Interactive management control via analytic hierarchy process: an empirical study in a public university hospital

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Abstract: This paper describes an application of analytic hierarchy process (AHP) to enhance interactive budgeting in one of the biggest public university hospitals in Italy. AHP improved budget allocation facilitating elicitation and formalisation of units' needs. Furthermore, AHP facilitated vertical communication among managers and stakeholders, as it allowed multilevel hierarchical representation of hospital needs, and horizontal communication among staff of the same hospital, as it allowed units' need prioritisation and standardisation, with a scientific multi-criteria approach, without using complex mathematics. Finally, AHP allowed traceability of a complex decision-making process (as budget allocation), this aspect being of paramount importance in public sectors, where managers are called to respond to many different stakeholders about their choices.

Keywords: AHP; analytic hierarchy process; multi-criteria decision analysis; interactive budgeting; management control; accounts management.

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1 Introduction

According to Anthony and Young, management control (MC) is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organisation's objectives (Anthony and Herzlinger, 1980).

A major feature of most MC systems is the budget allocation process. Budgeting systems are used by top management as a mean of coordinating and communicating strategic priorities and, in conjunction with reward systems, are often used to facilitate lower-level managers' commitment to these priorities. According to the classification of budget systems proposed by Simons (1987), there are two main approaches to MC: diagnostic or interactive. In the former, budget is used to evaluate performance and attributing responsibility and is based on the assumption that managers have a clear idea on how to improve performance. In the latter, budgets can also be used as a dialogic process to learn and facilitate creation and diffusion of new ideas that can help to improve choices, to evaluate the consequences of decisions and to bring enhanced strategic vision. Diagnostic budget is implemented mainly through vertical communication among top management and subalterns, whereas interactive budget also requires lateral communication among managers of different units, across levels and functions. In fact, a distinctive feature of interactive use of budgets is the continual exchange of information between top management and lower levels of management, as well as interactions within various levels of management across functions.

This leads account managers to adopt scientific methods to facilitate this communication (Abernethy and Brownell, 1999). Moreover, public organisations are pushed to change under the pressure of systemic threads and challenges. This is the case of hospitals today, under the big pressure of global economic crisis. Management control in public university hospitals is a challenging task because of continuous changes owing to external pressures (e.g., economic pressures, stakeholder focuses and scientific progress) and internal complexities (top management turnover, shared leadership, technological evolution and researcher-oriented mission). This changing process creates a context where decision-making by top management becomes increasingly complex and unpredictable, as new opportunities or new constraints alter strategic objectives, or change their priorities. Therefore, methods to allocate budget should provide elasticity and a clear system of prioritisation. Furthermore, although hospital hierarchy exists, it is difficult to talk about subordinates and superiors, and medical doctors in operative units have at least the same weight as top managers in the steering to budget allocation process. This also complicates the leadership, requiring the adoption of methods to facilitate consensus finding (Abernethy et al., 2010).

Additionally, in democratic countries, in which the healthcare organisations are totally or partially supported by the public funds, hospital managers are ultimately responsible for the citizens regarding their decisions (Rosanas and Velilla, 2005). This requires the adoption of methods, which allow stakeholders not skilled in complex mathematics to understand the reasons of decisions. On the other hand, the use of *scientific quantitative methods to support decision-making* is considered necessary in healthcare organisations, where the personnel are committed to follow only the best available evidence according to well-designed trials (Bracale et al., 2012a), meta-analyses (Bracale et al., 2011) or network meta-analyses (Bracale et al., 2012b). In this study, we proposed the use of AHP as a method for budget negotiation within the context of a university hospital (Iadanza et al., 2009; Miniati et al., 2011a, 2011b) to support interactive MC. AHP is a scientific decision-making method, based on the idea that it is possible to prioritise factors affecting a decision by grouping them into meaningful categories and sub-categories; performing pairwise comparisons; defining a coherent framework of quantitative and qualitative knowledge and measuring also intangible domains. Several methods were proposed to enhance MC (Gil, 2010; Naranjo-Gil, 2009), organisation and planning (Grafton et al., 2011), and to measure productivity (Chang et al., 2011), performance (Islam and Rasad, 2006; Grigoroudis et al., 2012) and quality (Buyukozkan and Cifci, 2011). AHP was chosen in this study because it is multilevel, facilitating vertical communication of strategies and objectives; it is multidimensional and multi-factorial, facilitating inter-disciplinary communication among units' managers with different specialisations; it uses no complex mathematical methods to represent a decision-maker's needs, facilitating communication with stakeholders (politics and citizen), who may be not skilled in complex mathematics (Bruno et al., 2012). AHP was previously used for strategic planning (Partovi, 2006), for group decision-making under fuzzy environments (Hatami-Marbini and Tavana, 2011), for revenue management process (Islam and Abdullah, 2006), also under uncertainty (Tsai and Hung, 2009). A number of papers have highlighted the benefits of AHP use in healthcare (Liberatore and Nydick, 2008), because of its multidimensional and multi-criteria nature (Pecchia et al., 2009) and because is considered to be easy to use and time-saving (Chatburn and Primiano, 2001). Recent papers presented different applications in which the AHP was effectively used to support shared decision-making with bottom-up approaches, involving either healthcare professionals (Pecchia et al., 2013a) or patients (Pecchia et al., 2013b). As far as authors' knowledge is concerned, no previous studies applied AHP for budget allocation and MC in a university hospital.

In this paper, we present the results of an application of AHP to support the MC in one of the biggest Italian university hospitals.

2 Methods

This AHP is a mathematical method for multi-criteria decision-making consisting in the five consecutive steps.

2.1 Criteria identification

Interviewing managers and medical doctors in charge of complex units of the University Hospital Federico II of Naples those factors that in the last five years influenced the allocation of the budget were identified. These factors were then organised in categories and sub-categories. Finally, a tree of factors was designed, in which each node represented a category, each sub-node represented a sub-category and each leaf represented a factor.

To elicit how important it was to invest in each of those factors, questionnaires were designed to compare the relative importance of each factor with all the others into its sub-category. In these questionnaires, for each pair of factors (i, j), respondents were asked the following question: in accordance with the situation in your unit, how important do you consider investing in the *factor i* compared with the *factor j*? Respondents answered choosing one of the following judgements: much less, less, equally, more, or much more important.

2.2 Judgement matrix

In accordance with the natural scale by Saaty (1977), an integer numerical value was given to each judgement as follows: 1 if equally important, 3 if more important. The reciprocal values were given to the remaining judgements: 1/3 less important; 1/5 much less important. The process was then iterated, designing similar questionnaires to elicit the relative importance of each sub-category and each category.

For each category of needs, using the Saaty scale, a judgement matrix A_{nxn} was calculated, where 'n' was the number of needs in the category.

According to Saaty (1977), the matrix A had the following properties:

- the generic element (a_{ij}) referred to the ratio between the relative importance of the Factor 'i' (F_i) and the Factor 'j' (F_j);
- the element a_{ji} was the reciprocal of a_{ij}, assuming the reciprocity of judgement: if F_i was three times more important than F_j, then F_j was assumed to be 1/3 of F_i
- a_{ii} was equal to 1 (F_i was assumed to be equally important to itself
- the matrix A was supposed to be transitive (equation (1)):

$$\forall i, j, k \in (1; n), a_{ij} = a_{ik} \times a_{kj}. \tag{1}$$

If the matrix A satisfies these properties, then each column resulted proportional to the others and only one real eigenvalue (λ) existed, which was equal to 'n' (Saaty, 1977).

The eigenvector associated with this eigenvalue was again proportional to each column, and represented the relative importance of each need compared with each of the other needs in the same category.

2.3 Managing inconsistencies

In many cases, the matrix A was not transitive, especially if n is too high (i.e., $n > 3$). As a consequence, it had more than one eigenvalue. If the matrix was not transitive, the property number 4 was substituted with the 4.bis:

4.bis the matrix A was supposed to be quasi-transitive, if the consistency index (CI) was lower than the given threshold by 10% (equation (2))[AQ: Please check if the edited text retains the intended meaning]:

$$\text{CI} = \frac{\lambda_{\max} - n}{n-1} < 0.1 \times \text{RI} \tag{2}$$

where RI is the random index, calculated by Forman (1990) as the average of the CI of all the matrices obtained combining the values of the Saaty scale, assuming the transitivity property. Despite its name, the RI value is a deterministic value, as the number of matrices obtained combining the Saaty scale values are deterministic. RI changed only according to the value of n as reported in Table 1.

Table 1 Random index values according to n

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45

If A was quasi-transitive, the main eigenvector (the one corresponding to the eigenvalue bigger in module) was used to prioritise the relative importance of each factor.

In the case that properties 4 or 4.bis were not satisfied, the respondent was asked to reconsider the response given. It is proved elsewhere that respondents may lose transitivity when too tired (long questionnaires owing to complex hierarchies) or confused by the elevated number of factors to be compared (De Felice et al., 2013; Pecchia et al., 2013a).

This process is iterated at each level of the hierarchy to calculate the relative importance of each element, whether it is a need (leaf) or a category of needs (node).

2.4 Category and sub-category importance: global- and meso-importance of each factor

By applying the same algorithm to sub-categories of factors, it was possible to evaluate their relative importance within their categories. The relative importance of a sub-category k into a category m was called SCW^{km} or local importance of sub-category. The same was done between categories and the relative importance of a category m was called CW^m.

Finally, the relative importance of a factor i compared with the others in the same category m (across sub-categories) was defined as meso-importance (meso-weight) of the factor i into the category m (MW_i^m). The relative importance of the factor i compared with all the other (across categories and sub-categories) was defined as global importance (global weight, GW) of the factor i. Both were calculated by multiplying the local importance of the factor per one of the root elements into the hierarchy. For instance, the meso-weight of the factor i into the category m was calculated as the product of the local importance (weight) of the factor (LW_i^k) per the importance (weight) of its sub-category into the category m (SCW^{km}) (equation (3)).

$$MW_i^m = SCW^{km} \times FW_i^k. \tag{3}$$

Similarly, the global importance of the factor i (GW_i), which was in the sub-category k, and an element of category m, was calculated as follows (equation (4)):

$$GW_i = CW^m \times MW_i^m. \tag{4}$$

Finally, also sub-categories have a global importance ($GSCW$) as shown in equation (5).

$$GSCW^k = CW^m \times SCW^k. \tag{5}$$

2.5 *Response pooling*

For each node, the geometric mean of the A matrices of each respondent was calculated. The main eigenvector of the mean matrix obtained gave the global importance of each element for all the respondents involved in the study. Some authors calculate this geometric mean per groups of respondents to analyse divergences or to find consensus in small but homogeneous groups (Pecchia et al., 2013b).

2.6 *Result discussion*

Finally, the judgement matrix and the relative importance of each factor were discussed with each respondent to infer further information about the choices. Then, a final focus group meeting with respondents and managers was held, with the aim of discussing the results, to gather insights about the interpretation of such results and to evaluate the AHP as a candidate method to improve MC in the hospital settings.

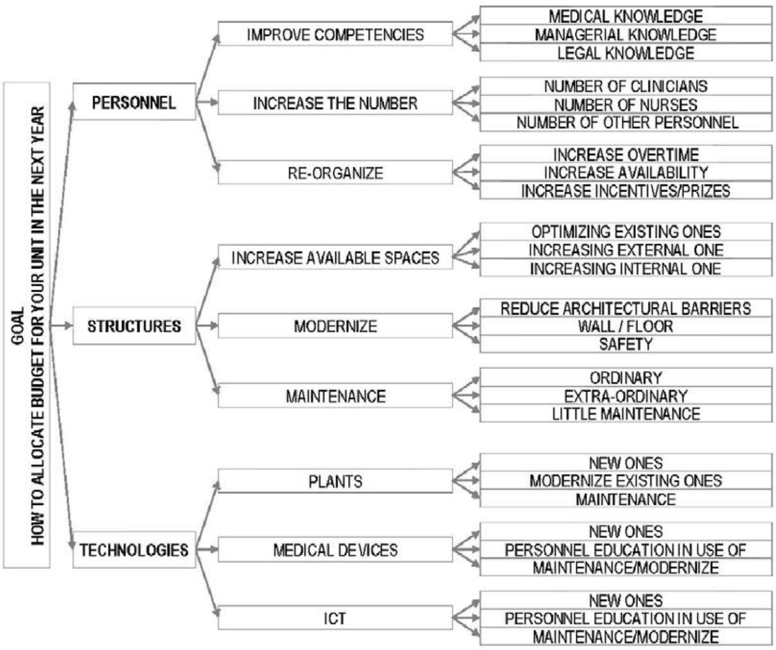
2.7 *Materials*

The whole study was performed using the beta version of a software that was designed by one of the authors (LP) using Matlab and excel. The final version of this software has been now released as an App for iPad (Pecchia et al., 2013c) and can be freely downloaded via the web (http://www.ahpapp.net/).

3 Results

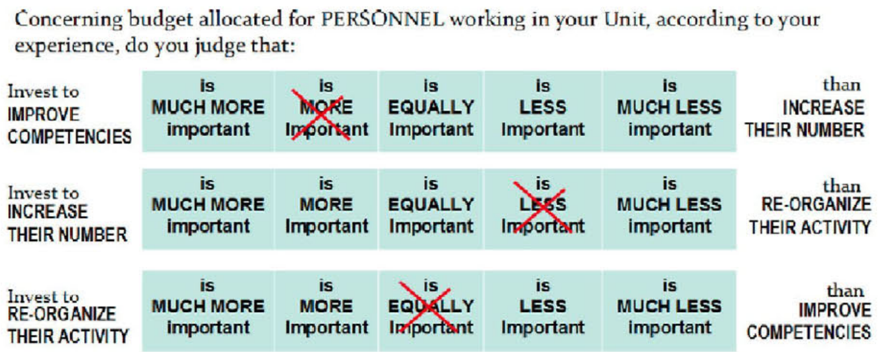
In collaboration with three managers and three medical doctors of the hospital, a hierarchy of 27 factors, grouped into nine sub-categories and three categories, was designed (Figure 1).

Figure 1 Hierarchy



Thirteen questionnaires, composed by three questions each, were designed and piloted in lab: 9 questionnaires (one per each sub-category) to elicit local importance of factors; 3 questionnaires (one per each category) to elicit relative importance of each sub-category into each category; 1 questionnaire to elicit the relative importance of each category of factors. Figure 2 shows the questionnaires developed.

Figure 2 Questionnaires (see online version for colours)



To reduce word confusion and to avoid mistakes, nine independent respondents piloted the questionnaire. Finally, seven medical doctors in charge of seven different medical units were randomly chosen among the 62 units of the case study hospital to answer the questionnaires. All the respondents answered consistently all the questionnaires. Therefore, the results based on the relative importance of categories, pooled among the seven final respondents, were the one presented in Table 2.

Table 2 Relative importance of categories

Categories	*Matrices*			*Weight*	
Personnel	1.00	2.89	2.04	0.55	2.89
Structure	0.35	1.00	0.70	0.19	1.00
Technologies	0.49	1.42	1.00	0.27	1.42

In the last column, the weights were normalised to the minimum weight (in this case 'structure'). This index allowed us to easily communicate the results to decision-makers not skilled in mathematical methods (i.e., "*investing in personnel is considered 3 times more important than investing in structures*"). Table 2 also presented the averaged judgement matrix (second, third and fourth columns). This was useful to understand the result comparisons.

The first row of the judgement matrix demonstrated that investing in personnel was considered, respectively, 2.89 and 2.04 times more important than investing in structures of technologies, while investing in structure was considered 70 times more important than investing in technologies. This explained why personnel is considered almost three times more important than investing in structures and the final prioritisation of relative importance of investing in different categories of factors: first in personnel, second in technologies and then in structures.

The local and the global relative importance of sub-categories, pooled among respondents, are reported in Table 3.

Table 3 Relative importance of sub-categories

Categories *Sub-categories*	*Matrices*			*Local weights*		*Global weights*	
Personnel							
Improve competences	1.00	0.60	1.26	0.29	*1.26*	0.16	*3.65*
Increase number	1.66	1.00	2.09	0.48	*2.04*	0.26	*6.04*
Activity reorganisation	0.79	0.48	1.00	0.23	*1.00*	0.13	*2.89*
Structure							
Spaces increment	1.00	0.48	0.79	0.23	*1.00*	0.04	*1.00*
Structure modernisation	2.09	1.00	1.66	0.48	*2.04*	0.09	*2.04*
Structure maintenance	1.26	0.60	1.00	0.29	*1.26*	0.06	*1.26*
Technologies							
Plants	1.00	0.38	0.53	0.18	*1.00*	0.05	*1.10*
Medical devices	2.67	1.00	1.41	0.48	*2.67*	0.13	*2.97*
ICT	1.89	0.71	1.00	0.34	*1.89*	0.09	*2.10*

ICT: information and communication technologies.

Also, the sub-categorical weights were normalised to the minimum to facilitate communication. For instance, regarding sub-category of factors concerning personnel, recruiting new members of staff was considered twice as important as reorganising their activities. Recruiting new members was also considered the most important action to do for the next year. In fact, this was scored six times more important than increment spaces, which was considered the last important one.

The relative weights of each individual factor were estimated too, and are reported in Table 4: local weights (within sub-categories), the meso-weights (among sub-categories) and the global weights (among all) are reported. Increasing number of nurses and auxiliaries were considered as the most important factors, followed by the 'improving managerial competences' factor, while increasing external spaces and technological plants modernisation were considered as the less important ones. The judgement matrices were omitted for space limitations.

4 Discussion

In this paper, an application of the AHP method to elicit the needs of complex units in a university public hospital, following a traceable bottom-up approach of budget allocation, was presented. The hierarchy proposed reflected the structure of National and Regional regulations on minimum requirement for structure offering healthcare services, both public and private. To enable respondents to familiarise themselves with the terminology and with the hierarchy, firstly we submitted questionnaires comparing factors and then those comparing sub-categories. Therefore, the respondent knew what was included in each sub-category. For the same reasons, all the questionnaires comparing sub-categories were submitted before the one comparing categories.

The respondents, who represent the 11.3% of all the units of the hospital, did not report difficulty with the questionnaires, and were extremely satisfied with the method. In particular, all have confirmed that the findings presented accurately reflected the needs of their units. Moreover, six of the seven respondents spontaneously stated that they would not be as effective in expressing their needs without this method. In addition, the timing of the questionnaire was considered satisfactory. In the last 5 years, the negotiation has required more meetings each of them taking at least 2 h. The questionnaire took about 30 min (28 ± 9) to be completed consistently. The results of the questionnaires facilitated the communication with elicitors.

Accounting managers reported the highest satisfaction about the adoption of the method and the intention to extend the experimentation of the method to all units next year, since the budget negotiation runs each year from October to November. The top management of the hospital has declared the maximum interest in this methodology especially to indicate convergences and divergences between the strategic objectives of the hospital and the needs of individual units. Finally, the results of this study were utilised by the hospital top management to discuss, politically, divergences between regional strategic goals (and regional budget allocation) and local needs. All the experts involved in the study were satisfied for the limited use of mathematics and for the easiness to communicate achieved results. Finally, the quantification of units' needs facilitated lateral communication and the achievement of consensus. Regarding the prioritisation of factors, sub-categories and categories for budget allocation, the results presented reflect the main problems of the hospital.

Table 4 Global, meso- and local relative importance of factors affecting budget allocation

Sub-category	*Local weights*		*Meso-weights*		*Global weights*	
Personnel						
Improve competences						
Medical competences	0.36	*2.25*	0.10	*2.25*	0.06	*8.16*
Managerial competences	0.47	*2.94*	0.14	*2.94*	0.07	*10.65*
Juridical competences	0.16	*1.00*	0.05	*1.00*	0.03	*3.63*
Increase number						
Medical doctors	0.27	*1.00*	0.13	*2.79*	0.07	*10.13*
Nurses	0.36	*1.33*	0.17	*3.72*	0.10	*13.50*
Other (auxiliary)	0.36	*1.33*	0.17	*3.72*	0.10	*13.50*
Activity reorganisation						
Overtired	0.33	*1.06*	0.08	*1.64*	0.04	*5.93*
Variability	0.31	*1.00*	0.07	*1.54*	0.04	*5.57*
Incentives and bonuses	0.35	*1.13*	0.08	*1.73*	0.04	*6.29*
Structures						
Increment spaces						
Optimise	0.35	*2.06*	0.08	*2.06*	0.01	*2.06*
Increase internal spaces	0.47	*2.76*	0.11	*2.76*	0.02	*2.76*
Increase external spaces	0.17	*1.00*	0.04	*1.00*	0.01	*1.00*
Structure modernisation						
Architectural barriers	0.35	*1.21*	0.17	*4.30*	0.03	*4.30*
Covering/paving	0.29	*1.00*	0.14	*3.56*	0.03	*3.56*
Anti-fire systems	0.35	*1.21*	0.17	*4.30*	0.03	*4.30*
Structure maintenance						
Ordinary maintenance	0.47	*1.88*	0.14	*3.49*	0.02	*3.49*
Extraordinary maintenance	0.25	*1.00*	0.07	*1.85*	0.01	*1.85*
Small maintenance	0.26	*1.04*	0.08	*1.93*	0.01	*1.93*
Technology						
Technological plants (*TP*)						
New TP	0.27	*1.00*	0.05	*1.00*	0.01	*1.86*
TP modernisation	0.35	*1.30*	0.06	*1.30*	0.02	*2.42*
TP maintenance	0.38	*1.41*	0.07	*1.41*	0.02	*2.62*
Medical devices (MD)						
New MD	0.48	*2.18*	0.23	*4.74*	0.06	*8.84*
MD personnel education	0.22	*1.00*	0.11	*2.17*	0.03	*4.05*
MD maintenance	0.29	*1.32*	0.14	*2.86*	0.04	*5.34*
ICT						
New ICT	0.4	*1.60*	0.14	*2.80*	0.04	*5.22*
ICT personnel education	0.35	*1.40*	0.12	*2.45*	0.03	*4.57*
ICT maintenance	0.25	*1.00*	0.09	*1.75*	0.02	*3.26*

The principal need that emerged was to invest in personnel. Particularly, it was required to enrol new staffs, which was scored first for global weight over the nine sub-categories, especially non-medical auxiliary personnel and nurses (scored first and second over 27 factors). This reflects the fact that the programmed recruiting of new non-medical staff is blocked for more than 10 years for economic constraints. Consequently, in 2011, the mean age of employed personnel into the hospital (2237 employees) was 53.71 years old (range from 29 to 72 years old). The age of employees per function reflected respondents' judgement. Concerning employed personnel, the main requirement was to improve competences (third among sub-categories), especially managerial competences (scored second among all factors) to diffuse the culture of affordability and appropriateness. This reflected the fact that, since 2007, any person responsible for the hospital (any level) was under the pressure of an austere economic recovery plan, a blueprint for a return to sustainable healthcare services, which was imposed by the Ministry of Health to reduce the deficit of the INHS in Campania Region, where the hospital is located. In the meantime, doctors in charge of units proposed to compensate the limited number of staff by reorganising their activities (fourth among the nine sub-categories), or promoting systems of incentives (seventh among factors) to increase the productivity of personnel. Among sub-categories, the second request for global weight was to invest in medical devices, especially to purchase new ones.

Although the above-mentioned result could be the same in many hospitals, owing to the continuous evolution and importance of medical device to improve the quality of care, this consideration reflects locally the mission of the hospital aimed at research and healthcare. Moreover, the method presented is traceable. For instance, it is possible to demonstrate that 'increase external spaces' was considered the less important among all the factors (GW = 0.01), because it was scored as less important into the sub-category of 'increment spaces' (LW = 0.17), which was scored the less important among sub-category felt in category called 'structure' (SCW = 0.23), which was scored the less important among categories (CW = 0.19). This is essential in a public no-profit organisation of a democratic country, where the national health services are fully supported by public funds. Regarding the methods, we adapted the AHP to the specific case in which it is used with respondents not experienced in its use. These adaptations are discussed in detail in a recent paper (Pecchia and Morgan, 2013), freely available online. The application of AHP to elicit the needs of healthcare professionals can be found in Pecchia et al. (2013c).

AHP fulfilled the needs of the hospital managers, as it meets five requirements of decision-making, which are fundamental in medicine:

- to facilitate the communication (horizontal and vertical, internal and external)
- to be elastic, transparent and traceable of prioritisation
- to simplifying the achievement of consensus
- to allow the involvement of stakeholders not skilled in complex mathematics
- to use a scientific (and elegant) approach as required by medical doctors who are committed to the use of evidence-based medicine.

The aim of this research work was to provide a first assessment on how AHP may be used as a multi-criteria decision analysis method to support budget prioritisation. Future research should combine AHP with other methodologies, covering the first and final phase of the intervention: in this study, the first phase (identification of categories, sub-categories and factors), as well as the final phase (evaluation of results) have been implemented through qualitative methods like focus groups and face-to-face interviews with respondents. Even though the advantage of focus groups lies in "spontaneous reactions and group dynamics" and serves to assess user needs and feelings (Nielsen, 1994), huge effort is needed for analysing the results. According to Nielsen, "Focus groups involve the risk that the users may think they want one thing even though they in fact need another". This method is good for getting new ideas but may be risky for extracting, collecting and analysing results. Further research is needed to explore how AHP may impact MC and interactive budgeting in more structured interventions and selecting it as a multi-criteria decision analysis process to be used in multi-methodology approach, which is one of the most important developments in management science literature.

5 Conclusions

The method proposed enabled eliciting analytically the needs of doctors in charge of units responsible for budget negotiation. The elicitation process was traceable, multilevel and fully intelligible, reflecting the needs of interactive MC systems in a public university hospital, facilitating vertical and horizontal communications. In fact, AHP supported accounting managers in: negotiating budgets, proving the reasons of their choices (also after years); communicating their options at any required level (medical doctors, top management, politicians and public opinion); ensuring maximum transparency of decision-making processes that impact on the allocation of the budget and finding consensus facilitating lateral communication. AHP supported clinicians in charge of hospital units to express and formalise their needs. Moreover, all the clinicians' needs were standardised improving horizontal communication among units. The overall process of budget negotiation was improved and accelerated.

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