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APPLICATION OF FUZZY SIMULATION FOR EVALUATING ENTERPRISE APPLICATION INTEGRATION IN HEALTHCARE ORGANISATIONS

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Abstract

Healthcare organisations have focused on the latest technological innovations to overcome their organisational and clinical problems. The information systems were not developed in a cordinated way but evolved as autonomous and hetrogeneous systems. Thus, the integration of these systems represents one of the most urgent priorities of healthcare organisations that allow the whole organisation to meet the increasing clinical, organisational and managerial needs. Recently, technological developments have emerged in the area of integration technology such as Enterprise Application Integration (EAI). This provides significant benefits to organisations to overcome the integration problem. This work therefore evaluates the adoption of EAI in healthcare organisations. In doing so, Fuzzy Cognitive Mapping (FCM) simulation is used to demonstrate the causal inter-relationships between the EAI adoption factors. FCM simulation provides insights into better understanding about interdependencies of the factors that influence EAI adoption in healthcare organisations.

Keywords: Healthcare Organisations, Enterprise Application Integration, Fuzzy Cogitative Maps, Simulation.

1 INTRODUCTION

For the past decades, organisations have focused on the latest technological innovations to overcome their organisational problems and automate their business processes. As a result, there was rarely a single approach for implementing Information Systems (IS), as organisations have developed their applications without a common enterprise architectural planning (Markus and Tanis, 1999; Themistocleous, 2004). Nowadays, dozens, if not hundreds of different types of open and proprietary systems exist in organisations (Chalmeta *et al.*, 2001). Many of these systems have their own database, networking, and operating systems. As a result, the majority of companies were left with a collection of disparate and, in many cases, incompatible systems (Erasala *et al.*, 2002). Therefore, this diversity of heterogeneous systems causes numerous problems due to the non-integrated infrastructure.

The first approach towards industry integration was focused on the technological aspects, solving the connection problems between different devices, and the exchange of information between computer applications (Sutherland and Heuvel 2000; Chalmeta *et al.*, 2001). Themistocleous *et al.*, (2001) and Puschmann and Alt, (2004) estimate that for x applications, a total of **x*(x-1)/2** interconnections are needed when each application is interconnected with the rest of the applications. Interconnecting applications is a very difficult task. To achieve interconnectivity among applications, programmers map data from the source's application format to the target's since applications require compatible data to store and manipulate them. In support of this, programmers invade and alter the code of systems to map data and create these interconnections Themistocleous *et al.*, (2001). However, this is a complex and time consuming process. In addition, the maintenance of applications is a problem, which costs more time and money. Each interface usually requires some amount of time to build, and then time and effort directed to maintenance Puschmann and Alt, (2004). Therefore, the maintenance of these interconnected IT solutions becomes a significant issue of concern. As a result, organisations spend at least 40% of their IT budget to solve the integration problem Puschmann and Alt, (2004).

Enterprise application integration have been introduced as a solution to intra and inter-organisational systems and process integration. For various reasons, it results in more organised business process, achieves Return On Investment (ROI), increases collaboration among partners, achieves process integration and reduces cost (Themistocleous *et al.*, 2001). In addition, EAI aims at integrating individual applications into a seamless whole, enabling business process and data to speak to one another across applications (Stal, 2002; Sharif *et al.*, 2005). EAI can efficiently incorporate custom applications, packaged systems and e-business solutions into a flexible and manageable infrastructure (Irani *et al.*, 2003).

In exploring EAI, this study seeks to expand the knowledge on EAI, and will focus on evaluting the adoption of EAI in healthcare organisations by using FCM simulation. The application of FCM simulation identifies casual inter-relationships among EAI adoption factors. This enhances the quality of the evaluation process, and highlights the importance of each factor and its inter-relationship with other factors. This evalution can be used as a decision-making tool to support the management of the healthcare when taking decisions regarding the adoption of EAI. In doing so, healthcare organisations may benefit from this. This paper consists of 6 sections. Section 2 provides an overview of FCM technique and section 3 discusses the FCM model for the evalution of EAI in healthcare organisation. Section 4 presents actul simultion of FCM model and comments on their charcteristics. In section 5 simulation results and the analysis is presented. Finally section 6 provides the conculsions.

2 FUZZY COGNITIVE MAPS

The technique of fuzzy cognitive mapping is based upon the science of Fuzzy Logic (Zadeh, 1965), is a natural extension to cognitive maps. An FCM is a method to graphically represent state variables within a dynamical system, by links that signify cause and effect relationships, being augmented with fuzzy or multivalent weights, quantified via numbers, or words (Kosko, 1990). The experts give qualitative estimates of the strengths associated with edges linking nodes. These estimates are translated into numeric values in the range –1 to 1. The experts themselves may be asked to assign these numerical values (Irani *et al.,* 2002; Lee *et al.*, 2004). The outcome of this exercise is a diagrammatic representation of FCM, which is converted into the corresponding edge matrix. This graphic display will clearly show which factor influences and what this degree of influence is. The advantage of modelling systems such as those mentioned via an FCM, is that even if the initial mapping of the problem concepts is incomplete or incorrect, further additions to the map can be included, and the effects of new parameters can be quickly seen (thus providing a holistic picture of the scenario being modelled).

3 FUZZY COGNITIVE MAP MODEL FOR EAI EVALUATION

Khoumbati *et al*., (2006) developed a FCM based model for the evaluation of EAI in healthcare organisations. This model is represented in Figure 1.

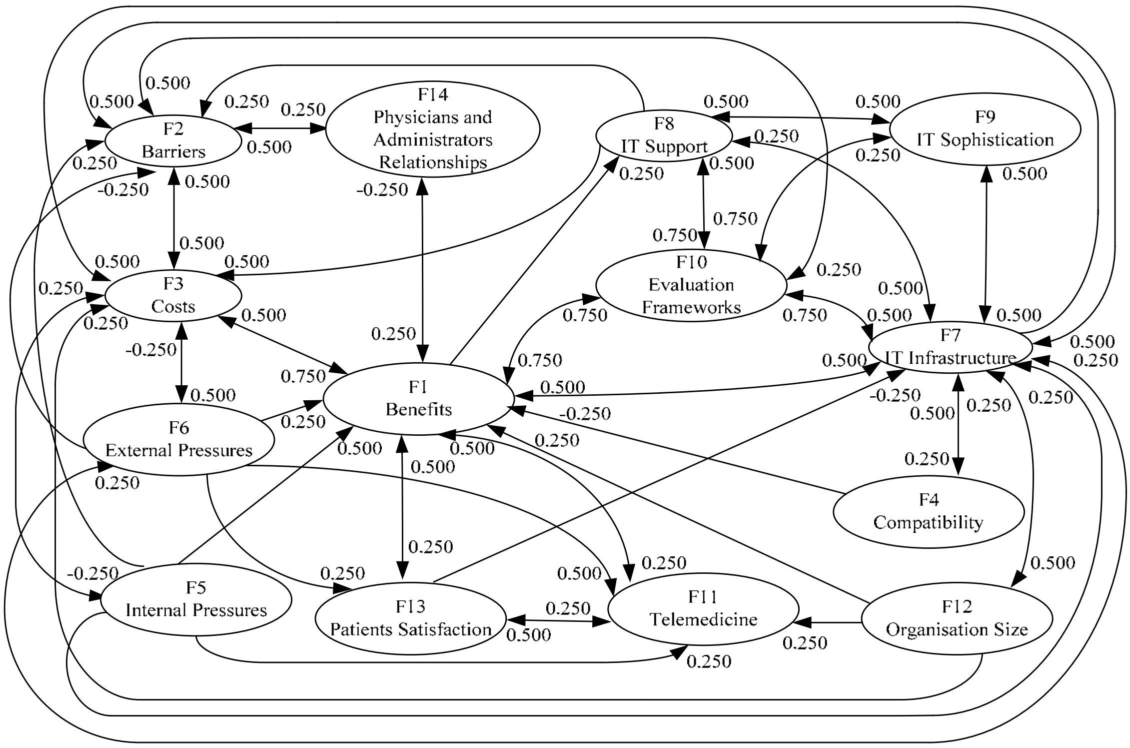

Figure 1. FCM Model for the Evaluation of EAI in Healthcare Organisations

In this model 14 key factors associated with the take-up of EAI have been discussed, which through a robust evaluation approach explain the adoption of EAI in healthcare organisations. The case study research was adopted for the development of this FCM based model. The hospital where this study was conducted serves a population of approximately 360,000 persons and is located in the Northwest of England. The hospital was facing the challenge to provide secure, accurate and up-to-date electronic records that would be available and improve clinical governance. As a result, the concept of an integrated electronic health record was introduced as a means of sharing a summary of the patient record for the benefit of clinicians, partner organisations and patients. The application of FCM demonstrates inter-relationships of influencing factors for the adoption of EAI in this case hospital. This provides insights into the direction of better understanding of the factors like (F1) Benefits, (F2) barriers, (F3) Costs, (F4) Compatibility, (F5) Internal Pressures, (F6) External Pressures, (F7) IT-Infrastructure, (F8) IT Support, (F9) IT Sophistication, (F10) Evolutions Framework, (F11) Telemedicine, (F12) Organisation Size, (F13) Patients satisfaction and (F14) Physician and Administrators Relationships that influence EAI adoption. As such, a detailed analysis of this FCM model is now given in terms FCM simulation in the following section.

4 SIMULATION OF FCM MODEL FOR THE EAVLAUTION OF EAI

In this section the manually developed FCM models is used to see the simulated behaviour of the causal inter-relationships of the EAI evaluation factors in healthcare organisations. The computation of the node's output is based on the combination of a summing operation followed by the use of a non-linear transformation such as threshold function. The summing operation involves multiplying each input Ci with the weight or strength eij of the corresponding causal link by using the following equation:

$$C_i^{t+1} = f\,\left(\sum_{j=1}^{n} E_{ij}\, C_i^{\,t}\right) + C_i^{\,t-1} \qquad (1)$$

Equation (1) describes by Kosko (1990) a functional model of FCM, which is used to perform simulation. In this equation (1) C_i^{t+1} represents the value of the node at the t+1 iteration, C_i^{t-1} represents the value of the node at the t-1 iteration, *f* is a given threshold or transformation function, E_{ij} is a corresponding fuzzy weight between two given nodes, i and j and C_i^{t} the value of the interconnected fuzzy node at step *t*.

The transformation function is used to confine the weighted sum to a certain range, which is usually set to [0, 1]. The transformation function can be constructed by using the most commonly used transformation function as described below:

- Bivalent (x = 0, 1),
- Trivalent (x= -1, 0 or 1),
- Hyperbolic (tanh(x)), and
- Logistic (x = 1/1 +e^{-cx}, where c is constant).

The possible results of a simulation performed with FCM depend on the transformation function. Therefore, it requires the additional definition of the fuzzy wrights, $E_{ij,}$ within a connection matrix, *E* and the initial or starting input vector at time t, C^t.

As such the strength of relationship between two nodes usually takes on any value in the [-1, 1] range. The value -1 represents full negative, whereas +1 full positive casual effect. Zero denotes no causal effect. Thus, the definition of system relationships can be described by a matrix, called connection matrix. Considering the system with n factors nodes, with n by n matrix, this can be written as $E= E_{iJ}$. The initial state of the systems is determined by an initial rowvector that can be represented as:

$C^0 = (Ei,j, \ldots\ldots.., E^n_{i+1, j+1})$

The initial rowvector value specifies the current values of all factor nodes in a particular iteration. The value of the given node is calculated from the preceding iteration values of nodes. Thus, the simulation proceeds by computing the C_i^{t+1} based upon this initial starting rowvector, the given threshold function in *f*, and the causal connection strengths in the n X n matrix, E. Therefore, for the purpose of this study threshold function, f, for FCM simulation as given in equation (1) was set to hyperbolic function, f(x) = tnah (x). Table 1 shows a number of initial rowvectors C0 which were used by the authors to demonstration the interrelation of each factor with other factor at the successive time steps.

Factors	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**	**F12**	**F13**	**F14**
F1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
F2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
F3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
F4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
F5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
F8	0	0	0	0	0	0	0	1	0	0	0	0	0	0
F9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
F10	0	0	0	0	0	0	0	0	0	1	0	0	0	0
F11	0	0	0	0	0	0	0	0	0	0	1	0	0	0
F12	0	0	0	0	0	0	0	0	0	0	0	1	0	0
F13	0	0	0	0	0	0	0	0	0	0	0	0	1	0
F14	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 1: Initial Starting Vectors for the FCM

5 SIMULATION RESULTS AND ANALYSIS

The simulation results of factor benefits are presented in Figure 2. It can be seen that an equilibrium steady-state point reaches within iteration 12. Initially at fully switched on state other factors do in fact shows the inter relationships at various levels of activations. The factors Costs, Evaluation Frameworks, IT Infrastructure present the very strong relationship with the factor benefits.

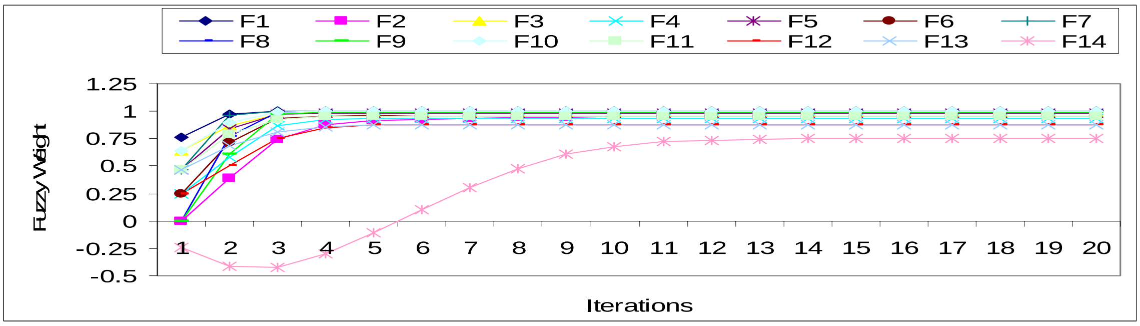

Figure 2: Simulations of Benefits

This relationship represents that the EAI evaluation frameworks provide the benefit to overcome market place confusion regarding the selection of particular EAI technology. The benefits show strong inter-relationship with patient satisfaction and telemedicine. The results suggest that the existing IT Infrastructure of the case hospital was not integrated; owing to this hospital was facing several problems. However, the adoption of EAI supports to overcome these problems and thus, resulted in an increase in patient satisfaction. The inter-relationship of benefits with internal pressures shows with the adoption of EAI internal pressures from several stakeholders such as physicians, regarding the availability of patients' information at the right place and right time. Thus, the adoption of EAI provides support in reducing these pressures. On the other hand physicians and administrators relationships factor shows less weak of inter-relationship with benefits.

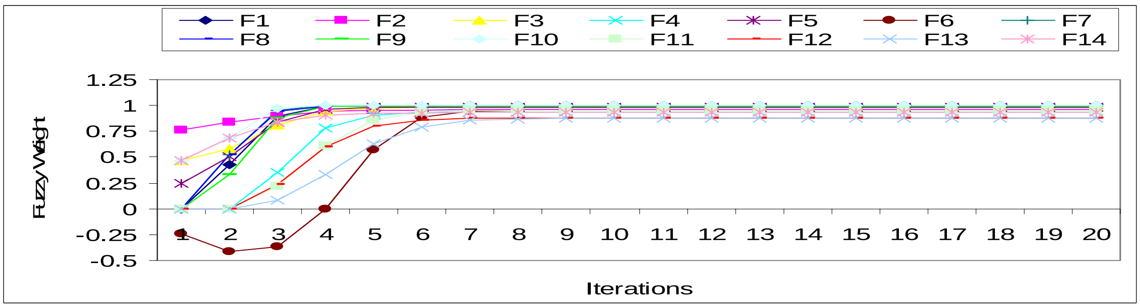

Figure 3: Simulations of Barriers

The factor **Barriers** show equilibrium steady-state fixed point reaches within iteration 7. The fully switched on state shows the inter-relationships with other factors at various levels of activations. It shows modrate inter-relationship with Costs, Evaluation Frameworks and Physician and Administrator relationships. These relationships are in line with the findings of the normative literature that suggests EAI technology represents an important barrier due to the variety of EAI technologies in the market; thus, organisations spent lot of resource and time to evaluate EAI technologies (Themistocleous *et al.*, 2004). On the other hand internal pressures factor shows less weak of inter-relationship with barriers.

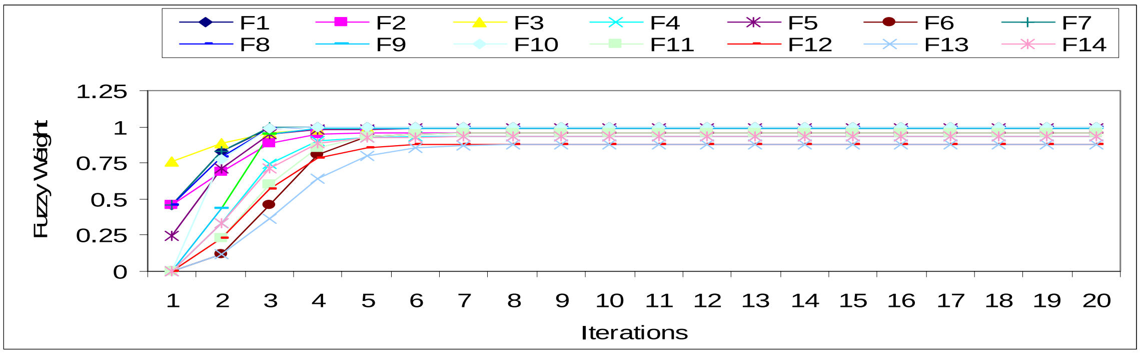

Figure 4: Simulations of Costs

Costs factor in Figure 4 at the fully switched on state shows the inter relationships with other factors at various levels of activations. A very strong inter-relationship with benefits is due to, hospitals, before the adoption of EAI technology conducted a cost benefit analysis. Therefore, the analysis of the expected benefits supported the case hospital for the investment of such amount. However, modrate relationship of costs is also represented in the Figure 4 with Barriers and IT infrastructure and weak relationship with Internal Pressures.

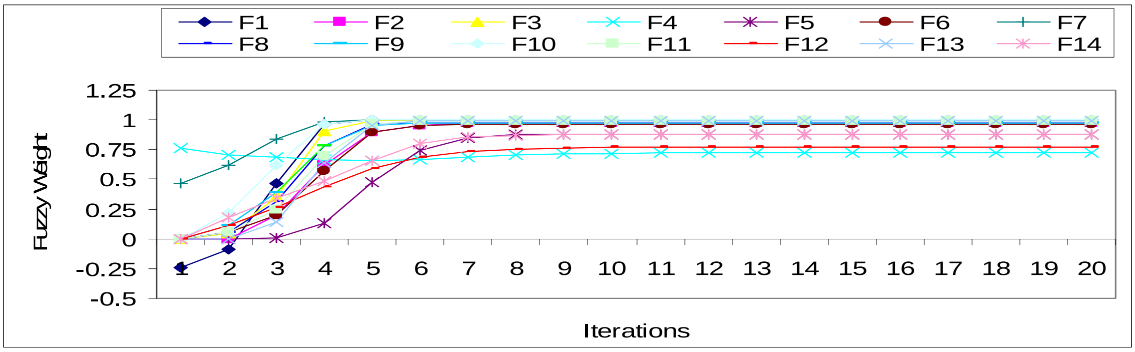

Figure 5: Simulations of Compatibility

The factor **Compatibility** shows that it presents moderate relationship with IT infrastructure. It is due to hospitals finding that EAI is consistent with their past values and practices, as the hospitals clinical staff have been using IT in their work at different levels. On the other hand it shows weak with costs, barriers, and internal pressures.

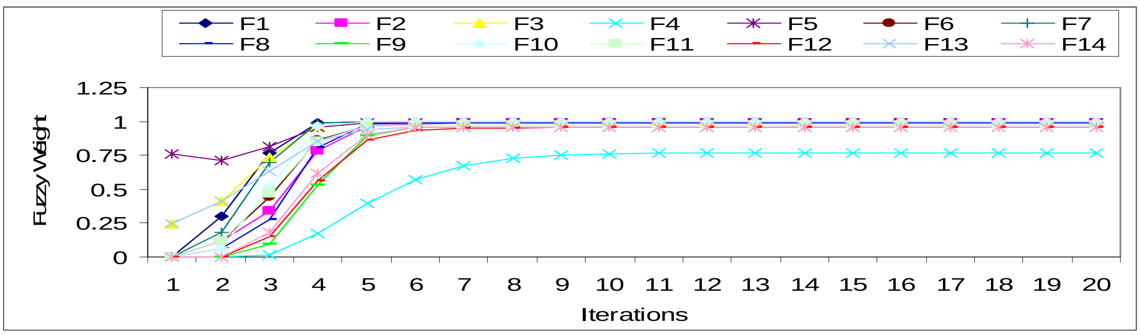

Figure 6: Simulations of Internal Pressures

The Figure 6 presents that at iteration 2 **Internal Pressures** have strong relationships with Benefits, IT Infrastructure and Costs. It appears that the internal pressure from the various stakeholders was one of the factors that initiated for the adoption of EAI in the hospitals. Most of the pressures were for the better utilisation of the existing IT infrastructure and getting the maximum benefits of the IT for the provision of better healthcare services. Internal pressures also represent a weak inter-relationship with organisation size.

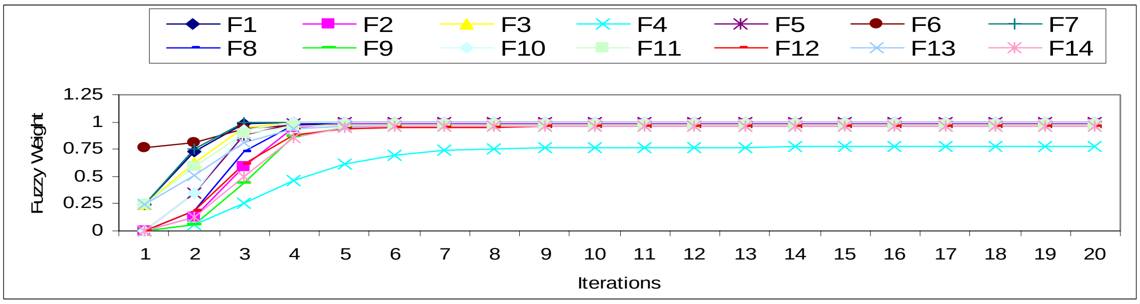

Figure 7: Simulations of External Pressures

External pressures appear to have a fully switched on state and shows the inter relationships with other factors at various levels of activations and reachises at equilibrium state at iteration 7. Figure 7 shows a weak inter-relationship with factors like benefits and modrate with telemedicine, costs and IT infrastructure. This inter-relationship demonstrates that the integration of telemedicine applications with the rest of the hospitals department was one of the motivations that initiated the adoption of EAI. Moreover, the external pressures from the patients and government organisations regarding the provision of better healthcare facilities initiated the adoption of EAI in case hospitals.

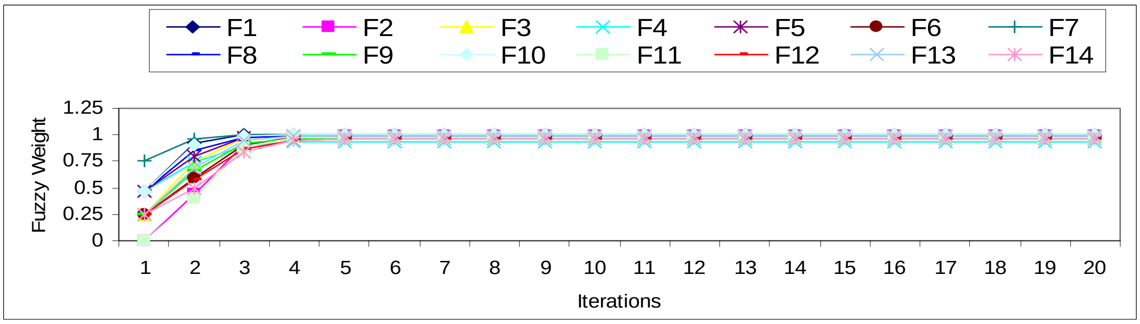

Figure 8: Simulations of IT Infrastructure

Based on Figure 8 it appears that the simulation occurs at iteration 5, the factor **IT Infrastructure** shows a modrate inter-relationship with Evaluation frameworks and benefits, strong inter-relationship with, costs and patients' satisfaction and weak inter-relationship with, IT support. The relationship of IT infrastructure with Evaluation framework shows that there is no single product that covers all integration requirements for its IT infrastructure. Thus, it is very difficult to decide which EAI product is suitable for the proposed IT infrastructure. Therefore, there is a need for a tool that can support organisations to select a particular technology according based on the requirements of their IT infrastructure.

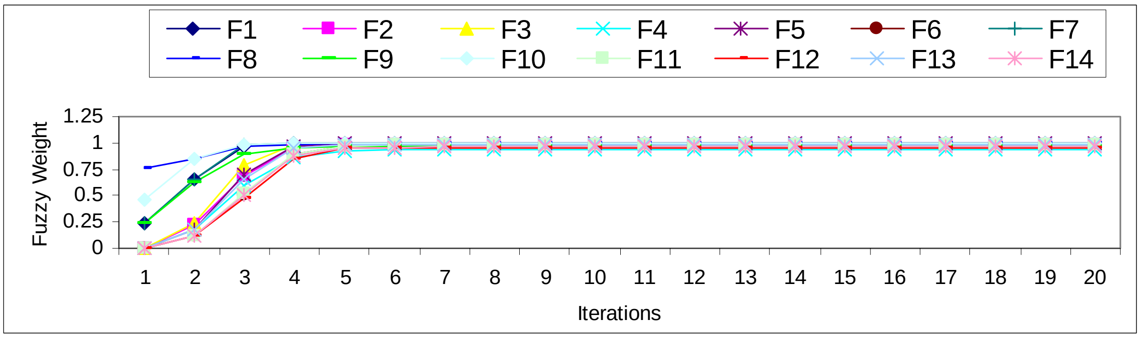

Figure 9: Simulations of IT Support

The simulation of **IT Support** can be seen at a particular point of interaction at iteration 5, where it can be seen a inter-relationship with the evaluation frameworks, moderate relationship with IT infrastructure, benefits and costs, weak relationship with barriers. The strong relationship with Evaluation Frameworks shows that hospitals were lacking the EAI experts which can access and select the particular EAI technology and packages. Therefore, the hospitals employed the services of external consultants to provide them the support for the selection of a particular EAI solution.

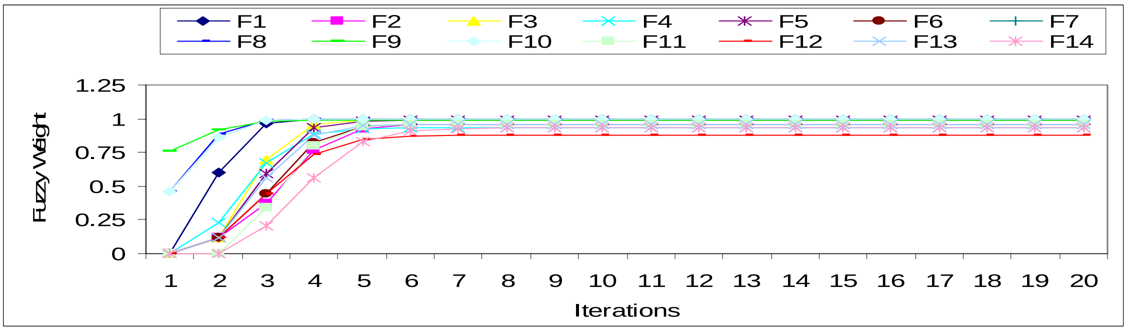

Figure 10: Simulations of IT Sophistication

The combined FCM simulation in Figure 10 depicts **IT Sophistication** has inter-relationship with factors like IT infrastructure, IT support and EAI evaluation frameworks. The strong inter-relationship of IT sophistication with evaluation framework shows that the hospitals were lacking the required level of knowledge of EAI skills to decide for a particular technology.

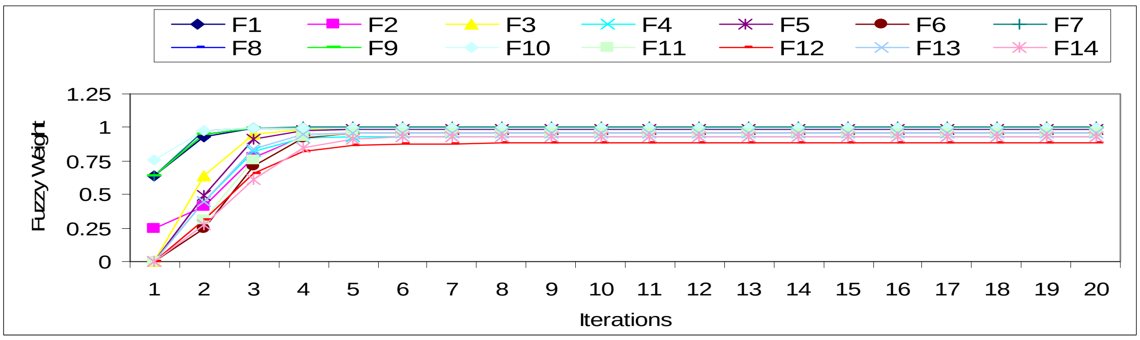

Figure 11: Simulations of Evaluation Frameworks

The factors in Figure 11 illustrate at iteration 2 a very strong relationship between **Evaluation Frameworks** and benefits. This finding is in accordance to the literature that suggests that EAI evaluation frameworks contribute towards the elimination of the marketplace confusion regarding the selection of particular package or technology. The evaluation frameworks show a strong relationship with barriers, IT infrastructure and IT support and weak relationship with IT sophistication.

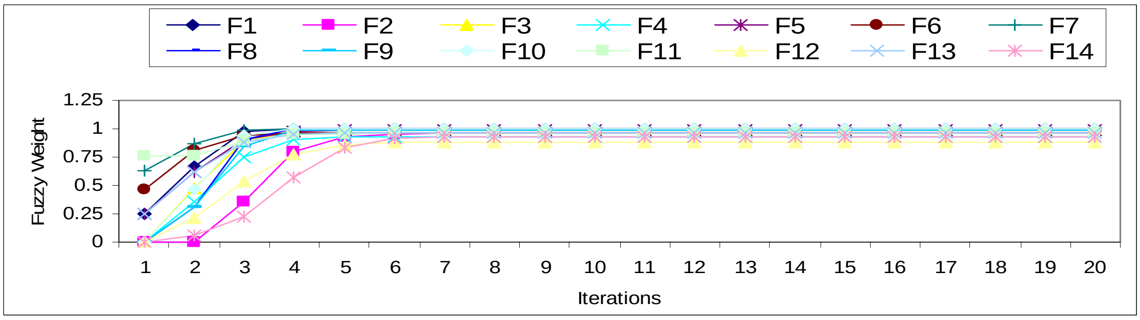

Figure 12: Simulations of Telemedicine

In Figure 12 **Telemedicine** shows strong inter-relationship with benefits and patient satisfaction at iteration 2 when the simulations are fully active. The finding shows that the integration of Telemedicine applications with the rest of the applications will provide an increased access to services for remotely located patients. As a result of such facilities, the patient's satisfaction has increased.

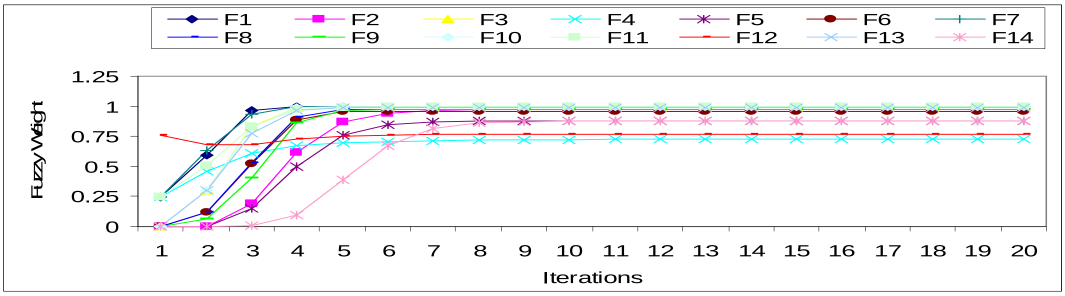

Figure 13: Simulations of Organisation Size

In Figure 13 at iteration 3 a particular point of interest can be seen for the factor O**rganisation Size.** It shows a very little interaction such as a moderate inter-relationship with IT infrastructure and patients satisfaction. This shows that the organisation size with a large number of different types of IT applications results in the non-integrated IT infrastructure. This finding is according to the literature findings that suggest that larger size healthcare organisations will likely to implement the IT innovations.

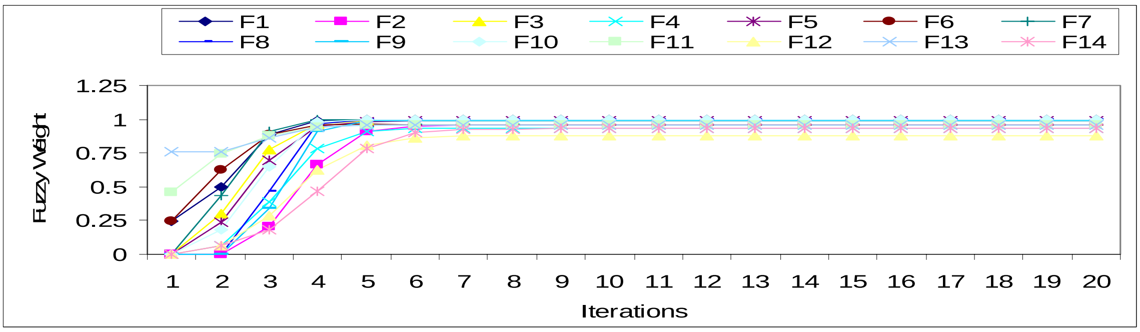

Figure 14: Simulations of Patient Satisfaction

Patients' Satisfaction has been represented in the Figure 14 with strong inter-relationship with benefits, moderate with Telemedicine. It appears that the adoption of EAI at the case hospitals, results in providing patients with several facilities such as: (a) online booking, (b) selecting a particular GP online, (c) changing the GP online and (d) viewing the medical record online. Also it provides many other facilities at the secondary care level such as: (a) the availability of laboratory results at the proper time has supported physicians, and (b) reducing medical errors has enhanced patient satisfaction.

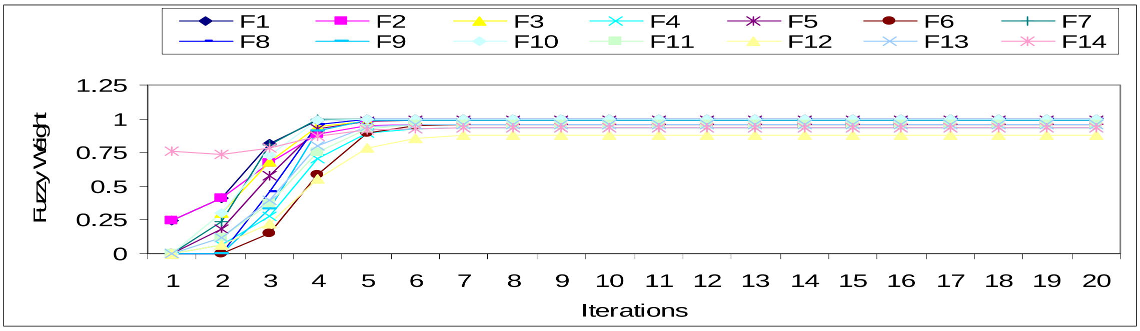

Figure 15: Simulations of Physician and Administrators Relationships

The factor P**hysician and Administrator Relationship** shows strong inter-relationship with barriers and moderate inter-relationship with the benefits and patients satisfaction. The inter- relationship with Barriers shows that due to the integration of healthcare information systems, the political barriers between administrators and physicians is particularly important.

6 CONCLUSIONS

The integration of healthcare information systems represents one of the most urgent priorities of healthcare organisations that allow the whole organisation to meet the increasing clinical, organisational and managerial needs. The research presented in this paper addresses the growing need to evaluate EAI adoption in healthcare organisations. Khoumbati *et al.*, (2006) analysed several factors and tested them through case study strategy that support the adoption of EAI in heathcare organisation. Using the concepts of these factors, the researchers further expanded the scope of the research by exploring the areas of EAI by using the FCM simulation.

The application of FCM simulation demonstrates the inter-relationship of the influencing factors for the adoption of EAI in heathcare organisations. This revealed how the map is constructed, and how the numeric values are assigned and simulated to represent the inter-relationship of each factor. This enhances the quality of the evaluation process, and shows the importance of each factor and its inter-relationship with other factors. This highlights the importnace of each factor and simulated interlationship with the other fcators. Thus, it provides insights into the direction of better understanding of interdependencies of the factors that influence EAI adoption. This approach may support the quality of decision making in healthcare organisations when considering the adoption of EAI. Further, it can support the researchers to analyse and understand the adoption process of EAI.

7 REFERENCES

Chalmeta, R., Campos, C. and Grangel, R. (2001) '*Reference Architecture for Enterprise Integration'*, The Journal of Systems and Software, 57(4): pp. 175-191.

Erasala, N., David, C. and Rajkumar, M. (2002) '*Enterprise Application Integration in the Electronic Commerce World'*, Computer Standards & Interfaces, 25(2): pp. 69-82.

Irani, Z., Sharif, A., P., L. and Kahraman, C. (2002) '*Applying concepts of fuzzy cognitive mapping to model: The IT/IS investment evaluation process'*, International Journal of Production Economics, 75(1-2): pp. 199-211.

Irani, Z., Themistocleous, M. and Love, P. (2003) '*The Impact of Enterprise Application Integration on Information Systems Lifecycles'*, Information & Management, 41(2): pp. 117-187.

Khoumbati, K., Themistocleous, M. and Irani, Z. (2006) '*Evaluating the Adoption of Enterprise Application Integration in Healthcare Organisations'*, Journal Management Information System, 22(4): (In Press)

Kosko, B. (1992) *Neural Networks and Fuzzy Systems,* Prentice-Hall International, Inc, Hammersmith, London.

Lee, S., Kim, B. G. and Lee, K. (2004) '*Fuzzy Cognitive Map-based Approach to Evaluate EDI Performance: A Test of Causal Model'*, Expert Systems with Applications, 27(2): pp. 287-299.

Markus, L. and Tanis, C. (1999) *The Enterprise Systems Experience-From Adoption to Success,* Pinnaflex Educational Resources, Oklahoma, USA.

Puschmann, T., and R. Alt. '*Enterprise application integration- the case of the robert bosch group'.* Journal of Enterprise Information Management, 17, 1 (2004), 105-116.

Sharif, A., Irani, Z. and Love, P. (2005) '*Integrating ERP using EAI: A Model for POST hoc Evaluation'*, European Journal of Information Systems, 14(2): pp. 162-174.

Stal, M. (2000) '*Web Services: Beyond Component -Based Computing'*, Communications of the ACM, 45(10): pp. 71-76.

Sutherland, J., and Heuvel, W. (2004) '*Enterprise application integration and complex adaptive systems'.* Communication of the ACM, 45**,** 10, 59-64.

Themistocleous, M. and Irani. Z. 'Evaluating and Adopting Application Integration: The Case of a Multinational Petroleum Company'. In Proceedings of 35th Hawaii International Conference on Systems Sciences, [CD-Proceedings]. 2002. USA: [CD-Proceedings].

Themistocleous, M., Irani, Z. and O'Keefe, B. (2001) '*ERP and Application Integration: Exploratory Survey'*, Business Process Management Journal, 7(3): pp. 195-204.

Themistocleous, M. (2004) '*Justifying the Decision for EAI Implementations: A Validated Proposition of Influential Factors'*, The Journal of Enterprise Information Management, 17(2): pp. 85-104.

Zadeh, L. A. (1996) '*Fuzzy sets, Information and Control'*, Fuzzy Logic Computing with Words, IEEE Transactions on Fuzzy Systems, 4(2): pp. 103-111.