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Government Policy and Health Care management: proposal of a shared decision-making model

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Abstract
As a consequence of the current economic crisis many changes have been introduced to health systems on national levels to reduce expenditure and to introduce more cost-effective methods. Then recent developments in medical technology have led to a shift in the traditional framework of physician-patient responsibility in health care decision making. In this context, the health community urges, in any case, decision makers to ensure that all changes introduced are in accordance with Health System Values. This paper presents a new decision making platform, as a tool to facilitate shared decision making, to improve the quality and transparency of tactical and strategic decisions. This new application, based on analytic quantitative method, is a component of a wider distribute web system under development, which aims to inform the new effective health technologies supporting designers in the user need elicitation and early stage health technology assessments. A case study aiming to elicit the user needs affecting the decision of whether to adopt a new magnetic resonance imaging (MRI) is also presented.

Keywords: Analytic Hierarchy Process, government policy, magnetic resonance imaging, user need elicitation, decision making.

1. Introduction

Since the 1980s, due to the fiscal crisis of the welfare states and the reorganization of public expenditure, the provision of welfare and healthcare services in many countries has undergone important changes (Borzaga and Fazzi, 2014). It became important to guarantee services in a context of reduced coverage by the state.
The Italian case is of particular interest for empirical verification of the reorganization of healthcare services. Italy's national health service (Servizio Sanitario Nazionale, SSN) was instituted in 1978. The SSN provides universal coverage and is financed out of taxation. All citizens can in principle access services without private insurance.
Thus, as stated by Friedman *et al.* (2014), the capability to share data, and harness its potential to generate knowledge rapidly and inform decisions, can have transformative effects on complex systems that produce goods and provide services. It represents a key strategic success factor for health care management and for a good government policy.
In this context health policy research has an important and expanding role in efforts by the government and the private sector to address issues of health financing and costs. Health policy researchers frequently worry about whether government decision makers will use their work. Many health policy debates can usefully be read as involving competition among three major academic-professional traditions: *public health, economics, and medicine* (Etheredge, 1984).
The public health tradition has been largely concerned with determining the needs of groups of people and matching resources to those needs. It has thus been most influential in efforts both to expand and to regulate the supply of health resources and to change the organization of health care. The influence of economics on health policy began growing early in the 1970s. Economists tend to emphasize notions of consumer sovereignty, investigate how actors are and can be influenced by economic motives, and suggest widespread use of financial incentives rather than regulation. Some observers may view the growing role of economic concepts in shaping government health policy as evidence that economics is inherently superior to other disciplines in addressing health policy issues. Medicine is the third major profession whose ways of thinking about health care strongly influence health policy. The view of medical schools and physicians of optimal national health policy could be summarized as (1) find the best people to be physicians and give them the best

training; (2) get physicians and patients together; and (3) have everyone else do (and pay for) what the physician decides is best for the patient.

Nowadays patients and all stakeholders are increasingly participating in serious health care decisions, resulting in a *"shared decision-making model"*. It is essential that all of them find a way to develop strategies that allow them to understand and evaluate their health care options in a clear manner.

Health technologies, differently from other technologies, are designed for different lead or end users, including, but not limited to: medical doctors (i.e. GP, surgeons, clinicians with different specializations), nurses, public health monitoring authorities, informal careers and patients, which have the most heterogeneous cultural backgrounds. Each of these users has different needs and different rules in determining the whether a new health technology will succeed or not. Accordingly, biomedical engineers and other health technology designers are required to consider a much more complex and dynamic set of user needs, which are often conflicting and in the majority of the cases subjective and based on personal experiences. This is different from other research fields, where technologies are designed, acquired and used by professionals having a similar, if not the same, technological background. Therefore the assessment of user needs in healthcare is a complex challenge, requiring specific decision making methods and skills to identify, classify, prioritize and formalized user needs in objective and quantitative reports.

Investment in rapid-learning initiatives would enable a new generation of health policies to realize the benefits of our expanding knowledge base.

As stated by Oshima Lee and Emanuel (2013) in a 2001 report, Crossing the Quality Chasm, the Institute of Medicine (Institute of Medicine, 2001) recommended redesigning health care processes according to 10 rules, many of which emphasize shared decision making. Studies also illustrate the potential for wider adoption of shared decision making to reduce costs. The public's health care needs have changed as well. The improved quality of care and savings gained through shared decision making can be maximized using a proper by decision making tool.

In our view, it seems most critical when choosing amongst alternative courses of action, decision makers often have multiple, conflicting, objectives (De Felice and Petrillo, 2013). We investigated literature about decision making methods. Review of the decision making literature identified a number of theoretical and methodological approaches for research. There are several decision methods that can be used. Macharis *et al.* (1998) presents a PROMETHEE procedure for group decision support. Another method, based on ELECTRE methodology, was proposed by Leyva-López and Fernández-González (2003) for group decision support. Other methodologies such as utility theory, which requires: an explicit formulation of the problem including alternative choices and outcomes, and an explicit quantitative representation of both uncertainty in the form of probabilities and preferences in the form of utilities, have been tried as a linear compensatory tradeoff approach for important decisions (Kahneman, 2000).

However, most lay persons find the assigning of probabilities to events and utilities to outcomes unnatural and unfamiliar. From this point of view the Analytic Hierarchy Process (AHP) development by T.L. Saaty (Saaty, 1977) is a decision methodology that has been successfully applied to a wide variety of situations and has great potential as a methodology for improved shared health care decision making. AHP is a particularly effective method for eliciting user needs in healthcare as it quantifies qualitative information (Pecchia *et al.*, 2011), also if based on personal experience and knowledge, to design a consistent decision-making framework. AHP is a *multi-dimensional*, *multi-level* and *multifactorial* method (Saaty, 1982) based on the idea that it is possible to prioritize elements by: grouping them into meaningful categories and sub-categories; performing pairwise comparisons; defining a coherent framework of quantitative and qualitative knowledge; measuring intangible domains. This hierarchical approach allows the construction of a consistent framework for step-by-step decision-making, breaking a complex problem into many small less-complex ones that decision-makers can more easily deal with. This paradigm, known as *divide et impera* (Benario, 2012) (often translated as "divide and conquer") and widely investigated in medicine (Raible and Brand, 2004; Scorrano, 2003) has been demonstrated to be effective in healthcare decision-making (Reinhardt, 2012).

This paper presents an adaptation of the AHP method for the user need elicitation in healthcare and a decision making platform system, consisting in an App for iPad and a web portal, to support the use of AHP for HTA and user elicitation studies. The paper is structured as follows: section 2 presents Methodological approach and hypothesis of our research; in section 3 a case study on the design of a new magnetic resonance imaging (MRI) is presented. Finally, section 4 and 5 present results and conclusions.

2. Methods and conceptualization: Methodological approach and hypothesis

In our opinion it is essential to promote a more effective approaches to implementing health care management and government policy, and better ways to protect democracy and human rights. Sound government policies and effective decision making play a critical role in reaching the full potential of globalization and good social conditions and better protection.

The question is: *What policies/strategies must the government introduce?*

In the present section we analyse methodological approach on which is based our model.

The model is based on the consideration that a complex idea often involves several aspects and the knowledge about them is distributed among several people. For this reason our approach is based on the following principles and hypothesis:

- H1: A high-performing health system ensures that people have access to a comprehensive range of services in a timely and convenient manner.
- H2: A high-performing health system minimises the risk of accidental injury or death due to medical care or medical error.
- H3: A high-performing health system supports individuals to make positive decisions about their own health and acts to maximise its positive impact on the broader determinants of people's health.
- H4: A high-performing health system supports individuals with long-term conditions to manage them effectively and achieve a high quality of life.
- H5: A high-performing health system delivers services to improve health outcomes in terms of successful treatment.
- H6: A high-performing health system delivers a positive patient experience.
- H7: A high-performing health system is equitably funded, allocates resources fairly, ensures that services meet the population's needs for health care, and contributes to reducing health inequalities.
- H 8: A high-performing health system uses the available resources to maximum effect. This requires higher productivity in the delivery of care, supported by economy in the purchase of the goods and services that a health service needs to deliver that care.

The research methodology employed made use of in-depth case study exploration. We consider the methodological approach (Figure 1) as divided in three stages: *research design*, *data collection* and *data analysis*.

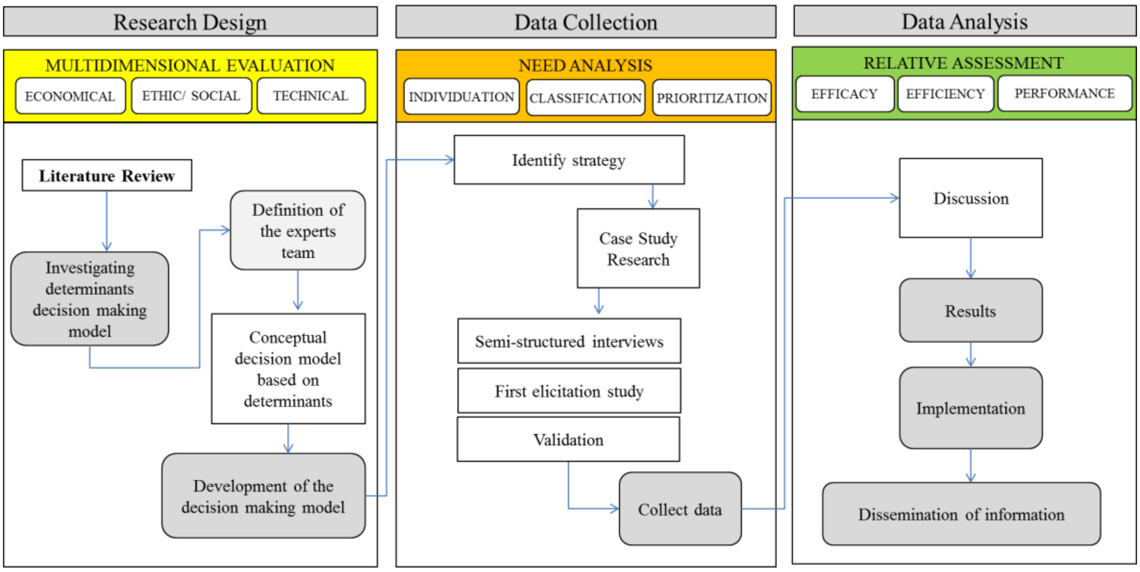

Figure 1: Methodological approach

During the research design phase an experts team was defined and a multidimensional evaluation, based on literature review, was performed in order to investigate determinants for the decision making model. The number of experts involved was established according to the variability among their opinions. In other words, no additional experts were involved in the piloting when the adding of an additional one was not significantly changing the hierarchy (Borsci et al., 2013). During the data collection phase a case study was conducted. In this phase a semi-structured interviews and a first elicitation study were completed in order to achieve the validation of the model. Finally during data analysis phase results were analysed in order to assess efficacy, efficiency and performance of the model and dissemination of information was conducted.

In the following paragraphs we will analyse the main features about the AHP and the decision making platform.

2.1 The Analytic Hierarchy Process method

A number of researchers highlighted the benefits of using AHP to explore user needs in healthcare (Hummel and IJzerman, 2009; Pecchia *et al.*, 2013) particularly for HTA (Danner *et al.*, 2011; Bridges, 2005), for choosing treatments (Dolan, 1995), and to improve patient centered healthcare (Dolan, 2010; Bridges, 2008). Other methods that have attempted to elicit and quantify user needs in healthcare as the conjoint analysis (CA) (Bridges, 2012), discrete choice experiments (de Bekker-Grob, *et al.*, 2012) and best-worst scaling (Gallego *et al.*, 2011). Compared to these other methods, the AHP seems to be more flexible (Ijzerman *et al.*, 2008) and robust (Scholl *et al.*, 2005), especially when an assessment involves many attributes (Mulye, 1998). However, other studies highlighted some limits of the AHP when proper tools are not utilized (Ijzerman, *et al.*, 2012).
The AHP method consisted in the seven main steps (Figure 2). In this section each step is briefly described.

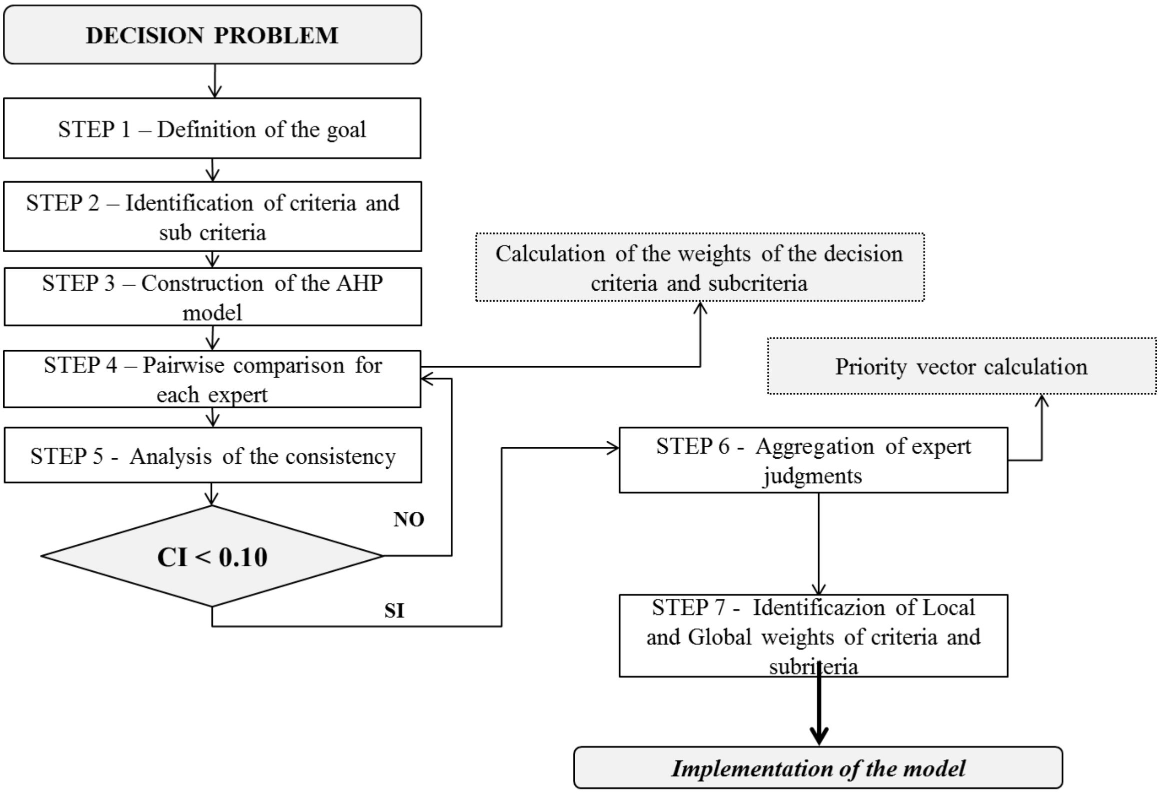

Figure 2: AHP methodological approach

The first step consists in defining the goal of the decision making model. The second steps consists in defining needs (leafs) in meaningful categories (nodes). In case of multilevel hierarchy, also subcategories of needs would be defined (child nodes). Step 3 consists in defining the AHP model or in other word in defining the hierarchy. Once the hierarchy is emended, pairwise comparison with questionnaires (Step 4) are developed. It is paramount important to emend the hierarchy before starting developing the questionnaires as a small changes in the former imply big and time-consuming changes in the latter, with an elevated risk of generating errors. Starting from the inner level of the hierarchy, for each node (category of needs) or child-node (sub-category of needs), the questionnaire asks to the final responders to compare each child with all the other children of the same node. This is then iterated at each node of each level of the hierarchy, whether it is a category or a sub-category node. Therefore, for each node, a total of $n_m*(n_m-1)/2$ questions are posed, where "n" is the number of children of the m^{th}-node. Particularly, for each pair of needs (*i*,*j*), responders are asked the following question: "*according to your experience, how important do you consider the need "i" compared to the need "j"*?" (Figure 3). Responders answer by choosing one of the following judgments (a_{ij}): *extremely less, much less, less, equally, more, or much more important*. In accordance with the Saaty natural scale (Saaty, 1977), these values are given to each judgment: 1 if equally, 3 if moderately mode important, 5 if more important, 7 if much more important and 9 if extremely more important. The reciprocal values were given to the remaining judgments: 1/3 if moderately less important, 1/5 if less important, 1/7 if much less important and 1/9 if extremely less. In-between numbers are used for in-between judgments. Although several scales have been proposed for this process (Ji and Jiang, 2003; Salo and Hamalainen, 1997), in this study an adaptation of the Saaty natural scale was used as it resulted easier to understand for responders who were not skilled in complex mathematics or with the AHP method.

a)

Technical issues	are	*much more*	*more*	*equally*	*less*	*much less*	Important than	*Clinical factors*
Clinical factors	are	*much more*	*more*	*equally*	*less*	*much less*	Important than	*User needs*
User needs	are	*much more*	*more*	*equally*	*less*	*much less*	Important than	*Technical issues*

b)

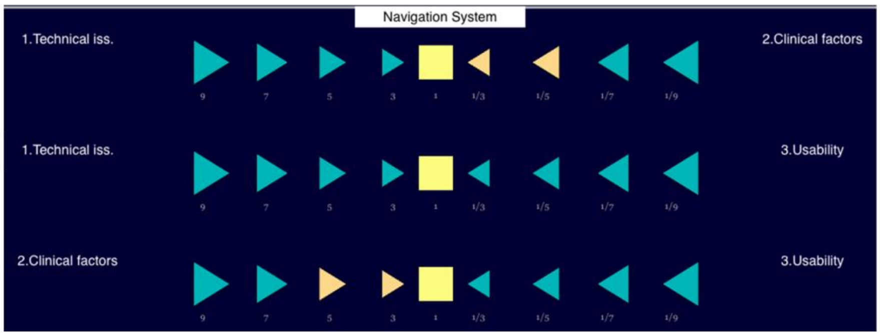

Figure 3: Questionnaire layout

For each category of needs (for each node), a judgment matrix $A_{nxn} = \{a_{ij}\}$ is composed (step 4), where a_{ij} represented the ratio of the relative importance of the need "i" on the relative importance of the need "j", according to the Saaty natural scale. The matrix A had the following properties (Saaty, 1980):

1. (identity) a_{ii} was equal to 1 (*i* was assumed to be equally important to itself);
2. (reciprocity) the element a_{ji} was the reciprocal of a_{ij} ($a_{ji}=a_{ii}^{-1}$), assuming the reciprocity of judgment (if *i* was 3 times more important than *j*, then *j* was assumed to be 1/3 of *i*);
3. (transitivity) the matrix A was supposed to be transitive (Equation 1):

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

The transitivity property reflected the assumption that, considering three needs (*i*, *j*, and *k*), if a respondent give a first judgment G1) like "*i* is *moderately more important than j (3 according to the Saaty scale)*" and a second judgment (G2) like "*j is 2 times more important k*", the same respondent should give a third judgment (G3) like "*i* is *6 time more important than k*". However, human judgments are not perfectly transitive, and a G3 like "*i=5 times k*" or "*i=7 times k*" is accepted too. What is rejected is a G3 completely contradicting G1&G2 as "*i is equally important as k*". If the matrix A satisfied these 3 properties then each column is proportional to the others and only one real eigenvalue (λ) existed, which is equal to "n" (number of children under comparison in that node). The eigenvector associated with this eigenvalue is again proportional to each column, and each component of the eigenvector, normalized, represented the relative importance of each need compared to each of the other needs in the same category.

If the transitivity property was not respected (Step 5), the matrix had more than one real eigenvalues. In this case, the components of the main eigenvector, which is the one corresponding to the main eigenvalue (bigger in module), is used to prioritize the needs. In this case, in similarly to other methods aiming to minimize the decisional space (i.e. principal component analysis (Abdi and Williams, 2010)), the majority of the information is considered to be associated only to the main "direction" as given by the main eigenvalue. This approximation generated and an error is generated. This error is estimated by posing some redundant questions: considering again three needs (*i*, *j*, and *k)* the respondent is asked to perform the pair comparisons *i-j* and *j-k*, and then the redundant comparison *i-k*. The answer to the redundant question (G3) is compared with the one deduced from the first two (G3'=G1*G2), assuming the transitivity of judgment. The difference between the real answer and the transitive one represented the degree of errors (ε=G3-G3'), which is called *"inconsistency*". This is empirically estimated by measuring the difference between the major eigenvalue λ_{max} and "n" (number of child in the node). The consistency index (CI) of the

derived weights could then be calculated by: CI = (λ_{max}−n)/ n−1. In general, if CI is less than 0.10, satisfaction of judgments may be derived.
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/sub-category of needs (node).
For each node, the geometric mean of the A matrices (Â) of each respondent is calculated (Step 6). Some authors calculate this geometric mean per groups of responders to analyze divergences or to find consensus in small but homogenous groups, as further discussed in (Pecchia *et al.*, 2010; De Felice and Petrillo, 2013) In other studies, the A matrices were also weighted, before the geometric mean, with an index reflecting the relative importance of each responder involved in the user need elicitation as described in (Pecchia *et al.*, 2011). No user weighting was adopted in this study.
For each inner node, those whose children were all leaves (needs) and not nodes (category or subcategory of needs), the main eigenvectors of the geometric means Â were used to estimate the relative importance of each need (Step 7). These importance were called *local importance* of *needs* as they reflected the relative importance of each need in respect to the other needs into the same category or subcategory (node). The same process is iterated for each sub-category node estimating the local importance of each subcategory compared to all the other into the same category of needs (Step 7). The same is done for each one of the main category of needs.
The global importance of each need (Step 7) is calculated by multiplying its local importance for the one of each father node, whether sub-category of category. The hierarchy is not fully symmetric: one sub-category had 4 leafs (needs), while all the other 3 leafs. Therefore, the global importance of the needs of this sub-category is multiplied for a correction factor of 4/3. Without such a correction, the relative importance of the needs falling in a more crowdie sub-category would be penalized. Finally, since 2 sub-categories had no leafs, the global importance was normalized to the sum to be expressed in percentage.
In order to understand the reasons behind the prioritizations provided by each of the responders, their results were discussed with them immediately after they had completed the questionnaire.

2.2 The decision making platform: The AHP App
The system developed to perform the user elicitation using the AHP consisted of an App for iPad, a web portal, two databases and several web services (Pecchia *et al.*, 2014). The architecture is described in Figure 4.

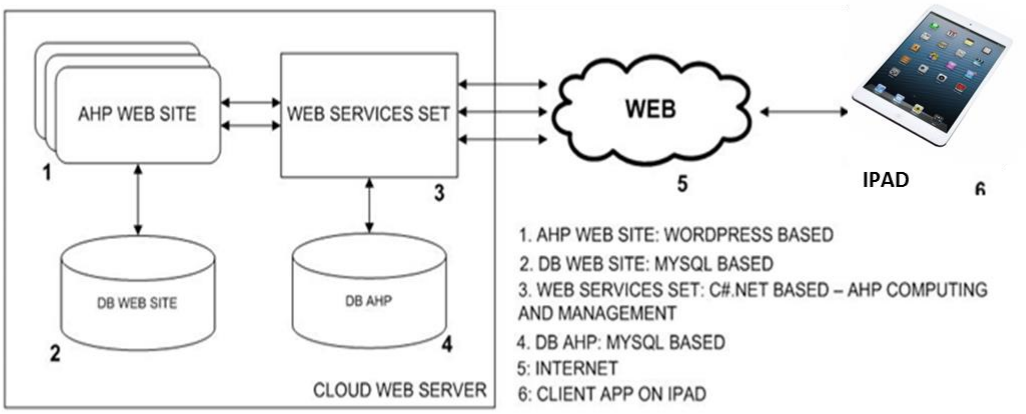

Figure 4: system architecture

This App was designed for three different users:

1. *The elicitor*, which was granted permission for: 1) hierarchy and the questionnaires designing and piloting; 2) inviting the domain experts and final responders; 3) pooling the results; 4) publishing the results on the web portal.

2. *Domain expert*, which was granted the permission for: 1) reviewing specific projects (hierarchy and questionnaires) under invitation; 2) suggest final responders or other domain experts to the elicitor.
3. *Final responder*, under invitation, download the hierarchy and answer the questions.

This App can be used alone or in strong relation with the web portal. In the former case, the elicitor works in the same place with domain experts and the final responders. In the latter, the elicitor, the domain experts and the final responders are in different places and cooperate in the different phases of the elicitation process via the web.

The App offers the following functionalities:

1. *Create the Hierarchy*: the elicitor may define the problem, identify the needs and organize them in meaningful categories and subcategories (Figure 5).
2. *Download an existing hierarchy*: as create a new one, but the elicitor may start from an existing hierarchy, which can be downloaded by the web portal.
3. *Generate the questionnaires:* the questionnaires are generated according to the hierarchy.
4. *Invite domain experts*: once created the hierarchy, the elicitor may invite domain experts to revise hierarchy and questionnaires.
5. *Amend the hierarchy/questionnaires*: once the domain experts provided their feedback, the elicitor may amend the hierarchy. From now on, the hierarchy cannot be modified, unless opening a new project. In this case, the portal will see this as a new hierarchy.
6. *Invite responders*: the elicitor may invite responders via email. The responders will receive an email with an explanation of the problem and a link to the App (for those that do not have the App yet) or a link to the hierarchy (for those that have the App).
7. *Participate to the study*: an invited responder may answer to the questions, prioritizing the needs.
8. *Analyze and Pool results*: once the elicitation process is concluded the elicitor receive via email a report and an excel file with the answers given by all (or part) of the responders.
9. *Publish*: the elicitor can publish on the portal one or all the following elements: the hierarchy, the results, the report and scientific papers related to the study, if appropriate.

In order to avoid conflict between the information in the App and in the web server, a rigid system of functional states was adopted:

1. *Definition*: in this state the elicitor may design the hierarchy and the questionnaires.
2. *Piloting*: in this state the elicitor invite the domain expert for the piloting of the hierarchy and the questionnaires.
3. *Active*: the final responders are invited. In this state no more modification of the hierarchy are admitted.
4. *Completed*: no more responders are admitted. In this state no more questionnaires are accepted.
5. *Public*: the hierarchy model is published on the web portal.

The elicitor change manually these states form its App.

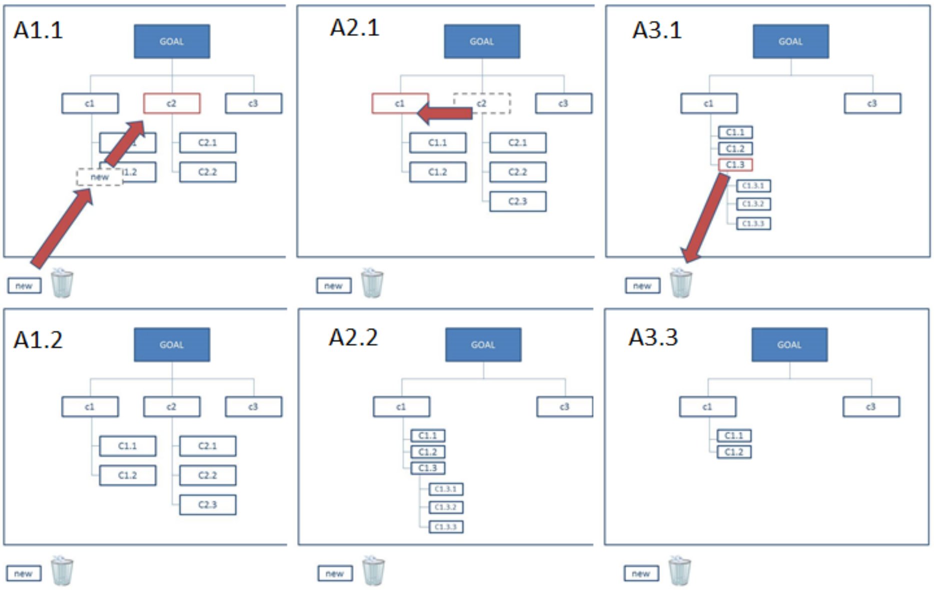

Figure 5: Different moment of a hierarchy creation: add a leaf (A1.1 and A1. 2); move a node (A2.1 and A2.2); delete a node (A3.1 and A3.2)

3. Case study: design a new magnetic resonance imaging (MRI)

The App and the methods has been validated with data from a user need elicitation study aiming to elicit the relative importance of those factors affecting: 1) the design of a new magnetic resonance imaging (MRI); 2) the decision of whether to adopt it. A literature review was performed to identify all possible user needs for a new magnetic resonance imaging and a preliminary hierarchy of need was drafted (Craven *et al.*, 2013). In Figure 6 some MRI models are shown.

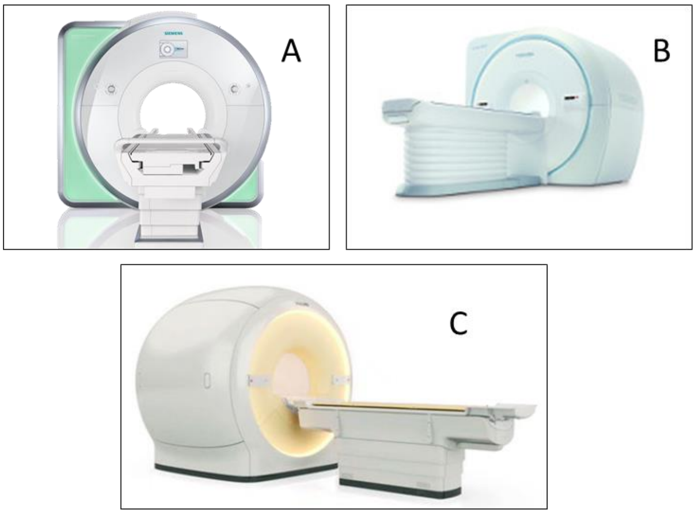

Figure 6: MRI – example of some models

Semi-structured interviews were conducted in face-to-face meetings with three specialized medical doctors from three different Hospitals in Rome (Italy) to review the drafted hierarchy, to identify any additional needs and to emend the final hierarchy. A total of 23 needs were identified and organized into a 2-layer hierarchy composed by 3 main categories and 8 sub-categories as shown in Figure 7.

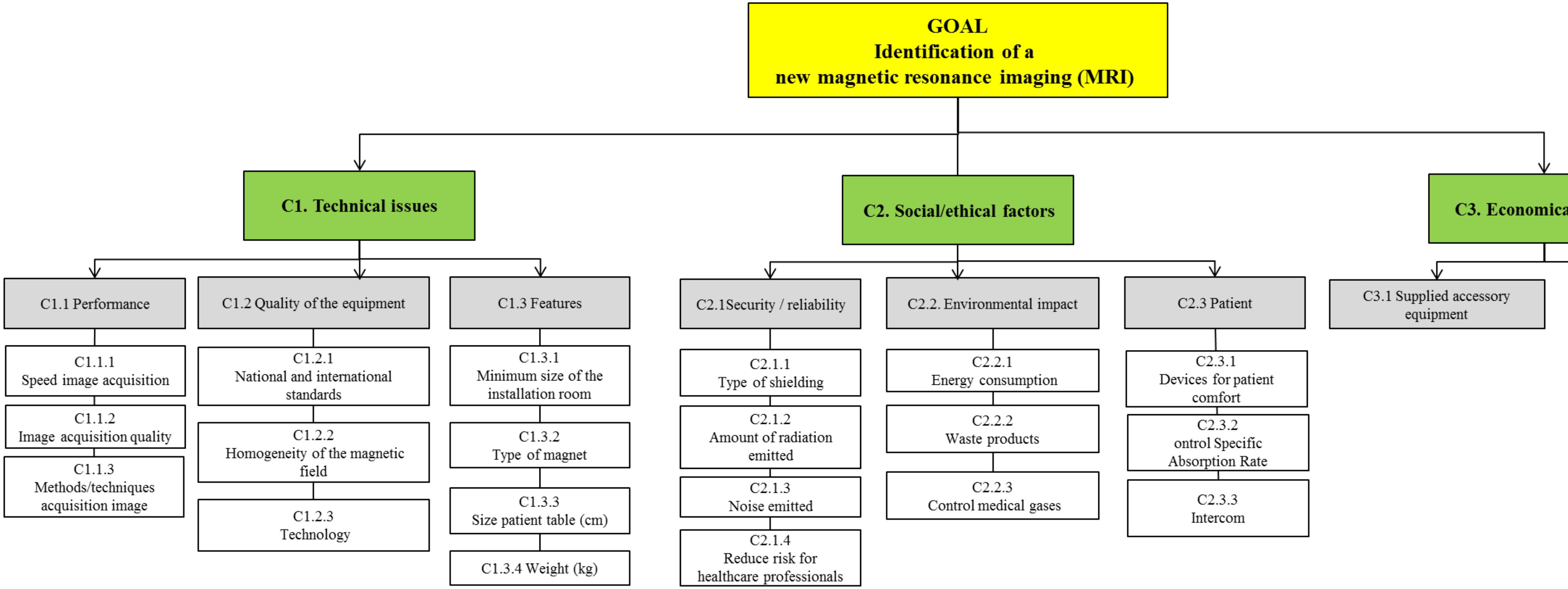

Figure 7: AHP Hierarchy

Starting from this hierarchy, questionnaires were designed and piloted with the same specialized medical doctors via the web (sent via email and discussed in videoconferences). The final version of the questionnaires was emended. The layout of one of the sessions of the questionnaire is illustrated in Figure 3.
User needs were prioritized using the AHP method with pencil and paper tools. The AHP algorithm was executed in Excel and using Matlab compiled libraries to estimate the eigenvalues and eigenvectors. Recruited from Hospitals of Rome, 8 specialized medical doctors participated in the *first elicitation study*. The participants had a range of lengths of experience and a variety of specialisms. The results from these 8 users used to elicit the user needs impacting on the design a a new magnetic resonance imaging (MRI), to show the value of the AHP method and were presented in the result session of this paper.
The model was validated by implementing the same hierarchy and questionnaires with the App and enrolling: *four experts* of AHP that did not participate to the design and development of the App and *four specialized medical doctors* from the three Hospitals of Rome. The former 4 AHP experts validated the easiness of use of the App during the hierarchy and questionnaires design and piloting. The latter 4 users, the specialized medical doctors, were asked to answer both the paper-version and App version of the questionnaires. To avoid biases 2 answered first the paper-version and 2 first the App. The specialized medical doctors were asked to use the App alone, supported by 1 of the experts of AHP and then in group to achieve consensus and to further identify strength and weakness of the App. At this regard, the following parameters were adopted to assess the App versus the paper version: weight precision; time to answer the final questionnaire; number of errors; % of inconsistences, number of questionnaire sessions repeated.
Finally, a piloting of the hierarchy and the questionnaires was simulated in order to verify the effectiveness for the App during the revision of the hierarchy/questionnaires and not only during the final survey. At this purpose, the 4 AHP experts were observed during the use of the pencil-paper and during the use of the App and the following parameters was measured: number of typos in questionnaires, time to prepare questionnaires, time to correct the hierarchy.

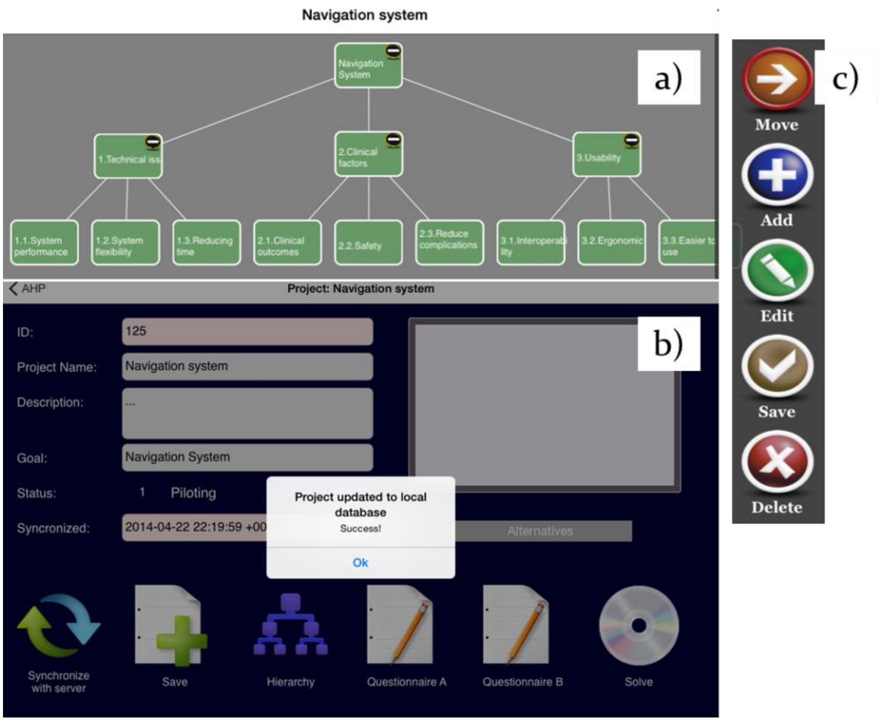

Fig 6: iPAD AHP App for user elicitation in healthcare: a) hierarchy design/visualization; b) main interface; c) GUI tools for hierarchy design

4. Results and discussion

The results of the elicitation study conducted with the specialized medical doctors are reported in Table 1.

Table 1: Relative importance of categories and sub-categories of needs according to surgeons]

	local weights (%)		global weights (%)		
	seeds	sub-cat.	cat.	sub-cat	needs
C1 Technical issues			42.0		
C1.1. Performance	39			13.8	
C1.1.1 Speed image acquisition		15			7.7
C1.1.2 Image acquisition quality		53			9.3
C1.1.3 Methods/techniques acquisition image		32			10.4
C1.2 Quality of the equipment	35			11.4	
C1.2.1 National and international standards		20			3.2
C1.2.2 Homogeneity of the magnetic field		29			4.1
C1.2.3 Technology		51			4.8
C1.3 Features	26			9.8	
C1.3.1 Minimum size of the installation room		21			2.1
C1.3.2 Type of magnet		35			3.8
C1.3.3 Size patient table (cm)		24			1.8
C1.3.4 Weight (kg)		20			
C2 Social/ethical factors			36.0		
C2.1Security / reliability	45			18.5	
C2.1.1 Type of shielding		29			3.9
C2.1.2 Amount of radiation emitted		36			8.9
C2.1.3 Noise emitted		10			2.2
C2.1.4 Reduce risk for healthcare professionals		25			6.5
C2.2. Environmental impact	37			14.2	
C2.2.1 Energy consumption		30			3.2
C2.2.2 Waste products		36			2.9
C2.2.3 Control medical gases		34			3.1
C2.3 Patient	18			11.3	
C2.3.1 Devices for patient comfort		33			2.8
C2.3.2 Control Specific Absorption Rate		42			3.7
C2.3.3 Intercom		25			2.1
C3 Economical factors			22.0		
C3.1 Supplied accessory equipment	45			8.7	
C3.2 Service management	55			12.3	
C3.2.1 Maintenance		46			7.6
C3.2.2 Customer service		29			3.3
C3.2.3 Degree of obsolescence		25			2.6

The last column of Table 1, gives the global importance of each sub-category, allowing the direct comparison of need that were originally too different to be directly compared among them. Reading the table form the left column (needs global importance), it was clear that, according to the specialized medical doctors interviewed, the most important need is C1.1.3 Methods/techniques acquisition image with a global importance of 10.4%. Other important needs are C1.1.2 Image

acquisition quality (9.3%) followed by C2.1.2 Amount of radiation emitted (8.9%) and by C1.1.1 Speed image acquisition (7.7%).
Discussing this result with responders it emerged that the some of those factors were considered less important because the specialized medical doctors consider "Performance" a priority to further increase the quality of the diagnosis.
The following four factors were considered rather important: C3.2.1 Maintenance (7.6%); C2.1.4 Reduce risk for healthcare professionals (6.5%); C1.2.2 Homogeneity of the magnetic field (4.1%) and C1.2.3 Technology (4.8%).
Regarding the categories, the priority for the specialized medical doctors was C1 Technical issues (42% of importance). Among the sub-categories of technical issues, the most important was considered C1.1.2 Image acquisition quality (53%).
The result of the testing of the App in solving the AHP problem (4 responders) and in the simulated piloting (4 AHP experts) are reported in Table 2.

Table 2: App versus paper-pencil AHP problem solving and piloting

	Paper			App		
	mean	DS	range	mean	DS	min
Responders (AHP solving)						
Time to answer (min)	40.50	4.20	35-45	17.50	2.38	15-20
Errors	1.00	1.15	0-2	0	0	0
% of inconsistence	2.75	1.26	1-4	0	0	0
Repeated questionnaire sessions	3.25	0.50	3-4	1.25	0.50	1-2
AHP experts (piloting simulation)						
Time to prepare the questionnaires (min)	105.00	21.21	90-120	0	0	0
Time to correct the hierarchy after discussing with responders (min)	17.50	3.54	15-20	0	0	0
Time to modify the questionnaires after discussing with responders (min)	27.50	10.61	20-35	0	0	0

Regarding the testing of the App, the results presented in Table 2 demonstrated that the use of the App was paramount important for the elicitor as it dramatically reduced the time to prepare and revise the questionnaires, which are automatically generated by the App, and to revise the hierarchy. Particularly, the App allowed to modify the hierarchy, using the graphical touch interface of the tablet, and to generate in real time the questionnaires while discussing hierarchy modification with the domain experts. This required a time when using the paper version, that the elicitor had to spend after discussing modification with domain experts. Often these modification generated new requests of changes that, using the App, were experimented and discussed in real time, while in the past this piloting required a second (and sometime a third) meeting between the elicitor and the domain expert to be experimented and discussed.
Also the AHP questionnaire responding benefited from the App, confirming results from previous studies describing electronic questionnaires, particularly for the reduction of the time execution and the reduction of errors and inconsistences, At this regard a check of consistency was inserted in the App and a warning is given to responders in case the CR in one of the questionnaires' session was above the threshold of 0.1. The majority of errors in the paper version were due to distractions and to the absence of controls in the answering on paper.

Some limits were reported from the App testers. The AHP experts reported that the change of states in the App was not easy to understand. The fact that once moved in active mode the hierarchy and the questionnaire were not anymore editable was found quite difficult. However, this rigid design was mainly conceived for shared decision making and was necessary for scenarios in which the elicitor the domain expert and the final responders are not in the same place. A future relies of the App specifically conceived for stand-alone elicitations is under design.

5. Conclusions

This paper presented a software system for the application of the AHP method to the user need elicitation, facilitating quantitative assessment of user needs that may affect the design or the adoption of an innovative health technology. A case study is presented to test the App that is the main component of the software system to support the elicitor in performing the user elicitation study and the responders, whether domain experts or final users, to express their preferences.

As far as author knowledge, this is the first tool specifically designed to apply the AHP to the user need elicitation in healthcare. The main benefit of using the App is for the elicitor, which could also be not particularly skilled in the use of the AHP method. The App allowed to dramatically reducing the time to pilot the hierarchy of needs and the elicitation questionnaires reducing the time to zero. A part from the direct benefit of this time reduction, the elicitor may modify the hierarchy and the questionnaires in real-time, while discussing changes with domain experts and verify the impact of the proposed changes.

Regarding the AHP method to elicit user needs, the result presented in this paper confirmed its effectiveness. The main benefit of this method is in the quantification of user needs that are generally based on personal expertise and therefore subjective and quantitative. The prioritization of the needs and of needs' categories and sub-categories represent a paramount starting point to discuss innovation in healthcare with designers using a consistent framework of priorities in a language (number), definitively more familiar to biomedical engineers than other typology of reports on user needs. The level of detail achieved by this hierarchical method is much more effective that those achieved with other methods to prioritize user preferences. Confirming previous findings, the AHP method resulted to be flexible and robust, especially when the assessment involved many attributes.

The main limit of this study was that the users of the App found difficult the mechanism to change the states. This should be improved in a future version of the App specifically conceived for assessment performed while meeting the final responders.

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