A Nurse Reallocation method for successful change management during Electronic Health Record systems implementations

Fotios Panagiotopoulos
Department of Management Science and Technology
International Hellenic University
Kavala, Greece
fpanag@mst.ihu.gr

Leonidas Fragidis
Department of Management Science and Technology
International Hellenic University
Kavala, Greece
fragidis@mst.ihu.gr

Vassilios Chatzis
Department of Management Science and Technology
International Hellenic University
Kavala, Greece
chatzis@mst.ihu.gr

ABSTRACT

In recent years, most hospitals worldwide are trying to implement systems regarding the Electronic Health Record (EHR). The EHR systems are part of wider information systems used in healthcare. In EHR implementation in hospitals, nurses' resistance to change is considered as one of the most important factor for adoption or failure of the digital technologies application. Researchers have proposed several alternative strategies for successful implementation of EHR, which focus to reduce the nurses' resistance. This paper proposes an innovative approach to the management of nurses' resistance during the change process of the EHR implementation. The development of information systems has provided us with direct access to information and data that may be used for the successful implementation of changes, which typically rely on controlling the employees' inherent resistance to change. More specifically, during implementation the nurses' allocation should be adjusted at an appropriate time, which is found by the proposed monitoring and Nurse Reallocation (NuRe) method.

CCS CONCEPTS

• **Applied computing** → **Operations research**; **Health informatics**; • **Social and professional topics** → **Management of computing and information systems**; • **Information systems**; • **Computing methodologies** → *Model development and analysis*;

KEYWORDS

Resistance to change, E-health innovations, Electronic Health Record, Human resource allocation, Optimizing algorithm

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1 INTRODUCTION

The digital transformation of healthcare has been started from healthcare 1.0 (1970) to the present day to healthcare 4.0. The digitalization of the healthcare refers to diverse kinds of innovation such as the Electronic Medical Record (EMR), and Electronic Health Record (EHR) systems [18]. EHR information systems reduce medical errors, costs and patient waiting time before receiving their treatment by providing better access to patient data [1, 8]. All this, leads to the improvement of the quality of care and patient safety [14]. Apart from the benefits, there are barriers such as technical, financial, organizational and legal, that affect the implementation of EHR. Research results of Salma et al. show that the high cost of EHR adoption, lack of computer experience, security concerns, adoption of new technology and resistance to change are significant barriers to implementation and EHR adoption [4]. In this paper, the main proposed innovation is that during implementation of EHR systems, the allocation of nurses to tasks should be adjusted at a certain appropriate time. In this way, the reduction of nurses' resistance to use the EHR system is succeeded. In addition, with this process, the benefits are maximized and the possibility of failure during EHR implementation is reduced.

The rest of this paper is organized as follows. In Section 2, the literature review is presented. The proposed method is described in Section 3 and the experiments and results are shown in Section 4. Section 5 provides the conclusions.

2 LITERATURE REVIEW

Studies show that resistance to EHR used by physicians is the main obstacle to its adoption in hospitals [15]. Other researches show that the nursing staff plays a key role in the implementation of the EHR [9]. Moreover, another research has suggested that nurses, compared to physicians, are more likely to recognize the benefits associated to EHR due to the nature of nurses' work and consequently are less resistant to EHR use [10].

Lack of support and negative reaction to any change from medical, nursing and administrative staff is considered the most critical failure factor of EHR implementation [5]. Furthermore, it has been observed that user resistance appears more strongly when the use of the information system such as the EHR is mandatory as it affects the hospital's work processes [7]. User resistance behavior is often overlooked when implementing EHR in Hospitals because over resistance behavior is not common [3]. In the research of Thakkar and Davis a significant correlation was found between the work efficiency of the medical staff and time management and the size of the hospital [19]. Therefore, it is necessary to understand why users resist to the implementation of EHR in hospitals.

In another research, it is expressed that the satisfaction of nurses and doctors depends both on the computer experience and on the perception about the use of the EHR and the effects of the EHR on the quality of care [11]. Furthermore, a study showed that computer experience and self-confidence greatly influence the acceptance of technology [12]. Lack of education and inadequate computer skills often act as barriers to adoption of EHR. The study of Spatar et al. concludes that the effective use of EHR is mainly influenced by system functions, user interface, integration, task-technology fit, information quality and accessibility [16]. Resistance to change (RtC) was found to be the strongest predictor of user resistance behavior among mediating factors followed by perceived usefulness and perceived ease of use [3].

The literature of change management includes several research models, which collect information by using qualitative or quantitative methods [17]. These methods are quite time-consuming with the consequence that they do not manage the problem of RtC on time with possible result the abandonment or incomplete implementation of changes. Employee performance and Resistance to Change (RtC) is correlated with the type of work provided [13].

Human resources, nurses and doctors, can play a decisive role in the success of implementation and EHR adoption and managers should look for the most effective tools to optimize the use and distribution of available resources among the various services or systems, aiming to maximize or minimize certain functions related to performance.

Numerous mathematical models and methods have been presented in order to demonstrate the significance of the best solution to the human resource allocation problem (HRAP). In Bouajaja and Dridi [2], a variety of methods for addressing HRAP in various real-life scenarios are described.

3 METHODOLOGY

3.1 Problem description

The issue that this paper aims to address is how to decrease nurses' resistance to using EHR systems. Although higher performance is anticipated as a result of the change, the hospital's digital transformation usually has the opposite outcomes. This occurs frequently because significant resistance to change prevents the anticipated transformation from being completely realized.

Figure 1 contrasts what usually happens in information systems implementation in general and specifically in EHR implementation problem. The blue curve shows what is expected to happen based on hospital managers believes and the yellow curve shows what really occurring in many cases. "Change curve" is the term used in the literature to express this behavior [6]. This curve shows that the transition process during the change will result in a significant decline in employee performance (usually more than expected). Therefore, it will take more time for the modifications to produce the expected improved outcome. In many information systems implementations, the performance decrease and/or the increased time might be so crucial that results to the abandonment of the EHR implementation.

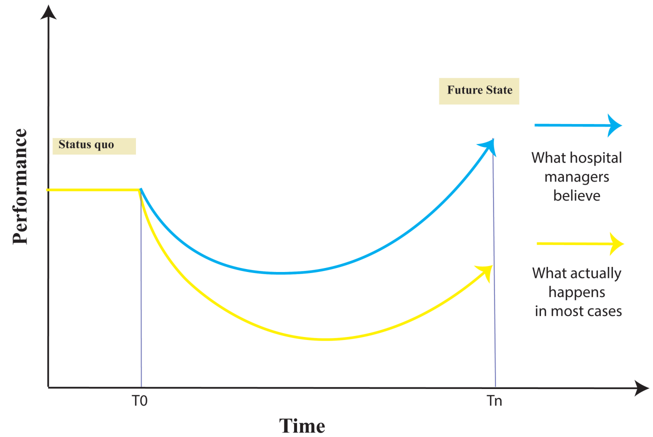

Figure 1: Comparison between what hospital managers believe and what actually happens in many change processes.

In order to face the above-mentioned problem, this paper proposes the use of Nurses Reallocation (NuRe) method. This method uses the optimal solution of the human resource allocation problem with one optimal reallocation given by NuRe method during the change process. This reallocation will reduce overall nurses resistance to use the EHR system.

NuRe method is governed by the following constraints:

(1) Every task is assigned to only one human recourse.
(2) Every human resource is assigned to only one task.

With the following assumptions:

(1) Each human resource will be able to carry out all available tasks.
(2) Each human resource has an initial known performance for each task.
(3) The resistance presented by each human resource during change follows the Change Curve model [6].

A simplified problem that will be used in the following to show the improvement in overall performance, makes the assumption of having a hospital, which wants to implement a new EHR system. A certain process that will be improved involves n tasks, which should be carried out by n humans resources (nurses). The goal is to maximize their performance by reducing resistance through a better resource allocation.

The HRAP's mathematical model serves as the foundation for the problem's formulation. The resistance to change (R_{ij}) of every human resource (i) in every task (j) is part of the objective function. For optimal performance, this goal function should be minimized. The mathematical model of resistance follows:

Proposed mathematical model - Objective function:

$$\text{Minimize} \sum_{i=1}^{n} \sum_{j=1}^{n} R_{ij} x_{ij} \tag{1}$$

Subject to constraints:

$$\sum_{i=1}^{n} x_{ij} = 1 \quad \forall j = 1, ..., n \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad \forall i = 1, ..., n \tag{3}$$

$$x_{ij} = 0 \quad \text{or} \quad 1 \tag{4}$$

where $x_{ij} = 1$ if human resource i is assigned to task j, 0 if not, and R_{ij} is the Resistance to change of assigning human resource i to task j.

3.2 Description of the proposed method application

The NuRe method application starts with the first allocation of humans to tasks, by using the Hungarian algorithm to find an optimal solution. Then, the resistance to change will start and the performance of human resources will start to change during time as it is described in Equation 5:

$$P_{ij}(t+1) = P_{ij}(t) - R_{ij}(t) \tag{5}$$

where $R_{ij}(t)$ is the Resistance at time t, $P_{ij}(t)$ is the performance at time t and $P_{ij}(t+1)$ is the performance at time $t+1$.

The resistance to change and subsequently the performance of humans are both time dependent. The proposed method tries to find the appropriate time (T_{change}) when only one reallocation will be applied in order to maximize the overall performance and minimize the possibility of EHR system implementation failure.

In order to apply the proposed method, the following steps should be followed:

(1) The performance matrix (of size $n \times n$), which contains the performance achieved by each human resource for each task, is defined.
(2) The Hungarian algorithm is used for calculating the initial optimal human resource allocation to get the maximum total performance.
(3) According to the current human resource allocation, the total performance is calculated.
(4) The Resistance to Change matrix (of size $n \times n$), which contains the Resistance to Change presented by each human resource for each task, is defined.
(5) The Hungarian algorithm is used for calculating the optimal human resource allocation to get the minimum total resistance. (This step is executed only when $t = T_{change}$).
(6) Human resource Performance matrix ($P_{ij}(t+1)$) is recalculated according to Equation 5 and return to step 3 if it is less than the end of the change period.
(7) Calculate the Average Total Performance during the period of implementation of EHR system, by using the performances calculated on step 3.

4 EXPERIMENTS AND RESULTS

In this part, appropriate tests were designed and carried out to confirm the effectiveness of the suggested NuRe method. The findings of the experimental testing of the suggested approach are presented in graphical and numerical form. The method's applicability is examined, and the benefits derived from the experiment's findings are assessed.

The Python programming language is used for the simulation, which was developed on Anaconda Navigator's Scientific Python development environment (Spyder).

Change models state that different human resources behave differently. This behavior begins with denial, as explained in Section 3, and it progressively intensifies its resistance. After that, acceptability gradually picks up, and performance eventually rises noticeably. Quantifying this behavior was the first stage in establishing the ground truth for the experiment.

Simulating Figure 1's yellow curve was the initial goal. It was decided to divide the horizontal x-axis (the time of change period) into 15 intervals ($T = 15$). Based on Figure 1's yellow curve, the vertical y-axis (performance) values for $t = 0$ to 15 were measured. These performance values are measured as a percentage of the maximum initial performance that is always assumed to be 100%. The simulation of the change management models curve, which incorporates and mimics human behavior during the change process, is depicted in Figure 2 as the Average curve.

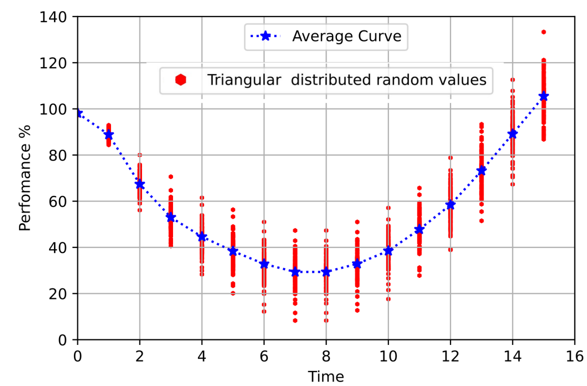

Figure 2: The simulated change curve (SCC) used as a ground truth.

While the Average curve in Figure 2 depicts the typical behavior of human resources throughout a change process, performance metrics are not always consistent. In the experiment, this uncertainty about the performance values is modeled by applying a triangular probability distribution to the performance values and by utilizing these random performance values to repeat the experiment several times. Additionally, Figure 2 also shows with red color points the random performance values after 100 iterations of the simulation.

The Simulated Change Curve (SCC), which is shown in Figure 2, presents the simulation of human behavior during a change period. Table 1 shows the limits of resistance values that are calculated from Equation 5 in order to follow the SCC of Figure 2. The SCC will be used in the following experiment.

In this experiment, a hypothetical hospital is assumed to implement a new EHR system process. The process involves 10 human resources (nurses) and 10 corresponding tasks ($n = 10$) from different clinics. The change period was chosen to be divided into 15 intervals ($T = 15$).

Table 1: Limits of resistance values for all time intervals t

TIME (t)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R_t limits	[0,20]	[0,44]	[0,30]	[0,18]	[0,14]	[0,12]	[0,8]	[-]	[0,-8]	[0,-12]	[0,-20]	[0,-22]	[0,-30]	[0,-34]	[0,-34]

Table 1 shows the resistance between the minimum and maximum values for each time interval from $t = 0$ to $t = 14$. It shows the lower and upper limits of resistance. These boundaries are considered as the lower and upper bounds of the triangular distribution, resulting in random resistance values used during repeats of the experiment. From $t = 0$ to $t = 6$, the range of resistance values is positive, which means that people's attitude towards change is negative. From $t = 8$ to $t = 14$, the resistance value becomes negative. This really shows people's positive attitude towards change. Then, by using Equation 5, the corresponding performances are calculated for the following time intervals.

4.1 Algorithm implementation

By following the algorithm presented at Section 3.2, in Step 1 an initial 10×10 performance matrix is created using the following process: This is the moment ($t = 0$) when the implementation of the EHR system plan begins. Employee performance is assumed to be between 90% and 100%. This follows the first assumption of the problem statement presented in Section 3.1 (all human resources can perform all available tasks). Therefore, human performance for each possible task takes a random value between 90 and 100 as the initial condition for applying the algorithm. Then, in step 2, we use the Hungarian algorithm to find the task that maximizes the overall performance and define the corresponding optimal staff allocation. In step 3, the overall performance is calculated according to the optimal staffing allocation. The nursing staff performance value and the total performance at time $t = 0$ are calculated as the sum of all performances. Assuming that everyone (10 humans) has maximum performance (100) on all tasks, the overall maximum performance could be equal to 1000 (100 x 10). At this point, change has not yet begun, and RtC has not yet emerged. This allocation and the corresponding total performance will be used as the start point for the algorithm. At step 4, the change starts, the RtC appears and this resistance reduces employee's performance. A resistance matrix of 10×10 is created for each human resource and task with random values in the range from 0 to 20 according to Table 1. The Hungarian algorithm is used for calculating the optimal human resource allocation to get the minimum total resistance according to Equation 1 in step 5. This step is executed only when $t = T_{change}$. Subsequently at step 6, a new performance matrix will be calculated, by using Equation 5 and the algorithm will return to step 3 to proceed for the next time interval ($t = 1$). Finally, at step 7, after the completion of all the time intervals, the Average total performance during the period of implementation of EHR system will be calculated.

The main innovation of the proposed NuRe method is that it monitors and reallocates the human resources to tasks once (at $t = T_{change}$) during the change period. The classical methods keep the human resource in the same position for all the change period, as it was in the initial time, and cannot utilize new information in change adoption ability of human resources, provided during the change time.

4.2 Experimental Results and Analysis

In order to test the proposed NuRe method, we have repeatedly run the algorithm trying to minimize the possibility of influencing the results by the random values the algorithm uses, also for the initial state of the Performance matrix and for the Resistance matrix used during iterations. The algorithm was also repeated 10,000 times. For each case the average total performance was calculated. The results of 10,000 repetitions were not significantly different from the results of the 100,000 repetitions, so it is not necessary to increase even more the repetitions. In order to find the best time interval for reallocation the experiment was repeated 15 times. In each repetition the time interval of the reallocation (T_{change}) took value from $t = 1$ to $t = 15$.

Table 2 shows the Average Total Performance (AVG TP) using the proposed NuRe method for every Reallocation Time and the corresponding results by using the SCC method. Also, Table 2 presents the Average Lower Total Performance (AVG LTP) of each method during the change period, which is a metric that is critical for the possible abandonment of change process.

According to the results, the higher Average Total Performance (AVG TP) was at time interval $T_{change} = 3$ with the value of 769.43 and at $T_{change} = 4$ with the value of 765.56, by using the proposed NuRe method. In addition, the best Average Lower Total Performance (AVG LTP) was at $T_{change} = 4$ with the value of 478.55 and at $T_{change} = 3$ with the value of 467.70, by using the proposed NuRe method. These values are significantly better compared to SCC method. With these results we can conclude that the critical time for the Hospital manager to apply the reallocation of the nurses is between the time period $t = 3$ and $t = 4$.

Figure 3 illustrates the comparison between the average results of the proposed method (NuRe) and the results based on the Simulated Change Curve (SCC) for $T_{change} = 3$ and $T_{change} = 4$.

5 CONCLUSIONS

This paper introduces and tests a new innovative method (NuRe) for addressing and managing nurses' resistance during the change process of the EHR implementation. The innovative idea is based on the continuous monitoring and one reallocation of nurses to tasks, during the period of change. It takes into account the changes in employee performance and the resistance to change at regular intervals during the change period and reallocates once the human resources.

In order to verify the efficiency of the proposed NuRe method, suitable experiments were designed and executed. It can been concluded from the experiments results that the critical time for the hospital manager to apply the reallocation of the nurses is at the early stages, between time interval t=3 and t=4 of the total time

Table 2: Comparison of numerical Results for 10,000 repetitions between the proposed NuRe method and SCC method (bold indicate the two best total performance values). AVG TP: Average Total Performance, AVG LP: Average Lower Total Performance.

Reallocation Time ($t = T_{change}$)	SCC (AVG TP)	NuRe (AVG TP)	SCC (AVG LTP)	NuRe (AVG LTP)
1	612.04	658.85	286.50	332.95
2	611.70	749.56	284.93	433.87
3	612.89	***769.43***	285.94	***467.70***
4	611.27	***765.56***	286.47	***478.55***
5	612.38	757.57	285.88	441.32
6	611.90	746.63	286.18	376.27
7	611.99	735.00	285.25	320.22
8	611.60	721.19	286.44	286.44
9	611.94	708.51	286.23	286.23
10	611.07	695.90	287.15	285.76
11	612.38	686.06	285.80	285.80
12	611.37	674.31	285.99	286.99
13	611.90	663.83	285.13	285.132
14	611.99	650.03	286.68	286.68
15	612.53	633.53	285.02	285.02

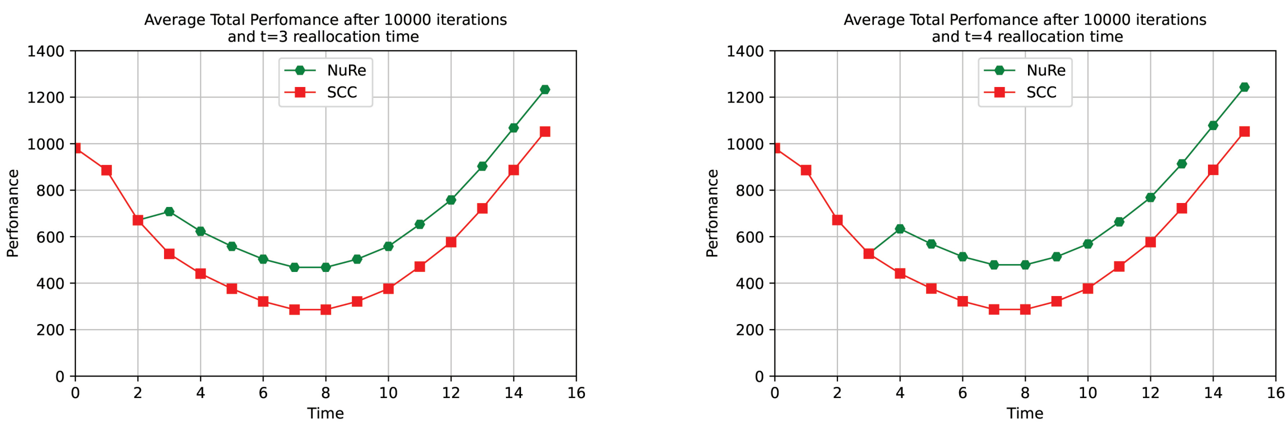

Figure 3: Comparison between the average results of the proposed method (NuRe) and the results based on the simulated change curve (SCC) for $T_{change} = 3$ and $T_{change} = 4$ reallocation time.

period ($T = 15$), something that can be interpreted as at the 20-25% of the expected change time. Thus, the overall performance will be significantly improved and the possibility of a failure in the implementation will be reduced.

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