.33)^2+(3.75-3)^2+(3.50-4)^2+(6.83-5.67)^2+(9-9)^2}$$

= 1.49 is the best fitting scale for this participant.

Verbal scale	Equal	Equ/ mod	Mod erate	Mod/ Str	Strong	Str/ verStr	Ver Str	Verstr/ Extreme	Extreme	
	1.17	1.20	2.00	1.50	2.50	3.00	3.00	5.00	9.00	
Participant evaluation	1.14	1.13	1.33	2.00	2.00	3.50	4.00	6.00		
			1.25	1.66	2.33	4.00		7.00		
			1.40	1.60	2.66	4.50		8.00		
			1.34	1.80	3.00			9.00		
			1.50		1.50			6.00		
			1.28		1.75					
					2.00					
					2.25					
					4.50					
p(average)	1.16	1.16	1.44	1.71	2.45	3.75	3.50	6.83	9.00	
Scales										**Total Euclidean Distance**
Linear	1	2	3	4	5	6	7	8	9	**5.79**
Power	1	4	9	16	25	36	49	64	81	**111.09**
Geometric	1	2	4	8	16	32	64	128	256	**283.51**
Logarithmic	1	1.58	2	2.32	2.58	2.81	3.00	3.17	3.32	**6.91**
Root square	1.00	1.41	1.73	2.00	2.23	2.45	2.64	2.83	3	**7.40**
Asymptotical	0.00	0.12	0.24	0.36	0.46	0.55	0.63	0.70	0.76	**11.56**
Balanced	1.00	1.22	1.50	1.86	2.33	3.00	4.00	5.67	9	**1.49**
Inverse linear	1.00	1.13	1.29	1.50	1.80	2.25	3.00	4.50	9	**2.91**
Balanced power scale	1	1.32	1.73	2.28	3	3.95	5.2	6.84	9	**1.92**

Table 3: Matching Table

4. Case Study: Selection of Cloud computing/Storage Strategies

4.1. Introduction

Cloud computing has grown tremendously recently. It is becoming an established option due to its cost-efficient and needs-oriented information system. It can provide almost immediate access to hardware resources with no upfront capital investments, which lead to a faster time to market. It lower IT barriers to innovation and make easier for enterprises to scale their services [31, 32]. Recent IDC cloud research [33] shows that Worldwide revenue from public IT cloud services exceeded $21.5 billion in 2010 and will reach $72.9 billion in 2015, representing a compound annual growth rate of 27.6%. This rapid growth rate is over four times the projected growth for the worldwide IT market as a whole (6.7%). Therefore, there are clear opportunities for companies. This technology includes also risks: security, confidentiality, regulatory compliance, interoperability, provider lock-in and portability issues [34, 35]. In particular, security is a hot topic as data and machine management are delegated to the cloud provider, its sub-contractors and employees, which means that they also have access to them [36-38]. Maintenance becomes more complicated due to the increased size of the infrastructure [39, 40]. By consequence, a recent study has found that IT companies do not foresee to adopt cloud computing until its associated uncertainty, e.g. on security, standardisation, are not reduced [39].

The case study company is a world leading enterprise data storage infrastructure supplier organisation. To address cloud-scale business opportunity, they are unsure about which strategy to adopt to target the cloud infrastructure market. They asked the first author, full-time employed by the company as Systems Integration Specialist and part-time MBA student at the time of the study, to facilitate the decision process. The second author is a faculty member acting as impartial external advisor. In the next section, we will describe the decision workflow.

4.2. Decision workflow

The real case study company had no previous experience in multi criteria methods, but are convinced that such strategic decision needs to be supported by analytical methods. To solve their problem, we developed a structured decision workflow of five phases (Figure 1), where the researchers acted as facilitators. The decision-makers were very busy persons, therefore they asked us to be efficient in the process. One hour meeting in each phase between the decision-makers and researchers was required for phase I, II, III, and V. Phase IV is based on a questionnaire taking in average half an hour. Therefore, the problem has been processed in 4 and half hours by the decision-makers. Each session held at one week interval, apart between session IV and V, where a two week interval has been given for the questionnaire completion. These intervals are needed by the facilitators to analyse the previous session and to prepare the next session. It also gives time to the participants to reflect on the session and validate or reconsider their choices at the beginning of the next session.

I. *Problem presentation*: The company explains the problem to the researchers and a discussion on possible solutions is conducted.

II. *Problem structuring*: In a brainstorming exercise, the task force lists all the criteria relevant to the decision problem.

III. *Awareness session*: An awareness session on the AHP methodology was given along with the presentation of several success studies [41-44]. An understanding of the AHP and required inputs is necessary in order to avoid improper use of the method [45]. The advantages of the new decision method needs to be clearly explained in order that everybody accepts it and to avoid reluctance and objections during the decision process.

IV. *Evaluations collection*: A questionnaire is sent to each decision-maker by email. The respondents have two week to return it.

V. *Results presentation*: Priorities are aggregated in Expert Choice. A sensitivity analysis is conducted and results are discussed with the decision-makers.

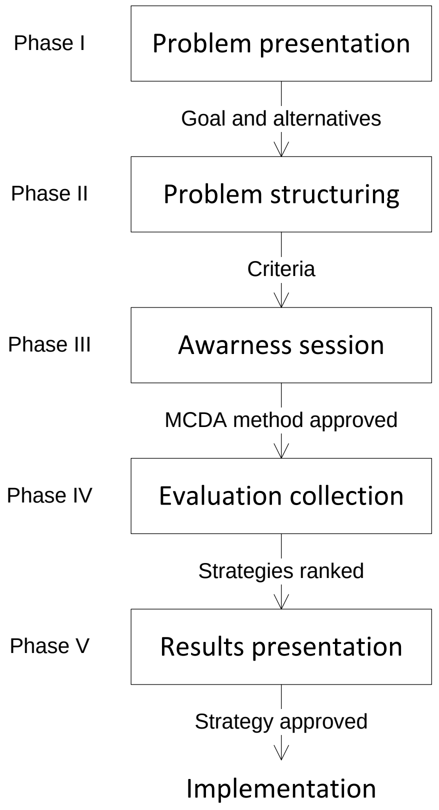

Figure 1: Decision workflow

4.2.1. Problem presentation

A task force of 15 key members, with the mission to take the most appropriate decision, has been created. They are divided into three categories with equivalent number of participants:

- Five Senior Vice Presidents and Vice Presidents, who are specialised in the external and internal competitive landscape, opportunities for expansion, customers, markets, new industry developments and standards in storage domain.
- Five Senior Directors and Directors, who have expertise in creating business plans.
- Five Senior Managers and Managers, who are specialised to organize the production of the work, the workforce, the training and the necessary resources to meet the specified goals.

Each member falls in various levels in the organisation hierarchy, each with dissimilar stakes, expertises, preferences and power in the organisation. All members agreed that a similar weight will be given to all participants as any opinion has the same importance in the success of the project.

Initially, the task force provided only two alternatives. After some debate on the risks attached to cloud computing, the members found safer to include an alternative delaying the entry to market until risks were lower. The three alternatives are:

- **Integrated Cloud Solution (Integrated)**: It delivers differentiated solutions that are a combination of appliances, software and services. This will develop and take to market cloud-scale infrastructure solutions with a compelling value proposition targeted predominantly at cloud solution providers. It also maximises the use of internal and external resources to deliver integrated solutions to cloud solution providers.
- **Hardware for Original Equipment Manufacturer (Hardware)**: It offers a series of storage building blocks to Original Equipment Manufacturers (OEMs) to accommodate their most demanding cloud storage requirement. This enables OEMs to deliver more powerful intelligent storage solutions along with their most advanced software capabilities directly to end users. This alternative is more cautious as it enters the market with organization network storage hardware platforms by building the low-margin cloud hardware infrastructure to an OEM customer set.
- **No Market Entry (No entry)**: It is not the right time to enter the cloud computing market as it encompasses too much uncertainty. It would better to wait when standards and regulations are defined. This solution is also risky as the company may lose a large market share if the standardisation and regulations are not set quickly.

4.2.2. Problem Structuring

The problem structuring has been done in a brainstorming exercise in the premises of the company. The exercise was facilitated by the authors, who had done literature review on cloud computing in preparation of the exercise. Six criteria were found to be relevant for this decision. All the criteria found in the literature review by the facilitators were also mentioned by the task force, which confirms the high expertise of the task force in the area.

Core competency: It evaluates if the proposed strategy is in line with the core competencies of the company. For Cloud storage market strategies, competencies such as expertise in right-scale hardware integration, file system appliance integration, early access to new drive technologies, software development skills play a major role in evaluating the strategies [46].

Market opportunity: It is the size of the addressable market, which in cloud computing seems promising [33]. General purpose applications (office applications, email, collaborative technologies) are the prime candidate to be migrated on the cloud. For large systems, SMEs are certainly the most interested companies that would adopt cloud computing because otherwise their access would not be possible due to the prominent investment required. They can also test, change or upgrade applications on the spot. For large enterprise, the current cloud computing services are often not cost-effective because they have already invested in large systems [31, 47].

Customer satisfaction: It evaluates the capacity to provide products/services/solutions of highest quality with less number of post release defects and deliver more value to customers with a high level of customer satisfaction [48].

Cloud computing will allow customers an immediate access to resources, with no upfront capital investment. This permits enterprises to scale up their services and lower barriers to innovation. However, many organisations may fear the lack of control over their data and the possible vendor lock-in [31].

Time to market: In fast-cycle, the speed and rate at which high technology industries can introduce products into the market are critical for sustaining competitive advantage and market share. The time to market is essential in industries such as cloud storage, where products are outmoded quickly. The lesser time to market, the best will be the position in market place of the company.

Risk: Threat that an event or action adversely affect the organization ability to achieve its objectives and to successfully execute its strategies. Specific to Cloud storage markets, risks with open source technologies, partners product viability, relative easy market access for OEMs, customer acceptance to pay premium price for appliances, relationship with existing OEM customers, possible slow data intensive applications and traditional IT divisions resisting to change have to be considered carefully with the proposed strategies .

Financial benefits: It is the difference between the cost of the product/solution and its selling price. If there is a large market that is not restricted geographically [46], there is also flexibility to choose the pricing strategy. Several models exist such as flat fees, pay-per-use fees, two-tier mix of flat and pay-per-usage fees and even auction for unused cloud capacity [49].

The hierarchy of the problem has two levels: six criteria and three strategic alternatives (Figure 2).

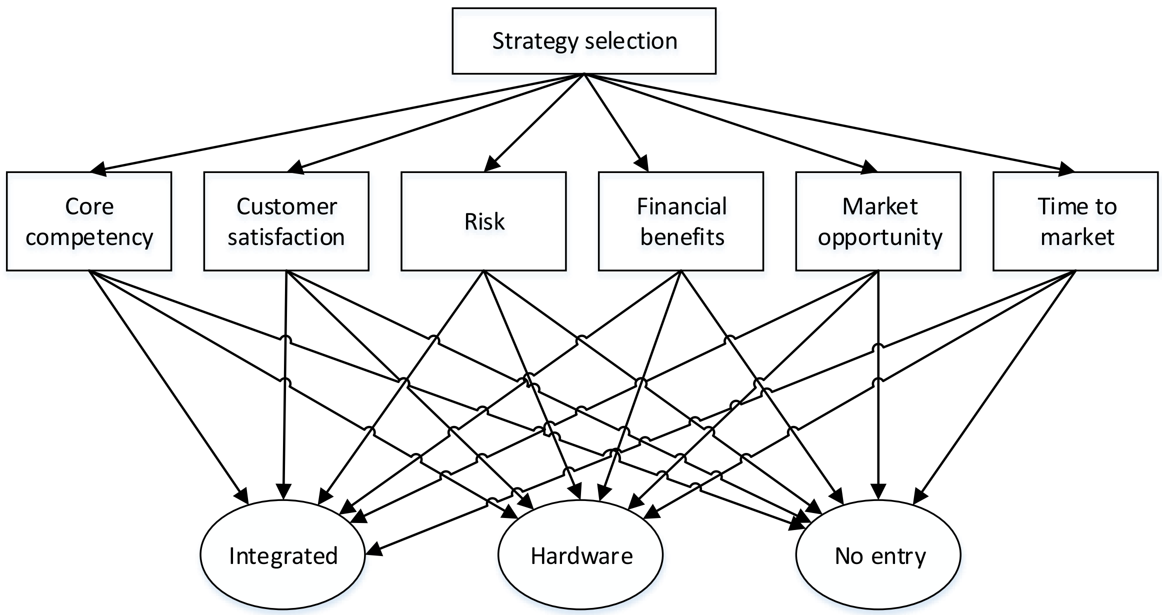

Figure 2: Hierarchy of the strategy selection

4.2.3. Awareness session

An hour awareness session was given to all members of the task force. The methodology of AHP without mathematics (too complicated for the audience) and a simple example of holiday resort selection was presented. In particular, it was explained the collection of preferences in a pairwise mode and the verbal scale (Table 1). The advantages of the AHP were clearly perceived. This phase is fundamental because, the way a new method is presented (and then used) can significantly impact its efficacy. This session was a Go or No Go point. The investment in time and money of using AHP and its preliminary scale mapping questionnaire [19, Table 3] was approved due to the strategic importance of the decision. It was decided to continue with the next phase.

4.2.4. Evaluations collection

The evaluations collection was done through a questionnaire. As the questions were precise and identical to everybody, and the respondents were trained, then the facilitators did not need to be present. Questionnaires have the advantage to be anonymous to the other members of the task force. The respondents can also take all the time they require to answer, without any pressure to be observed and judged.

The questionnaire was based on three parts. The first part asked to compare pairwise the geometrical figures of [19, figure 2]. In the second part, the participants were asked to compare the criteria of Figure 2 in Table 4. In the third part, the participants were asked to compare the alternatives pairwise as regards to each criterion in a similar style as the questionnaire in Table 4.

Pairwisely compare the relative importance of 6 criteria with respect to Goal: "<u>Cloud computing strategy selection</u>"

A - Equ: Equally importance/preferable
B - Eq/mod: Equal to Moderately more importance/preferable
C- Moderate: Moderately more importance/preferable
D - Mod/Str: Moderately to strongly more importance/preferable
E - Strong: Strongly different more importance/preferable
F - Str/verStr: Strongly to very strongly more importance/preferable
G - Ver Str: Very strongly more importance/preferable
H - verStr/Extr: Very strongly to extremely more importance/preferable
I – Ext: Extremely more importance/preferable

(click the box you think is the most appropriately described the relationship between each 2 criteria.)

	I	H	G	F	E	D	C	B	**A**	B	C	D	E	F	G	H	I	
Financial Benefits	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Market Opportunity
Financial Benefits	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Low Risk
Financial Benefits	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Core Competency
Financial Benefits	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality
Financial Benefits	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Less Time to Market
Market Opportunity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Low Risk
Market Opportunity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Core competency
Market Opportunity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality
Market Opportunity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Less Time to Market
Low Risk	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Core Competency
Low Risk	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality
Low Risk	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Less Time to Market
Core Competency	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality
Core Competency	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Less Time to market
Quality	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Less Time to Market

Table 4: Pairwise questionnaire for the criteria importance

4.2.5. Results presentation

Only the strategy selection in section 4.2.5.2, at the exception of Table 10 and Table 11 (to ensure the anonymity of the respondents), was presented to the task force. Section 4.2.5.1 was not presented. It is not an informative result for the task force but it is a necessary result to calculate the priorities given to the selection strategies.

4.2.5.1. Matching scale

For each participant, a matching table (as Table 3) was constructed to find the best personal fitting scale. Table 5 shows the scale that minimises the Euclidian distance for each participant. Table 6 gives the proportion of each scale. The logarithmic scale is found to be the most often (40% of the cases) best fitting scale. Then, the balanced and balanced power scales are both selected in 20% of the cases. The traditional linear scale of Saaty has never been found to be the best matching verbal representation of the participants.

Participant	Best matching scale
P1	Inverse Linear
P2	Balanced
P3	Balanced
P4	Balanced
P5	Balanced Power Scale
P6	Logarithmic
P7	Logarithmic
P8	Balanced Power Scale
P9	Inverse Linear
P10	Logarithmic
P11	Logarithmic
P12	Logarithmic
P13	Balanced Power Scale
P14	Logarithmic
P15	Root Square

Table 5: Best matching scale for each participant

Scale type	Number	Percentage [%]
Linear	0	0
Power	0	0
Geometric	0	0
Logarithmic	**6**	**40**
Root square	1	7
Asymptotical	0	0
Inverse linear	2	13
Balanced	3	20
Balanced power scale	3	20

Table 6: Percentage of selected scales

The converted verbal evaluations are then entered manually in Expert Choice. This automatic conversion cannot be used because this supporting AHP software converts automatically only to a linear scale and in our case each participant has a different scale. Then, Expert Choice is used to calculate the local priorities with the eigenvalue method [21] and the global priority with an arithmetic weighted sum. Finally, the global priority of each expert are aggregated with a simple arithmetic mean as all experts have the same weight [50]. The consistency Ratio is calculated with (2). The participants have been highly consistent in their evaluation, i.e all have been below the recommended threshold of 10% inconsistency (Table 7). This high consistency indicates that the decision method has been well understood and the participants were not confused or uncertain in their evaluations [51].

Participant	P1	P2	P3	P4	P5	P6	P7	P8	P9
Inconsistency	0.02	0.06	0.02	0.07	0.01	0.05	0.04	0.08	0.03

P10	P11	P12	P13	P14	P15	Combined
0.1	0.04	0.06	0.08	0.05	0.05	0.01

Table 7: Consistency index

4.2.5.2. Strategy selection

The average weight of each criterion given by the respondents is presented in Table 8. Their scores are very close, which means that all criteria have almost the same importance. The difference between the best individual matching scale and the linear scale of Saaty is small but can induce some rank reversals.

Judgment scales / **Criteria**	**Best matching scale**	**Linear (Saaty's) scale**
Financial benefits	**19.4% (1)**	21.3% (2)
Market opportunity	**19.4% (1)**	**21.6% (1)**
Low risk	11.3% (6)	8.0% (6)
Core competency	14.3% (5)	12.6% (5)
Customer satisfaction	18.5% (3)	19.0% (3)
Less time-to-market	17.0% (4)	17.6% (4)

Table 8: Weight of the criteria and its rank in brackets

Table 9 indicates that the Hardware Sale to the Original Equipment Manufacturers is the preferred solution. In particular, as Hardware construction is the core competency of the company, it has a low risk and time to market and also a possible high satisfaction of our existing customers (Figure 3). However, this strategy has a lower market opportunity and financial benefit.

Judgment scales / Alternatives	Best matching scale	Linear (Saaty's) scale
Integrated Cloud Solution	37.0% (2)	39.5% (2)
Hardware Sale	**40.1% (1)**	**43.3% (1)**
No Market Entry	22.9% (3)	17.2% (3)

Table 9: Priority of each alternative and its rank in brackets

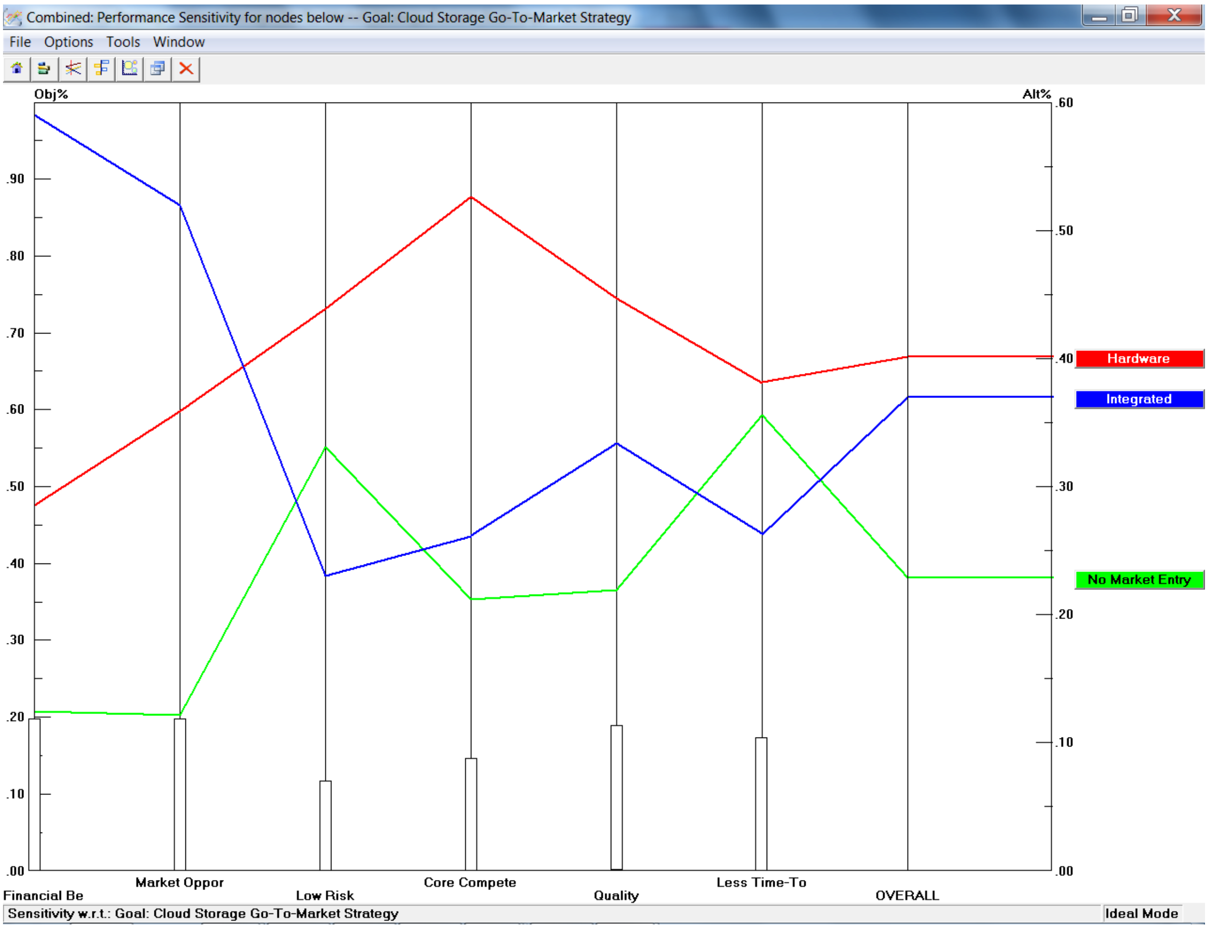

Figure 3: Strategies ranking

Table 10 distinguishes the criteria weights by group of specific responsibility in the organisation. It is to remark that each group had a different emphasis. The Senior Vice Presidents and Vice Presidents have the financial benefits as the most weighted criterion. The Senior Directors and Directors have the financial benefits, the market opportunities and the customer satisfaction as very close most important criteria. The Senior Managers and Managers, who are closer to the client, prefer to give the highest weight to the customer satisfaction.

The decision in Table 9 is not unanimous. Table 11 shows the different strategy priority by groups. The Senior Vice Presidents, Vice Presidents, Senior Directors and Directors prefer slightly the Integrated Cloud Solution over the Hardware Sale. Integrated Cloud Solution responds to their strategic vision. The Senior Managers and Managers clearly prefer the Hardware sale strategy as it is their core competence which has always satisfied their customer.

Group / Criteria	**Senior Vice Presidents and Vice Presidents** Best matching scale (Saaty's Scale)	**Senior Directors and Directors** Best matching scale (Saaty's Scale)	**Senior Managers and Managers** Best matching scale (Saaty's Scale)
Financial benefits	**27.4% (35.5%)**	19.1% (22.4%)	13.3% (10.3%)
Market opportunity	19.6% (21.3%)	**19.2% (22.0%)**	18.5% (18.2%)
Low risk	10.3% (6.5%)	13.1% (9.8%)	10.2% (6.9%)
Core competency	10.7% (7.0%)	15.9% (15.0%)	16.4% (16.7%)
Customer satisfaction	13.6% (11.1%)	19.1% (17.8%)	**23.0% (28.5%)**
Less time-to-market	18.5% (18.6%)	13.6% (13.0%)	18.5% (19.3%)

Table 10: Group comparison for weight criteria

Group / Alternatives	**Senior Vice Presidents and Vice Presidents** **Best matching scale (Saaty's Scale)**	**Senior Directors and Directors** **Best matching scale (Saaty's Scale)**	**Senior Managers and Managers** **Best matching scale (Saaty's Scale)**
Integrated Cloud Solution	**43.0% (51.0%)**	**39.1% (43.7%)**	30.6% (27.2%)
Hardware Sale	35.6% (34.1%)	36.3% (36.9%)	**47.4% (56.4%)**
No Market Entry	21.4% (14.9%)	24.6% (19.4%)	22.0% (16.3%)

Table 11: Group comparison for alternatives priorities

5. Discussion

AHP has been developed to prioritize alternative based on pairwise comparisons given by decision-makers. As qualitative judgments are more familiar to our daily lives than quantitative judgments, Saaty [13] has proposed to use them and then transform in a linear quantitative judgments from 1 to 9. In our paper, it has been proposed to select the best matching scale according to each decision-maker. The difference between both ranking obtained with these two scale is not large but enough to induce rank reversal. Therefore, our two step method provide more precision in the decision process.

Companies operate in a dynamic environment, where they need constantly to take decisions. This case study presents a structured methodology to support decision processes. The recommendations of the model have been implemented with the general satisfaction of all stakeholders. The successful acceptance of the proposed methodology can be attributed to the following reasons:

1. Significant reduction of time and effort in the decision process due to a simple structured methodology;
2. Facilitated problem description by breaking down decision criteria into manageable components;
3. Easiness for the decision makers to arrive at a consensus, because the hierarchy model brings a common reference, which can be debated;
4. Enhancement of the decision quality, due to the consistency check, scale mapping and sensitivity analysis embedded in the AHP method;
5. Documentation and justification of the decision made.

This structured methodology has been approved and recommended to be used for any future strategic decision by the task force.

6. Conclusion

The choice of a numerical scale corresponding to a verbal scale has an important role in deriving precise priorities. In this paper, we have presented a new way to find the best fitting numerical scale representing the verbal representation of each individual participant. In our case study, we have seen that there is not a unique scale for the conversion: each person has its own representation. In particular, in our study, the Saaty scale was not the best scale for any participants. Even if the difference in the final calculation is not large, it can also introduce variation that may lead to a rank reversal.

To illustrate our new mapping scaling method, we applied it to a real case of strategy selection. The suggested first choice has been implemented successfully, so that the company decided to go further and implement the second ranked strategy, i.e. the integrated solution. The cloud computing is now generating a large turn-over, which totally justify the right strategy selection to enter the cloud computing market. As the decision has been fully documented and retraceable, it could at any time be justified again and therefore its acceptance and implementation was easier.

The selection of individualised scales can be easily added as a supplement exercise to any AHP decision problem. However, additional time for completing the supplementary questionnaire must be planned. It is to note that if other scales are proposed in the literature, they can be added in the selection list. The best scales will then be selected with the same algorithm proposed in this paper. As a further study, it would be interesting to find the minimal number of supplementary questions needed to achieve a precise calibration.

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