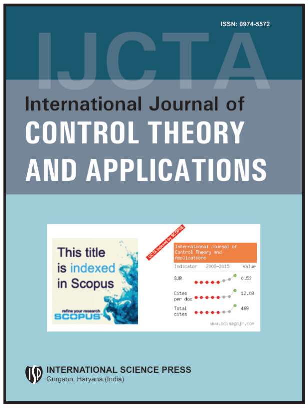

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A Hybrid Model for Selecting Improvement Projects: a Case Study in Medical Industry

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Abstract: This paper presents a hybrid model based on DEMATEL-ANP to select and prioritize improvement project alternatives in healthcare companies so that they can identify the most significant projects and their importance level but selecting the best alternative requires a multicriteria decision making system (MCDM). First, a project evaluation model is designed; then DEMATEL (Decision Making Trial and Evaluation Laboratory) is applied to calculate interrelations between criteria. Finally, the criteria weights are calculated by ANP (Analytic Network Process). A case study in medical industry is presented, showing the effectiveness of this model. Its application led the medical company towards the identification of "COST OF HUMAN RESOURCES" as the most important criterion and the use of its financial resources in the improvement of its obstetric process obtaining the maximum return on investment (ROI).

Keywords: DEMATEL, ANP, Medical Industry, Project selection, Multi-criteria Decision Making.

1. INTRODUCTION

To provide a high quality service for patients, the medical industry needs to make decisions about how financial resources should be invested in order to improve the overall performance of healthcare systems. It is extensively known that these types of decisions correspond to a Multicriteria decision making model (MCDM) since healthcare services should respond to a wide variety of stakeholders with different needs. Therefore, it is mandatory to meet their requirements although; capturing stakeholders´ requirements in healthcare area is extremely complex. In medical services, the primary aims are safety and quality; however, many other aspects have to be taken into account to guarantee an effective selection of improvement projects such as economic aspects, market opportunities and risks.

The topic of stakeholders´ requirements is very interesting to different medical organisations that are asked for making decisions with respect to the choice of the most convenient project for the improvement of their healthcare systems. Nevertheless, research has revealed that collecting and analysing this information is a challenge; a lack of knowledge of suitable techniques for data collection and analysis might result in an incomplete collection of data, incorrect interpretation and error in the design of questions of interest.

The multifaceted nature of stakeholders´ requirements means that each stakeholder has its proper patterns, attitudes and inclinations which affect the decision-making process since the chosen project should satisfy each requirement. However, this information must not only be collected and analysed, but dissimilarities and conflicts must be balanced. This is a critical aspect for healthcare companies upon investing their financial resources since the decisions should be based on the best possible evidence accessible at the time.

The use of scientific quantitative techniques to support decision making is estimated as important in healthcare companies. Nevertheless, the difficulty of project selection involves a structure of qualitative and quantitative information. Nonetheless, the nature of qualitative methods could restrict their utilization in decision making process like the selection of improvement projects in healthcare sector. Investigators have found some problems when using qualitative data in these kinds of processes. Therefore, it is fundamental to establish new methods that allow these data can be measured and ranked so that transparency can be guaranteed [1]. In addition, the decision should be clear and easy to comprehend for healthcare staff. The hybrid model DEMATEL-ANP proposed in this paper enables medical industry in the selection of the most suitable improvement project in a clear, easy-to-understand, transparent and effective way.

Decision Making Trial and Evaluation Laboratory (DEMATEL) is a potent method that allows collecting group knowledge to detect causal relations [2]-[3]. Analytic Network Process (ANP) is used to deal with the problem of dependence and feedback between sub-factors and decision alternatives. In this way, a causal structure can be designed to select the most suitable improvement project. DEMATEL and ANP are effective for measuring qualitative knowledge such as subjective preferences. This is a key aspect since not all the important information is objective or numerical. Several studies have proved the benefits of using the hybrid model DEMATEL-ANP. [4]- [5] used this method to solve the complex relations between criteria dimensions to further select the ideal system implementation model. [6] proposed an effective solution based on a combined ANP and DEMATEL approach to help companies that need to evaluate and select knowledge management. [7] developed an integrated approach between ANP y DEMATEL for logistics industry to identify critical projects and their prioritization.

Other techniques have been explored to select improvement projects. [8] presented a hybrid approach between ANP and fuzzy sets for Six Sigma project prioritizing. In this, starting from a set of projects previously identified, ANP was applied to model decision making process [9]- [10] and fuzzy sets to determine and assign the respective weights [11]. Particularly, we focus on the use of DEMATEL-ANP to obtain the most suitable improvement project for a healthcare company, identifying the most critical strategies and sub-factors in the selection process.

2. METHODS

A. Design of Project Evaluation Model

A decision-making group identified a total of 3 tactics, 4 categories and 15 criteria that supports the selection of improvement projects in medical industry. This evaluation model was based on the personal experience of the group, literature review, government policies and studies of medical industry. This decision-making group involved 6 clinicians, 2 financial consultants and 2 industrial engineers, who are corresponding author and co-author of this paper respectively. The 2 industrial engineers acted as facilitators, and based on their experience in MCDM methods, designed the evaluation model (refer to Figure 1), which was reviewed with the rest of the group to verify if it was clear, easy-to-understand and effective. The resulting project portfolio was composed by the following projects: A (Reduction of outpatient's waiting time for an appointment - Gynecology and Obstetrics Department), B (Reduction of outpatient's waiting time - Internal Medicine Department), C (Increasing of accuracy and precision - User Information System), D (Increasing of information opportunity – Systems Department), E (Reduction of waiting time in Emergency Department) and F (Increasing of fill rate in Drug Inventory).

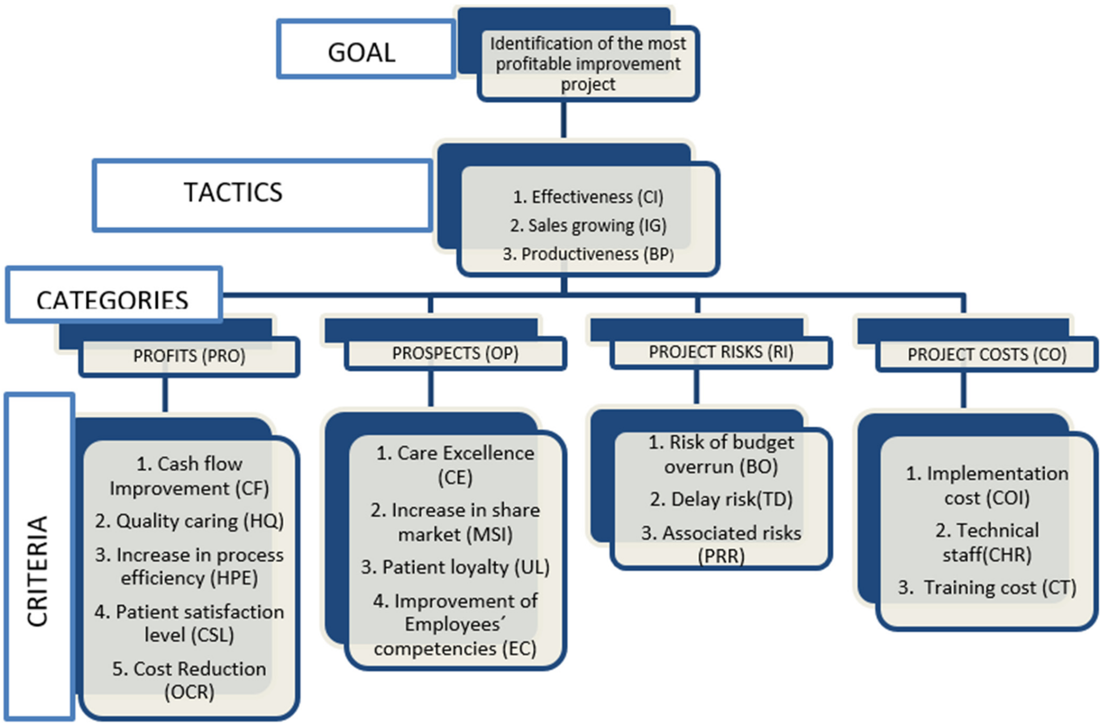


Figure 1: Evaluation model for the selection of improvement projects in medical industry

B. Questionnaire Design

When applying DEMATEL, questionnaires were designed with the aim of facilitating decision-making group to make pairwise comparisons for each cluster. For each pair of tactics or criteria, participants were asked the following question: ¿How much impact does tactic/criterion *i* have on tactic/criterion *j*? Each respondent answered by selecting one of the following values established for DEMATEL: non-existent impact (0), low impact (1), medium impact (2), substantial impact (3) and very substantial impact (4).

For ANP, responders were asked the following question: ¿How relevant is tactic/criterion i over tactic/criterion *j* with respect to the category *k*? Each responder answered by using Saaty's scale where 1 represents equal relevance and 9 represents extreme relevance of one tactic/criterion over another. In addition, the decision-making group was also asked the question: ¿How relevant is improvement project alternative i over improvement project alternative *j* with respect to a tactic or criterion l? Each participant answered according to the same Saaty's scale.

C. Decision Making Trial and Evaluation Laboratory

(a) *Phase 1: Direct-relation matrix generation:* 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 $n \times n$ matrix called direct-relation matrix B, in which b_{ij} represents the degree to which the criterion i affects the criterion j.

(b) *Phase 2: Direct-relation matrix normalization:* The normalized direct-relation matrix N is obtained from matrix B by formulas (1) and (2).

$$k = \min\left(\begin{array}{c} \mathrm{M} = k \cdot \mathrm{A} \\ \dfrac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} \left|a_{ij}\right|}, \dfrac{1}{\max\limits_{1 \le j \le n} \sum_{i=1}^{n} \left|a_{ij}\right|} \end{array}\right) i, j \in \{1, 2, 3, \ldots, n\} \quad (1)$$

(c) *Phase 3: Total-relation matrix calculation:* 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:

$$\mathrm{S} = \mathrm{M} + \mathrm{M}^2 + \mathrm{M}^3 + \ldots = \sum_{i=1}^{\infty} \mathrm{M}^i = \mathrm{M}\left(\mathrm{I} - \mathrm{M}\right)^{-1} \quad (3)$$

(d) *Phase 4: Identification of dispatcher and receiver groups:* With the use of D + R and D – R, where R is the sum of columns and 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". Moreover, the value of D + R indicates relation degree between each criterion with others.

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

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

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

(e) *Phase 5: Calculation of threshold value and graphing the impact-diagraph map:* Map the dataset (D + R, D – R). The threshold value is set to indicate the influence level between criteria.

(f) *Phase 6: Identification the inner dependencies:* The sum of each columtn is equal to 1 through normalization process; then, inner dependencies matrixes are obtained.

D. Analytic Network Process (ANP)

(a) *Step 1:* Developing of the structure model

A structure model is designed through researches, studies and relevant information that correspond to the decision that must be made.

(b) *Step 2:* Pairwise comparisons on clusters

The team of experts makes pairwise comparisons by applying nine-level Saaty's scale where 1 is equal and 9 is upmost, comparing two components about how they contribute to a criterion.

(c) *Step 3:* Formation and transformation of Supermatrix

The Supermatrix is composed of local priority vectors. It is transformed in Weighed Supermatrix and then is raised until the weighs have been converged. This matrix is called "Limit Matrix" and gives a list of priorities to be chosen.

(d) *Step 4:* Selection of the best decision

This step is about identifying the alternative that should be selected. The alternative with the higher score is selected.

E. Consistency Estimation

Inconsistencies could be generated because of the loss of interest or distractions during the evaluation process. These affect 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). This ratio is called consistency ratio (CR). A CR value ≤ 0.1 is considered suitable.

3. RESULTS

Table 1 shows the initial-direct relation matrix for TACTICS cluster. Figures 2-4 present the impact-diagraph map for each cluster. Both consistency ratios and global weights are described in Figure 5b. All matrixes got the required threshold (CR ≤ 0.1). Figure 5(a) presents the global scores of improvement project alternatives.

Table 1
The Initial Direct-Relation Matrix for TACTICS from Healthcare Evaluation Model

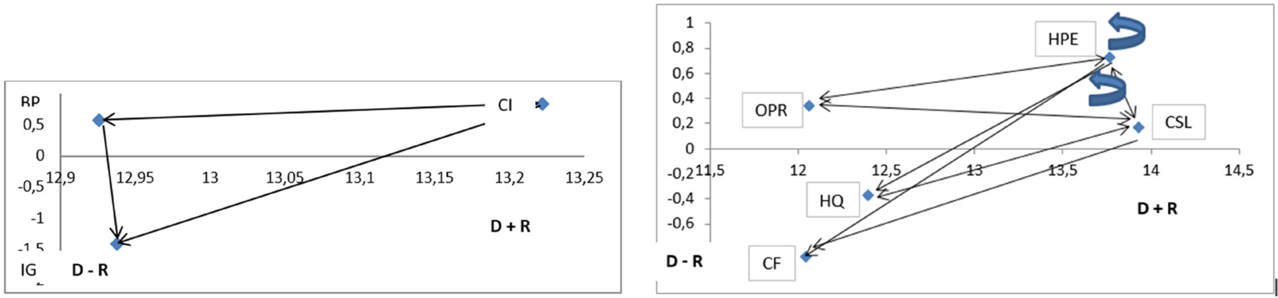
	CI	*IG*	*BP*
CI	0	4	3
IG	3	0	3
BP	3	4	0

4. DISCUSSION

As case study, the decision-making group focused on criteria and tactics that are relevant for healthcare operations. The centre of all these operations is the patient, so that the effects of the improvement project should be measured considering the impact on his/her expectations and requirements. First, the initial direct-relation matrix for TACTICS is obtained. Then, by applying Eq. 2-6, the impact diagraph for TACTICS is done by locating the dataset of (D + R, D – R) as seen in Figure 2(a). In this case, the threshold value α is calculated as 2.17.

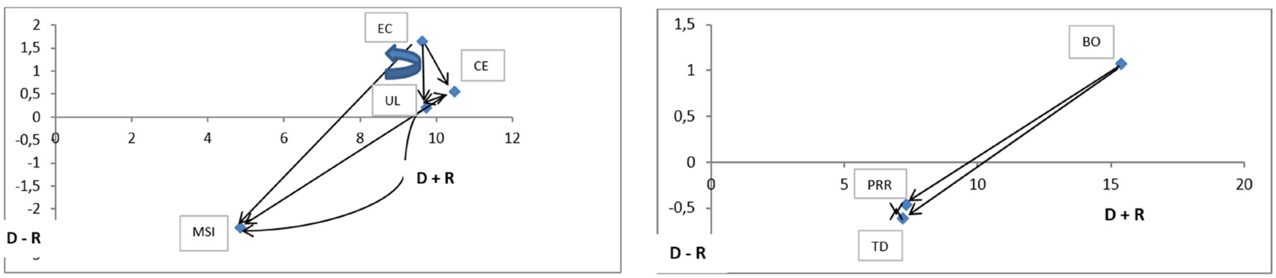
It is noticed that EFFECTIVENESS and PRODUCTIVENESS are the dispatchers; on the other hand, SALES GROWING is the receiver. Looking the impact-diagraph-map over, EFECTIVENESS and PRODUCTIVENESS have a high impact on SALES GROWING in tactics cluster for this healthcare organization. Finally, the D + R values for tactics components show a strong inner relationship. Then, the impact diagraph for PROFITS is done by locating the dataset of (D + R, D – R) as seen in Figure 2(b). The threshold value α is calculated as 1.28.

It can be also noted that INCREASE IN PROCESS EFFICIENCY, PATIENT SATISFACTION LEVEL and COST REDUCTION are the dispatchers; on the other hand, CASH FLOW IMPROVEMENT and QUALITY CARING are the receivers. Finally, the D + R values for PROSPECTS components show a strong inner relationship. Then, the impact diagraph for PROFITS is done by locating the dataset of (D + R, D – R) as seen in Figure 3(a). The threshold value α is calculated as 1.21.



(a) **(b)**

Figure 2: The impact-diagraph-map of total relation for (a)TACTICS (b) PROFITS



(a) **(b)**

Figure 3. The impact-diagraph-map of total relation for a) PROFITS b) RISKS

It can be observed that CARE EXCELLENCE and PATIENT LOYALTY are the dispatchers; on the other hand, INCREASE IN SHARE MARKET and IMPROVEMENT OF EMPLOYEES´ COMPETENCIES are the receivers. Finally, the D + R values for strategy components do not show a strong inner relationship. As next step, the matrixes for PROJECT RISKS were designed. Then, the impact diagraph for PROJECT RISKS is done by locating the dataset of (D + R, D – R) as seen in Figure 3(b). The threshold value α is calculated as 2.52. In addition, it can be concluded that RISK OF BUDGET OVERRUN is the dispatcher; on the other hand, ASSOCIATED RISKS and DELAY RISK are the receivers. Finally, the D + R values for strategy components do not show a strong inner relationship. In the same way, matrixes for PROJECT COSTS category were set. Then, the impact diagraph for PROJECT COSTS is done by locating the dataset of (D + R, D – R) as seen in Figure 4. In this case, the threshold value α is calculated as 0.684.

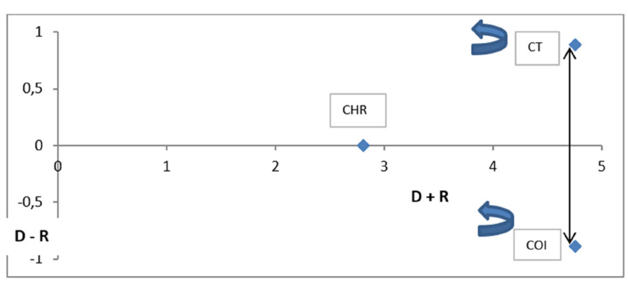
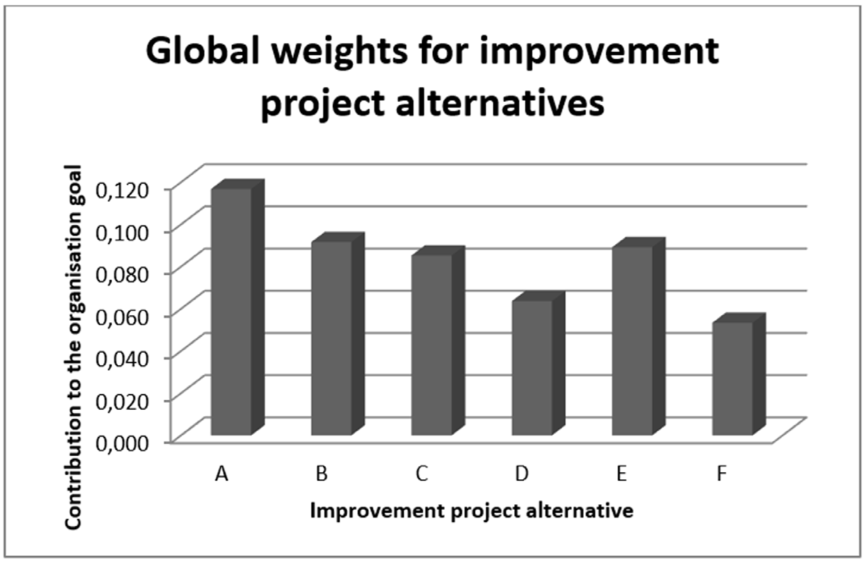


Figure 4: The impact-diagraph-map of total relation for PROJECT COSTS from healthcare evaluation model

The D + R values for PROJECT COSTS components do not show a strong inner relationship. After verifying the inner dependency for each subsystem of the model, ANP is used to estimate the weight of each element. The DEMATEL-ANP model shown in this study is solved through Superdecisions software. Previously, CR (Consistency ratio) values were calculated and proved as satisfactory (refer to Table 2). Then, the eigenvalues are registered in the unweighted supermatrix. With the aid of Superdecisions software, the results are obtained.

Regarding global weights, Table 5 presents that the top five important criteria for selecting the most relevant improvement project are: *technical staff, risk of budget overrun, implementation costs, associated risks* and *delay risk*. It is observed that the decision making group did not consider any prospect or profit criterion as important for this decision. The most relevant criteria were selected from project costs and project risks clusters. It is particular to note that all the criteria that are within project risk cluster are included in the top five. This result could be linked to the fact that some participants of the healthcare sector estimates as a priority to guarantee financial sustainability.

With respect to global weights of improvement project alternatives and their contribution to the organization aims, *reduction of outpatient's waiting time for an appointment - Gynaecology and Obstetrics Department* got the highest result (refer to Figure 5). The decision-making group expressed that a big part of the population that requests their services were composed by pregnant women, which is the primary focus of the company.



(a)

Cluster	Global weights	Cluster	Global weights
Profits (0,03)		**Project costs (0,04)**	
Cash flow improvement (CF)	0,024	Training cost (CT)	0,028
Quality caring (HQ)	0,028	Technical staff (CHR)	0,054
Increase in process efficiency (HPE)	0,027	Implementation costs(COI)	0,041
Patient satisfaction level (CSL)	0,023	**Project risks (0,07)**	
Cost reduction (OCR)	0,021	Associated risks(PRR)	0,04
Prospects (0,09)		Delay risk(TD)	0,039
Care excellence (CE)	0,035	Risk of budget overrun(BO)	0,045
Increase in share market (MSI)	0,021	**Tactics (CR=0,05)**	
Patient loyalty (UL)	0,032		
Improvement of employees´ competence (EC)	0,036		

(b)

Figure 5: (a) Global weights for improvement project alternatives (b) Global Weights for Criteria

5. CONCLUSIONS

The selection and prioritization of improvement projects is a fundamental aspect for healthcare industry upon achieving high standards of quality in patient caring. The method described in this paper allowed decision makers of a healthcare company determine the most convenient project under different selection criteria and tactics. Moreover, the hybrid model DEMATEL-ANP provided an easy-to-understand framework for the decision-making process, which is important when justifying the decisions to different interested parties. This paper has demonstrated that, for this case study, risk and cost criteria are the most important when selecting an improvement project in healthcare industry. This fact should be considered upon assigning budget for project development which can be used by governments as a tool to allocate financial resources in profitable projects. This technique led the healthcare company towards the reduction of outpatient's waiting time for an appointment in Gynaecology and Obstetrics which represents the best contribution for organizational goal achievement with 11.68%, a low project risk level of 9.9%, a positive impact of 11.63% on the attainment of benefits and an influence of 14.32% on factor corresponding to the advantage of opportunities in healthcare sector. Finally, this study contributes to helping researchers and practitioners to select more effective approaches for project improvement selection. For future research, it is suggested to explore the effectiveness of this method when adding more criteria and improvement project alternatives to the model.

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