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An integrated approach of AHP - DEMATEL methods applied for the selection of allied hospitals in outpatient service

Abstract

Nowadays, the citizens are more aware of high-quality medical care than ever. They pay much attention to medical treatment safety, instructions from physicians, and the overall service quality performed by the hospital. To manage a hospital successfully, the important goals are to attract and then retain as many patients as possible by meeting potential demands of various kinds of the patients. In this context the decision making process is important in order to achieve a strategic decision and strategy. When the decision making problem occurs there is usually a limited number of possible alternatives but a large number of criteria according to which the optimal solution is selected. It is important to use an appropriate approach. This study presents a hybrid methodological approach based on the Decision Making Trial and Evaluation Laboratory (DEMATEL) method and Analytic Hierarchy process method to define the best allied hospital for an integrated network of outpatient service. The goal of this paper is to present a methodological approach and a practical application of hybrid method in a real case study.

Keywords: DEMATEL, AHP, Hospitals, Multiple Criteria Decision Making, Medical Engineering.

1. Introduction

Healthcare sector is an important industry to serve high-quality services and healthcare treatment to citizens in every country in the world (Ismail *et al.*, 2014). Continuous efforts have been carried out in order to improve the hospitals service in the healthcare industry. Physicians and patients today are encountering great pressures from the healthcare setting. In the perspective of physicians, their irritation is originating from heavy patient loads, administrative tasks, and losing patient care decision control (Lee et al., 2012). While patients are complaining during the medical interaction, more consideration should be provided to them (Kassirer, 2000).

In this context many countries produce strategic policies for their large scale health systems which are aimed at providing benefits to their citizens (Omachonu and Einspruch, 2007).

To manage a hospital successfully, the important goals are to attract and then retain as many patients as possible by meeting potential demands of various kinds of the patients.

In order to meet potential demands of the various kinds of the patients, each medical organization focuses on not only purchasing advanced medical equipment but also developing and implementing services quality.

However many important strategic decisions are made on the basis of self-evidence, intuition and not always fully comprehend relationships among evaluated factors. Decision making is important and no less difficult part of a strategic business. When the decision making problem occurs there is usually a limited number of possible alternatives but a large number of criteria according to which the optimal solution is selected (Franek and Kashi, 2014).

Over the past two decades, numerous studies have been made on multiple criteria decision making (MCDM) analysis in various fields. Traditionally, most importance-assessing methods used to demonstrate the importance among criteria (Yang and Tzeng, 2011).

It is important to use decision making methods or model that make possible to increase the success probability of a project (Yang and Hsieh, 2009). That is why methods like Analytic Hierarchy Process (AHP) (Saaty, 1980), Analytic Network Process (ANP) (Saaty, 1996), Goal Programming (Charnes, 1955), Delphi (Dalkey and Helmer, 1963), Decision Making Trial and Evaluation Laboratory (DEMATEL) (Gabus and Fontela, 1972), and Fuzzy Logic (Zadeh, 1965) have been widely used for this purpose.

In the present research our aim is to propose an integrated multiple criteria decision making (MCDM) technique that combines the DEMATEL and AHP method.

The Analytic Hierarchy Process is a technique that allows to modelling decision making processes through problem decomposition under a hierarchical structure composed by goals, criteria, sub-criteria and alternatives, in which a set of participants evaluates each of these components by pairwise comparisons (Saaty, 1978).

On the other hand, DEMATEL has been widely used to extract a problem structure of a complex problem (Fontela and Gabus, 1974). By using DEMATEL it is possible to quantitatively extract interrelationship among multiple factors contained in the problem. Thus, not only the direct influences but also the indirect influences among multiple factors are taken into account. Furthermore, it is possible to find the dispatching factors that will rather affect the other factors, the receiving factors that will be rather affected by the other factors, the central factors that the intensity of sum of dispatching and receiving influences is big, and so forth. Definitely, DEMATEL is an extended method for building and analysing a structural model for analysing the influence relation among complex criteria.

For the above reasons DEMATEL technique has been applied in many situations, ranging from manufacturing planning and control to multi criteria decision making and analyzing world challenging such as administration control systems (Hori and Shimizu, 1999), marketing strategy and customer performance (Chiu *et al.*, 2006), safety and security measurement (Liou et al., 2007), fuzzy approach and expert systems (Wu and Lee, 2007; Lin and Wu, 2008), modernization strategy set for Taiwan’s SIP Mall (Huang *et al.*, 2007); selection management systems of SMEs (Tsai &Chou, 2009). Success factors of hospital service quality (Shieh *et al.*, 2010) and industry material selection process (Shih-Chi *et al.*, 2011).

Furthermore DEMATEL has been incorporated into other methods such as Analytic Hierarchy process (AHP), Analytical Network Process (ANP), Multiple Criteria Decision Making (MCDM), fuzzy set theory, etc., to vitalize these traditional methods and explore new applications for the hybrid methods.

Our decision to integrate DEMATEL approach with AHP method is because one of the weaknesses of AHP is in the fact that does not allow to evaluating interrelations and influences between the elements that compose the decision making process. Hence, Saaty developed a general structure called Analytic Network Process (ANP) (Saaty, 2014; Saaty and Vargas, 2013). This method is a generalization of AHP and is currently used in decision making processes in which it is known that decision alternatives and criteria may have very strong interrelations and influences generating a high impact on the decision (Jharkharia and Shankar, 2007; Raisinghani *et al.*, 2007)

Even though ANP permits to evaluate the influence and interdependence, in some cases, this not understandable by decision makers; hence that DEMATEL starts plying a relevant role since it permits to have a better comprehension of the influences by the analysis of elements in cause and effect relationships (Falatoonitoosi *et al.* 2004; Li and Tzeng, 2009). DEMATEL is based on graphs theory, reason by which decision makers can have a better understanding of casual relationships that are characterized by being complex and, in some cases, imperceptible.

This paper supports adequately the decision making process with the help of DEMATEL and Analytic Hierarchical Process.

The paper is organized as follows. The section 2 highlights the general features of AHP and DEMATEL methods and reveals their strengths and weaknesses. Section 3 analyses the procedures of the proposed methodological approach. Section 4 presents a case study through an illustrative example. Finally in section 5 results and discussions are analysed.

2. Integrated methods combined DEMATEL and AHP

In this section, an integrated method, combined DEMATEL method, and a novel cluster-weighted AHP method is developed. The procedures that are used in the proposed method are described as follows.

2.1 The Analytic Hierarchy Process (AHP) method

The Analytic Hierarchy Process (AHP) breaks down a decision-making problem into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationships between levels (De Felice and Petrillo, 2014). The AHP for decision making uses objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision. With the AHP, one constructs hierarchies or feedback networks, then makes judgments or performs measurements on pairs of elements with respect to a controlling element to derive ratio scales that are then synthesized throughout the structure to select the best alternative (De Felice, 2012).

The top level of the hierarchy is the main goal of the decision problem. The lower levels are the tangible and/or intangible criteria and sub-criteria that contribute to the goal. The bottom level is formed by the alternatives to evaluate in terms of the criteria. The modeling process can be divided into different phases for the ease of understanding which are described as follows:

PHASE 1: *Pairwise comparison and relative weight estimation.* Pairwise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion. Saaty suggested a scale of 1-9 when comparing two components (see Table 10). For example, number 9 represents extreme importance over another element. And number 8 represents it is between ‘‘*very strong important*” and ‘‘*extreme importance*” over another element.

Table 1: Semantics scale of Saaty

Intensity of importance a_{ij}	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

For a general AHP application we can consider that $A_1, A_2,\ldots,A_m$ denote the set of elements, while a_{ij} represents a quantified judgment on a pair of A_i, A_j. Through the 9-value scale for pairwise comparisons, this yields an [m x m] matrix A as follows:

$$A = a_{ij} = \begin{array}{c|ccccc|} & A_1 & A_2 & \ldots & A_m \\ A_1 & 1 & a_{12} & \ldots & a_{1m} \\ A_2 & 1/a_{12} & 1 & \ldots & a_{2m} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_m & 1/a_{1m} & 1/a_{2m} & \ldots & 1 \end{array}$$

where $a_{ij} > 0$ (i, j = 1, 2,..,,m), $a_{ii} = 1$ (i = 1, 2,…,m), and $a_{ij} = 1/a_{ji}$ (1; 2;…,m). A is a positive reciprocal matrix.

The result of the comparison is the so-called dominance coefficient a_{ij} that represents the relative importance of the component on row (i) over the component on column (j), i.e., $a_{ij}=w_i/w_j$. The pairwise comparisons can be represented in the form of a matrix. The score of 1 represents equal importance of two components and 9 represents extreme importance of the component i over the component j.

In matrix A, the problem becomes one of assigning to the m elements $A_1, A_2,\ldots,A_m$ a set of numerical weights $w_1, w_2,\ldots,w_m$ that reflects the recorded judgments. If A is a consistency matrix, the relations between weights w_i, w_j and judgments a_{ij} are simply given by $a_{ij} = w_i/w_j$ (for i,j = 1, 2, …, m) and

$$A = \begin{array}{c|cccc|} & w_1/w_1 & w_1/w_2 & & w_1/w_m \\ A_1 & w_2/w_1 & w_2/w_2 & & w_2/w_m \\ A_2 & & & & \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_m & w_m/w_1 & w_m/w_2 & \ldots & w_m/w_m \end{array}$$

If matrix w is a non-zero vector, there is a λ_{max} of $Aw = \lambda_{max}w$, which is the largest eigenvalue of matrix A. If matrix A is perfectly consistent, then $\lambda_{max}w = m$. But given that a_{ij} denotes the subjective judgment of decision-makers, who give comparison and appraisal, with the actual value (w_i/w_j) having a certain degree of variation. Therefore, $Ax = \lambda_{max}w$ cannot be set up. So the judgment matrix of the traditional AHP always needs to be revised for its consistency.

PHASE 2: *Priority vector*. After all pairwise comparison is completed, the priority weight vector (w) is computed as the unique solution of Aw = $\lambda_{max}w$, where λ_{max} is the largest eigenvalue of matrix A.
PHASE 3: *Consistency index estimation*. Saaty (1990) proposed utilizing consistency index (CI) to verify the consistency of the comparison matrix. 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.

2.2 The Decision Making Trial and Evaluation Laboratory (DEMATEL) method
Decision Making Trial and Evaluation Laboratory (DEMATEL) (Fontela and Gabus, 1976), a system analytical method, was proposed by the United States Bastille laboratory in 1971. This integrated method uses some mathematical tools such as matrix theory and graph theory to analyze factors relationship. DEMATEL is an effective method to analyze and evaluate influencing factors. It can synthesize the advice or experience of experts, simplifying the uncertain element of complex systems. This methodology is able to verify interdependence among the unpredictable features or attributes likewise containing reveals the characteristic with an essential system and development trend and try to reflect the interrelationship between variables by improving the directed graph (Gabus and Fontela, 1973).
DEMATEL is characterized there by 6 main steps:

1. **Making the direct-influenced matrix:** This phase consists of measuring the relationship between criteria. This requires a four-level comparison scale: non-existent impact (0), low impact (1), medium impact (2), substantial impact (3) and very substantial impact (4). An expert team makes pairwise comparisons, evaluating the influence and direction between criteria. The results form a n x n matrix called direct-relation matrix B, in which bij represents the degree to which the criterion i affects the criterion j.
2. **Calculating the direct-influenced matrix normalization:** The normalized direct-relation matrix N is obtained from matrix B by formulas (1) and:

$$M = k \cdot A \; (1)$$

$$k = \min\left(\frac{1}{\underset{1\le i\le n}{max}\sum_{j=1}^{n}\left|a_{ij}\right|}, \frac{1}{\underset{1\le j\le n}{max}\sum_{i=1}^{n}\left|a_{ij}\right|}\right) i,j \in \{1,2,3,\dots,n\} (2)$$

3. **Achieving the total-relation matrix:** After the normalization of the direct-relation matrix B, the total-relation matrix S is calculated by using the formula (3), where I represents the Identity Matrix:

$$S = M + M^2 + M^3 + \cdots = \sum_{i=1}^{\infty} M^i = M(I-M)^{-1} (3)$$

4. **Producing a causal diagram:** With the use of D + R and D – R, where R is the sum of columns and also D is the sum of rows in matrix S as shown in formulas (4) – (6). The criteria that have positive values of D – R have higher influence on the other criteria. These are called "dispatchers". The others with negative values of D – R receive more influence from another. These are called "receivers". On the other side, the value of D + R indicates relation degree between each criterion with others.

$$S = \left[s_{ij}\right]_{nxn}, i, j \in \{1,2,3,\ldots,n\} \quad (4)$$

$$D = \sum_{j=1}^{n} s_{ij} \quad (5)$$

$$R = \sum_{i=1}^{n} s_{ij} \quad (6)$$

5. **Obtaining the inner dependence matrix and impact relationship map:** Map the dataset (D + R, D – R). The threshold value is set to indicate the influence level between criteria.

6. **Obtaining the inner dependence matrix:** In this step, the sum of each column in total-relation n×n matrix is equal to 1 by the normalization method and then the inner dependence matrix can be acquired:

The product of the DEMATEL process is a visual representation (i.e., an individual map of the mind) that the respondent uses to organize his or her own actions.

3. Problem definition and formulation

In this study, four possible allied hospitals, named as Hospital 1, Hospital 2, Hospital 3 and Hospital 4, are evaluated to be part of an integrated network of outpatient service. This study was done in a leading hospital in Colombia that provides healthcare services with a main focus on outpatient service. This hospital is having problems in this service due to its patients are being cared with a more extended lead time. Some internal studies of the hospital have demonstrated that this problem is generated because of the growing demand of the service. Currently, in this hospital, the probability that the patient is not seen within the time standards is 15.3% and the lead time of this service continues to increase. It is noticed that this delay results in increased risk of admission to the emergency department, hospitalization or even more complex services (Mandelzweig *et al.*, 2006; Henriksen *et al.*, 2005)

For this case, to calculate the inner dependency between criteria, DEMATEL is used. Taking into account the pairwise comparisons obtained from DEMATEL, the inner dependency is structured and graphed on the model. Besides and according to the total-relation matrix, the impact-diagraph map is obtained. To get the relative influence between criteria, a set of experts in outpatient service were asked to collect their perceptions in a pairwise way. Both results and inner dependencies achieved in this process were placed into the Supermatrix to calculate, with the aid of AHP, the best allied hospital for an integrated network of outpatient service. The supermatrix calculations were solved through Superdecisions software. A framework of the proposed evaluation process is shown in Figure 1.

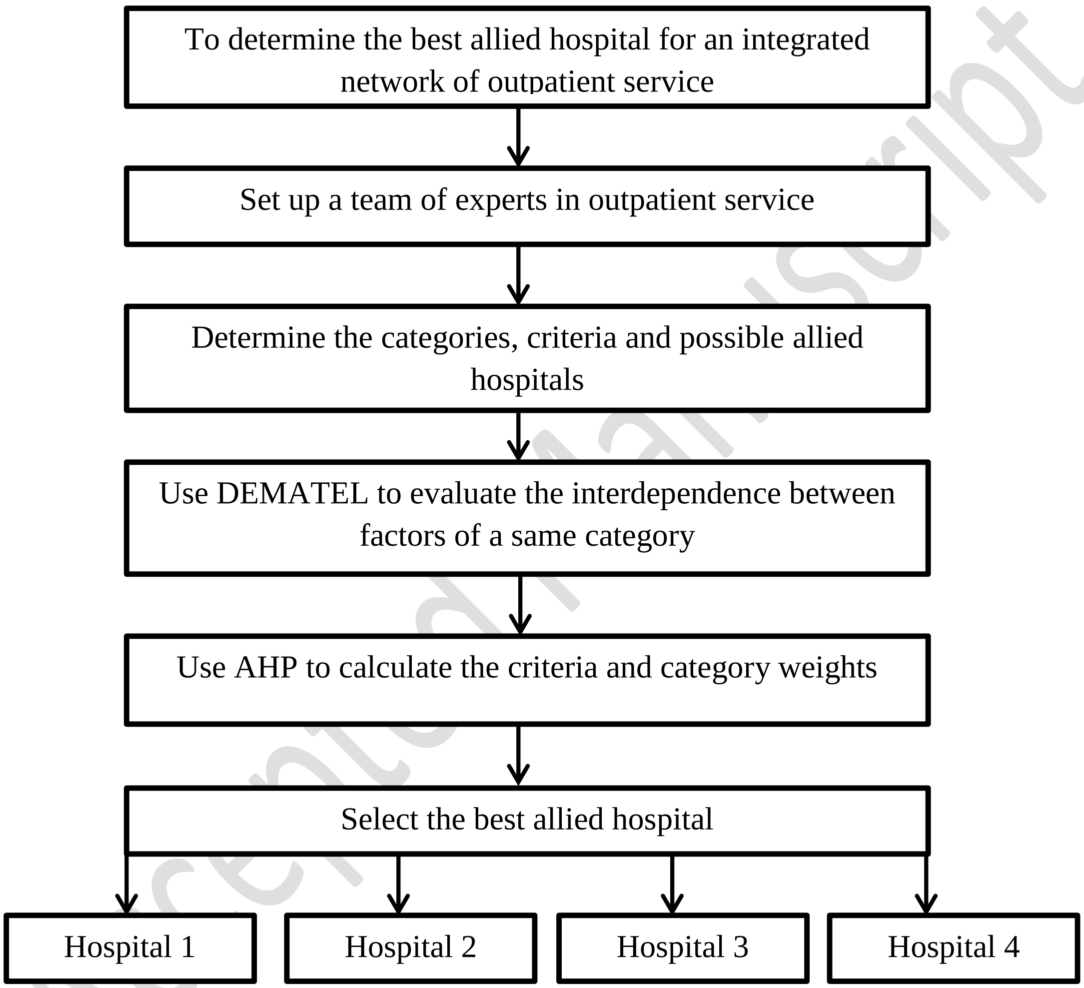

Figure1: Proposed evaluation model for the selection of the best allied hospital for an integrated network of outpatient service

4. An illustrative example

Ethical considerations

Prior to the start of the study, the protocol was presented to the medical industry and discussed with the director and ethics committee of each hospital. As this was an interview study with hospital staff and with no patient participation, no formal authorization was required. However, the participants gave informed consent to be part of the present work.

Hierarchy definition

The hierarchy was defined taking into account what Colombian law number 1438 of 2011 (Ministry of Health and Social Protection) expresses about the creation of integrated healthcare networks. Specifically, Chapter II, in its article 63-64, exposes the different criteria that have to be assumed in order to let these networks operate (See Table 2)

Table 2: Criteria definition for the design of integrated networks of outpatient service

Article part	Description	Criteria
63.4	Enough, valued, competitive and committed Medical staff.	Competence of medical staff (CMS)- number of doctors available (NAD)
63.5 – 63-13	Adequate structure of low-complexity services of caring	Compliance with standards of quality (CSQ) – availability of medical equipment (AME) – availability of consulting rooms (ACR)
63.6	Effective mechanisms of reference and contrarreference to guarantee comprehensiveness and continuity of caring on users throughout the different levels of care and intramural and extramural scenarios	Management of reference and contrarreference mechanisms (MRC)
63.7 – 64.10 – 63.1	Transporting and communication network	Availability of transportation for patients moving (ATPM) – Appropriate communication systems (ACS) – Closeness (C) – Quality of access roads (QRA)
63.10 – 63.11	Integrated management of administrative, financial and logistics support systems. Unique and integral information system of all the network actors	Appropriate information systems (AIS)

63.12	Adequate financing and monitoring and evaluation of results	Management of quality indicators (MQI)
64-2	Identification of risk factors and protecting factors	Efficacy of risk management (ERM)
64-5	The development of an epidemiological surveillance process that includes the notification and application of strategies	Efficacy of epidemiological surveillance mechanisms (EEM)

The focus group identified a total of 14 different criteria classified that must be satisfied by an allied hospital in outpatient services. These criteria into 4 categories: PROCESS STRUCTURE, LOCATION, LOGISTICS CAPACITY and PHYSICAL INFRAESTRUCTURE COMPANY (See Figure 2).

The focus group was composed by 2 industrial engineers with wide experience in healthcare sector, 2 directors of outpatient service who work in the two best hospitals in the city, the director of healthcare cluster and 2 of the most important directors in healthcare quality. One of the industrial engineers acted as the director and based on his experience about AHP and DEMATEL designed the hierarchy, which was verified with the rest of the team in order to check it was understandable and clear.

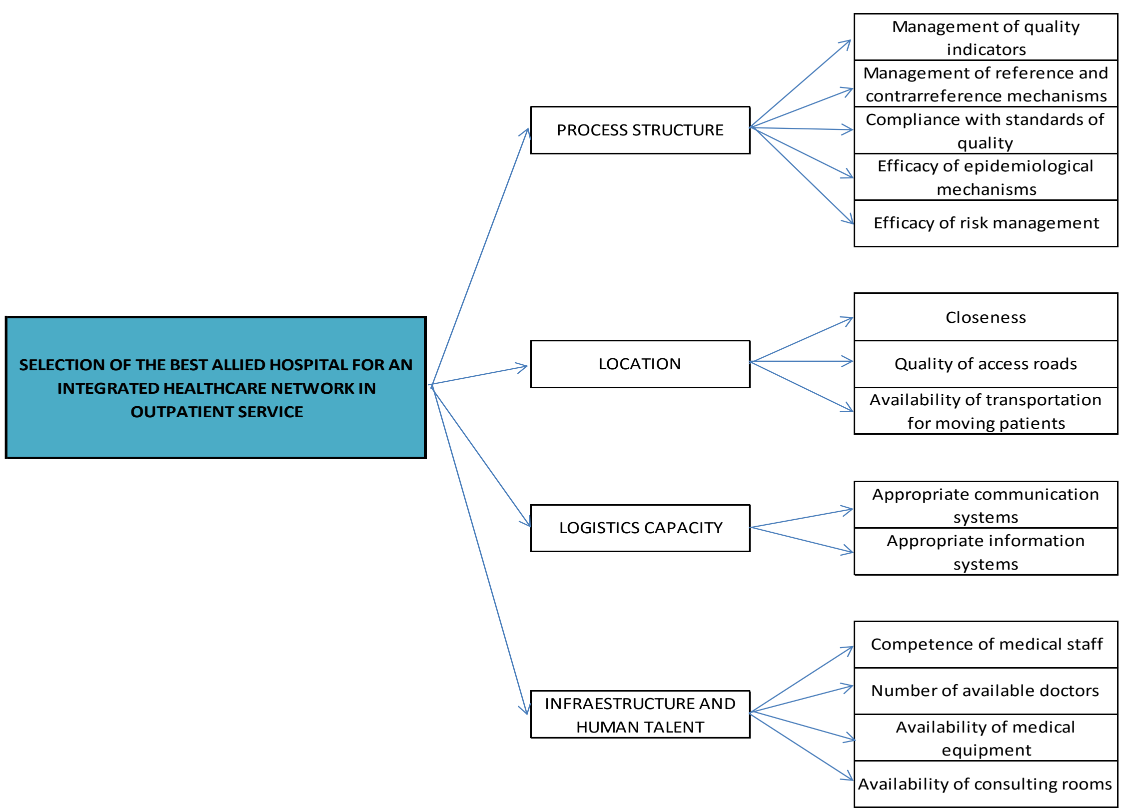

Figure 2: Criteria tree for the selection of the best allied hospital in outpatient services.

Questionnaires in AHP and DEMATEL

Questionnaires in AHP were designed with the purpose of letting each participant to do pairwise comparisons taking into account the relative importance of each criterion with all the criteria in the same category. The scheme of the questionnaire is presented in Figure 3.

SURVEY FOR THE DETERMINATION OF THE IMPORTANCE OF DIFFERENT EVALUATION CRITERIA IN THE SELECTION PROCESS OF ALLIED HOSPITALS IN OUTPATIENT SERVICE								
According to your experience, how important is each element on the left compared to each element on the right?								
Management of reference and contrarreference mechanisms	is	Much less	Less	Equally	More	Much more	important than	**Compliance with standards of quality**
Management of reference and contrarreference mechanisms	is	Much less	Less	Equally	More	Much more	important than	**Efficacy of epidemiological surveillance mechanisms**

Figure 3: Scheme of AHP questionnaire

For each pair of criteria (i,j), participants were asked the next question: "i*n the selection of an allied hospital in outpatient service, according to your experience, how important is each element on the left compared to each element on the right*" Participants answered by selecting one of these options: much less, less, equally, more or much more important. Taking into account Saaty´s theory (Saaty, 2004), an integer number is given to each judgement: 1 (equally), 3 (more important), 5 (much more important) and their reciprocals: 1/3 (less important) and 1/5 (much less important). Whether, Saaty´s scale is composed by 9 points, a variation was made in order to help responders who have not practised with the AHP technique. A 3-point scale was employed instead of 9-point due to some studies (Pecchia *et al.*, 2013; Pecchia *et al.*, 2010; Saaty, 2009) concluded that non-experts in the use of AHP, tend to judge with only 3 points as maximum. This procedure was reiterated until finishing with all the necessary judgments.

As AHP questionnaires, DEMATEL questionnaires were created for enabling each participant to judge taking into account the influence of each criterion on all the criteria in the same category. The design of the questionnaire is presented in Figure 4.

SURVEY FOR THE DETERMINATION OF THE IMPORTANCE OF DIFFERENT EVALUATION CRITERIA IN THE SELECTION PROCESS OF ALLIED HOSPITALS IN OUTPATIENT SERVICE								
According to your experience, how does each element on the left influence on each element on the right?								
Management of reference and contrarreference mechanisms	has a	non-existent	low	medium	high	very high	influence on	Compliance with standards of quality
Management of reference and contrarreference mechanisms	has a	non-existent	low	medium	high	very high	influence on	Efficacy of epidemiological surveillance mechanisms

Figure 4: Scheme of DEMATEL questionnaire

In DEMATEL, for each pair of criteria (i,j), the focus group was asked the next question: "in the selection of an allied hospital in outpatient service, according to your experience, how does each element on the left influence on each element on the right" Participants answered by choosing one of these alternatives: non-existent, low, medium, high or very high. An integer number is assigned for each alternative: 0 (non-existent), 1 (low influence), 2 (medium influence), 3 (high influence) and 4 (very high influence). As AHP method, this process was reiterated until concluding with all the needed judgments.

Judgement matrixes in AHP

For each category of criteria, a judgement matrix C_{nxn} was established where "n" symbolises the number of criteria in a category. According to (Pecchia *et al.*, 2013; Saaty, 1977), each AHP matrix has the following properties:

- The component a_{ij} is related to the ratio between the relative weight of the criterion "i" (N_i) and "j" (N_j)
- The reciprocal of c_{ij} is c_{ji} (If Ni was 5 times more important than N_j, then N_j must be 1/5 of N_i)
- The component c_{ii} is equal to 1.
- Transitivity of matrix C where:

$$“\forall\, i,j,k \,\in (1;n), c_{ij} = c_{ik} * c_{kj} \;(4)$$

$$c_{ij} = \frac{N_i}{N_j} = \frac{N_i}{N_k} * \frac{N_k}{N_j} = c_{ik} * c_{kj} (5)$$

Local weights, consistency estimation and category importance

(Saaty, 1977) demonstrated that when the matrix C satisfies the properties previously specified for AHP judgement matrixes, only one real eigenvalue (λ) can exist. As a result, the eigenvector related to this eigenvalue, denotes the relative importance of each criterion.

This relative weight of criterion "i" within the category "m" is called local weight LW_i^m.In this way, category importance RW^m is also calculated to evidence the relevance of each one in the decision.
On the other side, inconsistencies could be generated because of the loss of interest or distractions during the evaluation process. That is why, the leader of the decision making process should explain clearly the meaning of each element of the evaluation model so that the decision making group establishes more consistent judgements. If some inconsistency appears, the judgements have to be made again. Inconsistency affects the trustworthiness of the decision; although, some inconsistency is expected. For this case study, the responders' consistence was measured through the consistency index (CI). When, this indicator is equal to zero, the comparisons are entirely consistent ($\lambda_{máx}$= n). Considering literature, the CI is divided by random index (RI) whose values for $2 \leq n \leq 10$ are shown in table 3. This ratio is called consistency ratio (CR). A CR value ≤ 0.1 is considered suitable.

Table 3: Values of Random Index (RI)

n (Matrix size)	**RI**
2	0
3	0,58
4	0,9
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,51

Feedback of decision making group

At the end of the process, and with the aim of understanding the conclusions behind the ranking of criteria, categories and hospital alternatives, the results were shared with the participants of the decision making group and the director of each hospital. Each respondent felt nice and comfortable at the time of making the judgements. By the other side, the respondents expressed that the techniques were entirely comprehensible and they did not cause any misunderstanding.

5. Results and Discussions

In this paper, the results of a study on the application of AHP-DEMATEL are presented to help decision makers involved in the management of hospital operations to choose the best allied hospital at the moment of creating nets of outpatient service. As a starting point, figures

5-8 show the impact-diagraph maps for the categories as a result of DEMATEL application. First, impact-diagraph map for PROCESS STRUCTURE category is presented. The threshold value for this category was accepted as 1.3217.

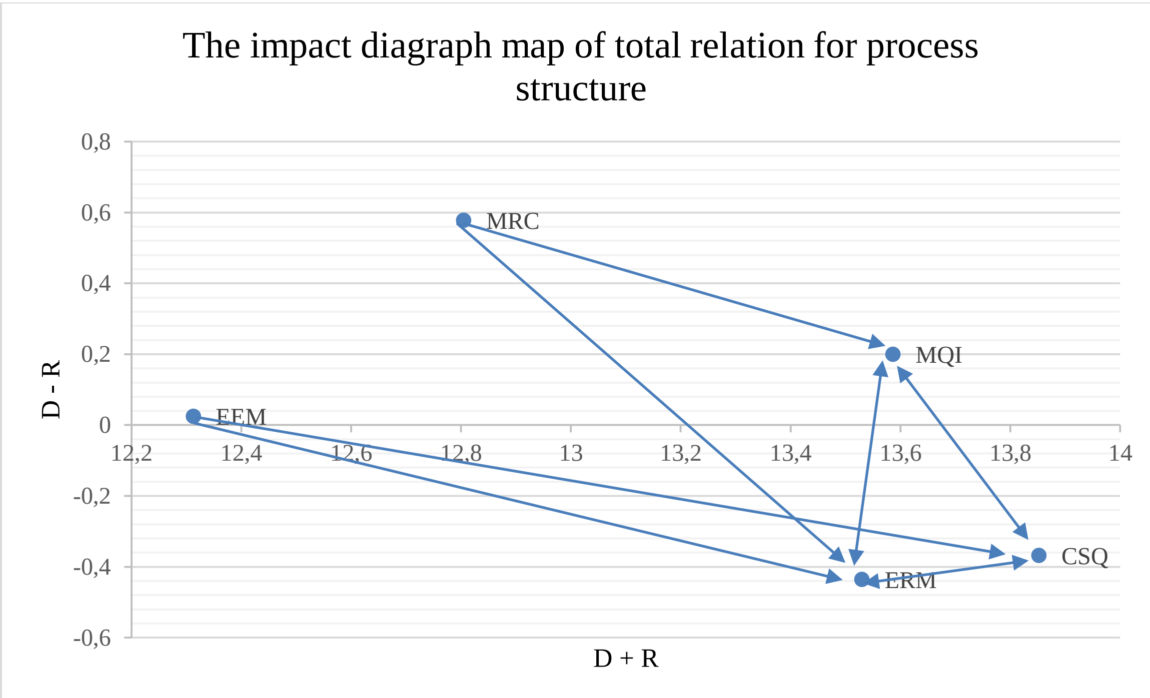

Figure 5: Impact-diagraph map for PROCESS STRUCTURE category

It is noticed that MANAGEMENT OF QUALITY INDICATORS, MANAGEMENT OF REFERENCE AND CONTRARREFERENCE MECHANISMS and EFFICACY OF EPIDEMIOLOGICAL MECHANISMS are the receivers, while COMPLIANCE OF STANDARDS OF QUALITY and EFFICACY OF RISK MANAGEMENT are the dispatchers. According to the graph, in PROCESS STRUCTURE category, it is seen that MANAGEMENT OF REFERENCE AND CONTRARREFERENCE MECHANISMS has a high impact on MANAGEMENT OF QUALITY INDICATORS and EFFICACY OF RISK MANAGEMENT. On the other hand, EFFICACY OF EPIDEMIOLOGICAL MECHANISMS has a considerable influence on COMPLIANCE OF STANDARDS OF QUALITY and EFFICACY OF RISK MANAGEMENT.

Second, impact-diagraph map for LOCATION category is analysed. The threshold value assigned is 0.8259.

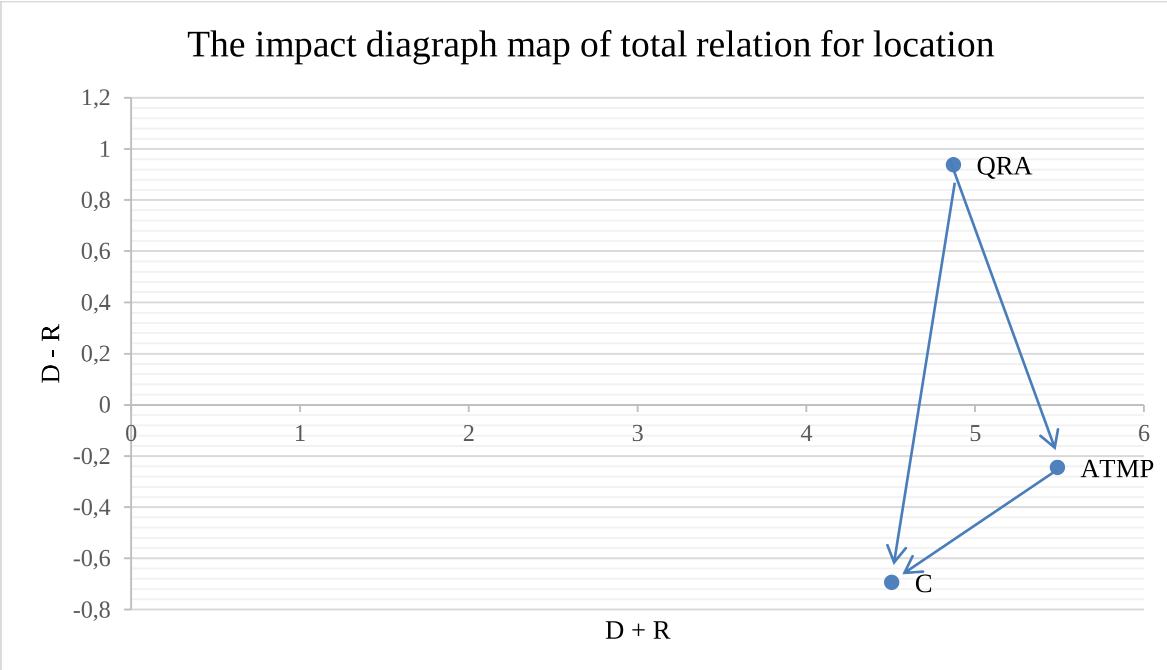

Figure 6: Impact-diagraph map for LOCATION category

It is observed that CLOSENESS and AVAILABILITY OF TRANSPORTATION FOR MOVING PATIENTS are the dispatchers; meanwhile, QUALITY OF ACCESS ROADS is the receiver. Upon analysing figure 6, QUALITY OF ACCESS ROADS has a high impact on CLOSENESS and AVAILABILITY OF TRANSPORTATION FOR MOVING PATIENTS in LOCATION category.

Then, impact-diagraph map for LOGISTICS CAPACITY is evaluated. The threshold value for this category is assumed as 1.25. It is detected that APPROPRIATE COMMUNICATION SYSTEMS is the dispatcher and APPROPRIATE INFORMATION SYSTEMS is the receiver. Figure 7 allows determining that APPROPRIATE COMMUNICATION SYSTEMS has a high influence on APPROPRIATE INFORMATION SYSTEMS.

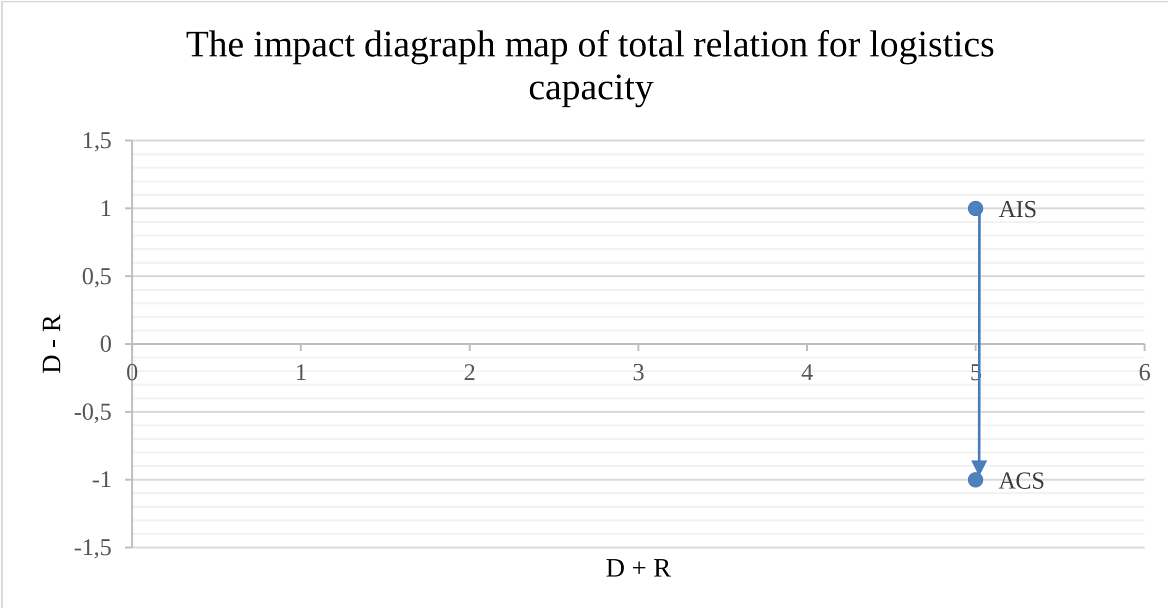

Figure 7: Impact-diagraph map for LOGISTICS CAPACITY category

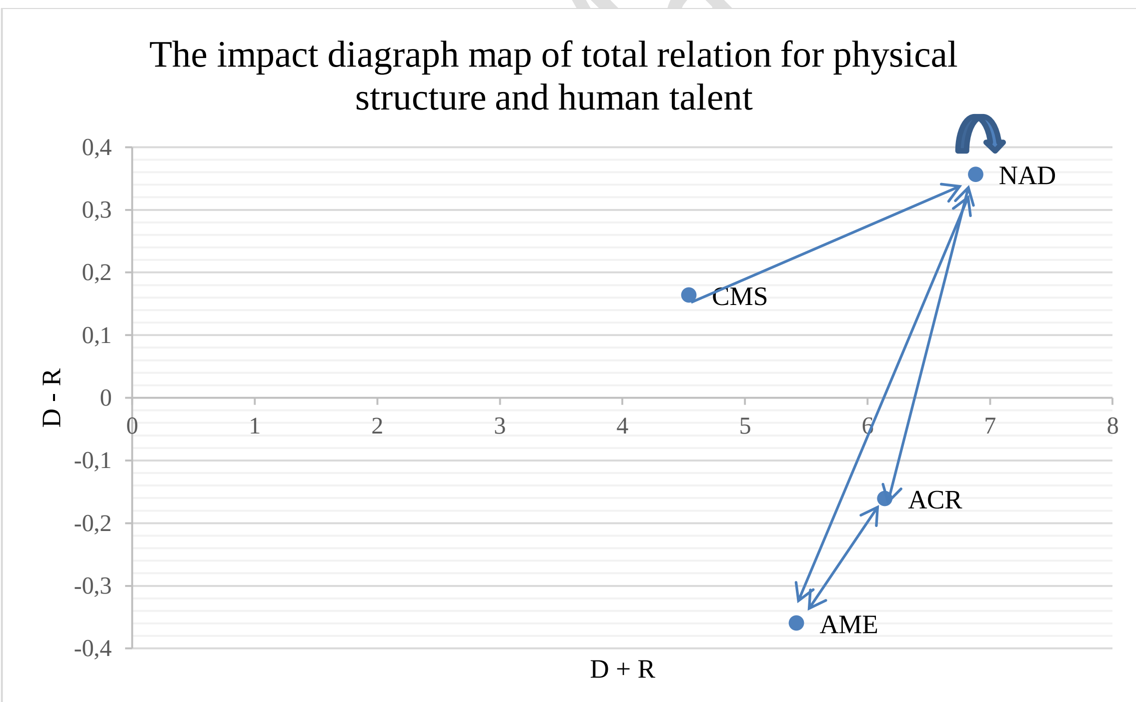

Figure 8: Impact-diagraph map for PHYSICAL STRUCTURE and HUMAN TALENT category

Finally, the impact-diagraph map for PHYSICAL STRUCTURE AND HUMAN TALENT is created. The threshold value for this category is accepted as 0.7184. It is identified that

COMPETENCE OF MEDICAL STAFF and NUMBER OF AVAILABLE DOCTORS are the dispatchers and AVAILABILITY OF MEDICAL EQUIPMENT and AVAILABILITY OF CONSULTING ROOMS are the receivers. According to Figure8, it is seen that COMPETENCE OF MEDICAL STAFF has a great effect on NUMBER OF AVAILABLE DOCTORS. It is also observed that the pairs of criteria: AVAILABILITY OF MEDICAL EQUIPMENT-AVAILABILITY OF CONSULTING ROOMS, AVAILABILITY OF CONSULTING ROOMS-NUMBER OF AVAILABLE DOCTORS and NUMBER OF AVAILABLE DOCTORS-AVAILABILITY OF MEDICAL EQUIPMENT have a double-way influence.

Table 4: - D + R and D – R values of each criterion

CATEGORY	ABREV.	D + R	D - R	DISPATCHERS	RECEIVERS
PROCESS ESTRUCTURE					
Management of quality indicators	**MQI**	13,58637789	0,200147448		X
Management of reference and contrarreference mechanisms	**MRC**	12,80446764	0,578104683		X
Compliance with standards of quality	**CSQ**	13,85199019	-0,36766776	X	
Efficacy of epidemiological mechanisms	**EEM**	12,31244413	0,025103772		X
Efficacy of risk management	**ERM**	13,52984987	-0,435688144	X	
LOCATION					
Closeness	**C**	4,50636401	-0,69363599	X	
Quality of access roads	**QAR**	4,871655102	0,938321769		X
Availability of transportation for moving patients	**ATMP**	5,488647555	-0,244685779	X	
LOGISTICS CAPACITY					
Appropriate communication systems	**ACS**	5	-1	X	
Appropriate information systems	**AIS**	5	1		X
INFRAESTRUCTURE AND HUMAN TALENT					
Competence of medical staff	**CMS**	4,543836052	0,163783558		X
Number of available doctors	**NAD**	6,883276745	0,356654382		X
Availability of medical equipment	**AME**	5,420745226	-0,359714833	X	
Availability of consulting rooms	**ACR**	6,141964764	-0,160723107	X	

By the other side, Table 4 takes into account the impact-diagraph maps and defines the dispatchers and receivers of the evaluation model. This is done with the purpose of identifying the interrelations between the elements of each category at the time of decision making. D+R values show a strong inner dependency between criteria in each category since these values are very close.

Meanwhile, the global and local contributions of each criterion of hybrid technique AHP-DEMATEL are described in Table 5.

Table 5: Local and global weights of criteria in AHP-DEMATEL technique (CR ≤ 0.1)

CATEGORY	**RW**	**GW**	**LW**
PROCESS STRUCTURE	0,25		
Management of quality indicators		0,0341	0,13638
Management of reference and contrarreference mechanisms		0,02385	0,0954
Compliance with standards of quality		0,00981	0,03923
Efficacy of epidemiological mechanisms		0,04329	0,17317
Efficacy of risk management		0,01395	0,05582
LOCATION	0,25		
Closeness		0,04608	0,18432
Quality of access roads		0,05613	0,22452
Availability of transportation for moving patients		0,02279	0,09116
LOGISTICS CAPACITY	0,25		
Appropriate communication systems		0.08929	0,35714
Appropriate information systems		0,03571	0,14286
INFRAESTRUCTURE AND HUMAN TALENT	0,25		
Competence of medical staff		0,03951	0,15803
Number of available doctors		0,01928	0,07712
Availability of medical equipment		0,03181	0,12722
Availability of consulting rooms		0,03441	0,13764

It is concluded that the top five of most important criteria at the moment of selecting an allied hospital for an outpatient service network is composed by: APPROPRIATE COMMUNICATION SYSTEMS, QUALITY OF ACCESS ROADS, CLOSENESS, EFFICACY OF EPIDEMIOLOGICAL MECHANISMS and COMPETENCE OF MEDICAL STAFF. It is noticed that two of the three elements of LOCATION CATEGORY are located in top five. On the other hand, COMPETENCE OF MEDICAL STAFF (0.15803) is the most important criterion in INFRAESTRUCTURE AND HUMAN TALENT category. It is also good to highlight that APPROPRIATE COMMUNICATION SYSTEMS (0.35714) is the criterion with the greater contribution in LOGISTICS CAPACITY category. By the other side, QUALITY OF ACCESS ROADS (0.22452) is described as the most relevant factor in LOCATION category. Finally, at the moment of analysing PROCESS STRUCTURE category, EFFICACY OF EPIDEMIOLOGICAL MECHANISMS is the most significant criterion.

Figure 9 exposes the global scores of alternatives, showing the best allied hospital to create an integrated network in outpatient service.
In this case, HOSPITAL 1 is the most suitable alternative for this purpose with a score of 0.26456. This hospital had the most significant weight as for LOCATION with 0.26535. It also had the best score as for LOGISTICS CAPACITY, PHYSICAL INFRAESTRUCTURE AND HUMAN TALENT and PROCESS STRUCTURE with 0.26444, 0.26417 and 0.26430 respectively.

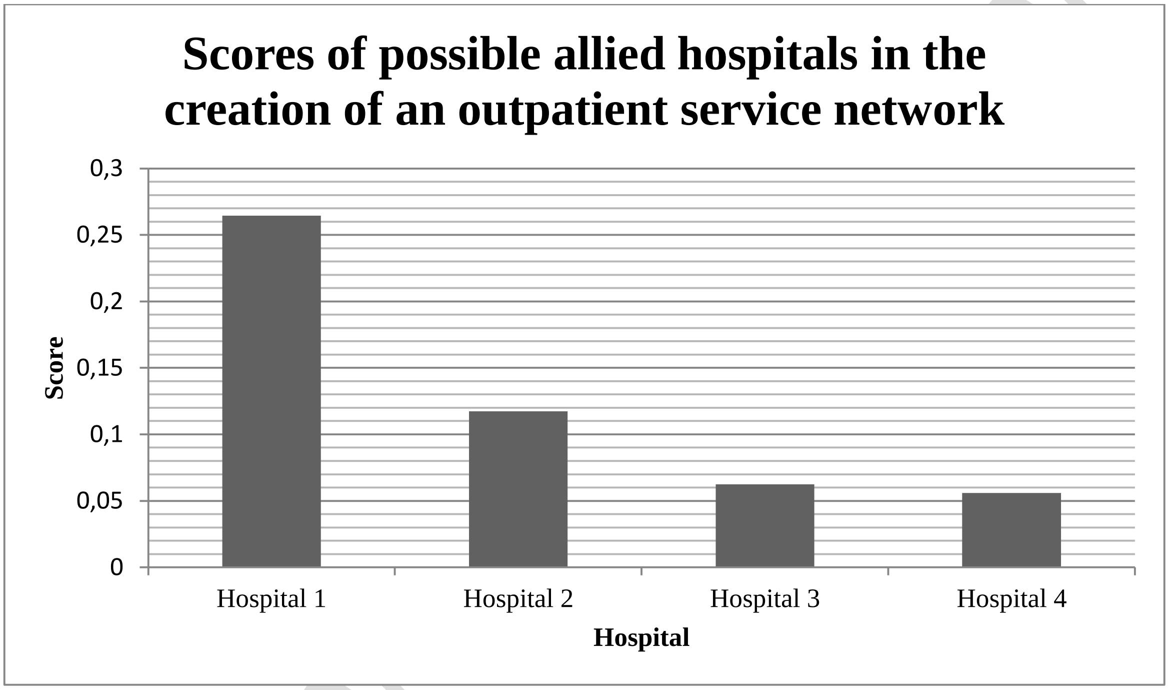

Figure 9: Scores of possible allied hospitals in the creation of an outpatient service network

Table 6 illustrates the consistency ratios for AHP-DEMATEL matrixes separately.

Table 6: Consistency ratios in AHP matrixes

CONSISTENCY RATIOS AHP MATRIX				
Respondent	**Process structure**	**Location**	**Logistics capacity**	**Physical structure and human talent**
1	0,1	0	0	0,0643
2	0,047684	0,047725	0	0,074074
3	0,09995	0	0	0,014945
4	0,099948	0	0	0,0643
5	0,035714	0	0	0,080835

6	0,070763	0	0	0,06893
SUM	0,454059	0,047725	0	0,367384

It is shown that the categories with the least sum of consistency ratios were LOCATION and LOGISTICS CAPACITY, while PROCESS STRUCTURE and PHYSICAL INFRAESTRUCTURE AND HUMAN TALENT had the highest sum. More deeply, it can be observed that according as the matrix size increases, the inconsistency increases too; since PROCESS STRUCTURE (Matrix size: 5x5) got a CR sum of 0.454059, then PHYSICAL INFRAESTRUCTURE AND HUMAN TALENT (Matrix size: 4x4) got a CR sum of 0.367384, LOCATION (Matrix size: 3x3) achieved a CR sum of 0.047725 and LOGISTICS CAPACITY (Matrix size: 2x2) achieved a CR sum of 0. Nonetheless, all matrixes reached the required threshold ($CR \leq 0.1$).

6. Conclusions

The proposed paper presents DEMATEL by providing an integrated approach based on AHP method which has been widely used in many applications.
For this case, the novel approach is applied to determine the best allied hospital for an integrated network of outpatient service.
In details DEMATEL has been used to evaluate the interdependence between factors of a same category. While AHP has been used to calculate the criteria and category weights
Both results and inner dependencies achieved in this process were placed into the Supermatrix to calculate, with the aid of AHP, the best allied hospital for an integrated network of outpatient service.
The proposed methodology is simple and straight forward and is well suited for the specific case study.
The limitation of this methodology is that it does not include a cost criterion. The aim of further research is to take into consideration also this particular aspect.

References

Charnes, A., Cooper, W.W., Ferguson, R., 1955. Optimal estimation of executive compensation by linear programming, Management Science, 1, 138-151.

Chiu, Y.J., H.C. Chen, J.Z. Shyu and G.H. Tzeng, 2006. Marketing strategy based on customer behavior for the LCD-TV. Int. J. Manage. Decision Making, 7(2-3): 143-165.

Dalkey, N. C. and Helmer, O., 1963. An experimental application of the Delphi method to the use of experts. Management Science, 9 (3), 458-467.

De Felice, F., 2012. Editorial Research and applications of AHP/ANP and MCDA for decision making in manufacturing. *International Journal of Production Research*, 50(17), 4735–4737.

De Felice, F., Petrillo, A., 2014. Proposal of a structured methodology for the measure of intangible criteria and for decision making. International Journal of Simulation and Process Modelling, 9(3), 157-166.

Ismail, N.I., Abdullah, N.H., Shamsuddin, A., 2014. Adoption of Hospital Information System (HIS) in Malaysian Public Hospitals. Procedia - Social and Behavioral Sciences 172 (2015) 336 – 343

Falatoonitoosi, E., Ahmed, S., Sorooshian, S., 2014. Expanded DEMATEL for Determining Cause and Effect Group in Bidirectional Relations. Sci. World J 2014, 2014: 7.

Fontela, E., Gabus, A., 1974. DEMATEL, innovative methods, Technical report no. 2, Structural analysis of the world problematique. Battelle Geneva Research Institute, 1974.

Fontela, E., A. Gabus, 1976. The DEMATEL observer, DEMATEL 1976 report. Battelle Geneva Research Center, Switzerland Geneva.

Franek, J., Kashi, K.,2014. A Review annd critique of hybrid MADM methods application in real business. In Proceedings of International Symposium of the Analytic Hierarchy Process 2014, June 29- July 2, 2014, Washington D.C., U.S.A.

Gabus, A., Fontela, E., 1972. World Problems an Invitation to Further Thought within the Framework of DEMATEL. Battelle Geneva Research Centre, Switzerland, Geneva.

Gabus, A., Fontela, E., 1973. Perceptions of the World Problematique: Communication Procedure, Communicating with those Bearing Collective Responsibility.

Henriksen, K., Battles, J. B., Marks, E. S., Lewin, D. I., Schiff, G. D., Kim, S., ... & McNutt, R. A. (2005). Diagnosing diagnosis errors: lessons from a multi-institutional collaborative project.

Huang, C.Y., J.Z. Shyu and G.H. Tzeng, 2007. Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry. Technovation, 27(12): 744-765.

Hori, S. and Y. Shimizu, 1999. Designingmethods of human interface for supervisory control systems. Control Eng. Pract., 7(11): 1413-1419.

Jharkharia, S., Shankar, R., 2007. Selection of logistics service provider: An analytic network process (ANP) approach. Omega 2007, 35(3): 274–289.

Kassirer, J.P. 2000. Patients physicians, and the internet, HealthAff. 19 (6) (2000) 115–123.

Lee, H.W., Ramayah, T., Zakaria, N., 2012. External factors in hospital information system (HIS) adoption model: a case on Malaysia, J. Med. Syst. 36 (4) (2012) 2129–2140.

Li C.-W., Tzeng, G.-H., 2009. Identification of a threshold value for the DEMATEL method using the maximum mean de-entropy algorithm to find critical services provided by a semiconductor intellectual property mall. Expert Syst. Appl 2009, 36(6): 9891–9898.

Lin, C.J. and W.W. Wu, 2008. A causal analytical method for group decision-making under fuzzy environment. Exp. Syst. Appl., 34(1): 205-213.

Liou, J.J.H., G.H. Tzeng and H.C. Chang, 2007. Airline safety measurement using a hybrid model. J. Air Transp. Manag., 13(4): 243-249.

Mandelzweig, L., Goldbourt, U., Boyko, V., & Tanne, D. (2006). Perceptual, social, and behavioral factors associated with delays in seeking medical care in patients with symptoms of acute stroke. *Stroke*, *37*(5), 1248-1253.

Omachonu, V.K., Einspruch, N.G., 2007. Systems engineering inthe healthcare service industry, Int. J. Healthc. Technol.Manag. 8 (1) (2007) 161–172.

Pecchia, L., Bath, P. A., Pendleton, N., & Bracale, M., 2010. Web-based system for assessing risk factors for falls in community-dwelling elderly people using the analytic hierarchy process. *Internationa Journal of the Analytic Hierarchy Process*, *2*(2).

Pecchia, L., Martin, J. L., Ragozzino, A., Vanzanella, C., Scognamiglio, A., Mirarchi, L., & Morgan, S. P., 2013. User needs elicitation via analytic hierarchy process (AHP). A case study on a Computed Tomography (CT) scanner. *BMC medical informatics and decision making*, *13*(1), 2.

Raisinghani, M.S., Meade, L., Schkade, L. L., 2007. Strategic e-Business Decision Analysis Using the Analytic Network Process. IEEE Trans. Eng. Manag 2007, 54(4): 673–686.

Saaty, T. L. 1978. Modeling unstructured decision problems - the theory of analytical hierarchies. Mathematics and Computers in Simulation. Volume 20, Issue 3, September 1978, Pages 147-158.

Saaty, T. L., 1980. The analytic hierarchy process. New York: McGraw-Hill.

Saaty, T. L., 1990. How to make a decision: The Analytic Hierarchy Process. European Journal of Operations Research, 48, 9–26.

Saaty, T. L., 1996. Decision making with dependence and feedback: Analytic network process. Pittsburgh: RWS Publications.

Saaty, T.L., 2004. Decision making — the Analytic Hierarchy and Network Processes (AHP/ANP). J. Syst. Sci. Syst. Eng 2004, 13(1):1–35.

Saaty, T.L., Vargas, L.G., 2013. Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks. Springer Science & Business Media, 2013, 380.

Saaty, T. L., 2009. An essay on how judgment and measurement are different in science and in decision making. *International Journal of the Analytic Hierarchy Process*, *1*(1).

Shieh, J.I., Wu, H.H., Huang, K..K. 2010. A DEMATEL method in identifying key success factors of hospital service quality. Knowledge-Based Systems 2010, 23:277–282.

Shih-Chi, C., C.C. Sun and A. Herchan, 2011. The DEMATEL approach applied to solar cell industry material selection process in Taiwan. Session Interd. Manage. Sem., 15(13): 253-267.

Tsai, W. H., & Chou, W. C. (2009). Selecting management systems for sustainable development in SMEs: A novel hybrid model based on DEMATEL, ANP, and ZOGP. Expert Systems with Applications, 36(2), 1444–1458.

Wu, W.W., Y.T. Lee, 2007. Developing global managers' competencies using the fuzzy DEMATEL method. Exp. Syst. Appl., 32(2): 499-507.

Yang, J.L., Tzeng, G.H., 2011. An integrated MCDM technique combined with DEMATEL for a novel. Expert Systems with Applications 38 (2011) 1417–1424.
cluster-weighted with ANP method.

Yang T., Hsieh C.-H., 2009. Six-Sigma project selection using national quality award criteria and Delphi fuzzy multiple criteria decision-making method. Expert Syst. Appl 2009, 36(4): 7594–7603.

Zadeh, L.A. (1965). "Fuzzy sets". Information and Control 8 (3): 338–353.