Multi-criteria Decision Model for Assessing Health Service Information Technology Network Support Using the Analytic Hierarchy Process

Modelo de Decisiones Multi-criterio para Evaluar el Soporte de la Tecnología de Información en un Servicio de Salud Utilizando el Proceso Analítico Jerárquico

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Abstract
This paper presents a multi-criteria decision making (MCDM) model for evaluating an Information and Communication Technology (ICT) network system in health care .The competing goals existing in Health Institutions need a special treatment, thus the MCDM approach is essential for identifying ICT network quality of service (QoS) requirements and implications. A pilot study based on user perception is explored involving three categories of hospitals in Chile. Data is collected considering various health sector representatives. The main contribution is the proposed decision methodology to develop criteria for evaluating QoS issues of an ICT network system within a healthcare environment using the Analytical Hierarchy Process (AHP). The results provides a framework to make decisions concerning an information technology networked system, characterizing end users and their needs and enabling tradeoffs in agreement with the institution objectives.
Keywords: AHP, Health service decision support, ICT, MCDM

Resumen
Esta publicación presenta un modelo multicriterio de toma de decisiones (MCDM) para evaluar un sistema de información y tecnología de comunicación (TIC) en un servicio de salud. Los objetivos, conflictivos entre si, existentes en instituciones de salud, necesitan un trato especial. El enfoque de MCDM es esencial para identificar requisitos y trascendencia de la calidad de servicio (QoS) en un sistema de TIC. Un estudio empírico basado en la opinión del usuario involucrando tres categorías de hospitales en Chile se lleva a cabo, considerando datos de varios representantes del sector de la salud. La contribución principal es la metodología propuesta para desarrollar criterios para valorar aplicaciones de QoS en una red de TIC de un servicio de salud a través del Proceso de Jerárquico Analítico (PJA). Los resultados proporcionan un marco para tomar decisiones referentes a un sistema de tecnología de la información, caracterizando usuarios, sus necesidades y permitiendo compensaciones de común acuerdo con los objetivos de la institución.
Palabras Claves: AHP**,** PJA, Decisiones multicriterio, TIC en servicio de salud.

1 Introduction

Nowadays, the health sector is adopting new information technologies and there is confidence that modern Information and Communication Technology offer a means to improve their performance. ICT appears as an emerging concept in health care accomplishing an essential role for health-related activities (Bourret, 2004). Many actions oriented to improve the operation and the quality of health service depends, to a great extent, on the level of information available and the communications system.(Huang Wayne et al., 2008).

There is growing scientific evidence that Health-related activities stand to benefit enormously from the Internet and an increasing use of modern ICT can bestow many advantages to improve the quality of a service. US Institute

of Medicine Decision makers states that computing is "an essential technology for healthcare", (Dick et al., 1991). However, Bailey and Pang (2004) point out the need for more research in the developing world to better understand users' information needs in providing a health related service.

From the clinic care representatives' perspective, an ICT system can improve the efficiency of care service. The Internet, enables professionals to obtain information on their patients including those elaborated by other, such as, complementary tests results, at the instant and at the place of attendance. ICT systems can also provide mechanisms of management of information that reduce paper work and support administrative transactions, public health supervision, professional education, and medical research as mentioned by the National research council, (2000).

However, the provision of these applications depends on the communications network infrastructure, the devices and communications links and its performance. Then, the challenge of providing QoS in a health environment is rather complex since QoS needs of individual health organizations vary over time. A poor implementation may generate a negative effect on patients and health care providers. Some authors, (Ammenwertha, et al., 2003) have drawn attention to the importance on relying on evaluation mechanisms for decision makers and users.

This paper presents a MCD model for evaluating a health service ICT network system. By the application of the Analytic Hierarchy Process (Saaty, 2001), it is possible to originate a framework to assist decision makers taking into consideration quantitative and qualitative factors. The AHP has been proposed in literature as an emerging approach to diverse , large, dynamic and complex real world multi-criteria decision making problems. (Alexander et al., 1990; et al., Chang-Kyo et al., 1994; Oddershede et al., 2005; Oddershede and Carrasco, 2006; Oddershede and Arias, 2007)

The purpose of this study is to develop a prototype decision model based on data collected from the main users of the health network system. What are in question are the implied needs of the different types of users, which must be worked out through user profiling and requirements analysis techniques. So far, it has not been possible to do very much work on defining appropriate techniques for characterizing users and their needs, but their importance has become increasingly obvious. In this context, the multi-criteria decision making (MCDM) approach is suitable for identifying priority activities and recognizing the essential ICT network support resources that lead to the improvement of the service. The process will permit to identify the main ICT network system applications and attributes for each kind of health related activity and to compare its relative importance level.

Hence, a pilot study have been carried out using data from three type of health institutions in Chile to examine priority criteria from end users perspective regarding the hospital ICT network system . Section 2 describes the system in study. Section 3 presents a simplified hierarchical decision model for health related activities and the evaluation method to reflect the relative importance of quality of service needs. The priority results and its discussion are presented in section 4. In section 5 the conclusions are provided.

2 System description

The study refers to the development of a decision model in relation to the assessment of network systems in health related activities. Different participants (patients, doctors, nurses, paramedics, health staff, managers and researchers) can be distinguished when a health service requirement takes place. Each participant has diverse expectations about the ICT network system and will desire certain characteristics to endow an ICT system. .To pursue each of the participant's activities, they have to deal with individual objectives that are in conflict among them. This fact involves that some of the attained objectives profit is only obtained in deterioration of another one.

The communications network infrastructure and its performance are crucial for delivering a service in a hospital. Health applications demand guarantees on the quality of service they can get across the network and Internet and several technical factors need to be considered in evaluating the performance.

For the evaluation process many questions arise. Which information and communications technology should be selected and implemented? What is the usability of the information technology? What are the implications of an information technology system on the quality of care? What are the technical attributes of the information

technology system that have an effect on its use? Is there any effect with regard to different users? (Patients, physicians, nurses, researchers, and administrative staff) Who are the main end users?

In previous work we have identified the main end users of health related activities (Oddershede and Carrasco, 2006). For this study the end users were classified into three groups: Clinic care representatives, a group constituted by the clinic care staff (Physician, nurses, paramedics); the medical Research professionals group conformed by those users who investigate new drugs, collect disease statistic and others and the group constitute by people performing administrative functions denoted Administrative group. The system under study considered data from three types of institutions: private, public and semi-private.

A team of experts was constituted including participants of each group and type of hospitals who expressed their judgments corresponding to their own expertise and knowledge. These judgments are incorporated and taken into consideration to state criteria and develop an initial basic model. The relative importance of the ICT network attributes and applications are recognize proceeding with a pair-wise comparison process.

3 The Assessment: Analytic Hierarchy Process

The AHP is a decision making technique for managing problems involving multiple criteria and multiple conflicting objectives (Saaty, 2001). The AHP engages decision-makers in breaking down a decision into smaller parts, proceeding from the goal to criteria to sub-criteria down to the alternative courses of action. Decision-makers then make simple pair-wise comparison judgments throughout the hierarchy to arrive at overall priorities for the alternatives. This approach provides the structure and the mathematics for helping decision-makers make rational decisions. A rational decision is one that best achieves the multitude of objectives of the decision maker(s). The three basic principles of AHP are: Hierarchy Representation and Decomposition, Priority Discrimination and Synthesis and Logical Consistency. (Saaty, 1990)

The first step in the AHP is to decompose the problem into a dominance hierarchy.

The top-most level represents the goal of the problem. Intermediate levels are the criteria or sub objectives, on which lower levels depend, and the lowest level is the list of alternatives. As many levels as necessary can be used. The lower levels act as the criteria or factors contributing to the level immediately above.

Figure 1 shows an illustration of a simple three level hierarchy.

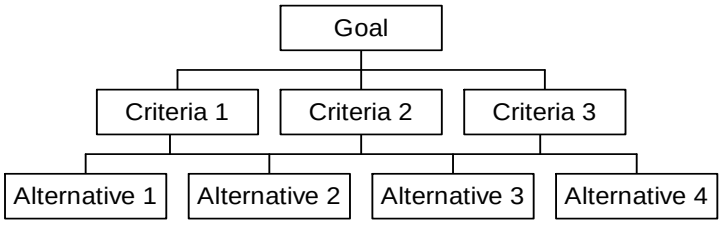

Fig. 1. Generic Decomposition of a Problem into a Hierarchy

The rationale of a hierarchy is to assess the impact of the elements of a higher level on those of a lower level or alternatively the contribution of elements in the lower level to the importance or fulfillment of the elements in the level above. This type of assessment is usually made by paired comparisons responding to an appropriately posed question eliciting the judgment. The mathematical definition of a hierarchy is given in Saaty's Book. (1990).

The assessment procedure consists of a pair wise comparison through the hierarchical structure to derive a priority matrix for each level of the structure. The final step involves applying the weights to the measured factors to derive a ranking on the critical attributes to support each application.

The AHP provides a ranking scale to assess the importance of each technical dimension to each class of applications. These dimensions are ranked from the fundamental 1-9 scale presented by Saaty (2001) to represent the ratio. Setting priorities in a hierarchy requires that we perform measurements throughout the structure. We must then

synthesize these measurements to obtain priorities for the bottom level alternatives. The AHP is based on ranking activities in terms of relative ratio scales. In the paired comparison approach of the AHP, one estimates ratios by using a fundamental scale of absolute numbers in comparing two alternatives with respect to an attribute and one uses the smaller value as the unit for that attribute. To estimate the larger one as a multiple of that unit, assign to it an absolute number from a fundamental scale. This process is done for every pair. Thus, instead of assigning two numbers w_i and w_j and forming the ratio w_i / w_j we assign a single number drawn from the fundamental 1-9 scale to represent the ratio $(w_i / w_j) : 1$. The absolute number from the scale is an approximation to the ratio w_i / w_j. The derived scale tells us what the w_i and w_j are. Let W be a matrix (1) whose row elements are ratios of the measurements w_i of each of n items with respect to all others.

$$W = \begin{bmatrix} w_1/w_1 & \ldots & \ldots & w_1/w_n \\ w_2/w_1 & & & w_2/w_n \\ \ldots & & & \ldots \\ w_n/w_1 & \ldots & \ldots & w_n/w_n \end{bmatrix} \quad (1)$$

A number in the matrix is a dominance judgment. A judgment of 1.0 means that two activities contribute equally to the objective or goal, a judgment of 3.0 means that slightly favor one activity over another or three times as much (if you are dealing with measurable), a judgment of 5.0 means that judgment strongly favor one activity over another, a judgment of 7 means that activity is strongly favored over another; its dominance is demonstrated in practice and 9.0 means that the evidence favoring one activity over another is of the highest possible order of affirmation. You should group your elements into homogeneous clusters so that it is not necessary to use a number larger than 9. In this way, we can interpret all ratios as absolute numbers or dominance units.

The AHP provides guidelines for a test of consistency of judgments to ensure that elements are grouped logically and ranked consistently according to a logical criterion. In general, the ratio should be in the neighborhood of 0.10 according to methodology described by Saaty. (1990). Too great a departure from the perfectly consistent value indicates a need to improve the judgments or to restructure the hierarchy.

3.1 Structuring

The first phase of the study consists of identifying the critical end users' activities, main health related ICT applications and technical aspects within a health institution. As a result, a great number of factors came up.

The next phase consisted of constructing a hierarchical structure incorporating decisive categories at each level and their relationships. Once the basic structure was stated, the effort was oriented to create a Team of Experts for all the three types of hospitals in consideration. The interdisciplinary Team included thirty people related to each of the Hospitals adding up to 360 participants.

3.2 The Hierarchical Structure

Provided that the main goal is to present a decision model to support the assessment of health networked system, the attributes for network performance and end users' priorities are considered as well. Consequently, a basic three level hierarchical structure model is designed taking into account considerations from network component performance, ISO quality software quality model and end users preferences.

A preliminary questionnaire was designed and carried out with the purpose of collecting information from each group representatives about the main applications they perform during their contractual obligation.

The first two levels refer to the essential ICT applications to satisfy a health service requirement, from the perspective of each end user. The third level and its nodes represent the decision factors that contribute to attain the goal. For this situation, the attributes considered were derived from standard ISO software quality model) (ISO/ IEC, 1997).

The standard provides a framework for organizations to define a quality model for a software product. On doing so, however, it leaves up to each organization the task of specifying precisely its own model. This may be done, for example, by specifying target values for quality metrics which evaluates the degree of presence of quality attributes.

At this point, many uncertainties about attaining desired attributes for the network were found. Are the required functions available? How efficient, reliable, serviceable and available is the network?

The initial basic hierarchical structure is shown in Figure 2, which is a realistic simplification of a larger hierarchy developed.

The hierarchical structure levels , represent as indicated below.

- Level 0: This level indicates the goal. In this case we denote the main objective as: "Health Networked System Assessment".
- Level 1: Includes the main actors/agents/participants that would contribute to achieve the goal expressed in level 0. In this case we have considered three clusters grouping the end users implicated in the study.
- Level 2: Includes the ICT network applications for each type of end users which would contribute to accomplish their own health care activity. For this study we have considered for all the users the applications: Data base, Email, Ftp, Web browsing and Video Conference.
- Level 3: Includes the alternative attributes that would mostly contribute that each end user may achieve their correspondent health related activity when using ICT network application.

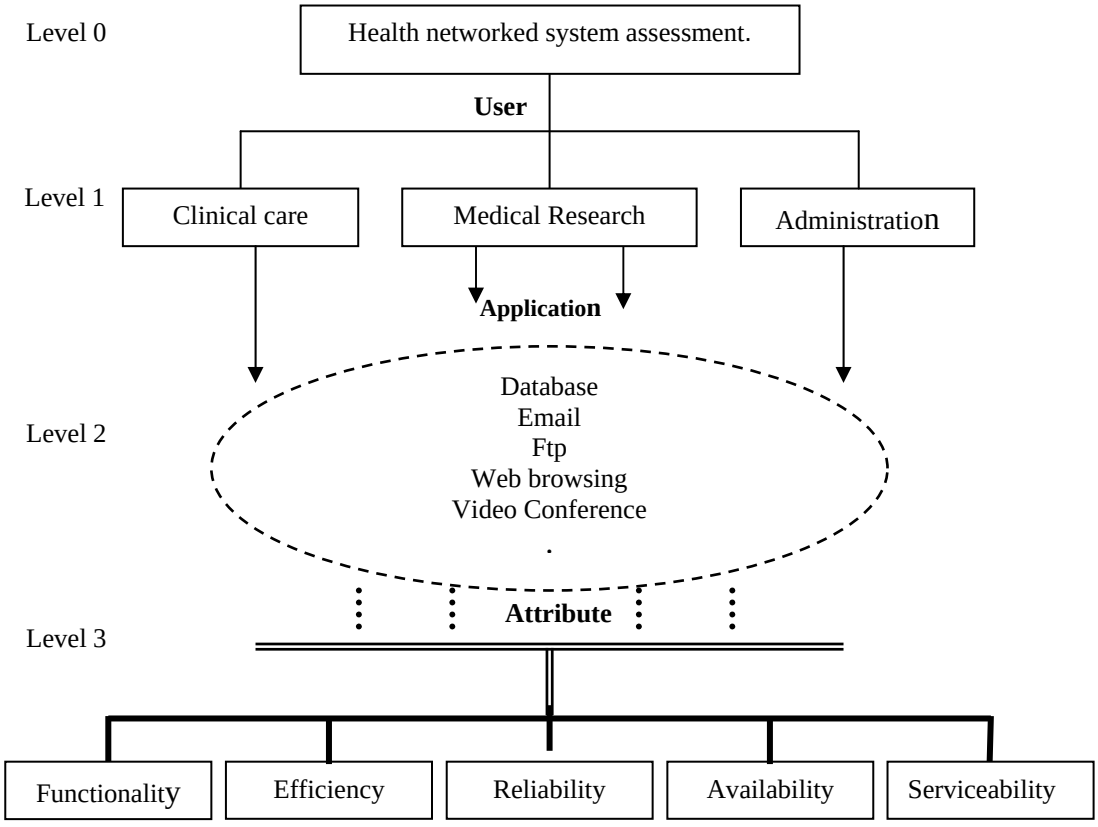

Fig. 2. Hierarchic Structure

Initially a set of five attributes were considered, as:

- Functionality - A set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs. Suitability, Accuracy, Interoperability, Compliance, Security.
- Reliability- A set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time. Maturity, Recoverability, Fault Tolerance.
- Availability refers to the continuous availability of the network, the individual links of which it is composed, and the services it offers
- Efficiency refers to a set of attributes that bear on the relationship between the level of performance of the network and the amount of resources used, understated conditions. .Time Behaviour, Resource Behavior
- Serviceability is also known as supportability, and is one of the aspects. It refers to the ability of technical support personnel to debug or perform root cause analysis in pursuit of solving a problem with a product.

3.3 Priority Process

With the described basic hierarchic structure, a pair-wise comparison was made, in such a way that all the elements at the same level are compared and weighed with each other. This procedure is repeated for all the elements of the whole structure, obtaining a ranking, reflecting the relative importance of the applications and attribute requirement. In addition, it was possible to detect inconsistencies when experts emitted judgments. Under such situations, it was necessary to review them until obtaining an acceptable index.

4 Priority Results Analysis

The priority results indicated that ICT network provision is most important for the clinic care group representatives (62.5 %) compared to the other groups.

Through figure 3, it is possible to appreciate the overall prioritization results for end users'.

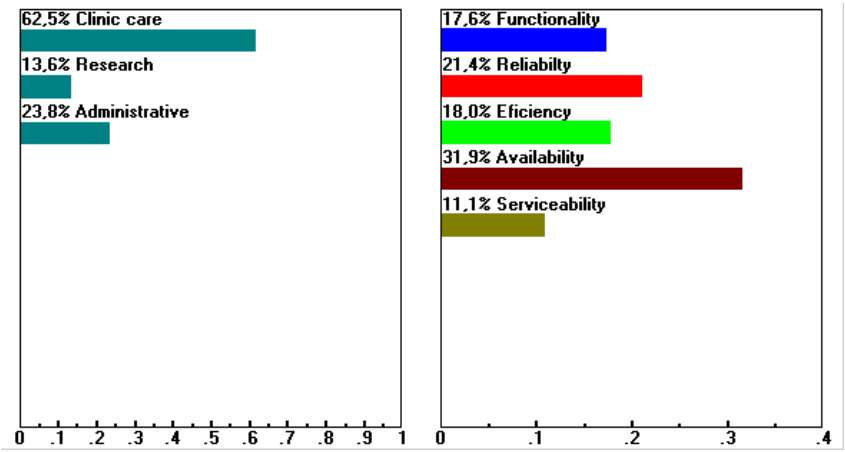

Fig. 3. Users Overall Priority and Dynamic Sensitivity for Overall Priority result

Globally, the greatest impact of ICT network system provision is on supplying clinic care service. This service is concerned with the activities developed by the physician, nurses, and paramedics. Regarding, the ICT network attributes it can be seen that the overall result indicated that "availability" attribute is the most desired attribute with a 31.9 % of relative importance. Then, the "reliability" attribute with 21.4%. This outcome reflects the relative level of importance the three groups estimate.

Subsequently, the expert panel considered "efficiency" and "functionality" attributes to have a very similar degree of importance.

Through the process it is possible to make a comparison between the attributes for each of the end users group. When comparing the importance of a pair of attributes taking into account all the groups of participants the importance rank they give to the attributes vary. Figure 4 shows a comparison of the "functionality" vs. the "availability" attribute for each type of user.

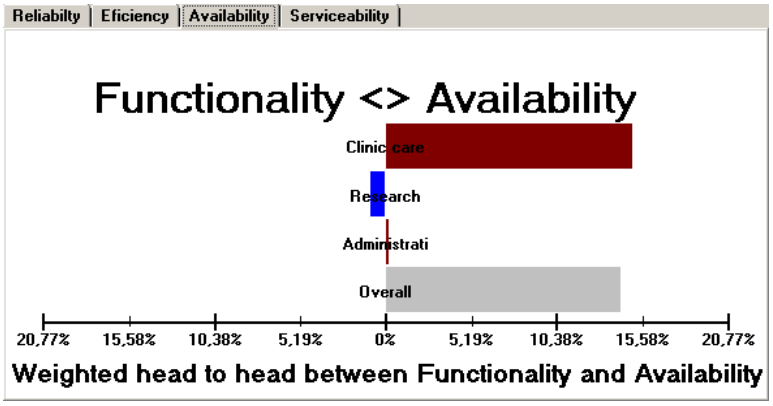

Fig. 4. The importance of Functionality attribute vs. Availability attribute for each type of user

The results indicated that the "availability" attribute is more important for the Clinic care group while the Research and Administrative group gave more importance to the Functionality attribute. This result would be in concordance with the professional demand, who wants relevant and rapid information for better decisions.

It is of interest to be aware of the different degree of importance each group give to each attribute in agreement to the activity they perform. This result could be applied by decision makers when deciding resource distribution. Another important aspects is related to the ICT network system applications for health care activities, the ranking of relative importance for the applications vary conditional on the end user group.

Figure 5 and figure 6 show differences of the relative importance and/or priority for the applications for Clinic care and Research groups.

From Clinic care group perspective the greatest importance is for data base incorporated at the hospital (52.6 %). A strong interaction with database applications, to have access to patient records, clinic history, laboratory tests and others, is strongly desired by this group.

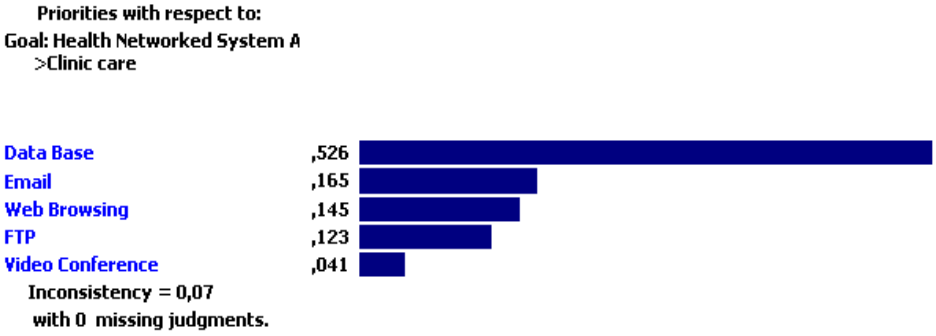

Fig. 5. Priorities for Clinic care group applications

The use of great data base to collect health social and economic data indicates that files concerning the health of millions of people can be useful to predict future health requirements in a given population. (Huang et al., 2008).

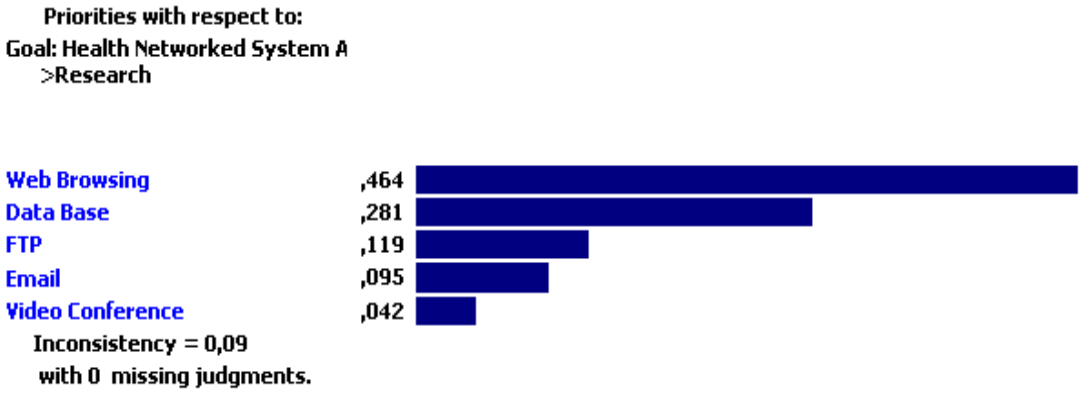

Fig. 6. Priorities for Research group applications

The research group showed a strong interaction with Web browsing application (46.4%) followed by data base application. This result would be in agreement to the nature of their work.

Relative Importance

Table 1. Relative Importance for applications and attributes

User Type	Application	Local %	Global %	Attributes		Overall Attributes %
Clinic Care 62,5 **%**	**Database**	**52.6**	**32.9**	**Availability**	**39.3**	Availability 31.9
	Web browsing	14.5	9.1	Reliability	21.3	
	E mail	16.5	10.5	Efficiency	15.5	Reliability 21.4
	Ftp	12.3	7.7	Functionality	15.3	
	Video Conference	14.5	9.1	Serviceability	8.6	Efficiency 18.0
Medical Research 13.6%	**Web browsing**	**46.4**	6.3	**Functionality**	**27.3**	
	Database	28.1	3.8	Availability	20.2	Functionality 17.6
	Ftp	11.9	1.6	Efficiency	19.0	
	E mail	9.5	1.3	Reliability	18.6	Serviceability 11.1
	Video Conference	4.2	0.6	Serviceability	14.9	
Administrative 23.8**%**	**Database**	**60.2**	14.4	**Efficiency**	**24.1**	
	E mail	17.3	4.1	Reliability	23.3	
	Ftp	12.2	2.9	Availability	19.1	
	Web browsing	10.3	2.5	Functionality	18.0	
	Video Conference	0.0	0.0	Serviceability	15.5	

From the Administrative group perspective, the first three preferences are for data base, email and file transfer protocol. This group develops activities such as, delivering and obtaining test and exams results, within the institution, would imply interaction with database application.

A summary of the applications relative importance is depicted in table 1 according to the end users perspective.

5 Conclusions

This paper has presented a practical assessment of an ICT network system for health care related services through the scientific MCDM method, the Analytic Hierarchical Process, offering a decision making process based on end user's perceptions.

Given the existence of competing goals within a clinical environment, the model development using the AHP was advantageous, for obtaining an insight into the high-priority requirements for an ICT network system.

Through the process the relative importance of quality service requirements are revealed. It permitted the different group representatives to be aware of the ICT network support.

The resultant prioritization indicates that efforts should be aimed at improving the QoS of the ICT system in keeping easy access to the network, ubiquity, continuity, and security.

It is indispensable to count on better information about the needs, expectations of the users and the services operations, to integrate the economic, welfare, and clinical information.

The results of this pilot study may be considered as a starting point for analyzing the performance issues in ICT Health Service Network.

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