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A Fuzzy Multi Attribute-Simulation decision making approach to study healthcare performance in RFID based systems

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With this research, author presents an understanding of business value that would be enhanced by adopting a new technology into the system. A healthcare center is the case here and the technology considered is radio frequency identification (RFID). To present such framework for evaluation purposes, a two-phase analysis is introduced. In the first phase and with the help of a multi attribute decision making in the context of hierarchical fuzzy TOPSIS, an RFID-based system among a set of proposed RFID based-systems is selected. In the second phase, with the help of system dynamics approach, the behaviors of system for goal variables are determined. To fully understand this approach, a sample case is provided and analyzed. This type of integrated decision-making approach can provide a deep understanding of the system because of providing one or more trends on key system variables based upon the optimal decision made at the present time using an MADM tool. Due to the fact that this research combines four fields of knowledge into an interesting research problem, of highly concerned to the users, it makes a true contribution to health, system dynamics, RFID and MADM. Integration of MADM and SD approaches in healthcare system has some very important benefits for healthcare managers. It allows managers in seeing the system behaviour now under the decision made at the present time using multi attribute decision making approach. A case dealing with three systems options to choose among was taken into the study. System with 60 percent RFID and 40 percent Barcode capability gained higher priority and hence employed for further analysis. RFID penetration factors were implemented to the scenarios to perform a sensitivity analysis on profit and productivity of the system. Results shows that as the level of RFID penetration increases the level of profit and productivity of the system increases as well.

Keywords: *RFID-based systems, Fuzzy MADM, healthcare management, system dynamics, policy analysis.*

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1. Introduction

RFID technology is a tool that is used for tracking the product and dealing with drug counterfeiting. Experts in industry believe that "between" five percent to eight percent of drug trading is counterfeiting and far more than that is occurring in the developing countries. RFID technology has tremendous potential for helping to solve this problem provided that industry is ready to pay for the technology. At the present time, this technology is used for tracking automobile in park lots, parts in computer stores,

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And books in bookstores, to mention a few. Although, this technology demands initial capital to begin with, it has potential to reduce operating expenses, increases overall productivity, and enhances total profit.

In research conducted by Yao and co-researchers [35] it was reported that in US alone, between 44000 to 98000 deaths per year occurs as a result of medical errors. Usually, problems related to healthcare operational failure are reported to be: medical mistakes, theft loss, drug counterfeiting, and increasing costs (Yao, et al. [35]. Some researchers conducted researches in health industry to deal with such problems using RFID technology. Haddara and Staaby [9] conducted research on the RFID application and adoptions in healthcare. Dinarević et al. [8] conducted research on the assessment of SAR using simplified body representation due to RFID field exposure. Camacho-Cogollo et al. [4] conducted research on the use of RFID in emergency room management while Kumar et al. [18] studied healthcare supply chain management. Paaske et al. [26] worked on the Benefits and Barriers to RFID Technology in Healthcare systems. Emergency room management was studied by Camacho-Cogollo et al. [4] and the public views of mobile medical devices and service was conducted by Katz and Rice [16]. Najafi et al. [23] performed a study on emergency supply chain management using system dynamics approach. Corchado et al. [5] reported on the intelligent environment using RFID for monitoring Alzheimer patients while Crayton and October [6] discussed incorporating RFID into the healthcare system. Rahimi et al. [28] conducted research on optimization model for hierarchical location and districting problem in healthcare system under uncertainty.

In this research, author demonstrates how the coupling of RFID technology with healthcare industry is cost effective and profit generating. Such research is needed for presenting to those managements not believing on investing in new technologies, especially in developing countries. By now, there are some healthcare services using this technology but what about those who ignore this technology and postpone its use to the future. The objective of this research is two folds: (1) to choose an RFID-based system among a set of available alternatives, as their set up and use in the healthcare system is possible; (2) predict systems performance using system dynamics approach. For this purpose, MADM and SD approaches will be used in this study. First, with the help of MADM, the ranking of alternatives get possible. Second, once management knows which alternative is the best, then he/she can evaluate its true impacts on the system's goal variables and their long terms behaviours. This empowers management in seeing the system behaviour now under the decision made at the present time using MADM approach. Author was motivated to find a response for the following question in healthcare area. Knowing that healthcare system equipping with full RFID technology is in demand now, is it possible to use partially equipped system as an alternative, instead of waiting for its full RFID implementation sometime in the future? Finding a way to choose the best alternative among all and then tracking the impacts of such decision on the system's behaviour through system dynamics is this research innovation.

The remaining of this work is organized as below: section 2 provides some descriptions of background materials broken down into: multi criterion decision making (MCDM), system dynamics (SD) and RFID technology. Section 3 is devoted to the research contribution and methodology. Our case study is presented in section 4. RFID risks and benefits in healthcare is the topic of section 5. Research proposition is presented in section 6 and then it is evaluated in section 7 using system dynamics approach. Model building by the mathematics of the problem is the topic of section 8. The proposed model is verified and validated in section 9. Research limitations are discussed in section 10.

Propositions for research extension are given in section 11 while articles' conclusion is given in section 12.

2. Background

2.1 MCDM

Multi criterion decision making is comprised of two broad fields of decision making known as multiple objective decision making (MODM) and multi-attribute decision making (MADM). By using MADM, it is possible to obtain the most attractive solution with the highest degree of satisfaction considering all alternatives and utilized criterions into consideration. In TOPSIS, the logic is based upon two solution points namely, positive ideal solution point (PISP) and negative ideal solution point (NISP). Alternatives to be ranked are evaluated based upon the relative similarity to these ideal solution points in such a way that alternative should have largest distance from the NISP and smallest distance to PISP.

The literature of multi-criterion decision making (MCDM) is comprised of many approaches for dealing with multi attribute decision making problem. One approach proposed by Kahraman and his co-researcher [13] is known as hierarchical fuzzy TOPSIS. In order to show the application of MCDM method to healthcare systems, this author searched the literature and found no work to be close to the type of the problem defined here. The fact that this is a new problem and demands the attentions of researchers, the number of articles published on healthcare performance under RFID technology using MCDM methods is insignificant. Most research reported on healthcare performance is based upon the statistical tools, and some are based upon the systemic approaches using systems thinking and system dynamics. In table 1, author used "X" sign to indicate that such decision-making approaches is not used for the type of the problem define in this research.

Table 1: Reported studies with MCDM methods in association with healthcare performance at the presence of RFID technology

	MADM approaches	**MODM approaches**	**Systemic and simulation approaches**	**Integration of MCDM and systemic approach**
Risks and benefits analysis	Hierarchical fuzzy TOPSIS (HFTOPSIS) (This study)	X	X	This study
Assessment of Strategies and prioritization	This study	X	X	This study
Integrated RFID and Healthcare performance	This study	X	Systems thinking, SD (This study)	This study
Scenario Analysis	X	X	This study	This study

2.2 Dynamic Thinking

System dynamics is a methodology offering an opportunity for seeing the long terms trends and behaviors of goal variables of the system under study. Although mind setting modeling of the problem is not an easy task for the beginners it gets easier as practicing on such modeling endures. Once the mind setting model is constructed using system thinking approach then the dynamic thinking can be converted into a new model for writing the formulas using the relations and interrelationships among the variables. By now, there are many applications of system dynamics in various areas of science and industries. Health and healthcare industries are benefiting from this methodology utilization for situation modeling and policy making. Since, the type of healthcare problem defined here is somehow different with previous cases it deserves a distinct and unique study.

2.3 RFID applications in healthcare

By now, many industries have employed RFID into their systems. This is done either by incorporating the RFID fully or partially as their needs has arisen. In healthcare systems, more especially in developing countries, managements hesitate to use RFID technology for its large first time set up cost and the maintenance costs associated with that. Table 2 shows some current uses of RFID technology in health industry and healthcare centers.27]

Table 2: Healthcare sample applications with RFID technology and/or system dynamics

	Topic	Researcher
1	Tracking surgical patients by using tags	Bacheldor [2]
2	Use of RFID technology in emergency room	Camacho-Cogollo et al. [4]
3	Monitoring Alzheimer patients	Corchado, et al. [5]
4	Tracking hospitals assets and patients	Davis (2004) [7]
5	Blood bank modelling	Katsiri et al. [15]
6	RFID-based Psychiatric Patient Localization System (2008)	Huang [10]
7	Internet-mobile-RFID technology in health systems	Katz [16]
8	Healthcare SCM and RFID	Kumar et al. [18]
9	RFID and healthcare	Podaima et al. [27]
10	A new health system for the 21st century	Martínez Pérez [22]
11	RFID and healthcare	Iranmanesh et al. [11]
12	The use of RFID in hospitals	Wang et al. [33]
13	RFID employments in hospital systems	Wicks et al. [34]
14	Efficient healthcare systems	Zare Mehrjerdi [39-41]
15	Health Care Management	Lebcir [19]
16	Healthcare dynamics	Jones et al. [12]
17	Benefits of systems dynamics in Health systems	Keolling et al. [17]
18	Studying weight related health problems	Zare Mehrjerdi [42]

3. Research contribution and methodology

3.1 Research gap, contribution and novelties

This research contributes to the literature of decision making in three ways. (1) By proposing a new problem that managements deal with in healthcare industries. Due to the facts that healthcare systems utilizing full RFID technology are in demand now, this research contribution is the presentation of a new problem regarding healthcare intelligent system. To identify best system among many (many partially equipped RFID-based healthcare system is possible to develop), experts' opinions on RFID's risks and benefits factors should be taken into consideration. Hierarchical fuzzy TOPSIS approach can be used as a tool for making decisions taking criterion, sub-criteria, sub-sub-criteria, and alternatives into consideration. (2) Proposing a hybridizing approach for studying the impacts of a decision made now by the management on the future of healthcare system, year after year. This portion of research uses systems thinking and system dynamics approaches. Modeling of problem is demonstrated through causal loop and stock and flow diagram. (3) Demonstrating the integration of multi attribute decision making and system dynamics for a real problem from healthcare industry.

3.2. Research methodology

There are three groups of approaches for studying alternatives known as (1) value measurement models (AHP, MAVT, MAUT, WSM), (2) outranking models (ELECTRE and PROMETHEE) and (3) goal aspiration models (VIKOR, TOPSIS). See article by Ruchser [29] and Manoj [21] for more details on that. In a review conducted by Socorro Garc´ıa-Cascalesa et al. (2012) four advantages of TOPSIS are listed as shown below:

(1) Its understandability and rationality,
(2) Having straightforward computation process,
(3) The best alternative among a set of alternatives that can be pursued in a simple mathematical form,
(4) Criteria weights are incorporated in the comparison process.

Ruchser [29] also claimed that since TOPSIS does not take uncertainty into account, it is often used in combination with fuzzy set theory. More on this can be seen in the work of Kahramann, et al. [13], Zare Mehrjerdi [37], Baykasoglu, A., Golcuk, I. [3], and He et al. [10]. However, a review by researchers Velasquez and Hester's [20] confirms that TOPSIS is used in a broad variety of different fields. The literature review shows that Baykasoglu and Golcuk[3] used a MADM via fuzzy cognitive maps and hierarchical fuzzy TOPSIS while Zare Mehrjerdi [37] utilized hierarchical fuzzy TOPSIS approach to study risk-benefit analysis in library systems. Recently, Amiri and Zare Mehrjerdi [1] used fuzzy TOPSIS to study food system security and sustainability. For the reasons given above this author has chosen hierarchical Fuzzy TOPSIS as a tool for assessing alternatives.

This research demonstrates the impacts of RFID technology on healthcare systems through two separate phases. In Phase I, some alternatives suitable for starting to use RFID technology are provided. Then, these alternatives are ranked using hierarchical fuzzy TOPSIS methodology. In the second phase, author evaluates the long terms impacts of the decision made on the healthcare's productivity and profit generation through simulating the model of the problem. System dynamics approach is used for modeling this phase of the problem. More details of phase I and Phase II are discussed in the following sections. Figure 1 depicts more details on steps used in these Phases.

Phase I: Choosing the best alternative

Risks and benefits criterions are used for identifying the best alternative systems using hierarchical fuzzy TOPSIS approach (Kahraman [13]

Phase II: Evaluation of long terms effect of Phase I's decision

Once the best alternative is determined then this system is examined using system dynamic approach. For this purpose, following steps must be followed:

- System's boundary and variables (factors) need to be identified
- Internal and external variables should be determined
- Causal diagram need be developed
- Rate and Level variables must be identified
- Stock and flow diagram need to be drawn
- Mathematical model of the problem must be developed
- Vensim software need to be used for simulating mathematical model of the problem
- Verification, validation and scenario analysis is in order.

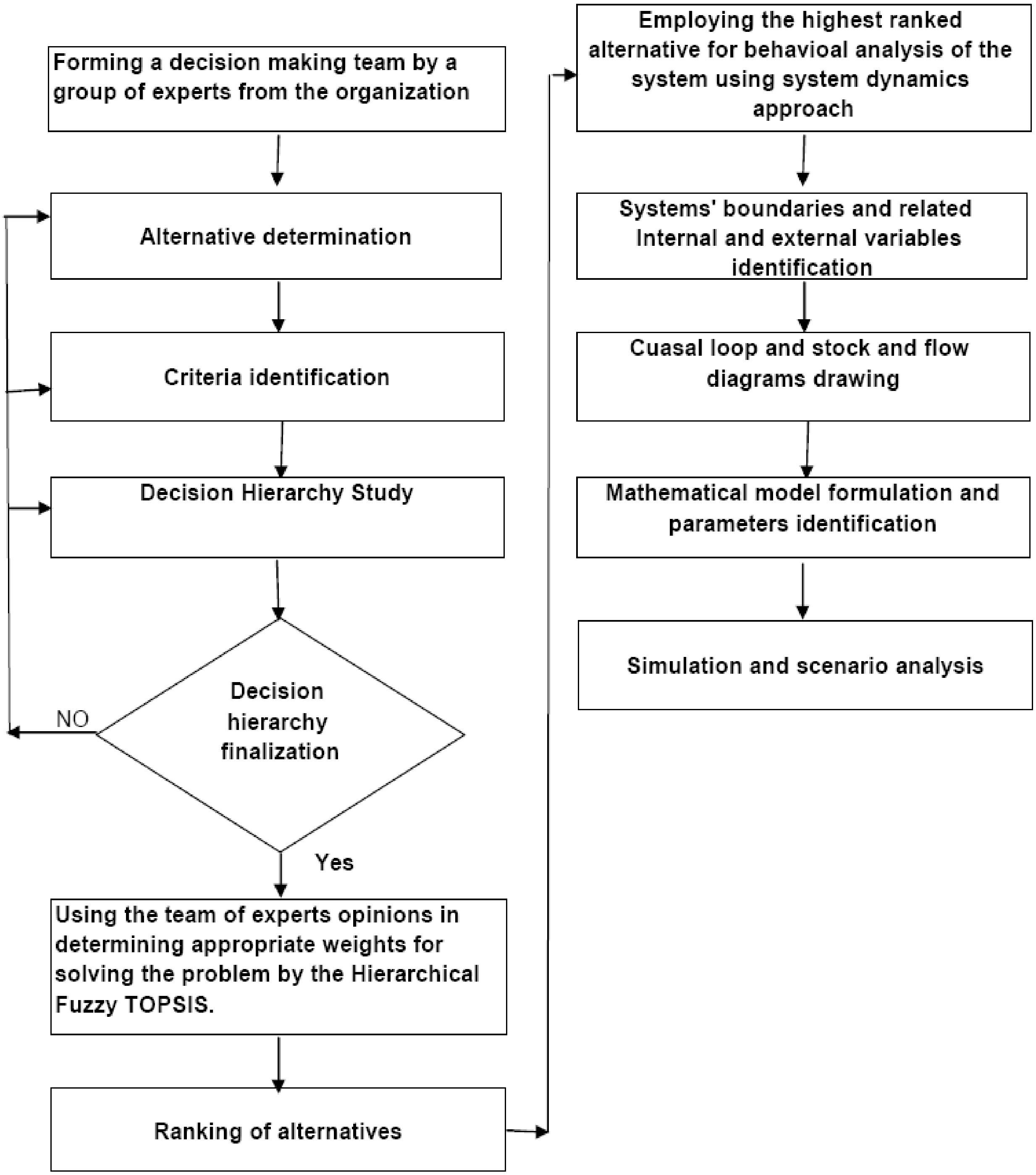

Figure 1: Steps to follow the research methodology

4. Hierarchical fuzzy TOPSIS method

The steps to follow and formula to use are discussed in seven steps below.

Step 1: Start with linguistic variables of Triangular Fuzzy Numbers (TFN) type, weighting vector of $W_j = (\lambda_j . \beta_j . \Psi_j)$ and fuzzy variable $X_{ij} = (a_{ij}.b_{ij}.c_{ij})$. Now go to step 2.

Step 2: Construct decision matrix of $D=[\tilde{x_{ij}}]$ using following formula to determine normalized fuzzy decision matrix of D′=[r_{ij}] where,

$$r_{ij}=\begin{cases} x_{ij}(+)x_j^*=\left(\frac{a_{ij}}{c_j^*},\frac{b_{ij}}{b_j^*},\frac{c_{ij}}{a_j^*}\right) \\ \bar{x}_{ij}\,(-)x_{ij}=\left(\frac{\bar{a}_j}{c_{ij}},\frac{\bar{b}_j}{b_{ij}},\frac{\bar{c}_j}{c_{ij}}\right) \end{cases} \tag{1}$$

Step 3: Now, obtain fuzzy weighted normalized decision Matrix of $v=[v_{ij}]$ where,

$$v_{ij}=\begin{cases} r_{ij}(.)w_j^*=\left(\frac{a_{ij}}{c_j^*}\lambda_j,\frac{b_{ij}}{b_j^*}\ \beta_j,\frac{c_{ij}}{a_j^*}\ \varphi_j\right) \\ r_{ij}\,(.)\,w^*_j=\left(\frac{\bar{a}_j}{c_{ij}}\ \lambda_j,\frac{\bar{b}_j}{b_{ij}}\ \beta_j,\frac{\bar{c}_j}{c_{ij}}\ \Psi_j\right) \end{cases} \tag{2}$$

Step 4: Determine PIS (Position Ideal Solution) and NIS (Negative ideal solution) of A* , $\bar{A}$, respectively.

$$A^*=[v_1^*,v_2^*,....,v_n^*] \tag{3}$$

$$A^-=[v_1^-,v_2^-,....,v_n^-] \tag{4}$$

Where,

$$v_j^*=\max_i v_{ij} \tag{5}$$

$$v_j^-=\min_i v_{ij} \tag{6}$$

Step 5: Using following formula, calculate mean value for fuzzy number of v_{ij} as shown below:

$$M(v_{ij})=\frac{-a_{ij}^2+d2_{ij}-a_{ij}b_{ij}+b_{ij}c_{ij}}{[3\,(-a_{ij}+d_{ij})]} \tag{7}$$

Step 6: Now calculate

$$S_i^{*}= \sum_{j=1}^{n} D_{ij}^{*} \quad (8)$$

$$\bar{S}_i= \sum_{j=1}^{n} \bar{D}_{ij} \quad (9)$$

Where, D_{ij}^{*} and $\bar{D}_{ij}$ are calculated by formula (10) and (11), respectively.

$$D_{ij}^{*}= \begin{cases} 1-\dfrac{c_{ij}-a^{*}}{b^{*}+cij-a^{*}-b_{ij}} & \forall b_{ij} < b^{*} \\ 1-\dfrac{c^{*}-a_{ij}}{b_{ij}+c^{*}-a_{ij}-b^{*}} & \forall b_{ij} > b^{*} \end{cases} \quad (10)$$

$$\bar{D}_{ij}= \begin{cases} 1-\dfrac{c^{-}-a_{ij}}{b_{ij}+\bar{c}-a_{ij}-\bar{b}} & \forall \bar{b} < b_{ij} \\ 1-\dfrac{c_{ij}-\bar{a}}{\bar{b}+c_{ij}-\bar{a}-b_{ij}} & \forall \bar{b} > b_{ij} \end{cases} \quad (11)$$

Step 7: calculate

$$C_i=\frac{\bar{S}_i}{\bar{S}_i+S_i^{*}} \quad (12)$$

Rank alternatives in ascending order of C_i index.

5. RFID risks and benefits in healthcare

Articles from a number of researchers Ngai [24], Camacho-Cogollo et al. [4], Crayton [6], Zare Mehrjerdi [36, 37, 39], Tzeng et al. [32], and Wang [33] on the RFID and health industry are studied and a summary of risks and benefits are extracted and listed in tables 3 and 4, respectively. Table 3 describes risk factors such as costs (C), RFID Experts (RE), Access Rate (AR), Patient Privacy (PP), Data Security (DS), and Barcode Factor (BF). Cost is one of the major factors influencing the adoption of RFID technology. The key risks factors relate to the healthcare system are explained in Table 3.

Table 3: Classifications of RFID Risks along with their descriptions

	Risks of RFID	Descriptions
1	Costs (C)	RFID requires a good initial investment in hardware, application software, tags, middleware, legacy system integration, and employee training. The cost of RFID tags may continue to present a major hurdle for RFID deployment. Hence the cost can be treated as risk for the system.
	RFID Experts	Expert inefficiency and lack of knowledge on the subject causes risks to arise.
2	The Access rate (AR)	There are many factors of metal, mist, distance, and incorrect positioning of antennas that causes the problem. A distance among tags may produce interference between tags or erroneous access.
3	Patient Privacy (PP)	Patient information can be recorded on the tag including personal info, sickness issues, reaction to medicines, and blood type.
4	Data Security (DS)	The biggest issue for a new technology is the level of the security that it may provide or needs in order to keep system's data at the safe level. Therefore, organization data security policies must be examined to ensure that security of customer data is not compromised at any price.
5	Barcode Factor (BF)	Barcode is a very popular all around the world both for service and health industries. Hence, the popularity of barcodes is an issue since almost all businesses around the world are set up with the Barcoding system.

RFID-based systems include many benefits that surpass their dis-benefits and risks. Healthcare can use RFID in many of its forms all around the system to gain the advantages of: (1) reducing and preventing medical errors; (2) tracking medical devices and medical wastes; (3) increasing interaction with patients; (4) patient and healthcare provider information; (5) information management and traceability; (6) data accuracy and reliability; (7) extending internal security of the healthcare system (ISH); (8) lowering the cost of medicine at the pharmacy through waste reduction; (9) traceability and tracking information (TT), and (10) efficiency of medical inventory and management (EMIM). More description of key benefits used in this study is discussed in Table 4.

Table 4: Classifications of RFID benefits along with their descriptions

	Benefits	Descriptions
1	Medical Errors Prevention (ME)	By incorporating RFID into a hospital tracking system, error will reduce in the areas of medication administration, medical diagnosis, and misplaced medical devices. RFID technology can be used in pharmacies to track counterfeit medicines, augmenting a medicine supply or medicine cabinet.
2	Tracking Medical Waste and Medical Devices (WM	Waste management companies test RFID tags to ensure medical waste reaches its proper disposal point using medical tracking devices. Two of these device-tracking tools are Data Label RFID tags, and Radiance ID tags. With the help of Radiance IPS device, RFID tags are placed on or inside of tools or objects to prevent tool misplacement.
3	Patient and Healthcare Provider Information (PH)	Hospitals concentrate on providing accurate Positive Patient Identification (PPI). RFID based systems can improve PPI by helping to ensure Patient Identification (PPI). There is an RFID Wristband that obtains hospital admission information, retains patient information, and can track hospital staff or a patient's whereabouts while on the hospital premises.
4	Information management (IM)	Since medications information, patients' info and experts' opinions can be stored on the RFID tags therefore such system is capable of locating the right place of medication, and patient in the hospital when it is necessary to be located.
5	Traceability and Tracking information (TT)	When RFID is integrated into the hospital information system, a patient can be tracked from the time they enter the hospital to the time they leave. This process starts when a patient is admitted and issued an RFID wristband.
6	Data Accuracy and Reliability (DR)	The effective deployment of RFID has a potential to quickly provide accurate and reliable data that exceeds the bar coding or manual capabilities available today. This can have major impacts particularly in busy hospitals, emergency rooms, pharmacies, and care taking centers in university health care systems and public clinics in populated areas.

6. Case Study

The case under investigation is determination of the best alternative among the set of alternatives available for a small private healthcare center. Possible alternatives to select one from that are listed below.

1. System type 1: a system with 60 percent RFID power and 40% barcode capability
2. System type 2: a system with 40 percent RFID power and 60% barcode capability
3. System type 3: a system with 20 percent RFID power and 80% barcode capability

To assess these alternatives, risks and benefits sub-criteria and sub-sub-criteria are identified. Our investigation ended with six risk factors and six benefit factors as are listed in the following table. To implement RFID into an organization, the support of its top management is in demand. However, to gain the managerial support, the study of ROI, return on investment, for RFID is necessary. Once management support is gained studies on risks and benefits is necessary. Note should be given that RFID-based systems include many benefits surpassing their dis-benefits. Table 5 lists some of these benefits and risks taken into consideration in this study. Hence, we can say that to justify the adoption of RFID technology into a business, risk-benefit analysis of a system is a must. Figure 2 shows the hierarchical structure of the problem under study here.

Table 5: Classifications of healthcare's Risks and Benefits

	Risks	Benefits
1	Costs	Medical errors prevention
2	RFID Experts	Tracking Medical wastes
3	Access rate	Patient healthcare pre. Info.
4	Patient Privacy	Information management
5	Data Security	Traceability and tracking info
6	Barcode Factors	Data accuracy and reliability

Table 6: weights to be used for main objectives

	Goal
Risks	(0.65,0.84,0.97)
Benefits	(0.24,0.47,0.65)

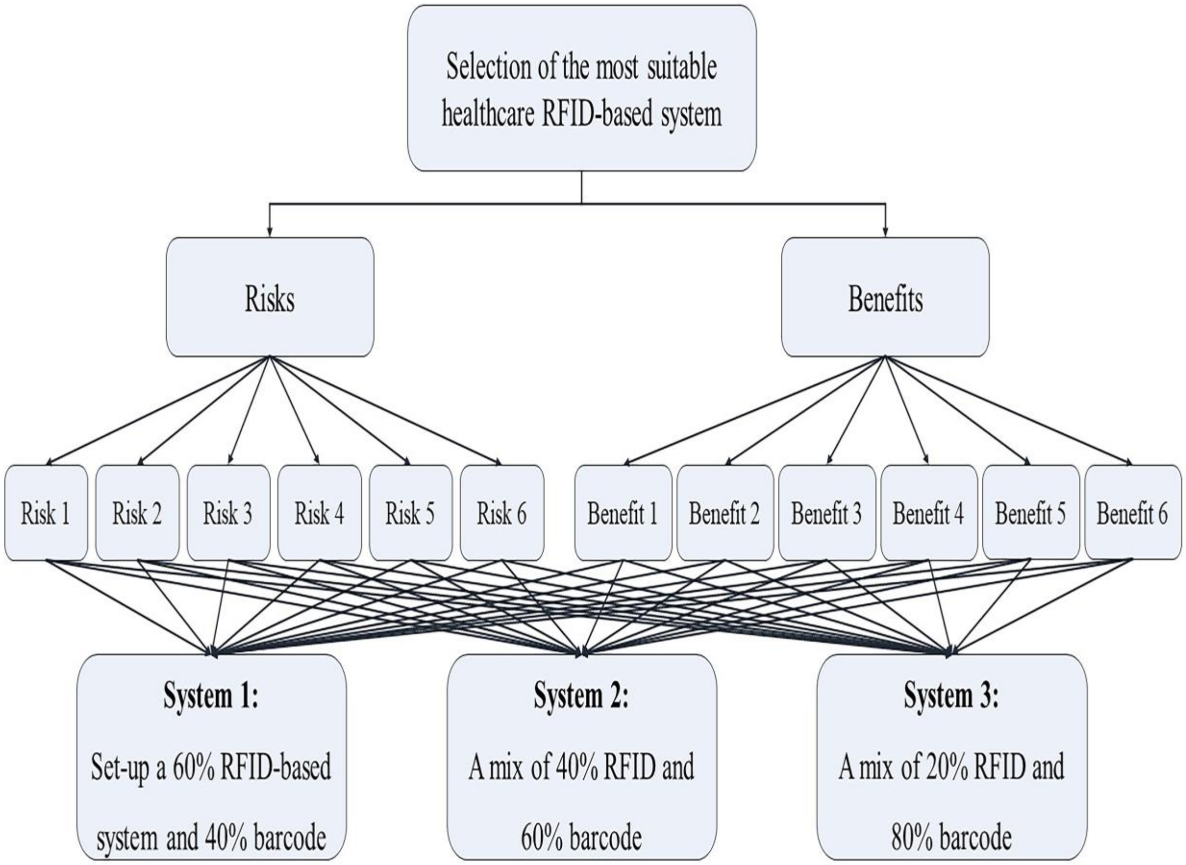

Figure 2: the graph of problem

Table 7: weights by main objectives

	Risk	Benefits
Risk1(Overall costs)	(0.33,0.46,0.77)	(0,0,0)
Risk2 (RFID experts)	(0.35, 0.74,0.89)	(0,0,0)
Risk3 (the access rate)	(0.32,0.71,0.88)	(0,0,0)
Risk4 (the patient privacy)	(0.32,0.61,0.83)	(0,0,0)
Risk5 (data security)	(0.34,0.46,0.55)	(0,0,0)
Risk6 (Barcode factors)	(0.13,0.41,0.68)	(0,0,0)
Ben1 (Medical errors prevention)	(0,0,0)	(0.36,0.63,0.85)
Ben2 (Tracking medical waste…)	(0,0,0)	(0.37,0.48,0.79)
Ben3 (Patient healthcare pro. Inf.)	(0,0,0)	(0.46,0.69,0.81)
Ben4 (Information management)	(0,0,0)	(0.21,0.56,0.71)
Ben5 (Traceability and tracking information)	(0,0,0)	(0.23,0.38,0.48)
Ben6 (Data accuracy and reliability)	(0,0,0)	(0.27,0.34,0.55)
Weights	(0.65,0.84,0.97)	(0.24,0.47,0.65)

The decision matrix (a matrix with X_{ij} elements) used in the model is a matrix of table 8 (number of systems) by 12 (six risks elements and 6 benefits elements) while the matrix of m(vij) of the decision matrix is shown in table 9.

Table 8: Decision Matrix

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	(45,53,74)	(16,31,46)	(29,69,86)	(13,21,36)	(26,41,51)	(34,41,53)
System 2	(23,38,48)	(42,59,71)	(41,53,78)	(38,55,67)	(44,56,65)	(10,21,36)
System 3	(29,39,52)	(32,42,55)	(13,41,68)	(29,37,41)	(41,53,62)	(9,17,33)
	Ben1	Ben2	Ben3	Ben4	Ben5	Ben6
System1	(45,78,89)	(41,52,63)	(36,67,85)	(59,74,85)	(47,61,76)	(67,79,87)
System 2	(41,53,62)	(16,30,39)	(13,45,72)	(25,33,37)	(12,30,51)	(53,74,88)
System 3	(27,51,75)	(29,38,51)	(21,56,78)	(47,68,75)	(16,31,46)	(61,85,91)
X^-	(23,38,48)	(16,31,46)	(13,41,68)	(13,21,36)	(26,41,51)	(9,17,33)
X^*	(45,78,89)	(41,52,63)	(36,67,85)	(59,74,85)	(47,61,76)	(67,85,91)

Table 9: m(vij)

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	0.33	0.76	0.60	0.73	0.56	0.27
System 2	0.65	0.31	0.46	0.26	0.35	0.83
System 3	0.49	0.41	1.27	0.35	0.37	0.93
	Ben1	Ben2	Ben3	Ben4	Ben5	Ben6
System1	0.50	0.39	0.55	0.38	0.27	0.22
System 2	0.33	0.21	0.43	0.14	0.15	0.22
System 3	0.38	0.28	0.48	0.29	0.14	0.23

Table 10: Table of Distance D*ij

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	0.1282	0.0000	0.0642	0.0000	0.000	0.2462
System 2	0.0000	0.1908	0.0675	0.4600	0.1134	0.0296
System 3	0.0083	0.0894	0.0000	0.1599	0.0912	0.0000
	Ben1	Ben2	Ben3	Ben4	Ben5	Ben6
System1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0300
System 2	0.1300	0.2200	0.1000	0.5000	0.3100	0.0500
System 3	0.1100	0.1100	0.0500	0.0500	0.3400	0.0000

Table 11: Table of Distance D-ij

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	0.0000	0.1979	0.0645	0.2749	0.1204	0.0000
System 2	0.1361	0.0000	0.0681	0.0000	0.0000	0.1852
System 3	0.1241	0.0981	0.0000	0.1009	0.0202	0.2534
	Ben1	Ben2	Ben3	Ben4	Ben5	Ben6
System1	0.1300	0.2200	0.1000	0.5000	0.3400	0.0200
System 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
System 3	0.0100	0.0700	0.0500	0.3200	0.0000	0.0500

Table 12: Final Ranking

	S_i^*	S_i^-	$S_i^* + S_i^-$	C_i	Rank
System1	0.4647	1.9692	2.4339	0.8091	1
System 2	2.1644	0.3894	2.5538	0.1525	3
System 3	1.0066	1.0953	2.1019	0.5211	2

Using information obtained for column C_i from table 12, we ranked these three types of mixed systems proposed to the healthcare center. The result is as shown below:

System 1 >> System 3 >> System 2

Hence, a system with 60 percent RFID power and 40% barcode capability is the ideal one for this healthcare center.

6.1 Simple Additive Weighting (SAW) method using Shannon entropy approach

Hwang and Yoon have proposed a technique named SAW for multi attribute decision making problems. This technique which is used by many in research areas is comprised of following steps:

Step 1: Identify the decision matrix D and prepare the common measureable matrix in accordance with the following formulas which are proposed for positive and negative criterion, respectively:

$$r_{ij} = \frac{x_{ij}}{\max_i \{x_{ij}\}} \tag{13}$$

and

$$r_{ij} = \frac{\min_i \{x_{ij}\}}{x_{ij}} \tag{14}$$

Step 2: Determine the weight vector of $W = (w_1, w_2, ..., w_n)$

Step 3: Choose the best alternative using following formula

$$A^* = \{A_i \mid \max_i \sum_{j=1}^{m} w_j r_{ij}\} \tag{15}$$

6.2 Shannon Entropy Weight

Using Shannon entropy weighting approach, we can calculate weight based upon the data gathered in original decision table. Shannon's weighting system is based upon the dispersion of data in the decision-making matrix. Due to the fact that W_j is calculated directly from dj, it can be said that there is a straight relationship between the weight and data dispersion. Steps to follow are as discussed below:

Step 1: Use following formula to calculate P_{ij} values.

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{16}$$

Step 2: Calculate E_j using following formula:

$$E_j = -k \sum_{i=1}^{m} [P_{ij} \cdot Ln\ P_{ij}] \quad ; \forall j \tag{17}$$

Where K = 1/Ln (m).

Step 3: Now calculate Wi using formulas given below:

$$d_j = 1 - E_j \quad ; \forall j \tag{19}$$

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad ; \forall j \tag{20}$$

To verify the ranking obtained by the hierarchical fuzzy TOPSIS approach, SAW technique was employed using two weighting systems of Hierarchical TOPSIS weight and Shannon weight. The ranking results of SAW is shown in Table 13.

Table 13: Final ranking by SAW using different weight vectors

	Hierarchical TOPSIS Weight	Shannon's Weight
System1	1	1
System2	2	2
System3	3	3

Using all those rankings obtained by Hierarchical fuzzy TOPSIS and SAW we can get certain that System 1 is the best and can be considered for further analysis. This means that, a system with 60 percent RFID power and 40% barcode capability is the ideal one for this healthcare center as experts presented their opinions.

7. Phase II

In this phase, author shows how the decision made in phase I may impact the healthcare system in the long run. For demonstration purposes, author uses systems thinking for model development and system dynamics for formulating the relationships and the interrelationships among the variables and those nonlinearity features that appear in the problem.

7.1 System dynamics background

The steps to develop a system dynamics model are discussed by Sterman [30] which is depicted by Figure 3. The description of each step is given below

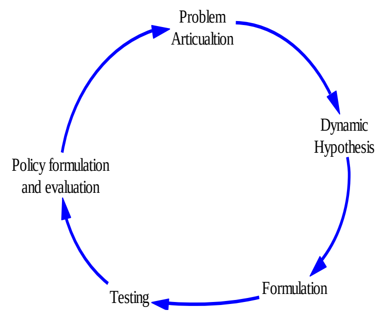

Fig. 3: System dynamics modeling process.

Step 1: Problem description

The aim of this step is to identify the problem and what really is the situation that we need to deal with. The reality that the problem is suitable for the dynamic study must be clarified. Management must be called in to support the study and to discuss about the data needed to deal with. Key variables and concepts must be identified at this stage.

Step 2: Dynamic hypothesis

The aim of this step is to develop a dynamic hypothesis of the face problem. Once this hypothesis is described then a casual loop diagram explaining links among the variables can be developed. Each loop must be self-describable and representing a concept matter. Once casual loop diagram is developed then the flow diagram consisting of level variables, rate variables and auxiliary variables should be developed. Usually, a level variable is shown by a square shape, rate variable by the water tap sign and an auxiliary variable by a circle.

Step 3: Formulation

In this step, we can translate the system dynamics, presented in the form of flow diagram, into equivalent formulas/equations. It is through these equations that the dynamics of system are thoroughly describable. If casual loop is correctly constructed and the dynamics of problem is actually kept into the model of problem then, the corresponding flow diagram of that should be the true problem identifier. Now, we can rely on the translated equations for simulation purposes and the behavioral relationship studies. Suryani et al. [31] has said that the writing equations will reveal gaps and inconsistencies that must be remedied in the prior description.

Step 4: Testing

In this step, we can run the model and then test the simulation results by checking systems' behavior against the real behavior that system has shown in the past or showing at the present time. Any inconsistencies seen in these trends would let us make more investigations in the model structure and the values of the parameters used in the equations.

Step 5: Policy formulation and evaluation

At this stage, model developer is sufficiently confident with the structure provided for the problem and the behavior expected for main goal variables. Now, model developer can propose, design, and evaluate policies suitable for the case. This author believes that the interactions of various policies proposed should be considered. This is because we all deal with real systems that are highly complex and nonlinear relationships exist among the variables. It should be mentioned that the impacts of combination policies is not equivalent to the sum of their impacts alone [31].

7.2 Causality and feedback

System dynamics play important roles in model developing for ill-defined and non-structured problems. For well-defined problems, we can use operations research to model the problem and then appropriate approaches to optimize that. For some ill-defined problems, one can use mental models and systems thinking to construct the basic thinking for modeling. Once this causal loop diagram known as CLD is constructed then, the stock and flow diagram (SFD) develop based upon that. The structure for any problem can be represented by feedback loops to show the nature of the problem and its closeness to real world life situations.

In the remainder of this article, the problem under investigation is described in the form of following proposition.

Proposition

In the integrated RFID healthcare management system, RFID technology can generate higher productivity level for the entire system, nurses, physicians, staffs, care givers, patients, and insurance companies to mention a few.

Problems key variables

Key variables found in the literature regarding the use of RFID in different industries are as listed below: quality and efficiency [14], effectiveness, productivity, inventory control, cost saving, expense management, labor costs reduction, human errors reduction, revenue increment, profit making, value generation [24], Alzheimer patient monitoring [5], information sharing, on-time data, and on-time decision making [24]. Other variables extracted from literature are: competitive advantages, asset utilization, staff activities, staff friendship, staff performance, patient health, patient satisfaction [39]. Using the key variables stated above and the proposition statement, the causal loop diagram presented below with 7 loops can be designed.

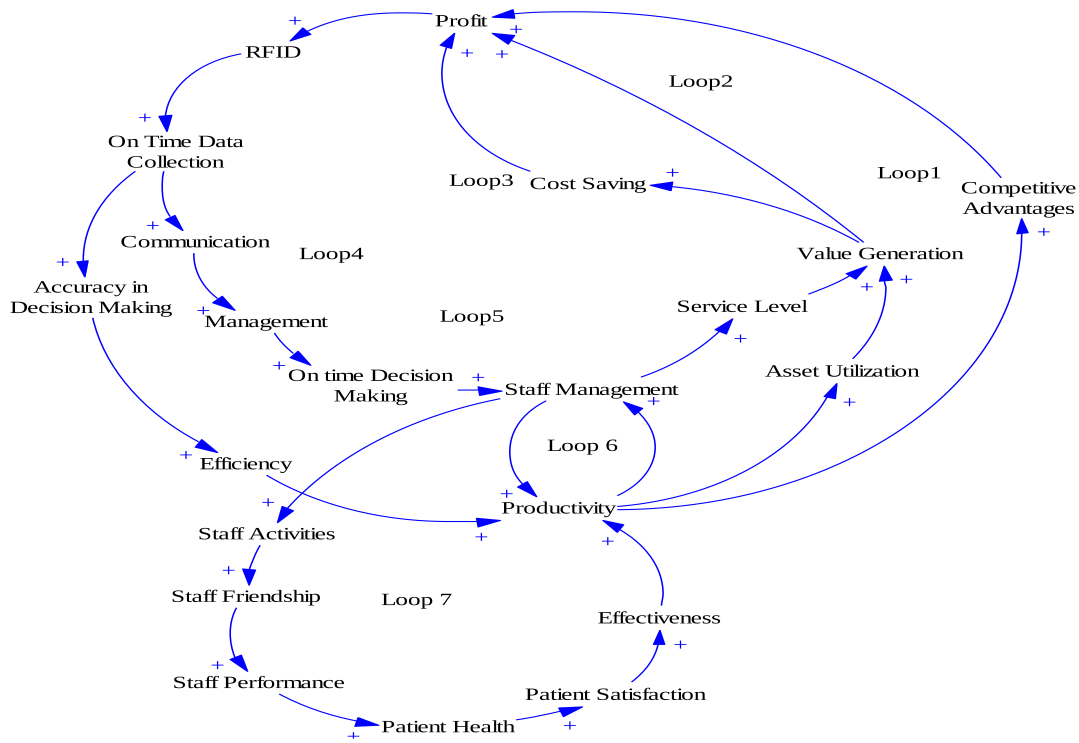

Figure 4: Casual loop diagram

Table 14: Feedback structures and reinforcing loops

Loops	Description	Feedback structure
Loop 1	The most outsider loop is the one that passes through Profit-RFID-Productivity-Competitive advantages profit endogenous variables. This is a reinforcing type loop with positive feedback structure, resulting in increased Productivity and Profit. This loop increases the profit as a result of competitive advantages occurrences.	Reinforcing loop
Loop 2	This loop passes through Profit-RFID-Productivity-Value Generation-Profit. This is reinforcing type loop resulting in increased productivity and Profit. This loop increases the profit as a result of value generation occurrences.	Reinforcing loop
Loop 3	This loop passes through Profit-RFID-Productivity-Value Generation-Cost Saving-Profit. This is reinforcing type loop resulting in increased productivity and Profit. This loop increases the profit as a result of cost saving occurrences.	Reinforcing loop
Loops 4 and 5	These two loops put emphasis on the communication, on time decision making and staff management. This is a positive type loop passes through Profit-RFID-Communication-Staff management-value generation /cost saving-Profit. These two loops points to the impact of RFID on communication and service level as a result of better staff management.	Reinforcing loop
Loop 6	This loop starts from Productivity and end with Staff management. It points to this reality that by increasing better management of staff we get better productivity and by increasing productivity we would go after better management of our staff.	Reinforcing loop
Loop 7	This is a reinforcing type loop and starts from staff management and after passing through staff activities, staff performance, patient health, effectiveness, and productivity then ends with staff management.	Reinforcing loop

Table 15: Variables for SFD

Class	Variables
Level Variables	Profit Productivity Cost Saving
Rate Variables	Increase in profit Increase in productivity Increase in staff management Increase in value generation Increase in cost saving Increase in competitive advantage Increase in efficiency Increase in effectiveness
Supplemental Variables	RFID acceptance On time data collection Accuracy in decision making Efficiency Asset utilization Competitive advantages Staff activities Staff friendship Staff performance Patient health Patient satisfaction

Figure 5: a causal loop showing the concept of proposed proposition

7.3. Proposition Evaluation using System Dynamics

After modeling the problem and formulating the situation in Vensim software, testing for unit consistency began. Then, the simulation begins and results are studied for accuracy and validation purposes. The simulation results of the problem in any degree of complexity can be shown by figures, and tables.

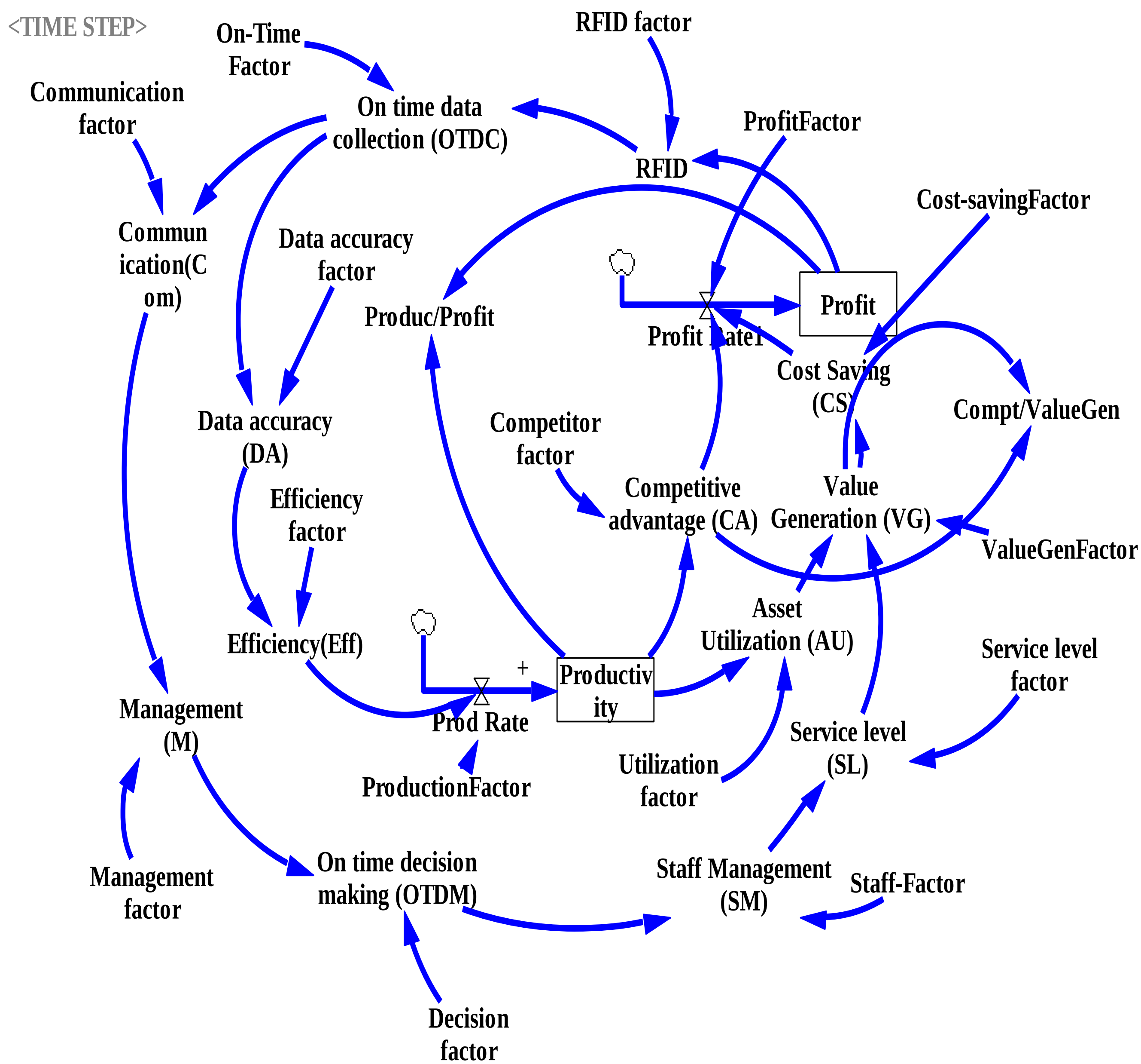

Figure 5: Stock and Flow diagram for healthcare performance problem

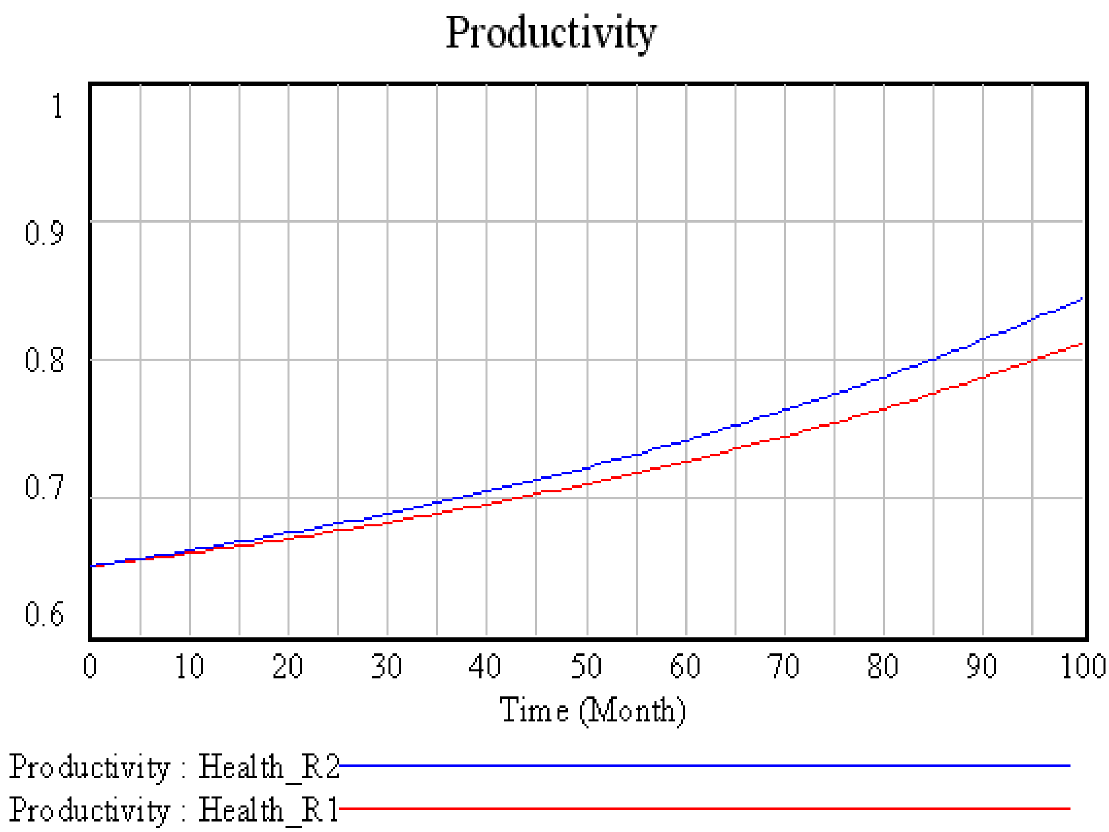

Figure 6: systems productivity behaviour over 100 periods

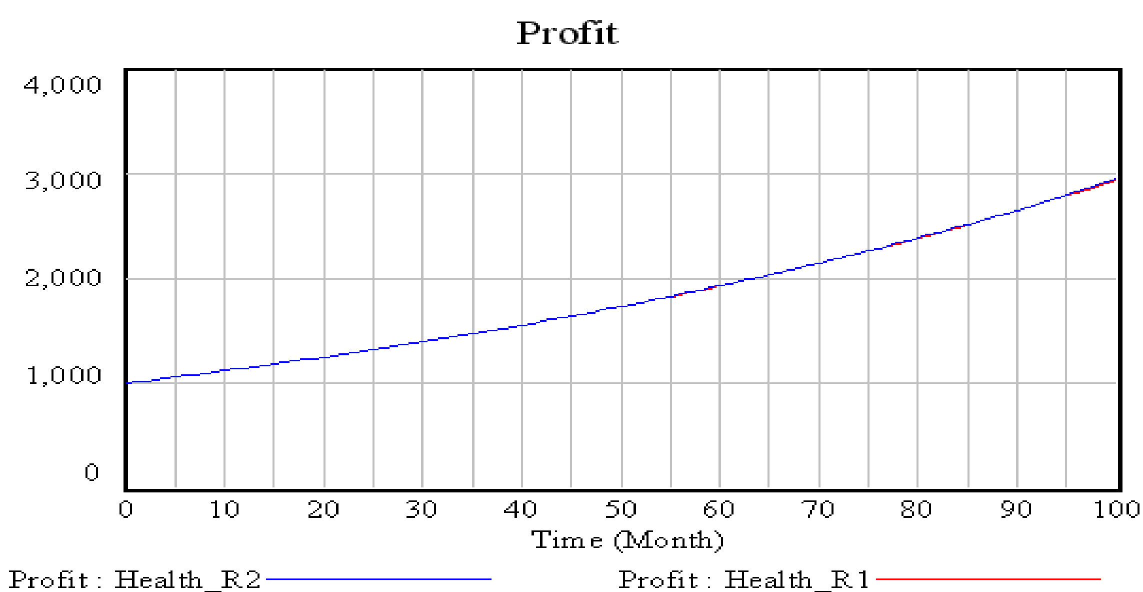

Figure 7: systems profit behaviour over 100 periods

The second run is related to the situations that activity toward the productivity improvement has increased by 20%. The result of the second run is an indication that although productivity would increase as a result of such new policy making but we will not notice too much impacts on the profit performance in the long run.

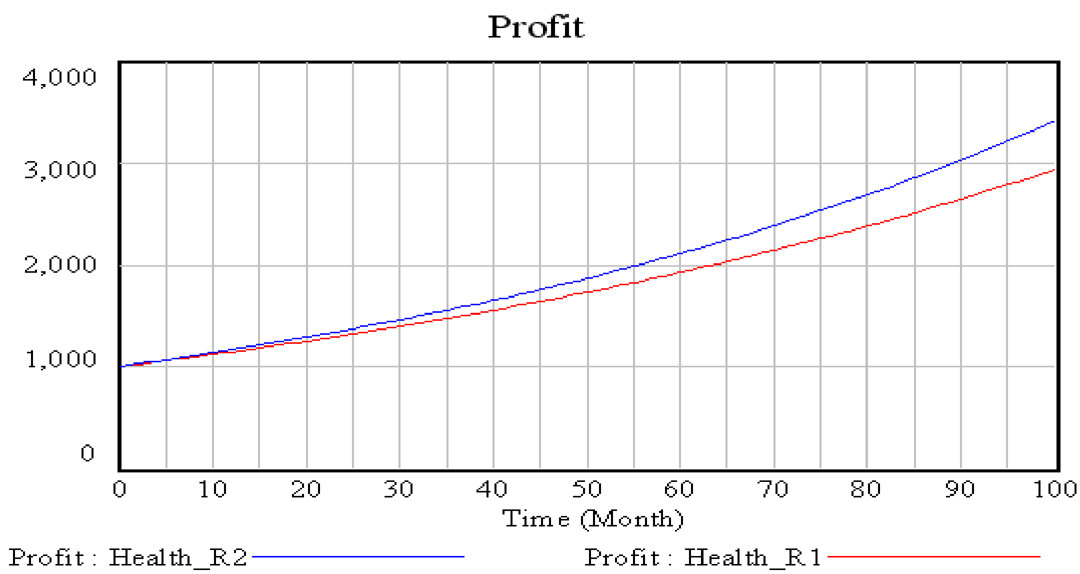

Figure 8: profit behaviour with 20% and 15% improvements in productivity and cost factors

7.4 Behavior reproducing test

System dynamics models are primarily used for policy analysis to ultimately lead to improved policy making in the organization [40-42]. After obtaining a valid system dynamics model that has passed various validation tests and understanding the behavior of current policy structure, this model should lead to design of alternative policies, which are usually improved [40-42]. For this purpose, in this study, three scenarios are discussed which are described below.

Table 16: real productivity values of health system without RFID set-up

Years	Productivity
2012	0.480
2013	0.485
2014	0.490
2015	0.490
2016	0.520
2017	0.543
2018	0.575
2019	0.601

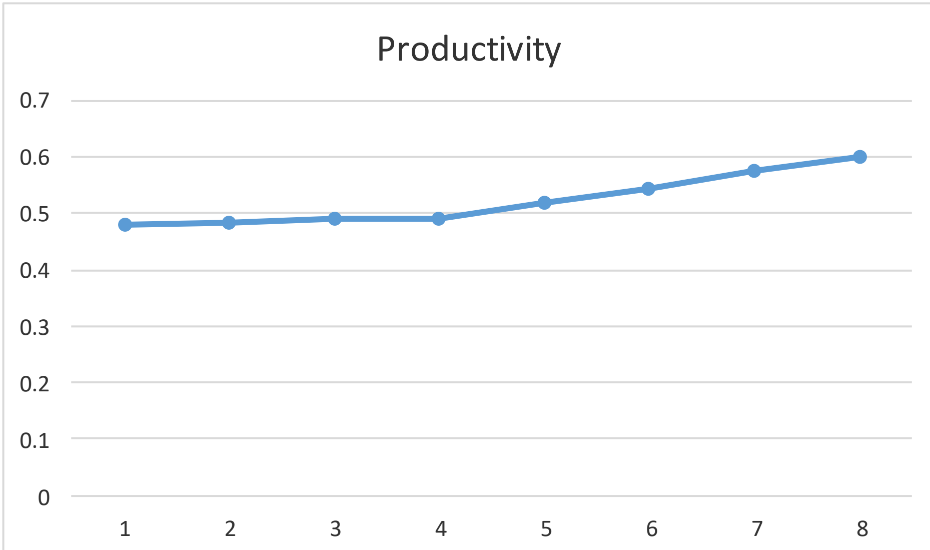

Figure 9: behavior of system's real productivity in 8 years from 2012 to 2019
Without using RFID technology

Using this validation test we will be able to show how much the solution obtains by the SD is consistent with the real-world trend of healthcare productivity. The case used here is a healthcare system with the overall productivity level of about 50 percent. The company manager is very unsatisfied with the level of productivity and looks forward to improve that using RFID technology. Knowing that other healthcare systems are performing much better by putting hands on RFID technology, management considered to get into RFID technology as well.

7.5 Scenarios consideration

Three scenarios are considered for this case which is defined below. The RFID factor values indicate the percentage of the profit associated to the RFID technology in each period by the management.

7.5.1 Base Scenario Data

All computer simulation results presented above are for the base scenario with RFID factor=0.10

7.5.2 Scenario 1 Data

RFID factor=0.12

7.5.3 Scenario 2 Data

RFID factor=0.15

7.5.4 Scenarios results

The results of two scenarios and one base model are shown by Figures 10 through 15. The results of base study are shown by the Health R2 sign and the results of scenarios 1 and 2 are shown by Heath_R2A and Health_R2B signs, respectively. Figure 10 shows that as RFID factor value increase from 0.1 to 12 for scenario 1 and to 0.15 for scenario 2, the profit values increase as shown by table 17 for some selected points of times. Figure 12 and 13 show the ratios of productivity to profit and ratio of competition to value generation, respectively. Figures 14 and 15 compare the profit levels under RFID factors for three scenarios and productivity levels as well.

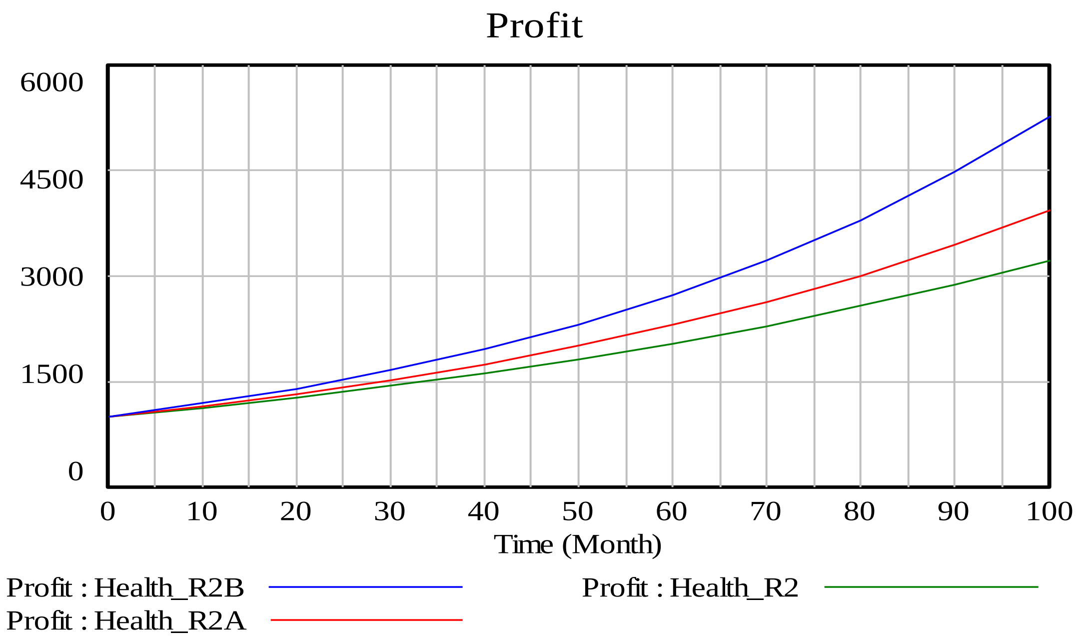

Figure 10: Profit behaviour's comparison for three scenarios

Table 17: comparison of profit for three scenarios

Time Month	Profit Base	Profit Scenario 1	Profit Scenario 2
0	1000	1000	1000
10	1128.97	1151.97	1186.47
20	1273.01	1325.2	1405.47
30	1433.88	1522.65	1662.64
40	1613.54	1747.72	1964.68
50	1814.2	2004.28	2319.39
60	2038.3	2296.72	2735.97
70	2288.6	2630.08	3225.23
80	2568.16	3010.09	3799.83
90	2880.39	3443.27	4474.67
100	3229.13	3937.06	5267.25

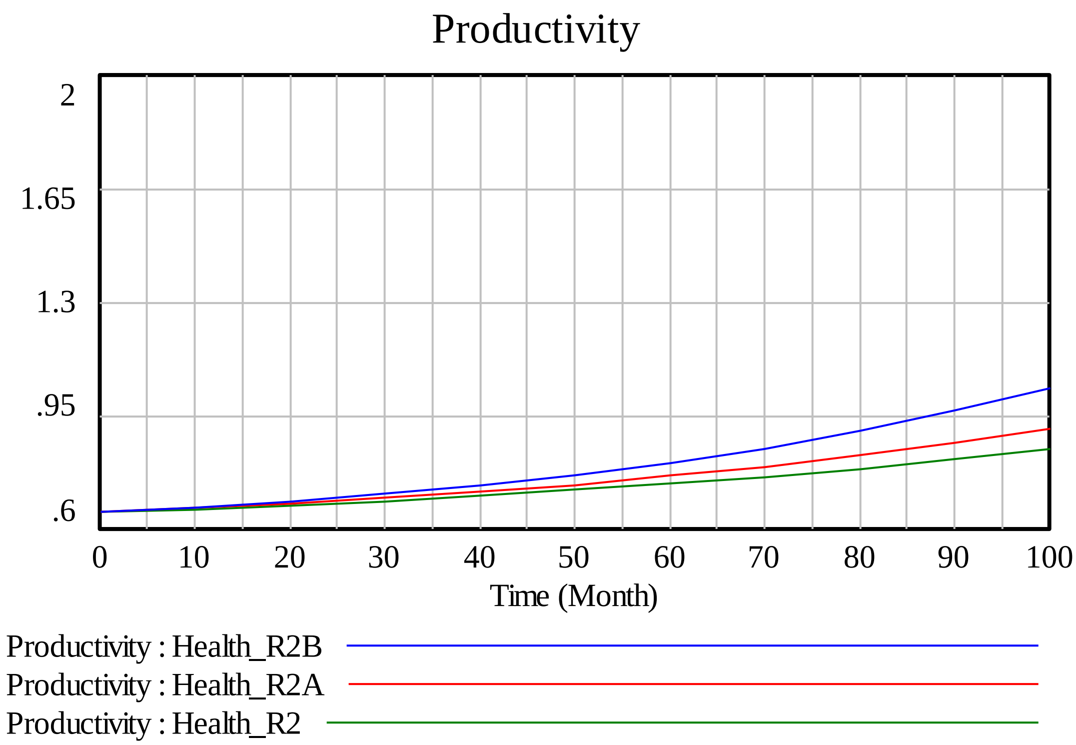

Figure 11: Productivity behaviours' comparison for three scenarios

Table 18: Comparison of productivity for three scenarios

Time Month	Productivity Base	Productivity Scenario 1	Productivity Scenario 2
0	0.65	0.65	0.65
10	0.66	0.66	0.67
20	0.67	0.68	0.69
30	0.69	0.70	0.71
40	0.70	0.71	0.74
50	0.72	0.74	0.77
60	0.74	0.76	0.80
70	0.76	0.79	0.85
80	0.79	0.83	0.90
90	0.81	0.87	0.96
100	0.84	0.91	1.00

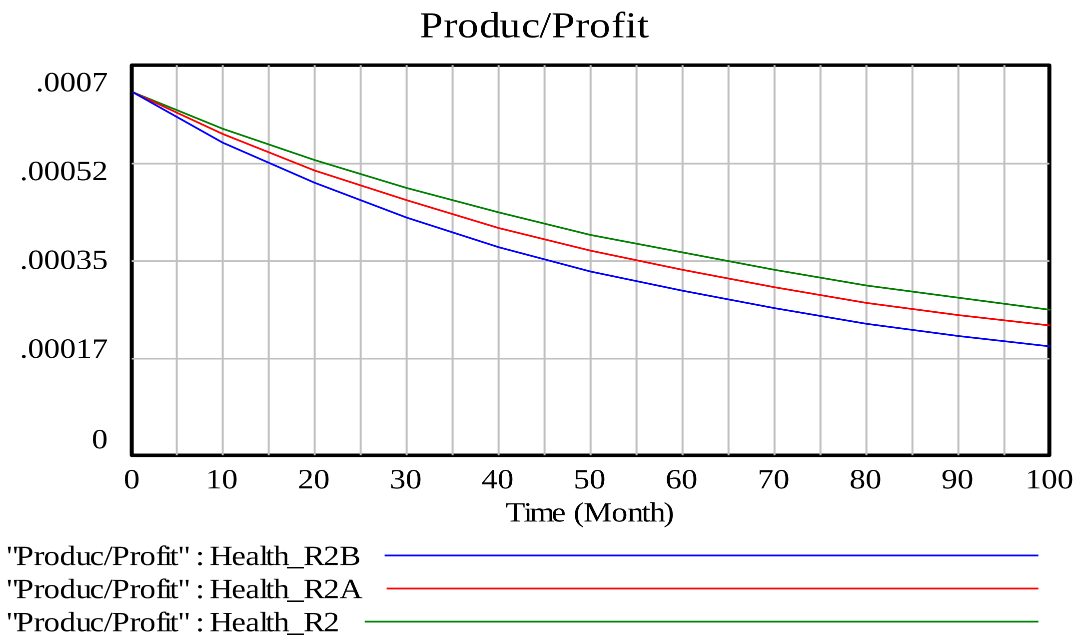

Figure 12: comparison of ratio of productivity to profit for three scenarios

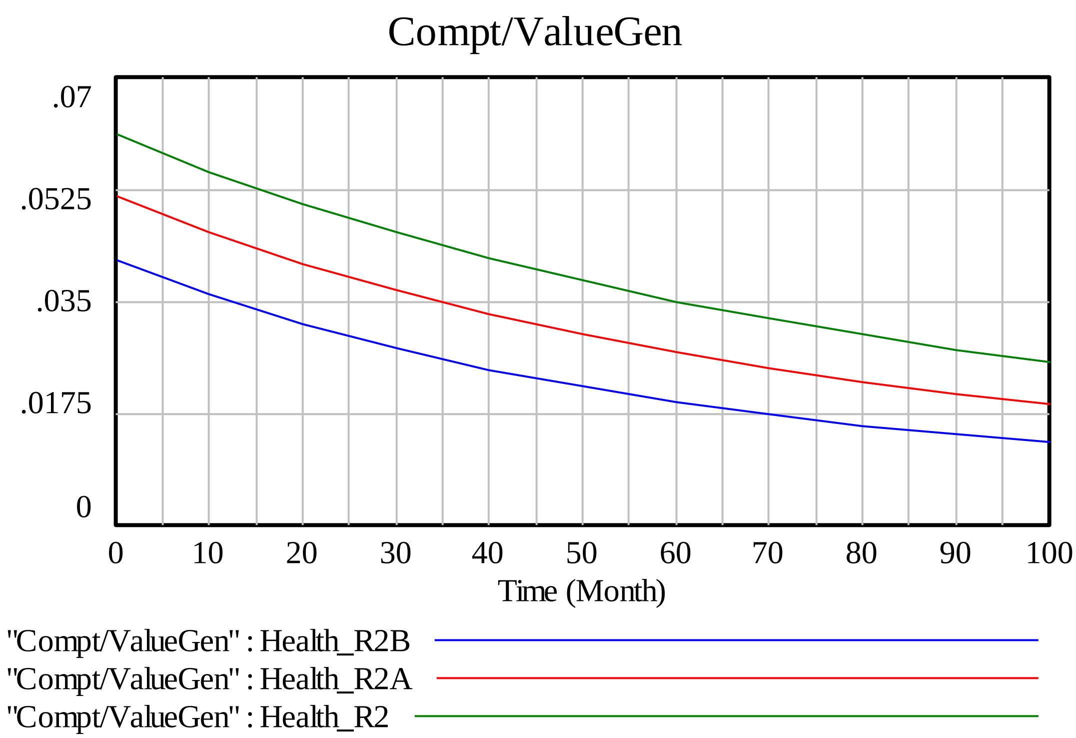

Figure 13: comparison of ratio of competitive to value generation for three scenarios

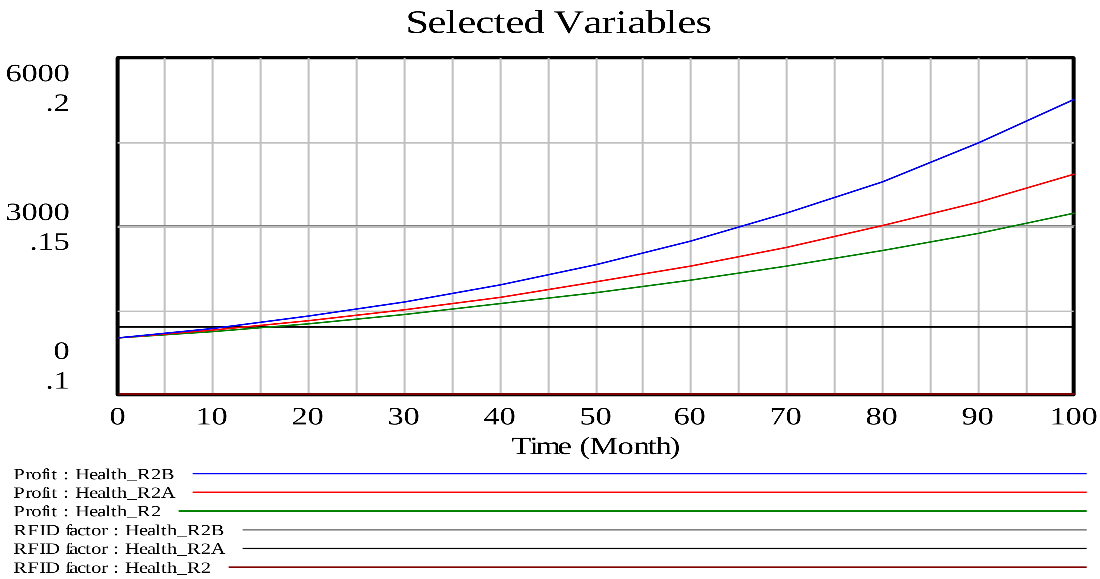

Figure 14: comparison of profit levels under RFID factors for scenarios

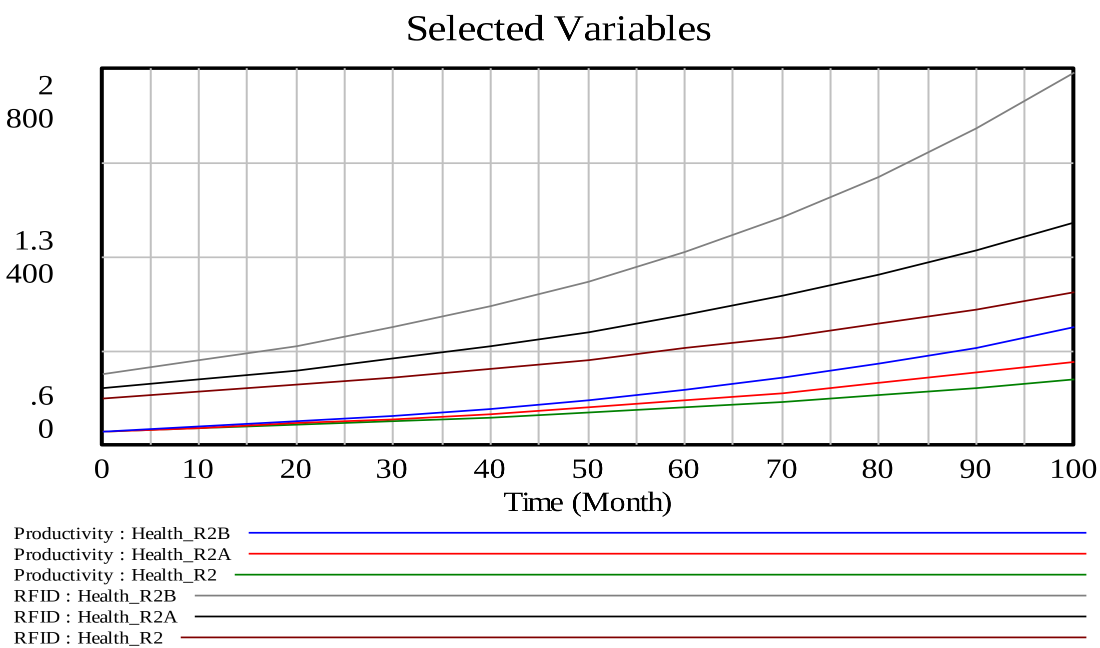

Figure 15: comparison of productivity levels under RFID factors for scenarios

8. Implications

In this section, theoretical contributions, managerial contributions, as well as policy contributions are presented.

8.1. Theoretical contributions

From the theoretical perspective, this paper contains several theoretical contributions. First, a new look at the RFID technology and how it can be implemented in health industry is provided. Such an understanding of new technology gives practitioners, academics, and researchers a precise view of RFID technology and its clear benefits and usages in healthcare industry. Second, this paper is the first to study interrelationships among RFID factors and healthcare factors. Third, a new hybrid approach using MADM and SD approaches to deal with complex healthcare problem at the company of RFID technology is modeled and simulated. Fourth, we know that system dynamics is based upon the global and holistic vision hence it is used for solving specific problems and analyzing complex systems. This article has shown that this approach is suitable for studying dynamic performance management.

Previous studies have neglected several benefits of RFID technology that may arise during crisis. Hence, a causality analysis of RFID's inspiring and stimulating factors in the presence of healthcare factors, within a new model, is presented. System dynamics is a felicitous tool for researchers and scholars in order to investigate the interrelationships among various factors. Lastly, we inquired experts from industry to provide data, which required a proper manner to deal with the ambiguity of input data. As a matter of fact, coping with the ambiguity of input data is one of the main steps in hierarchical fuzzy TOPSIS approach. In relation with what was argued, hierarchical fuzzy TOPSIS being used to handle the ambiguity of experts' opinions in the decision-making process. This approach is used by some researchers for choosing the most appropriate alternative among a set of alternatives at the presence of vague data.

8.2 Managerial Implications

Healthcare management is vital in a sense that it concentrates both on people's health and the economics of health in a long run. New technologies utilization in healthcare systems is a must providing that it can contribute both to the economics of the health management and peoples' health benefits. In other words, management should have eye on the fuzzy optimization problem of: Maximize {Return on new technology usages | budget constraints and health constraints}. Here, the technology under study is RFID and its usage in most healthcare systems, in a large number of countries, is at the verge of commencement. This paper aims at analyzing the interrelationships among the RFID factors and healthcare factors. So, the outcome of this study can act as a comprehensive guideline for managers in health industry as well as hygiene and sanitation industries. The extracted managerial insights of this study for managers and decision-makers are brought as follows:

1. Knowing that partial implementation of RFID technology system is possible, management can choose the best alternative that matches its in-house conditions.

2. Use a system dynamics approach to study the long terms' impacts of the selected RFID technology system on the healthcare system performance.

3. At the time of crises and pandemic outbreak when healthcare systems get deeply involved with the unwanted problems then a health system linked with the RFID technology system would work so more efficient than a one without.

4. Management of online data gathering by the RFID technology system allows making immediate decision by managers. This is a plus for the organizations dealing with RFID technology at the time crises and pandemic outbreak.

8.3. Policy contributions

Based upon the scenarios proposed in this study, our findings strongly support the fact that policy-makers can play a key role in providing a proper setting for businesses with better healthcare management. At the time of crises and pandemic outbreak as such as COVID-19 a healthcare system joined with the RFID technology system would work so more efficient than without. Taking our three scenarios into consideration we noticed that as the level of RFID impact in the system increased the level of profits and productivity generated also had increased. These results are shown by tables 17 and 18, respectively. Additionally, due to rapidly rising healthcare cost, policy makers should be aware of importance of on time decision regarding people's live, population health, health information technology (HIT), and electronic health records (EHRs). These all are in needs of an RFID technological-based system for the health organization.

9. Conclusion

In this research, author proposed a two-phase methodology for evaluating the business value of healthcare center through RFID technology. For this reason, in phase I the best alternative among a set of alternatives was determined using hierarchical Fuzzy TOPSIS approach. In the second phase, with the help of system dynamics approach the behavior of the system is evaluated. To conduct this current research author has taken some key steps as are identified in the research methodology section of the article. These steps are as listed below: (1) using risks and benefits criterions to identify the best available alternative systems. This is done using hierarchical fuzzy TOPSIS approach; (2) Once the best alternative is determined then this system is examined using system dynamic approach. To complete this second step of the problem, the following steps are pursued: (i) System and boundaries are identified, (ii) Internal and external variables are determined, (iii) Causal diagram is developed, (iv) Variables associated with rates and levels are identified, (v) Stock and flow diagram is drawn, (vi) Mathematical model of the problem is developed, (vii) Vensim software is used to simulate the model, and (viii) Verification, validation and scenario analysis are performed. For future works, this author suggests that other approaches as such as interval type-2 fuzzy MADM for TOPSIS to be utilized. Knowing that other MADM methodologies are suitable for alternatives ranking in phase I, the system dynamics model of phase II can be expanded to include other goal variables a such as expenses, service quality, and clients' satisfaction to mention a few.

The hybrid approach presented in this article is part of this research contribution in the sense that the output of the hierarchical fuzzy TOPSIS is being feed into the system dynamics modeling for further analysis of goal variables. The main contribution of this research is the development of the dynamic thinking of the problem using systems thinking approach and presenting a system dynamics and mathematical modeling of the problem for simulation purposes. In this study, author was motivated to find a response for the question of "knowing that healthcare system equipping with full RFID technology is in demand now, is it possible to use partially equipped system as an alternative, instead of waiting for its full RFID implementation sometime in the future?" Author's effort to find a scientific approach for responding to this question is the novelty of this research. Finding a way to choose the best alternative among all and then tracking the impacts of such decision on the system's behaviour is counted as this research novelty as well. With this research, author demonstrates a clear approach for combining multi attribute decision making and system dynamic approaches for system modelling and analysis. Care should be taken to use this hybrid approach for similar modelling of other problems in service industries. Due to the fact that this research combines four fields of knowledge into an interesting research problem of highly attractive to service industries, it makes a true contribution to the field of healthcare and system dynamics.

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