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Ranking the Macro-Level Critical Success Factors of Electronic Medical Record Adoption Using Fuzzy AHP Method

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ABSTRACT: Electronic Medical Record (EMR) has been introduced into healthcare organizations in order to incorporate better use of technology, to aid decision making and to facilitate searching for a medical solution. The EMR is an Information Technology (IT) tool supporting the examination, treatment and care of patients. Low adoption of the EMR persists despite the obvious benefits of centralized medical record management. The rate of EMR implementation among physician practices has been slow and limited. This needs those professionals in healthcare organizations to be in the process of changing from the use of paper to maintain medical records into computerized medical record keeping opportunities. The critical users are physicians, which play an important role in success of Health Information Technology (HIT) including EMR. Hence, study regarding individual level of adoption in EMR should be done to understand more about this issue. Hence, the objective of this paper is to finding out the imperative factors in affecting EMR adoption. The macro-level framework evaluated based on Fuzzy Analytic Hierarchy Process (F-AHP). Basically, surveys distributed to physicians who has experienced with using EMR technology in three Malaysian public hospitals. Findings showed the most important factors and sub-factors in macro-level context related to adoption of EMR. The results of F-AHP showed that the most important factors are Socio-pol-economic trends and HIS standards and the most important sub-factors are economic trends, standardized data, and political trends.

KEYWORDS: Electronic Medical Record (EMR), Health Information System (HIS), Health Information Technology (HIT), Fuzzy AHP.

1 INTRODUCTION

The main healthcare providers in developing countries are hospitals; therefore it is the first priority in hospital setting to be the one when there is a purpose on improving health information system [1]. According to [2] a medical record is defined as "file that contains records and documents about a patient's identity, and also medical examinations, treatments, actions, and other services provided to the patient". Medical records can be used to help physicians in documenting historical records and patient service management [2]. Compared to paper-based medical records, Electronic Medical Record (EMR) gives a greater possibility for physicians to improve their work performance quality [2]. The impact of the use of EMR is also mentioned in study of Lau et al. [3], which stated that 64.3% of studies on EMR found that it can improve the performance of

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medical personnel. The potential value for EMR is widely acknowledged, including improved office productivity, care coordination, and patient safety [17]. It is especially important for the EMR equipped public hospitals to perform efficiently whilst providing excellent services to the public [18]. Nowadays with large number of public hospitals, information is not integrated and mostly stored on paper. This causes significant challenges in the sharing of patient information due to duplication of information across the multiple healthcare service providers and geographic distances. This renders to decrease the quality in providing feedback by physicians to patients [15]. EMRs would remedy the intrinsic flaws of the conventional paper system through improvements in accessibility, efficiency, quality of data capture and cost saving [4]. Furthermore, the healthcare sector has also been reported to be slow in adopting of the EMR [19]. In relation with EMR, the current and emerging use of technology in healthcare is aimed at providing a well-integrated EMR in the effort to improve patient safety, increase quality of medical care and decrease healthcare costs to the community [11]. The purpose of this paper is to describe the factors that have more priority in affecting EMR to adopt in public hospitals in Malaysia.

The remainder of this paper is structured as follows. Section 1, describes the EMR and gives an overview of this research. Section 2 introduces the proposed research model. In Section 3, we explain the research methodology step by step. In Section 4, the data collection is discussed. Finally, the Fuzzy Analytic Hierarchy Process (F-AHP), results of F-AHP, and conclusion are expounded in Sections 5, 6, and 7, respectively.

2 PROPOSED RESEARCH MODEL

The framework for EMR physician adoption gives a conceptual framework to find out the most important factors that have an effect on acceptance of this new technology. This will follow Infoway Benefits Evaluation (BE) framework [10] (adapted from the [22] information system success model, which thereafter [23] in his study review developed Clinical Adoption (CA) framework based on three dimensions. It covers three aspects of micro, meso and macro-level dimensions. Each dimension has its own factors and sub-factors which could influence acceptance of physicians in adoption of EMR. In this study, macro-level factors have been concentrated to evaluate their impact on technology adoption. Physician adoption model at the macro-level determines Health Information System (HIS) success related to healthcare standards, legislation, policy governance, funding incentives and social-pol economic trends. Each of these has their own sub-factors which are found out their priority on EMR adoption. The physician adoption model was developed with a range of HIS in mind, including EMR. EMR adoption has been explained and impacted on physician practice, according to evaluation measures utilized in the studies. In regards of factors that have been caused by this impact, it has been described as the reasons cited that could explain the adoption and effect. Hence, in this study, it is concentrated on macro-level aspects that influence on EMR adoption. At the end, the proposed model has been enhanced and shown in Figure 1. At the macro-level, factors under HIS standards included standardized data [5,16]. Second, practice standards includes, medicolegal [21,16] prescribing practice [6], and guidelines [25] that affected EMR design/performance and user behaviors. Standardization would ensure that those who create data do so in a form that would be automatically recognizable and structured on receipt. The continuity of care record standard initiative specifies both the format and primary care owner of any report in a way that could be recognized by an Electronic Health Record (EHR).

Medicolegal is a phenomenon that has been addressed as a large concern which is the benefits of improved documentation [16]. In the Netherlands a Decision Support System (DSS) for prescribing drugs was introduced for General Practitioners (GPs) in 1998. The DSS was introduced to implement professional guidelines regarding the prescription of drugs. Prescription of drugs has great importance in modern health care [6]. Third, factors under legislative acts included need paper [21] and documentation [20]. Good documentation of patient records has been considered as a basis for good health care. The quality of patient records was found to depend on the electronic system used. The Electronic Patient Record (EPR) system seemed to have an influence on the documentation procedure. Documentation of records compared with legislation, the general informative value of records, and its relation to the experienced quality of consultations and to the electronic system employed [20].

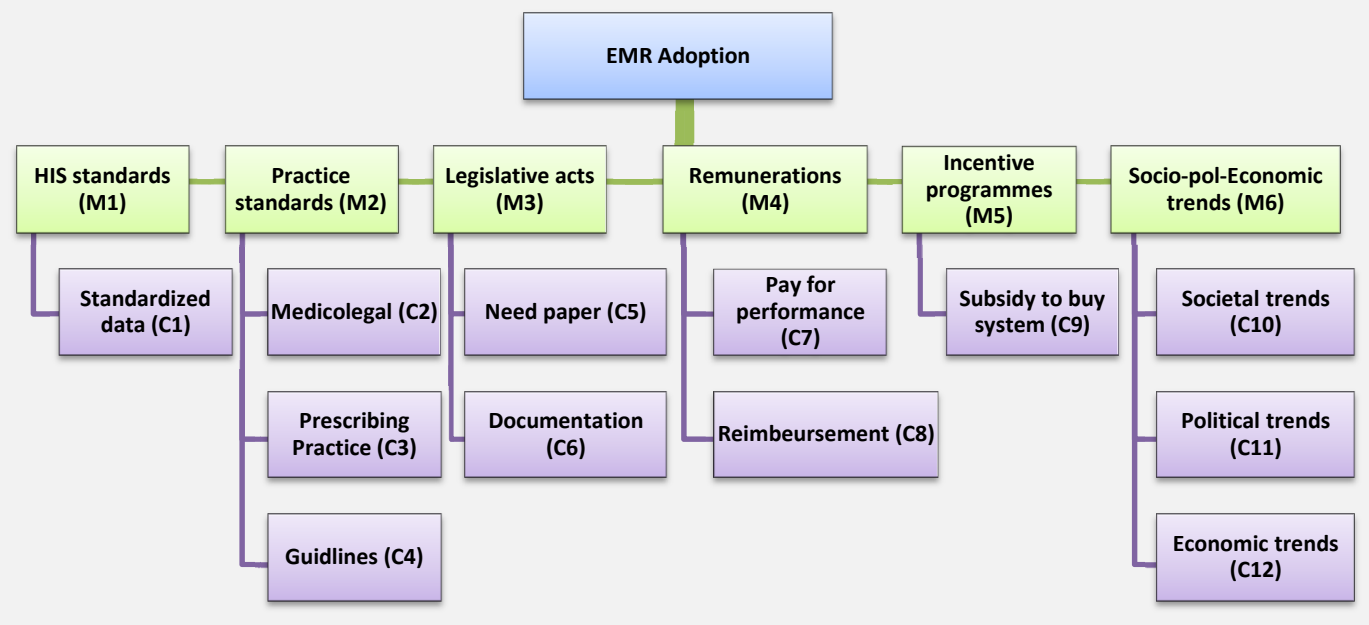

Fig. 1. Physician Adoption Model in Macro-Level

Fourth, factors under remunerations, are pay for performance [16,21,23] and reimbursement [24]. Fifth, factors under the incentive programmes are subsidy to buy the system [16]. Sixth, factors under socio-pol-economic trends are societal trends, political trends and economic trends [10]. Macro-level factors that found in previous research which has an effect on EMR adoption and effect were shown (see Table 1).

Table 1. Macro-level factors that influence EMR success

Factors	Sub-factors	References
HIS standards	Standardized data	[5,16]
Practice standards	Medico legal	[21,16]
	Prescribing practice	[6]
	Guidelines	[25]
Legislative acts	Need paper	[21]
	Documentation	[20]
Remunerations	Pay for performance	[16,21,23]
	Reimbursement	[24]
Incentive Programs	Subsidy to buy system	[16]
Socio pol Economic trends	Societal trends	[8,9]
	Political trends	[8,9]
	Economic trends	[8,9]

3 RESEARCH METHODOLOGY

A quantitative survey-based research study was performed and was analysed to explaining the factors that have an effect on EMR adoption. The three public hospitals in Malaysia practicing EMR have been chosen to conduct this research. A survey distributed to 12 physician experts in using EMR. The survey contains a number of questions that were designed to capture information about the factors and related sub factors in the research model. The questions that measured were HIS standards, practice standards, llegislative acts, remunerations, incentive programs and social-pol-economic trends besides

their sub-factors. F-AHP was used to obtain the ranking of these factors. Figure 2, contains a description of each step in this study.

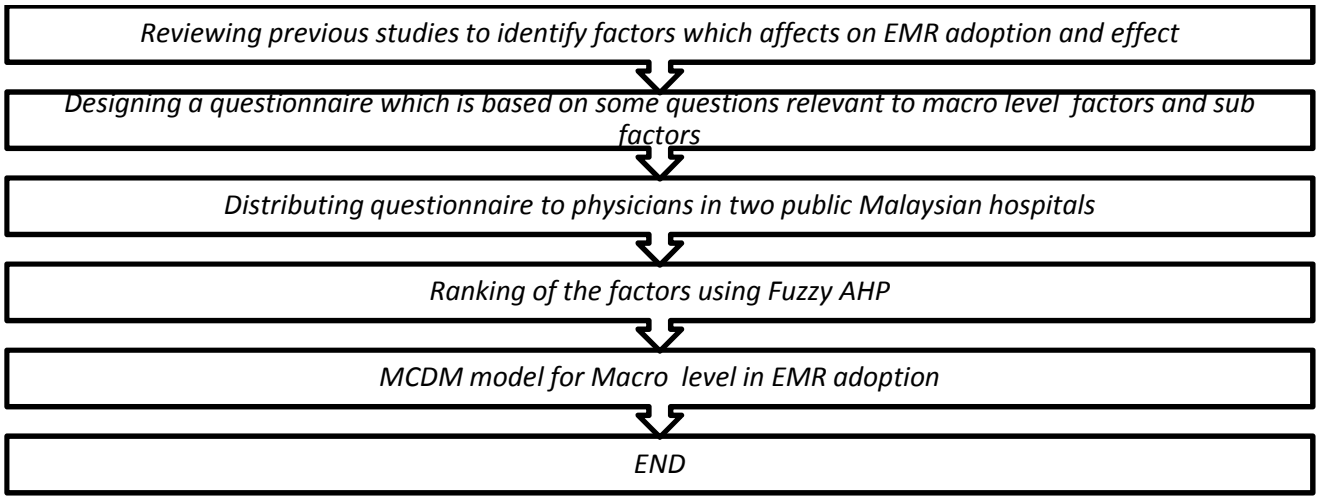

Fig. 2. Research methodology

4 DATA COLLECTION

In this study, the primary data was collected through sets of pairwise questionnaire which delivered to the physician experts in using the EMR systems. In this research, the questionnaires by email have been dent by researchers as an efficient and effective instrument to collect data from the respondents. For this study, numbers of respondents for pairwise questionnaire, were 12 (n=12) experts. All experts give the feedback in the pairwise questionnaire. The first section comprises of information on respondent demographic profile, six sections on the independent variables and twelve of their sub-variables. Five options (index) ranked from 1-5 for the raised questions as: 1= very low important 2=low important 3=moderately important 4= high important 5= very high important. Table 2 provides the respondents' demographic profile. About twenty five percent of physicians were male and the rest, were female who work as a medical professionals.

Table 2. The respondents' demographic profile

Pairwise Questionnaire			
Gender	Male	3	25%
	Female	9	75%
Age	30-40	4	33.33%
	40-45	5	41.66%
	45-50	3	25%
Years of electronic medical records	1-5	7	58.33%
experience	6-10	3	25%
	Over 10	2	16.66%

5 FUZZY AHP

The AHP method was proposed by [27,28]. Among Multi Criteria Decision Making (MCDM) techniques, it is a powerful approach to solve complex decision problems [7,12,13,14]. AHP rank and prioritizes the relative importance of a list of criteria in decision making problems. The elements for ranking can be critical factors and sub-factors which through pairwise comparisons amongst the factors by relevant experts using a nine-point scale are prioritized. F-AHP was proposed by Buckley [26] with incorporating the fuzzy theory into the AHP. Buckley [26] started the F-AHP derives more precisely results rather than AHP for vague and subjective decision making problems. Both quantitative and qualitative can be used in F-AHP. In F-AHP, the uncertain comparison, judgment can be represented by the fuzzy number. There are several types of membership

functions for F-AHP where triangular fuzzy number is the special class of the fuzzy number whose membership defined by three real numbers, expressed as (l, m, u). The triangular fuzzy numbers are represented as follows:

$$\mu_{\tilde{A}}(x)=\begin{cases}\dfrac{x-l}{m-l}, if\ l\le x\le m\\ \dfrac{u-x}{u-m}, if\ m\le x\le u\\ 0, \quad otherwise\end{cases} \tag{1}$$

.

For constructing pairwise comparisons of alternatives under each criterion or about criteria from the experts, similar to the pure AHP, a triangular fuzzy comparison matrix is defined as follows (it can be any type of membership functions):

$$\tilde{A}=(\tilde{a}_{ij})_{n\times n}=\begin{bmatrix}(1,1,1) & (l_{21},m_{12},u_{12}) & (l_{1n},m_{1n},u_{1n}\\ (l_{21},m_{21},u_{21}) & (1,1,1) & (l_{2n},m_{2n},u_{2n})\\ (\mathrm{l}_{n1},m_{n1},u_{n1}) & (\mathrm{l}_{n2},m_{n2},u_{n2}) & (1,1,1)\end{bmatrix} \tag{2}$$

.

Where $\tilde{a}_{ij}=(l_{ij},m_{ij},u_{ij})=\tilde{a}_{ij}^{-1}=(1/u_{ij},1/m_{ij},1/l_{ij})$

Different methods can be used for total weighs and preferences of alternatives which one of them is Fuzzy extent analysis proposed by Chang (1996). The steps of Chang's extensive analysis can be summarized as follows:

First step: In this step we compute the normalized value of row sums (i.e. fuzzy synthetic extent) by fuzzy arithmetic operations presented in Equation 3.

$$\tilde{S}_i=\sum_{j=1}^{n}\tilde{a}_{ij}\otimes\left[\sum_{k=1}^{n}\sum_{j=1}^{n}\tilde{a}_{kj}\right]^{-1} \quad . \tag{3}$$

In Equation 3, $\otimes$ denotes the extended multiplication of two fuzzy numbers.

Second step: In this step, we compute the degree of possibility of $\tilde{S}_i\ge\tilde{S}_j$ by Equation 4:

$$V(\tilde{S}_i\ge\tilde{S}_j)=\underset{y\ge x}{\mathrm{sub}}[\min(\tilde{S}_j(x),\tilde{S}_j(y))] \quad . \tag{4}$$

Which can be equivalently expressed as,

$$V(\tilde{S}_i\ge\tilde{S}_j)=\begin{cases}1 & m_i\ge m_j\\ \dfrac{u_i-l_j}{(u_i-m_i)+(m_j+l_j)} & l_j\le u_i\quad i,j=1,...,n;j\ne i\\ 0 & otherwise\end{cases} \quad . \tag{5}$$

Third step: In this step, using Equation 6, we calculate the degree of possibility of $\tilde{S}_i$ to be greater than all the other (n-1) convex fuzzy numbers $\tilde{S}_j$.

$$V(\tilde{S}_i\ge\tilde{S}_j\mid j=1,...,n;j\ne i)=\min_{j\in(1,...,n)j\ne i}V(\tilde{S}_i\ge\tilde{S}_j),\ i=1,...,n \quad . \tag{6}$$

Fourth step: In this step, using Equation 7, we define the priority vector $W = (w_1, ..., w_n)^T$ of the fuzzy comparison matrix $\tilde{A}$ as:

$$w_i = \frac{V(\tilde{S}_i \geq \tilde{S}_j \mid j = 1, ...n; j \neq i)}{\sum_{k=1}^{n} V(\tilde{S}_k \geq \tilde{S}_j \mid j = 1, ...n; j \neq k)}, i = 1, ..., n \qquad (7)$$

.

6 RESULTS OF WEIGHTING USING FUZZY AHP

Using fuzzy AHP, the end weights of all main-factors and sub-factors were calculated which are shown in Tables 3 and 4, respectively. It can be see that in the Macro-level, main factors such as M1 (0.2912) (HIS Standards) and M6 (0.3423) (Socio pol Economic trends) have the high level of importance rather than others. In addition, from the results it can be concluded that C12 (0.3592), C1 (0.2823), C11 (0.2129), C7 (0.2102) and C3 (0.2034) are the most important criteria for HIS adoption in the Macro-level.

Table 3. Weights of main-factors by Fuzzy AHP

Parameters ranking by Fuzzy AHP	
Parameters	Weight
M1	0.2912
M2	0.1311
M3	0.2567
M4	0.1762
M5	0.2289
M6	0.3423

Table 4. Weights of sub-factors by Fuzzy AHP

Parameters ranking by Fuzzy AHP	
Parameters	Weight
C1	0.2823
C2	0.1011
C3	0.2034
C4	0.1722
C5	0.1288
C6	0.1433
C7	0.2102
C8	0.1621
C9	0.1723
C10	0.1875
C11	0.2129
C12	0.3592

7 CONCLUSION

In this research, macro-level framework was evaluated by using Fuzzy AHP and the importance of sub-factors inside their appropriate factors was determined out. EMR adoption model was evaluated and investigated to increase the medical professionals' behavior in adopting and using of this specific type of technology which can positively affect their performance in doing their work routines. This study conducted in the physician's community in public hospitals in Malaysia and it is hoped that finding of this study provide the essential components to make sense of EMR adoption in the individual level. Findings showed the most important factors and sub-factors in macro-level context related to adoption of EMR. The most important

factors are Socio-pol-economic trends and HIS standards and the most important sub-factors are economic trends, standardized data, and political trends.

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