Artificial Intelligence and Multiple Criteria Decision Making Approach for a Cost-Effective RFID-enabled Tracking Management System.

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ABSTRACT

The implementation of RFID technology has been subject to ever-increasing popularity in relation to the traceability of items as one of the most advance technologies. Implementing such a technology leads to an increase in the visibility management of products. Notwithstanding this, RFID communication performance is potentially greatly affected by interference between the RFID devices. It is also subject to auxiliary costs in investment that should be considered. Hence, seeking a cost-effective design with a desired communication performance for RFID-enabled systems has become a key factor in order to be competitive in today‟s markets. This study introduce a cost and performance-effective design for a proposed RFID-enabled passport tracking system through the development of a multi-objective model that takes in account economic, operation and social criteria. The developed model is aimed at solving the design problem by (i) allocating the optimal numbers of related facilities that should be established and (ii) obtaining trade-offs among three objectives: minimising implementation and operational costs; minimising RFID reader interference; and maximising the social impact measured in the number of created jobs. To come closer to the actual design in terms of considering the uncertain parameters, a fuzzy multi-objective model was developed. To solve the multi-objective optimization problem model, two solution methods were used respectively (epsilon constrain and linear programming) to select the best Pareto solution and a decision-making method was developed to select the final trade-off solution. Moreover, this research aims to provide a user-friendly decision making tool for selecting the best vendor from a group which submitted their tenders for implementing a proposed RFID-based passport tracking system. In addition to that a real case study was applied to examine the applicability of the developed model and the proposed solution methods. The research findings indicate that the developed model is capable of presenting a design for an RFID-enabled passport tracking system. Also, the developed decision-making tool can easily be used to solve similar vendor selection problem.

Research findings demonstrate that the proposed RFID-enabled monitoring system for the passport tracking system is economically feasible. The study concludes that the developed mathematical models and optimization approaches can be a useful decision-maker for tackling a number of design and optimization problems for RFID system using artificial intelligence mathematical algorithm based techniques.

List of Publication

Journals

- **Dukyil, A**. , Mohammed, A. and Darwish, M. 2017. Design and optimization of an RFID-enabled Passport Tracking System. Journal of Computational Design and Engineering. Elsevier published , (10.1016/j.jcde.2017.06.002)

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AUTHOR’S DECLARATION

I declare and confirm that this thesis is my own work and efforts. Also, it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

Abdulsalam Dukyil
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Abbreviations

- AHP the analytical hierarchy process
- ANP Analytic network process
- AOF Aggregate Objective Function
- API Application Programming Interface
- DEMATEL Decision-Making Trial and Evaluation Laboratory
- EAP Employee Assistance Program
- EMC Electromagnetic compatibility
- EPC Electronic Product Code
- FFC Far Field Communication
- FMOM Fuzzy Multi Objective Model
- GDP General Department of Passport
- HF High Frequency
- LF Low Frequency
- MCDM Multi Criteria Decision Making
- MOOM Multi Objective Optimisation Model
- NFC Near Field Communication
- RFID Radio Frequency Identification
- SAR SAUDI RIYALS
- SQL Structured Query Language
- SWOT (Strengths, Weaknesses, Opportunities and Threats analysis)
- TGR Terminal Growth Rate.
- TOPSIS Technique for Order Performance by Similarity to Idea Solution
- UHF Ultra High Frequency
- UHL Ultra High Frequency
- WLAN Wireless Local Area Network

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. CHAPTER 1

Introduction

Introduction

Radio Frequency Identification (RFID) is an automatic identification technology that identifies objects within a given radio frequency range through radio waves without human intervention or data entry (Muller-Seitz et al., 2009). According to Tuba, 2014), RFID provides identification codes that can be related to human, livestock and other objects for tracing purposes. Moreover, RFID can correctly present real-time information about the locations of objects. A typical RFID system consists of three main components, namely, an RFID reader, an RFID tag and a data processing sub-system, the information being stored in the tag. This information can be read from several metres distance, using an RFID reader, which sends it to a sub-system to be analysed and presented in a usable format. In industry, the implementation of RFID has grown rapidly in different sectors, such as logistics and supply chain management (Nath et al, 2006; Mohammed et al., 201) and object tracking (Nemmaluri et al., 2008). However, this implementation faces several constraints from different sources, such as the economic challenge and the chance of collision between RFID readers. That is to say, implementing a new traceability system is associated with extra cost in investment, which is seen as a barrier for many decision makers, particularly small manufacturers and underdeveloped countries.

Karippacheril et al. (2011) have argued that reducing the cost of new tracking technologies, such as having cheaper RFID tags; will lead to better supply chains. Further, reducing costs and delivering efficient performance is expected to encourage (i) decision makers, to contribute to the development and implementation of tracking systems and (ii) countries such as China, to implement tracking systems aimed at increasing their industrial competitiveness in the world (Zhang). This has led to a growing desire for cost-effective designs for RFID-enabled tracking systems. To obtain a cost-effective design with reasonable performance, the design and optimisation of such systems need to take into account both economic and performance criteria. Moreover in today‟s competitive economy many parameters such as cost and potential market demand are subject to uncertainty. Nevertheless, in some cases such as encountering volatile market conditions or having capital limitations on large investments, it may be essential to think of making variations to the network design (Fattahi et al., 2015; Davis, 1993). Hence, in recent years, the problem of uncertainty has had to be taken into account regarding network design problems. A number of studies have used a fuzzy programming approach to tackle randomness in the input data of networks (Mohammed et al., 2017; Gholamiana et al., 2015).

The optimisation of an RFID-enabled system is a typical multi-objective problem associated with several variables and imprecise parameters. Specifically, multi-objective optimisation refers to the concurrent optimisation of multiple decision-making objectives, which may be in conflict.

In this thesis, a multi-objective optimisation model (MOOM) is developed for tackling a design problem for a proposed RFID-enabled passport tracking network. The model is aimed at minimising the costs of implementation and operation, minimising interference from the RFID reader and maximising the social impact as measured via the number of jobs created. Furthermore, to cope with the uncertainty of the critical input parameters (i.e., the costs and demands), a fuzzy multi-objective model is developed.

On the other hand Vendor selection is a key factor in implementing a robust business (Amid et al., 2006). This is based on the fact that enterprises depend greatly on vendors to contribute to their cost-effective high performance. Furthermore, purchasing activity is one of the main tasks for enterprises, since its costs represent more than 50% of all the internal costs of an enterprise (Aissaoui et al., 2007; and Yazdani et al., 2016). Vendor selection can be defined as the activity of selecting the best vendor on the basis of their tenders with reference to a number of criteria in order to stabilize the environment of their competition. Generally, it is a major concern and challenge to decision makers since several uncontrollable and unpredictable factors are involved (Bevilacqua et al., 2006). An inappropriate selection may compromise the financial and operational status of the enterprise, most of all when the purchasing is of high value, complex and perhaps critical (Araz and Ozkarahan, 2007; and Faez et al., 2006).

Vendor selection can be divided into two main types: (1) single-selection, where one vendor is invited to implement an enterprise‟s project and decision makers do not need to make a decision, i.e., when a unique project is involved that depends upon a single vendor; and (2) multiple-selection, the more common type, where multiple vendors are invited to submit their tenders for implementing an enterprise‟s project. In this case decision makers need to select the best tender. Multiple selection is preferred because it can more easily guarantee timely delivery and order flexibility due to the diversity of the enterprise‟s orders overall (Aissaoui et al., 2007; Jolai et al., 2011). Generally, vendor or supplier selection is a complex, multi-criteria decision-making process, because different and conflicting criteria must be assessed in order to find consistent suppliers. Davidrajuh (2003) and Kilic (2013) justify this complexity by the changeable key-factors that may be uncertain and conflict with each other, such as cost, delivery time, service level and product quality. Further supplier selection criteria can be found in Weber et al. (1991); Govindan et al., 2015; and Aissaoui et al. (2007). According to Shyur (evaluation always involves the vendor‟s criteria of performance and these may conflict with those of the enterprise. The Multi criteria decision making (e.g., AHP and TOPSIS) techniques are jointly derived in order to manage the problem.

Several research papers have managed to solve the vendor selection problem (DaiDebao et al., 201 , 2011; Davidraju, 2003; Jabbour and Jabbour, 2009;). However, the literature shows that few if any of the previous studies have presented an integrated approach which considers resilience criteria and traditional criteria simultaneously.

This study presents the development of a hybrid decision making tool aiming to select the best tender out of 7 submitted to implement an actual RFID-based passport tracking system. First, a framework was developed for defining the trasilience criteria and sub-criteria (e.g. traditional pillars such as costs and delivery commitment plus resilience criteria such as flexibility and agility). Traditional and resilience criteria were identified according to the literature review and discussions with the institution under study. Second, DEMATEL was used to determine the relative importance of each of the trasilience criteria and sub-criteria. Third, ELECTRE was used to evaluate and rank the vendors with respect to their trasilience performance. Fourth, TOPSIS was also applied to validate the ELECTRE results in the ranking of vendors. The relative importance levels revealed via DEMATEL were incorporated in the implementation of ELECTRE and TOPSIS.

Aim and Objectives

The aim of this study is to design an RFID-enabled passport tracking system. First, the optimal number of stages in the preparation should be established; and second, a compromise solution should be reached that satisfies three incompatible objectives (i.e. minimising the implementation and operational costs, minimising the RFID reader interference and maximising the social impact. This aim can be broken down into the following objectives:

. To understand the RFID technology for a tracking system through a comprehensive literature review.

. To develop a methodology to create and design a model of RFID-based management for a tracking system

. To design the requirements of an RFID model for a tracking system to develop a multi-objective optimization model.

. To develop a multi-objective optimization model that can be used for optimizing the proposed RFID-enabled tracking system.

. To obtain a compromise solution that satisfies three conflicting objectives, i.e., minimising the total implementation and operational cost, minimising the reader interference, and maximising the social impact.

. To develop a fuzzy multi-objective model to handle the uncertainty in the input date (demand and cost).

. To use an optimisation method to solve the developed model (e.g. ε-constraint and LP programming).

. To develop a user-friendly decision making tool as an aid to decision makers at the institution to select the best tender out of 7 proposals to implement the RFID-based passport tracking.

. To validate the developed model through its application within a case study.

Contributions to Knowledge

A review of the literature in this area reveals that no previous study has presented a cost-effective design for an RFID-enabled object tracking system that considers: (i) the strategic design decision regarding the numbers of related facilities that should be established; (ii) the total investment cost required for implementing the RFID; (iii) the uncertainties in the input data which have a significant impact on a network‟s strategic design; and (iv the social impact as an objective. Regarding the vendor selection, the literature shows that none of the previous writers presented an integrated trasilient approach that considers resilience criteria and traditional criteria simultaneously. This study presents a new trasilience tool for selecting a vendor.

This study contributes to the literature as follows:

. It presents the development of a fuzzy multi-objective model (FMOM) to obtain a design of a proposed RFID-enabled passport tracking system that is effective in cost and performance. This includes allocate the optimum number of related facilities to establish.

. Optimising the three key factors for effective cost and performance in the design of an RFID-enabled system i.e., minimising its implementation and operational costs, minimising RFID reader interference and maximising social impact requires a trade-off;

. Coming closer to the actual design task, the developed multi-objective model also incorporates the consideration of uncertainty in the input parameters of costs and demands.

. It introduces an optimisation methodology that can be used for optimising any similar fuzzy multi-objective model;

. It presents the development of a decision-making method for selecting the final trade-off solution from a pool of solutions derived from the fuzzy multi-objective mode;

. Two different solution methods used to solve the fuzzy multi-objective optimisation problem are employed and the quality of their solution performances is subsequently compared. This helps to obtain the best RFID-enabled system design and it also reflects the different perspectives and different preferences of the various decision makers.

. A case study is used to investigate the applicability of the developed model and methods proposed for solving it.

. To the best of my knowledge, this is the first research work that has applied a fuzzy multi-objective optimisation approach in an RFID-enabled system that takes into account all the three focal objectives (economic, performance and social) together.

Thesis Structure

This thesis is organised as follows:

Research background
Presents the research background and addresses the problems which motivated this research. The aim, objectives and contribution to knowledge form its content.

Literature review (Chapter 2)
This chapter provides a review of the literature related to this work. It includes previous studies of the operation of RFID systems also this cover previous studies and reviews the multi objectives and vendor selection techniques and models.

Key components of the RIFD system (Chapter 3)
This chapter outlines the database, RFID transmitter and receiver including the details of the tag and readers, the connectivity of RFID systems, RFID systems themselves, RFID middle ware and RFID software.

Technical overview and cost analysis (Chapter 4)
This chapter presents the technical architecture of the proposed system in detail. Starting with an Overview of the system, it also compares two vendors in terms of prospective costs, and includes the product details.

Multi criteria Decision making algorithm (Chapter 5)

An introduction of MCDM which include Multi Objective Optimisation and Multi attribute decision-making, presenting criteria, objective and methods used in the following chapters.

The multi-objective optimisation (Chapter)
This chapter studies the development of a multi-objective optimisation model which was used for obtaining a trade-off between three conflicting objectives. Furthermore, it contains new Decision making algorithms for the proposed RFID-passport tracking system design with a view to reconciling the conflicting objectives.

Vendor selection algorithms (Chapter)

This chapter presents the development of a hybrid decision making tool aimed at selecting the best tender out of 7 from various vendors to implement an actual RFID-based passport tracking system.

Discussion and conclusion (Chapter)

The final chapter includes an interview with an IT project manager to evaluate the design that was implemented and for improving future work. A conclusion is drawn, the thesis is summarised and some recommendations are made.

. CHAPTER 2

Literature Review

Introduction

This chapter contains a literature review on the subject of RFID tracking systems. It includes a comparison of the first generation with the second generation of the RFID in technical details.

In addition, it takes a historical approach to find the difference between barcodes and RFID. Then the applications of the RFID are described in detail showing the correspondence between them and the ways that they affect the supply chain. This chapter also covers the limited number of studies that have been written on the design and optimisation of RFID-enabled systems. Finally investigates vendor selection studies that adopt different methods and criteria.

Overview of Decision-Making methods using Artificial Intelligence

Regardless of their alternate points of view, the controls of the decisions and artificial intelligence (AI) science have regular roots and strive the comparative objectives. Specifically, the decision theory can give a significant system to tending to a portion of the essential issues in the AI, and the structures reason for a scope of the practice instruments. The artificial intelligence and the decisions that has been emerged by the research of science on the orderly strategies for the critical thinking and the decision-making, that bloomed in the 1940s (Eric, et al., 1988). These orders were empowered by new potential outcomes for the automated reasoning that has been released by the improvement of the computers. Despite the fact that the fields had basic roots, AI has distinguished itself from the others with self-ruling critical thinking, its focus on the symbolic rather the numeric data, its utilization of the declarative presentations, and its analogies interests between the human reasoning and the computer programs. AI has moved beyond the issues of the toy to think with the complexity, sufficient treatment of uncertainty, real world decisions has turned out to be progressively vital. In addition, the attempts to construct frameworks in such regions as aviation, medicine, human resources, investment and military arranging have revealed ubiquity of susceptibility related with deficient models. However the notion of the “Multiple Attribute Decision Making (MADM ” strategies are building and administration decisions guides in assessing as well as choosing the wanted one from the limited number of options, which are portrayed by the different characteristics (Casey & Kris, 2013). The MADM issues are of the significance in the assortment of the fields including designing, economies. It has been introduced the new FMADM approach in the light of the ideas of perfect and hostile to perfect indicates all together build up a weighted appropriateness choice framework to assess the weighted reasonableness of various choices versus different attributes. Furthermore, it has been considered about the "quality function deployment (QFD " arranging as a MADM issue and proposed another fuzzy outranking way to deal with the organize plan necessities perceived in the QFD and utilized a case of an auto configuration to outline the proposed approach. The researchers suggested that the attributes with respect to the fuzzy assessment can be identical or different, however, the subjectifies involvement in to the MADM issue, at that point this attribute is known as the "subjective attributes" (Bellman & Zadeh, 2000).

The objective and subjective attributes can be described in the two classes. Thus, the first is of 'cost' (or 'info') nature (the bigger, the less interest). The other is of 'advantage' (or 'yield') nature (the bigger, the more interest). The objective of the MADM is to decide the best option with the highest desirability as for every single attribute. The execution rating (or assessed rating) of all the option on every one of a given arrangement of characteristics is the reason for official choice. The majority of the fuzzy outranking strategies are only suitable for the assessment process for early designing the product stages, however not for a wide range of MADM issues. Since the majority of the exertion is required for the advancement of the arrangement of the fuzzy decisions standards, in choice settings with the numerous attributes to consider, building up the entire set of the rules of the fuzzy decisions that would be not really possible. In addition, FMADM strategy is proposed to defeat previously mentioned challenges (Olcer & Odabasi, 2005). The new FMADM calculation will be produced in the accompanying three major states: the attribute-based collection state, the Rating state, and the selection state. However, the rating state suggests that each professional gives his or her assessments (or execution appraisals) about the decisions regarding each subjective attribute. Whereas, in the attribute-based collection state for heterogeneous and the homogeneous expert groups is utilized. At times, it has been observed that the different experts are not correspondingly significant (or dependable). In such a case, it is known as the heterogeneous (nonhomogeneous expert"s group"s issue and something else homogeneous gathering of expert"s issue is considered (Brown, et al., 2011). However, the aggregation is important just for subjective attributes. Furthermore, after the weights of the attributes and the level of significance of the experts or the professionals are relegated, under each characteristic of the subjective attributes that all execution evaluations are collected for every option. Lastly, the fuzzy components of the aggregated grids of the decision making for homogenous or the heterogeneous gathering of the experts are defuzzified in the defuzzification period of the last state.

The rationale of the fuzzy choices has increased expanded consideration as a procedure for overseeing the uncertainty in a rule-based structure. In addition "the fuzzy logic inference system" more guidelines can fire at any given time than in a fresh master framework. Since the suggestions are demonstrated as probability distribution, there is a load of the considerable computation on the inference engine (James, et al., 1992). In the research, neutral network structure has been discussed with the three varieties of the system are depicted, however for each situation, the learning of the control (i.e., the forerunner and resulting conditions) are expressly encoded in the weights of the net. Despite the fact, the system decreases to fresh modus ponens when the information sources are fresh sets.

Tracking system

A tracking system is generally used for observing people or objects, following their movements and supplying a time-ordered sequence of the data of a location to a model and depicting the motion or variation in a display (Weijie, 2011).

RFID tracking system: RFID GEN1 and RFID GEN2

Despite the improvements that are embodied in the Gen2, Gen1 is still viable. Its straightforward functionality is helpful for people who have read-only capabilities; it costs little, is widely supported and is useful for mature products because of its ideal capacity to be cost-sensitive (Baars et al., 2008; Weijie, 2011; Berkhout, 2006;). It needs no extra bells and whistles. The anti-theft systems, asset tracking, sheer volume of the device for inventory control make the cost a large part of its benefits. Gen1 has more mature products and designs of quality reference (Brown, 200). Moreover, it contains app notes, development systems and various other devices that are easy to use. In comparison to the Gen1, the Gen2 is complicated and less well understood (Brusey & McFarlane, 2009; Martin,).

Consequently, low-cost, reliable and single-chip readers such as the “NXP Hitag HTRC11001T can easily be used and pasted in the embedded system to show applications of time-to-market (Nakhaeinejad & Nahavandi, 2013). The Gen1 reader is wrapped up or packaged in a little, low power, 14-pin SOIC which makes it suitable for battery powered mobiles and handheld readers (Chao et al., 2007). Additionally, included among its features are an integrated demodulated antenna, programmable filters and a serial interface of 3-(or 2)

The main difference introduced by Generation II is that it supports single mode and dual mode (Brown, 200 ; Weijie, 2011; Rousseau, 2014). The Generation II, whose budget is higher than that of the whole budget set for an entire reader, is still not proven to be cost-effective. A typical layout for the design of the Gen II is shown in the mentioned in table . below which uses a microcontroller as a host in order to drive the chip of the reader

Table - Comparison RFID Gen1 & Gen2(Razag, 2008).

Field description	GEN1	GEN2
Acceptance level	Not global standard	Global standard iso 180000 - 6 standard
Arbitration	binary tree for class0 and determining slotted for class	Probaplistic slotted
Q algorithm	n/a	yes
Air interface	Pulls width (pwm)	Pulse interval ,Miilar,FM)
Distance	Less than 10 meter	Less than 10 meter
Security password	8-24 bit password	32 bit
Covering coding	No	yes
Write speed for 96 bit EPC	TAGS PER SECOUND	MIN 5 TAGS PER SECOUND
SAME ID TAGS	Not allowed	allowed

The main difference showed that gen 2 the back scatter for the signal in two formats as Miller and FM0 whether in the GEN 1 is only one format and Q algorithm which allow locating the tag in indoor environment.

Barcode and RFID technology

Barcodes

Based upon a series of parallel black bars that represent identification data and information, the barcode is usually read by means of an optical device that includes a scanner (Baars et al., 2008; Lumban, 2013; Baars et al., 2008; Young, 2014). The data and information in the barcode are initially encoded by the variations in size (width) of a given bar and the amount of empty space between the bars (Gedik, 2013). Recently, barcode shapes have been used which are unlike the traditional bars and can be read by a huge range of other devices (Brown, 200). Nowadays, a different type of technology has been introduced in mobiles which allow them to scan and read the different types of barcode (Brusey & McFarlane, . See the Tables --------- for more details and comparison between Barcode and RFID.

Radio-Frequency Identification

The RFID is implemented by the use of radio waves to communicate data or information between the system and unique items. (Weijie, 2011). A typical kind of RFID system contains an RFID tag or a chip, an RFID reader and at least one antenna. The systems of RFID can be either passive or active (Brown, 200). Active RFID tags contain a battery by means of which they transmit the data or the information in a periodic way with a much greater range than passive tags have (Chao et al., 2007; Rousseau, 2014; Young, 2014). Passive tags with respect to the RFID reader are powered through electromagnetic induction (Brusey & McFarlane, 2009).

Table - comparison between barcode and RFID)

Standards	Barcodes	RFID
Convenience	the line of sight scan is required	Automatic scan in the absence of a sight line
Efficiency	It does not support the reading of batches.	Can read numerous tags at the same time.
Accuracy	Susceptible to human error and misreads	Reduced misreads and human error improve the accuracy of data
Traceability	It has limited traceability. It is impossible to track a barcode due to the stringent demands	It permits detailed tracking, and the process of tracing, output/input, and ends when all the steps have been taken

Table - Differences between barcodes and RFID (Cisco, 2010)(Brown,2006)

Speed	Not a real-time information process	Real-time information process
Reliability	They can easily be scratched or dirtied in a harsh manufacturing environment	RFID tags can endure challenging conditions, for example, high temperatures
Automation	More human labour is required to track and collect the data of the process.	Reduces or replaces human labor in tracking and collecting the data
Information	Yields limited information about the process	Yields abundant information about the whole procedure
Storage (data)	Allows only the storage of data that are centralized	RFID tags can carry huge amounts of data.

It is observed that once the user or reader powers the tag of an RFID, it responds by transmitting unique information (Chawla & Ha, 2007).

Advantages of RFID

The RFID has great advantages over barcodes. However, barcodes have already become a kind of a standard in several industries for various important reasons (Chawla & Ha, 2007). Cost effectiveness is important when people choose whether to adopt one or the other (Baars et al., 2008; Chao et al., 2007). Investing in barcodes is cheaper than in the RFID system but the latter has advantages owing to its power to increase efficiency and reduce error (Oztekin et al., 2010). A few of its significant major advantages are listed below:

The RFID tag is write/read

A barcode is readable only; once printed, a label cannot be changed. However, the data shown on the RFID tag can be replaced or modified (Brusey & McFarlane, 2009).

The RFID tag is durable and reusable.

Barcodes are easily rendered unreadable and damaged because they are always printed upon an unprotected surface or paper (Chawla & Ha, 2007). Depending upon requirements and needs, RFID tags are designed to be able to work and be read in harsh and demanding conditions. They can survive changes in the weather, moisture, heat and impacts (Brown,

; Baars et al., 2008; Chao et al., 2007).

RFID tags can carry encrypted data

Barcodes can easily be faked or counterfeited, and the data are themselves only readable. In the RFID tag, the data and the information are much safer because they can be encrypted (Lu& Yu 2014). Additionally, it is difficult to replicate the RFID tags in any system (Chao et al., 2007).

RFID tags are capable of storing more data.

The standard barcodes are usually limited in the quantity of information that they can showing or represent (Lu& Yu 2014). RFID tags, however, can easily store data in a memory that is non-volatile and capable of saving and storing around 8 kb of data per tag (Chao, et al., .

RFID tags can be read faster

Every single barcode must be scanned individually and entered in the system (Tuba, 2014). RFID systems can easily read multiple tags at the same time and do not require the line of sight that barcodes need (Brusey & McFarlane, 2009; Chao et al., 2007; Baars et al., 2008).

RFID tags can be printed with the barcode

If barcodes are being used and a switch needs to be made to the RFID system, the barcode and RFID are perhaps both required for this purpose, so RFID tags can be found which cope with labels made of printable paper (Chao et al., 2007).

RFID application in supply chain

The supply chain is a term that usually covers all the processes involved in the movement of goods from the time of manufacturing to the customer (DHS, 2006). It includes distribution, manufacturing and transportation. Thus, supply chain covers all these steps in association with the decisions about marketing, the demands of customers, strategy and the goals of general corporate alignment (Baars et al., 2008). It is considered to be a complex and knowledge intensive process; supply chain management can benefit from the practical employment of knowledge of RFID (Baars et al., 2008; Martin, ; Weijie, 2011).

The technology of RFID has increased to the extent that it has become a component of the revolution in supply chain management see Figure - . RFID is not only a replacement for the various barcodes, but also ensures that the right goods are in their proper places, whether by zero error or not (Razag, 2008). It goes far to make the supply chain more precise and accurate and further improves its reliability and efficiency throughout its length. It also improves the planning process and administration by making real-time data available, (Berkhout, 2006; Hagan, 2012; Baars et al., 2008).

The RFID application in shipping containers in the supply chain is huge; this is the most popular way of transporting large amounts of goods(Hagan, 2012). Containers are usually chosen because they ensure secure and safe transportation at lower cost, high transportation density and a standard type of packaging (Brown, 200). Different types of company use the RFID for managing and tracking their containers; at each link in the supply chain they can easily track their vehicle (Guangwei et al., 2014). It further is more efficient and accurate and offers a real-time view of the movement of cargo (Lumban, 2013). In the distribution process of a supply chain, the RFID accelerates the delivery speed, improves the efficiency, increases the accuracy and reduces the cost of distribution. Thus RFID a supply chain has further uses beyond the identification of the assets, shipments and products.

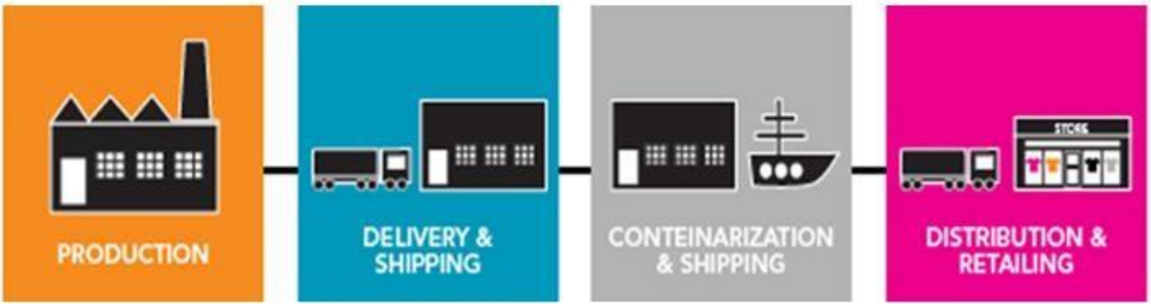

Figure - supply chain (Oxlade, 2013)

An RFID-based tracking system

Figure 2- demonstrates the design and implementation of the aspect of RFID that is known as the RFID tracking system (Razag, 2008). It develops a design or a system that can detect and identify a document and track it, thus lessening the risk of missing files or documents (Ilie-Zudor et al., 2006). One of the major issues or problems in offices or huge industries today is the loss of critical documents and files (Hagan 2012) and RFID helps to locate. Much time is wasted in chasing and finding misplaced files, which sometimes causes deadlines to be missed (Weijie 2011). This tracking system has revolutionised the tracking of individual documents. It benefits places that keep high value documents, where the loss of any of the will have a huge negative impact on the company (Berkhout, 2006). Unlike bar coding, the RFID system does not need line of sight detection or indeed any kind of manual scanning at far or close range (Razag, 2008). It consists of tags that are longer lasting and durable, some even being reusable (Chawla & Ha, 2007)

Design and optimisation of an RFID

There are few historical studies on the design and optimisation of RFID-enabled systems. Most of the previous research focused on the criteria for performance requirements, such as tag coverage and reader interference. Chen et al. (2011) proposed an optimisation model to be used for allocating locations to readers in an RFID-enabled network, with a multi-swarm particle swarm approach being used to optimise the model. The study by Oztekin et al. (2010) aimed to optimise the design of an RFID-enabled network in the healthcare service sector for tracking medical assets. Kardasa et al. (2012) investigated an RFID-enabled network planning problem via the development of a multi-objective artificial bee colony algorithm that sought a trade-off between optimal tag coverage, reader interference and load balance.

Mysore et al. (200) proposed an algorithm for allocating the minimum number of readers required for efficient coverage when a region is of irregular shape. Ma et al. (2014) presented a multi-objective artificial colony algorithm for solving an RFID-enabled network planning problem, whilst (Lu and Yu 2014) formulated a k-coverage multi-dimensional optimisation model for evaluating the network performance of an RFID-enabled network. The applicability of the proposed model was demonstrated via a plant growth simulation algorithm compared with other algorithms. Mohammed and Wang (2017) proposed a multi-objective programming model for an RFID-based meat supply chain, aiming to determine the optimal number of farms and abattoirs that should be established.

A review of the literature in this area reveals that no previous study has presented a cost-effective design for an RFID-enabled object tracking system that considers: (i) the strategic design decision regarding the numbers of related facilities that should be established; (ii) the total investment cost required for implementing the RFID; (iii) the uncertainties in the input data which have a significant impact on a network‟s strategic design; and (iv the social impact as an objective.

Vendor Selection

Several research studies have claimed to solve the vendor selection problem in light of traditional business criteria. Gadde and Snehota (2000) employed satisficing at the start of screen suppliers and AHP for the final selection. Similarly, Ellram (2009) applied programming of ANP multi objectives to a unit of refrigerator manufacturers. Chen (2010) proposed the model which combined structural modelling and a process of fuzzy analytical hierarchy. The approach of integration was developed and the quality function was deployed along with the theory of a fuzzy set and approach of AHP. This was done in order to select and evaluate the optimal third party providers of a logistic service. Amin et al. (2011) proposed a fuzzy SWOT method used to evaluate the vendor. Khaleie et al. (2012) used a ranking process on the two indices of score function and accuracy function, to rank the alternatives. Fazlollahtabar et al. (2011) proposed an AHP-TOPSIS approach, ranking suppliers on the basis of cost, quality, service, delivery, and innovation in turn. Liu and Zhang (2011) employed the ELECTRE III algorithm to solve the supplier evaluation problem, incorporating the technology available, service, management capability, and enterprise environment as evaluation criteria. Hague et al. (2015) proposed a TOPSIS-based approach to ranking and selecting the best supplier basing its performance in part on reliability and maintainability

Resilient vendor selection

In the last decade, interest from researchers and stockholders in supply chain resilience has grown rapidly as soon as they realized that a successful supply chain management should develop its resilience to cope with unexpected disruptions in supply and demand. Sheffi (defined supply chain resilience as "*its inherent ability to maintain or recover its steady state behaviour, thereby allowing it to continue normal operations after a disruptive event*". Since vendor or supplier selection is one of the main activities in supply chain management, a growing number of papers in the literature aims to generate a more resilient supply chain by using MCDM to check resilience in selecting vendors or suppliers. Haldar et al. (2014) developed a fuzzy multi-criteria decision making (MCDM) approach to this task ranking according to their degrees of importance such specific attributes as the linguistic variables formulated by triangular and trapezoidal fuzzy numbers. Torabi et al. (2015)

proposed a fuzzy stochastic bi-objective optimization model to improve the supply chain resilience under operational or disruptive risk by solving the SS/OA problem. Pettit et al. (2013) developed an evaluation tool called Supply Chain Resilience Assessment and Management designed to improve supply chain resilience. Rajesh and Ravi (2015) solved a resilience problem in supplier evaluation using a grey relational analysis algorithm that incorporates such resilience criteria as vulnerability, collaboration, risk awareness and supply chain continuity management. Finally, Hosseini and Barker (2016) proposed a Bayesian network approach for a supplier selection problem considering the resilience aspect in terms of unexpected disruptions.

The literature review shows that there is a gap in this body of knowledge; none so far has presented a trasilient vendor selection approach that can help decision-makers to invoke the traditional business criteria and unexpected disruptions by considering resilience criteria simultaneously

Summary

The second chapter, the literature review discusses it in a critical way. It briefly describes the tracking system in regard to the tracking system of RFID comparing RFID GEN1 with RFID GEN 2. Furthermore, a technology contrast between barcodes and RFID is made, showing the various benefits and advantages of each. The applications of the RFID are explained in detail, bringing out its value when applied to the supply chain. In addition, it gives information and a descriptive explanation of the system based upon the tracking of files with the help of RFID. The chapter included a historical survey of the multi objective model in terms of being fuzzy and finally it covered the previous research on the techniques of vendor selection.

. Chapter 3

Critical review of the RFID components

Introduction

This chapter presents a basic outline of all the RFID components: including the active tags, passive tags and semi-active tags, etc. This part of the study also covers the selection process and function of the tags at different points. It involves the technology and practical application of the RFID technology. Significantly, this part of the study explains the RFID antennas and their various characteristics. In additions, the readers of the RFID are described in depth, including their performance in practice. It is also important to learn, in this third chapter, about the ways of communication between the RFID readers and RFID tags. Importantly, the various characteristics of the RFID in the electromagnetic field are discussed, together with a brief demonstration of its performance in new field communication and far field communication. This chapter goes on to report on the RFID controllers and RFID software, explaining the application of RFID middleware and localization schemes for applying passive and active tags. It also proposes several schemes of localization.

Passive RFID Tags

The passive RFID tags are the ones that use no inter-source of (power (Mohammed, 2017). RFID tags are powered by electromagnetic energy that is transmitted from the RFID reader) (Lu & Yu 2014). They are used for various applications such as file tracking, supply chain management, race timing, smart labels and access control (Berkhout, 2006). The low price of these RFIDs makes them economical for industrial use (Karippacheril, 2011). They come in many sizes and are highly resistant to harsh environments and damage. They have, however, limited read range and are difficult to read through liquid or metal (Brown, 200).

Active RFID Tags

The active RFID system uses a different set of RFID tags“ these are battery powered and continuously broadcast their signals. These active tags are used as "beacons" to precisely track the location of things in real time What is tracked is any kind of asset; the tracking is quick even when tolling is included. These tags can be read at longer range than is possible with the passive tags, but they are expensive. They indicate the communications and the data are transmitted on a higher bandwidth. However, they are not suitable for small applications (Baars et al., 2008).

Semi-Active/Semi-Passive RFID tags

These RFID tags incorporate batteries and mostly use the power of the battery in order to run the circuitry of the tag and sensor (Harrop, 2010). This kind of tag is known as the battery assisted tag it communicates with its reader by means of the same techniques of backscatter as the passive tags use (Weijie, 2011). However, they have a longer read range because of the energy that they gain or gather from the reader which is then reflected back to the tag. It is also called a semi-passive RFID tag. The semi-active or active RFID tag is designed to broadcast signals at pre-set intervals. Semi/active or semi-passive tags are the same as passive tags (Ehrgott, 2005) the only difference lies in having small battery added (Baars et al., 2008). This particular battery allows the tag to be read through liquid or metal (Brown, 200). They enable the IC of a tag to be constantly powered and this makes the semi-active or semi-passive RFID tags even faster in their response than the passive tags are. However, they are less powerful and less reliable than the active tags (Wei, 2014).

Selection of RFID Tags

The selection of the RFID tag is based upon the application, with its particular characteristics and requirements. First of all, it should be remembered that the selection of the right frequency is highly significant; the frequencies to choose from are listed below:

- Low frequency (less than 135 kHz)
- Higher frequency (equal to 13 MHz)
- Ultra-high frequency between (850 and 960 MHz).

The various applications and their use determine the precise range of the frequency required (Wei, .

Before selecting the RFID tag, it is also important choose the right hardware, because the factors of the antenna type; size and price are related to the hardware. This helps to pick out the precise RFID tag based upon the type of the hardware (Bhattacharya & Roy, 2010). Other significant points are mentioned below

The reading dimensions should be checked before selecting one, because it involves three different ranges: Vicinity, where the range is less than 1 cm; b. Proximity, where the range is less than 10 cm; and Long Range where it is greater than 1 m) (Nath, 2006). Additionally, the material should be checked, because the frequency that is higher will have the higher influence and effect on the material and the environment (Brown, 200). However, different tags contain different levels of memory, and they display their UID (i.e. the serial number), One Time Programmable (OTP), the Segmentation File/Structure, W/R (Write/Read) and Multi-page (several types of independent pages) (Harrop). Usually, these tags also involve the factor of security, whether they are suitable for Plain communication, a Mutual type of authentication, and Password and PIN protected for writing or reading, and handle encrypted and encoded communication (DHS . Mutual and common authentication with encoded and encrypted communication and password or PIN protected write/read for different sectors can be selected according to the requirements and needs of the application (Baars et al., 2008).

The scale of the project includes the price/quantity of readers and price/quantity of tags. The choice of particular dimensions will depend upon the maximum size of the RFID reader, the maximum size of the RFID tag and the maximum size of the RFID antenna (Dao & Nguyen, 14). Various other general selection requirements include the robustness and toughness of the tag, anti-collision requirements, the type of material the tag is made from (e.g., glass, label, tube, coin etc.), temperature or environment, power consumption and depletion of the system, experience and Knowledge of HF designing and the use of a reader from the ledge or self-developed (Nath, 2006).

RFID Technology and Applications

Tracing the history of RFID is difficult, since some of the important decades in developing the technology of RFID were in the late 20th century. RFID is a term used to describe a specific system that transfers information about the identity of a particular object or person by means f radio waves (Nath, 2006). Furthermore, it is a method of automatic identification in which the RFID system can be easily stored and the data can be remotely retrieved by the use of chips, which are known as RFID readers and RFID tags (Baars et al., 2008).

A typical RFID system uses passive RFID tags to hold data or information, such as a barcode (Berkhout, 2006). These tags also contain some kind of extra information about the user. They are always read through the antenna that supplies power to the RFID tags by the process of interrogating them with a radio signal (Brown, 200). The system of RFID is huge in range; as its source of power it can use semi-active or active RFID tags that contain a battery, instead of using the interrogation of radio frequencies (Oztekin et al., 2010). These tags are normally used for identifying the large packets and pallets in sectors of the supply chain and its logistics (Brusey & McFarlane, . The implementation of the system of RFID has become well-known in healthcare settings. It helps nurses by checking their medication cabinets, tracking the medication inventory and tracking the patients, staff, and equipment within its system of RFID (Mohaisen et al., 20). In the big storage area of a supermarket, the system of RFId can trace and track the stock from the supplier to the customer‟s shopping trolley (Muller-Seitz.

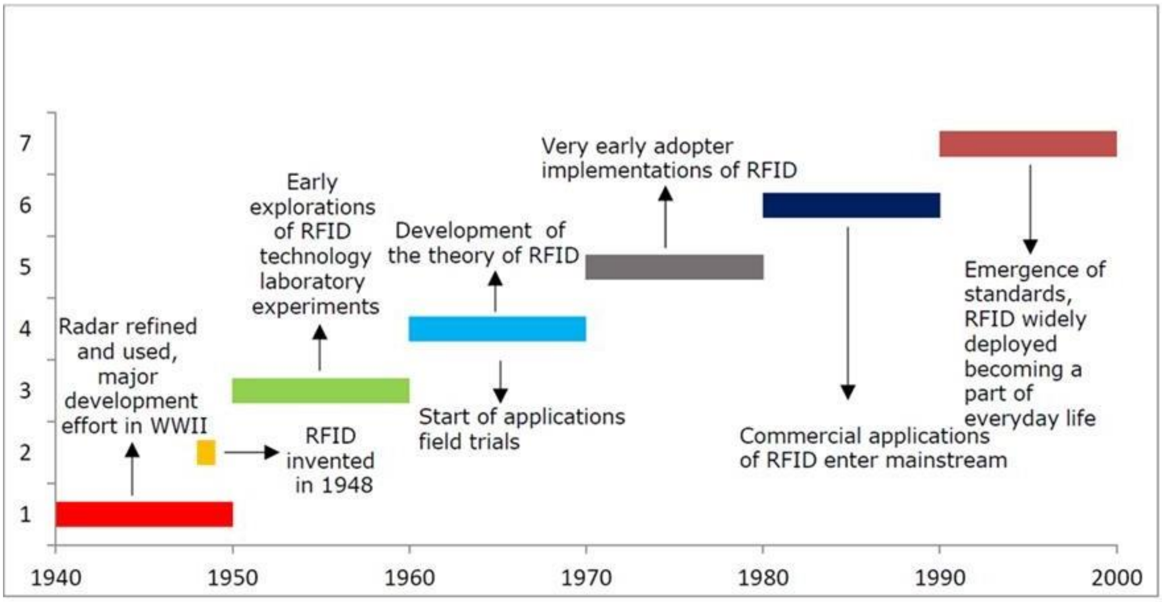

Figure - RFID Technology Evolution (Alyahya

RFID typically offers several advanced properties for easing the delivery of real-time information and data and of communication in general. The various benefits of using the technology of RFID have been summarized (Alyahya 2016). A study has shown that using the RFID technology is replenishes out of stock items three times faster than the use of barcodes does. It has also been claimed in several studies that the system of RFID is getting smaller, and is highly effective and less expensive because of the various developments in the sector of microelectronics and processing of data (Wei, 2014).

RFID tags are also being used in the for tracking luxury goods and in the automotive, healthcare, textile and retail industries. For example, the competitive fashion and textile industry uses the effectiveness of the system for providing a quick response to customers who want to identify possible counterfeit products. In the pharmaceutical industry RFID has been used to trace whole life cycle in the phases of storage, transportation, production and material supplies (Brown, 200). The percentage of each sectors and departments depicted in **Figure -** above, showing the use of the RFID system in different sectors.

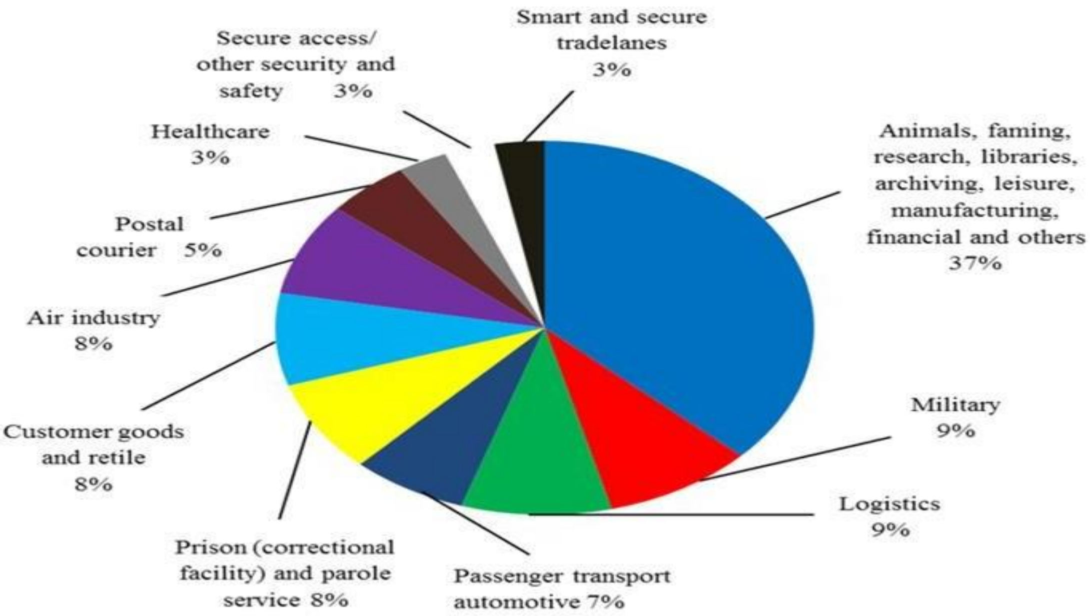

Figure - RFID applications, (Harrop, 2010)

The latest development of RFID techniques, which has attracted most attention, is applying it to supply chain logistics (see Figure -) (Harrop, 2010). Significantly, various possibilities and challenges arise in this application (Nakhaeinejad & Nahavandi, 2013). Comparing the technology of RFID with the approach of bar codes shows the significant improvements that it permits in the management of supply chain. It has improved the management of the supply chain by reducing the reliance on inventory and the various types of loss recorded there (Chawla & Ha, 2007). The approach of enterprise application integration is proposed for the dynamic measurements. The prototype design was made to demonstrate how accurate were the methods that are proposed in the environment of the shop floor (Brown, 200).

In manufacturing, some companies use the technology of RFID for tracking parts or components at every stage of the operations that make up production. The data or the information exchanged about this type of transaction can be stored in the RFID system and this makes it accessible to a firm‟‟ decision makers and managers **(**Alyahya,2016). There is a huge literature on the uses and applications of RFID for managing the inventory better and improving the various types of operation in the supply chain. It has been further analysed of the level and stages of the visibility of the inventory, shelf replacement and accuracy policies for the various operations of the inventory (Brown, 200).

The factorial structure has been used for analysing the benefits of non-credit relations and the return to investment in the implementation of management in real RFID. Additionally, writers note the ability of the technology or system of RFID to reduce significant sources of error in the inventory (Brusey & McFarlane, 2009). These common key errors include the misplacement of different objects or products, shrinkage and transaction errors (Chawla & Ha, 2007). Immense benefit has recently flowed from the increased interest that companies have in developing the visibility of the inventory for automated warehouses and realizing the significance of a management system that is based on the RFID technology. In addition, improvements can be further implemented in warehouses that are automated, to increase the speed and benefits of distribution (Brown, 200).

RFID Antennas

Generally, the RFID reader produces a modulated electric signal that carries information, instruction or data, which proceed to an antenna that is, attached externally (Harrop,(2010). Significantly, this antenna converts the electric signal into radio waves which it them broadcasts. Additionally, the antenna of the RFID tag receives the radio waves and changes or converts them into electric signals again in order to provide power to the chip of embedded IC and further decode the information or data (Brown, 200).

Antenna characteristics

The antennas have their own characteristics (Brusey & McFarlane, 2009), such as the basic and fundamental characteristics of:

. Impedance
. Bandwidth
. Polarization
. Effective radiated power or gain
. Appearance.

The type of antenna that is required usually depends on the exact specifications and conditions (Chawla & Ha, 2007). In most cases, antennas that have linear polarity are the most significant and common types but there are other types, including those with circular polarity (Wei, 2014). Importantly, the antennas that usually radiate along electrical wavelengths with linear polarization have more power and a longer range. Those with higher power and longer range are capable of producing stronger signals which are highly capable of penetrating many types of materials (Weijie, 2011). However, such antennas are highly sensitive to the angle and position of the orientation of the tag, making some of tags hard to read. In contrast, the radiation of the antennas which have circular polarization present no obstacle or difficulty in reading these tags, although the strength of their signal and range is comparatively weak in relation to the use of power (Baars et al., 2008).

RFID Readers

The RFID reader is the most significant part of the RFID system and is described as its central component. It relates to the capability and quality of reading and writing information or data to the tags of the RFID system (Brown.200). Significantly, it is becoming more and more important for RFID readers to exchange or move data securely with the proper use of some kind of authentication that will enable users to encrypt the text (Chawla & Ha, 2007). The data and the information in the reader are initially encoded by variations in the size (width) of particular bars and the amount of empty space between the bars. Recently, other shapes of reader are being used beyond the traditional bars and they are capable of being read by a huge range of various other devices (Berkhout, 2006).

RFID readers are usually in one of three forms:

- Stationary readers
- Handheld readers
- Mounted readers

Stationary readers are mounted on the gates of a warehouse (Wei, 2014). Handheld readers are highly convenient and flexible in use (Chawla & Ha, 2007). Mounted readers are between the other two regarding placement. They are usually mounted on the system or device used by the mobile (Brown.200). Choosing the type of RFID system and readers depend on details provided from the GDP which should include the distance, the metal, the items and the size of the room, all these factors need to be

Consider to find the best type and best frequency.theorcaly we can recommend for such systems for 13.56 MHz item-level which recommended by ISO 18000 for tracking and authentication,

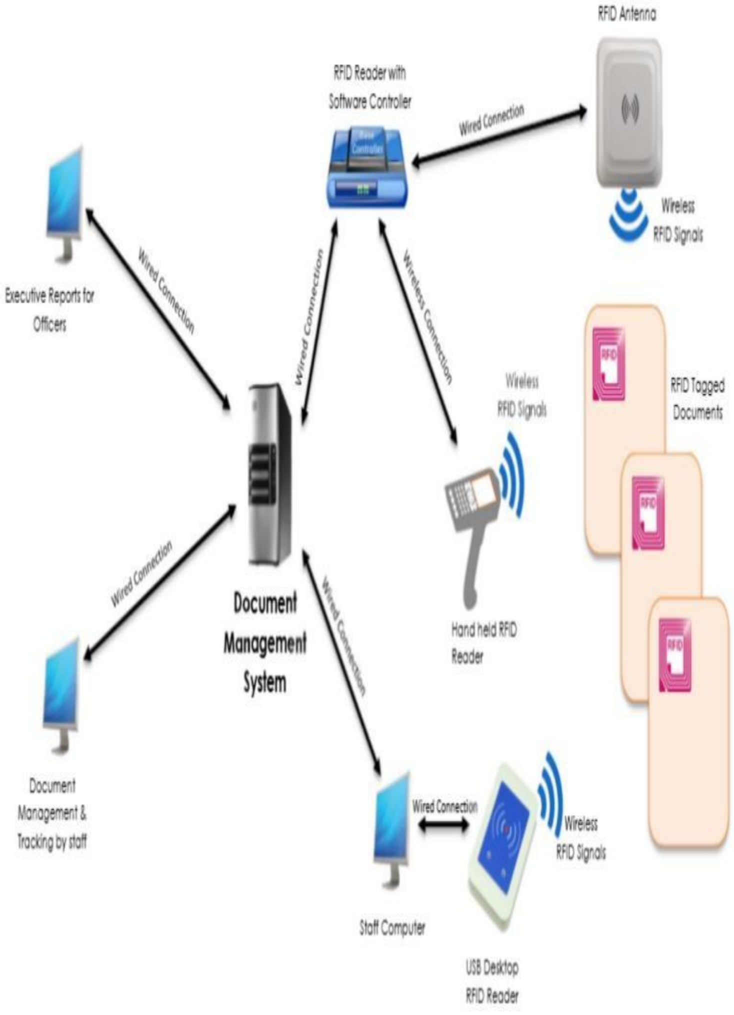

Figure - types of RFID readers diagram

The Figure 3- shows there are more than one type of readers handled fixed

They all do the same function to detect and track objectives however there are advantages for each one so for more details about the hand held antenna:

- Slim antennae
- Reliable quick detection

Fast processing

- Proven
- Varied functionality

However if the purpose is for a gate security using the fixed more valuable

Here we have advantages for the fixed RFID Modern design

- Counting solutions
- Audit reporting
- Remote Management

Most of the passive types of RFID reader operate best under specified terms and conditions. They contain external power because of they consume and put out more energy (Chawla & Ha, 2007).The RFID readers using this method are also known as interrogators. These readers are helpful in establishing a connection, usually wireless, with the tags of the RFID in order to capture information from them (Chao et al.,

.

The tags of the RFID system can easily be accessed by the RFID reader in the specified range of different tasks, including usually the encoding/writing tags of the system, filtering and the continuous and simple operations of the inventory (Brusey & McFarlane, 2009). The antenna is directly attached to the RFID reader for the purpose of collecting this information by performing the operations and tasks that are required. Significantly, after establishing the connection, the information is streamed to a computer or laptop for further processing. The reader of RFID can be used in fixed locations (Brown.200), such as stores or warehouses, while other RFID readers can be integrated with devices that are portable, such as handheld scanners. Additionally, there are various other models that can easily be embedded on the premises of electronic devices, including even vehicles (Weijie, 2011). However, in the management of warehouses, the system usually needs to be identified so that the items that arrive are safe and to ascertain in the warehouse or supply chain management whether every single item present in the store is effective or not. A record is kept of the database and data of the items that have the tags of RFID attached to them are stored (Weijie, 2011). This further, allows those specific items to be identified so that data can be retrieved about the availability of all items that are stored in the supply chain or the warehouse (Nemmaluri & Corner, 2008).

RFID reader performance

Selecting an RFID reader requires consideration. The most important feature is the ability to fulfil the requirements of the RFID system(Brown.200). Other performance parameters that should not be forgotten are the write range, write rate, read rate, read range, identification rate and identification range (Chawla & Ha, 2007). Going backwards, the identification range indicates the distance at which a specified tag can easily be identified. The rate of identification is the number of particular tags that can easily be identified within the range of the coverage. Additionally, the read range is known as the range or the distance at which a given tag can normally be read and the read rate is the maximum number of tags that can usually be read per second (Wei, 2014). The write range in the distance at which a given tag can easily be loaded with information and the write rate is the maximum number of tags that can easily be loaded with the data or the information per second.

This study demonstrates the design and implementation of the RFID that is known as the RFID management system. It develops a design or a system for detecting and identifying the document tracking which combats the risk of missing files and documents. It helps to locate the required documents and files which otherwise present a major problem of wasted time in offices and industries today (Hagan, 2012).This tracking system has revolutionised the tracking of documents. It is useful for any situation involving precious documents which should not go missing (Berkhout, 2006). Unlike bar coding, the RFID system does not need the line of sight and moreover requires no manual scanning at far or close range. It depends on tags that are very long lasting and durable, even reusable in some cases (Brown.200).

The environment in which the RFID system, including its input-output ports, is operating or is required can easily affect the performance or the working of the RFID reader (Weijie, 2011). Such interfaces involve different standards and components for a huge number of RFID readers. These readers have become highly or increasingly mobile and portable, improving the flexibility and convenience of the RFID systems and their various types of installation (Wei, 2014). Commercial devices are often designed with additional features and components, for example, input and output ports for the annunciator, additional memory and sensors, which help to maximize the effectiveness of the RFID reader communication between RFID tags and RFID readers

As noted above, the most significant characteristics of the RFID system compared to the barcode system is that its communication with the reader does not require wiring or a line of sight. RFID readers and RFID tags communicate by electromagnetic means. The frequencies used in RFID can be divided into three different categories according to their use: ultra-high (UHL), high (HF) and low (LF). The term frequency denotes the size of the radio waves that are used for the purpose of communication between the components of the RFID system (Brown.200).

The RFID system must work within a certain frequency band, depending on the disadvantages and advantages of the three kinds for a given task. In choosing a suitable operational frequency, the system specifications should be evaluated carefully because radio waves have different behaviour patterns in the different frequency bands (Nemmaluri et al., 2008). This can be understood through the example of the ability of radio waves at low frequency to pass through many liquids including water, and through many other substances and materials. Moreover, these waves even work better in contact with some metals. At higher frequencies, the behaviour of radio waves is generally similar to the behaviour of light, which tends to be reflected off other surfaces or absorbed by certain materials (IAITO, 2013).

The management of a retail inventory is one the applications for which ultra-high frequency are used. For the purpose of pharmaceutical anti-counterfeiting, low-frequency tags of RFID are generally readable from a distance. Low frequency tags are usually readable up to a distance of 1 metre. In relevance, High frequency transfer rates of data are attainable through the use of ultra-high frequency waves, but in practice their rates of performance over metals and liquids are significantly reduced, and data transmission becomes virtually ineffective (Wei .

However, the passive RFID tags that operate at ultra-high frequencies continue to gain the interest are still being improved. In supply chain management the motive using RFID tags that are UHF, as opposed to HF or LF tags, comes down simply to the reading range and cost-effectiveness of the choice of tag, coupled with the vendors‟ commercial offerings of comparatively inexpensive and simple RFID tags in the ultra-high frequency range. This is the frequency that is the most sensitive of the three to the interference of radio waves; but numerous UHF products, for example, reader antennas and tags are intended to work even in more challenging environments (Corer RFID, 2012).

RFID tags are selected upon different considerations, which include reading compatibility, range of frequencies, form factors, current conditions, and compliance with standards.

They have been developed and designed to transfer data only if the reader is within the range of the tags, to conserve the life and energy of the battery. The tags are typically produced as Disk tags, Wrist band mounted tags, Key-ring fob tags, Tags with a label backing for over-printing "Laundry" tags (heat chemical and temperature resistant), label tags that are tamper-proof, Self-adhesive tags with labels. They are 30mm x 26mm in size, plane, fixed on plastic (Alyahya).

Electromagnetic field

For powering the tags and transmitting the data two kinds of field are used

. Far-field communication (FFC)
. RFID near-field communication (NFC)

FFC and NFC differ in major ways with distinct criteria. The reading range of an RFID tag for NFC reading is less than a metre whereas tags for FFC can be read from 10-12 metres away. Moreover, they have different methods of transferring and storing data (Cisco, 2010).

Recognizing the variances in the functionality will help users to select the precise tolerance and capabilities to satisfy the specifications.

The kind of antenna that is required for operating the system also depends on the distance between the tags of RFID and the reader, which is known as the range of reading (Bhattacharya & Roy, 2010). Short range or near-field antennas are available, with a range of reading not more than 30-35 cm, whereas the long range or far field types have a range of reading of several metres, in optimal circumstances, possibly even double or treble this distance (Alyahya,2016) The maximum strength of field allowed is regulated by national principles. The EMC (electromagnetic compatibility) is restricted specifically to avoid interference with other systems and also damaging the environment (Cisco, 2010).

Far Field Communication vs Near Field Communication

Since RFID functions at any of three frequencies the best frequency to implement is determined by finding the distance from which the tags of RFID are to be read, the number of tags that can be read at once the shortest possible time in which these tags can be read and how the environment may affect the performance (Baars et al., 2008; Lionel & Liu, 2004).

The performance of FFC and NFC can be compared see Figure - (Alyahya,2016)

Read range in far field communication, the read range is up to 10-12 metres and the range is controllable whereas in near field communication, the range is 1 metre or less and the range control is fixed.

- Data transfer - in FFC it is fast but in NFC, it is slow.
- Security- in FFC the ID of the data is deposited and a server is required whereas in NFC data is deposited in the tag itself
- Design - the design of FFC is tamper proof whereas the design of NFC is standardized
- Queue management- FFC have automatic reading from measured distance whereas in NFC One by one reading from close distance
- Reading- FFC has multiple ways of being read, which are not present in the case of NFC
- Cost - the cost of FFC is moderate but that of NFC is even lower.

The figure below shows different frequencies used for far-field communication and near-field communication.

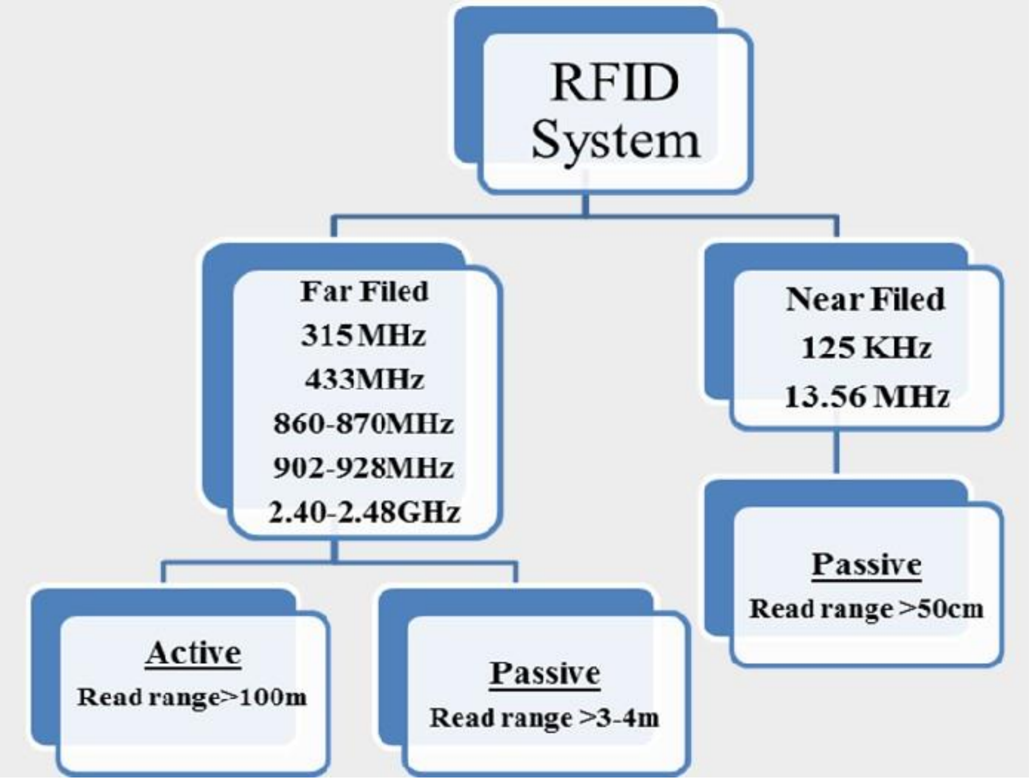

Figure - various frequencies between FFC and the NFC (Alyahya,2016)

RFID controllers

RFID systems comprise three components: the transponder (the tag), an antenna and a transceiver (these two are frequently combined in one reader). The antenna transfers a signal that stimulates the transponder (the tag) using radio frequency waves. When it is activated, the data are transmitted back by the tag to the antenna (Lu & Yu, 2014; Ilie-Zudor et al., 2006). All the data are used to alert a controller before the action occurs. The action could be anything from unlocking the gate to conveying a signal to a data bank that records a goods transaction from the organization to a buyer (Henrici .

Controllers are the devices that permit a group of RFID readers to communicate with the system of a computer, for example, the data server. With the increased complexity and proliferation\ of the RFID system, it has become necessary to line up a device that can

Control the communication between the host computer and the various readers of RFID, where all the data gathered from the RFID system are stored (Aggelos Bletsas, 2012). The system introduced by Reva, the leader in RFID integration in the current infrastructure of the network, is constructed to have a streamlined RFID reader network (DHS, 2006). This helps management by a product known as a Tag Acquisition Processor; the aim of this is to relieve uses from dependence on middleware by supplying a regulator that offers effective integration (Henrici .

Radio frequency identification is a technology that was established through integrating the use electromagnetic frequencies or the coupling of electrostatic in the radio frequency quota of the electromagnetic field to distinctively recognize a person, animal or object. The use of RFID in industry as a substitute to the bar code is increasing (Finkelzeller, 2003). The RFID advantages include freedom for line-of-sight constraints and no need for scanning or direct contact.

RFID Software

There are two groups of software for RFID

. RFID middleware

. Application software

RFID middleware:

RFID middleware uses reader devices for communication and the handling of data. As the name middleware‟ suggests it provides a filter of the middle level. Due to reading inaccuracies, nearly all the events of RFID management require cycles of repetitive reading. The raw data of high volume are processed by the middleware in reading cycles that carry detail along with the results and outcomes which contain the streams of data that are not of interest or use to the end end-users (Dimitriou et al., 2014).

The processing of data which are received from the reader devices of RFID provides users with more comprehensive and clearer outcomes at the level of events (Henrici, 2008). Furthermore, API is Provided, at a standard level of application, with information about the application level of the events. The information gathered can also be stored and saved by middleware; for example with the backend database which stores the information about the RFID tag (Finkelzeller, 2003). The middleware in RFID is logically positioned midway between the real application of the business end and the hardware which is the RFID infrastructure. The middleware is normally operated by the reader devices of the RFID through the server, which connects it to the readers of RFID or to the network of RFID readers (Brown.200). This allows the communication between all the devices to be controlled and directed. It enables the information about events to be processed and prepared, in a format which is standardized, at the higher level, for application to the business end.

In EPC (event specification at the application level) the standardization is defined and the logical architecture and RFID middleware implementation are set out and described (Brown,). The RFID middleware manages and communicates information on events, which is created by the RFID device in a format, which is standardized in order to connect the business applications at the higher level (Dao & Nguyen, 2014). It is recommended that the middleware work should be done under the constraints of security policies and corporate standards, along with the interface with the warehouse management system (Kern, 1999). However, every company has its own unique requirements and set of conditions.

Localization schemes for the RFID applications of active and passive tags

The localization of objective in two or three dimensions is a problem that has been well studied. Different authors has proposed various solutions using different techniques (Baars, 2008). Equipment that is used outdoors has the Global Positioning System (GPS) technology as its best and efficient solution for locating vehicles, equipment and people (Lionel & Liu, .

However, in spite of the vast advances in signal sensing indoors, it is not feasible to use the technology of GPS there because of its requirements of line of sight with the satellite of orbiting (Lionel & Liu,2004). The ZigBee and WLAN types of wireless technology are being considered as possible solutions (Brown, 2007).

Unfortunately, these technologies are not fully reliable and have high margins of error. They are not on the right scale to handle the tagging of individual items (Brusey & McFarlane, 2009). Additionally, the cost of localization by such means generally exceeds the total cost of the objects that are being tracked and hence it becomes economically unfeasible to use them (Jeremy, 2005).

However, RFID is the emergent technology for use in such cases; it is nowadays widely seen as the most promising solution. It can locate objects in a network of mobile nodes which can be used for tracking the objects and triggering the events hence, it embodies the latest applications of IT (Brown.200).

The localization of tags is the major requirement for present and forthcoming applications, for example, tracking at the item level on a conveyer belt, or localizing inventory losses in industry (Cisco, 2010). Various RFID based schemes of localization for indoor application have been proposed (Alyahya,2016).

The present scheme calculates the position of the tag by estimating the strength of the signal from different readers. However, schemes of this kind usually demand active or customized tags and these need the extensive planning to pre-install the interrogating readers (Dao & Nguyen, 2014).

The tags of RFID commonly include two main sub-parts, named passive and active (Brown,) and various algorithms of location estimation have been proposed to localize them. The localization of the active tags requires technologies such as LANDMARC and Spot ON which uses an algorithm of aggregation for sensing a location in 3D by means of the Received Signal Strength Indication (RSSI) (Lionel, & Liu,, 2004). In this system, the tags are customized to estimate inter tag distance from the attenuation of the radio signal. Although the system requires an unacceptable amount of processing and computational time, it yields accurate tracking and localization data (Wei, 2014). Identifying the location depends on the calibration of dynamic RFID techniques in a system of active tag based localization (Yu .

The readers in this scheme estimate the location of a tag within a certain sub-region. When the tags enter a sub-region, it calibrates and computes the present distance between the readers and the tag (Kardasa, 2012). Additionally, the reference tags are also presented at the location; this is a well-known way of determining the power fingerprints for such locations (Muller-Seitz, 2009). These reference tags usually work as landmarks in any kind of system. However, despite the effectiveness of the localization system, it usually needs pre-deployment planning and pre-installation of the anchor tags and tags of customized active RFID (Lionel, & Liu (.

The passive tag in contrast brings up repository based, multi-frequency and probabilistic solutions in its localization scheme. Significantly, it is in the probabilistic schemes that the pre-deployment probabilistic of the localization of passive tags is estimated. Additionally, once the passive tag is interrogated, it can inform the reader only about its own presence within the premises of the angular sector (Yu, 2007). The angular sector is usually created by the reader with an angular antenna of a rotating form. This rotating antenna usually snaps the environment in dissimilar angular sections, having different powers of transmission to the angular space of the fine grain. In this system, the accuracy of the localization importantly depends upon the pre-deployment estimation made, the enumeration of the readers and their various deployment patterns (Kimionis & Tentzeris, 2014).

Significantly, in the scheme of multi-frequency, the field generators usually increase the range of the reader sign use a frequency range of around 433 MHz for the process of tag signalling whereas the tags usually communicate with a reader by using a frequency of 916 MHz However, the use of the field generators increases error in finding allocation. This makes it unfeasible to use for localizing passive tags in 3 dimensions (Yu, 2007). In the scheme that is repository-based, the RFID system based upon Library Information Management (R-LIM) is generally maintained for tracking and localizing tagged books in libraries.

maintains a repository of the different IDs of the RFID tags on all the books, together with the addition of the Shelf ID where the book is at present (Yu, 2007). Additionally, this specific scheme effectively reports the location of book but only to the point of recording its shelf (Muller-Seitz .

Summary

The third chapter contains information about the tags. As it states, these are of different types: active tags, passive tags, semi active tags, etc. This part of the study also covers the selection process and ways of using the tags at different points. It involves the technology and practical application of RFID technology. Significantly, this part of the study describes the RFID antennas and their different characteristics. In additions, the readers of the RFID are described in detail together with their performance when applied. This information about the ways of communication between the RFID readers and RFID tags is important. The characteristics of the RFID in the electromagnetic field are described, including a brief demonstration of it in near field and far field communication. It outlined the function of the RFID controllers and RFID software and middleware and the localization schemes involving the application of passive and active tags. It also proposed some schemes of localization. Last, this chapter sent into the performance of radio transmission for better exposure.

. CHAPTER 4

Technical requirements of an RFID system based application. (Business proposal approach)

Introduction

This chapter details the technique for implementing the RFID system. It also discusses a technical architecture and development approach that could be taken to deliver the proposed RFID system. As the operational cost is important, a cost analysis of the components of the RFID system is discussed, as well as a comparison between the costs of two vendors from different countries.

This chapter has been written in order to specify how the proposed RFID system would implement a solution that meets the requirements specified in a bid request and seeks to show that the end product for the RFID technique will be a robust performance. In other words, this chapter is a feasibility study proposed for the General Directory of Passports (GDP).

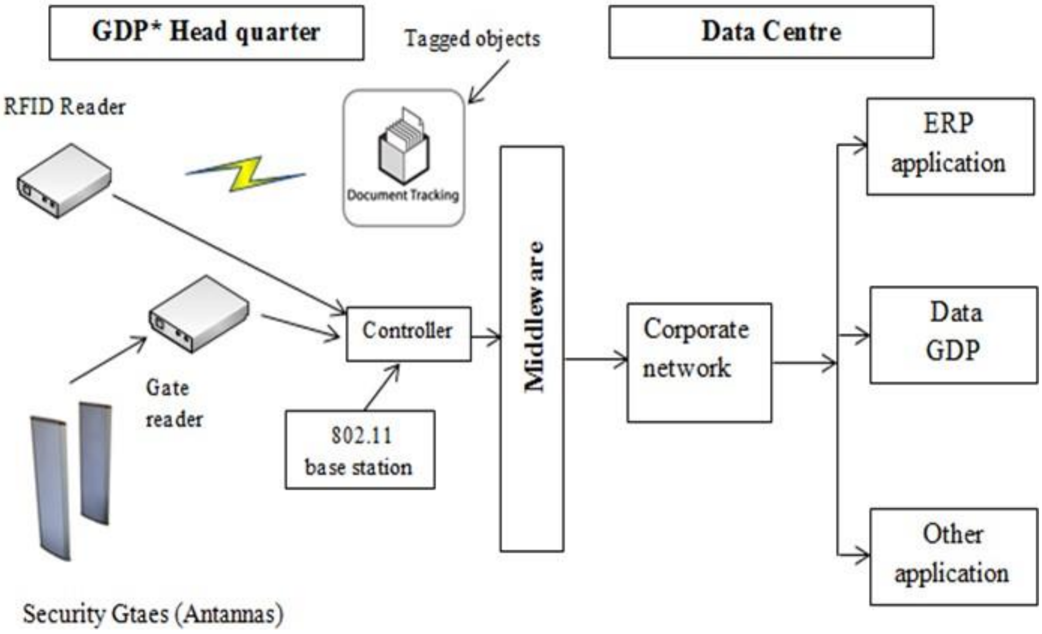

Figure - Technical architecture of RFID system

Scope

The technique of architecture that RFID system employs to deliver the tracking application is as follows. All tagged documents and items will be monitored, and information will be stored in a supported database and displayed in the central control system, see Figure 4- . However, the document does not include a detailed monitoring video as CCTV does. It can provide only a 3D perspective of the target building and mark the general location of the item of interest.

System Overview

The system consists of the following:

. Central Application Server for Business/Calculation Engine

. Remote / Web Access

. High performance user interface with advanced graphics

. Integration of the RFID system

. Database for Data Storage.

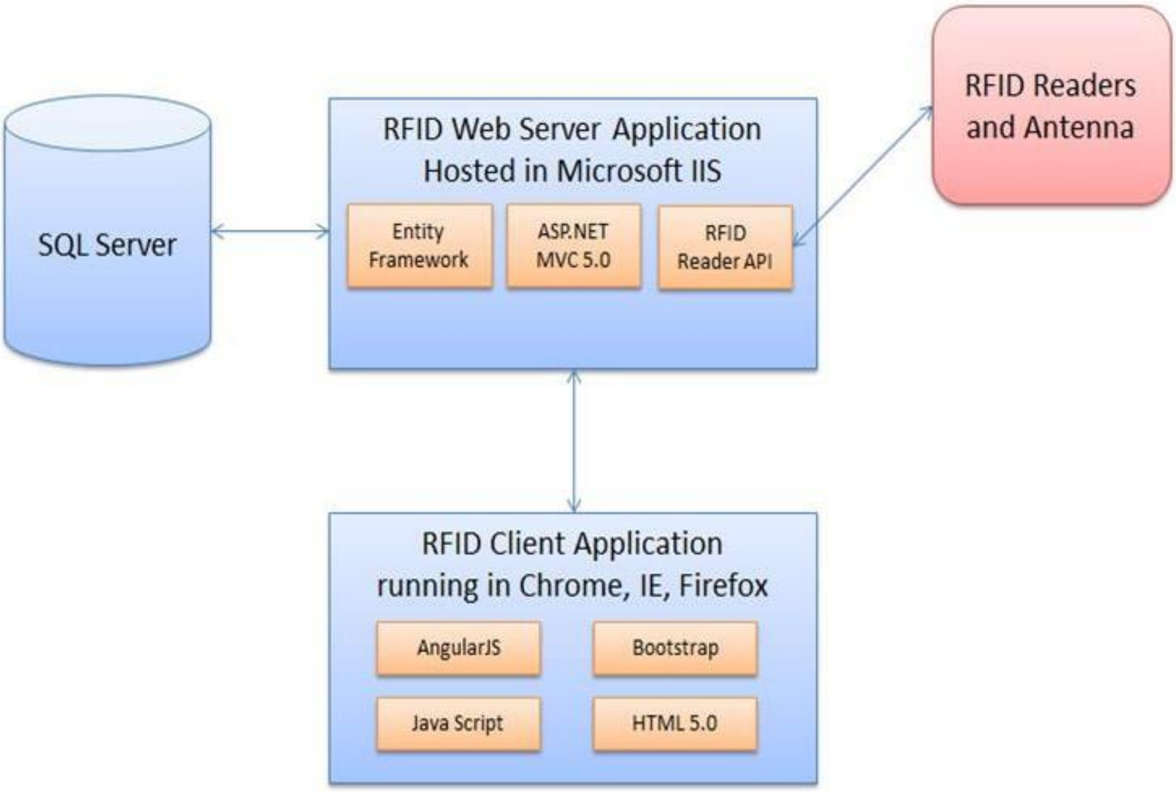

Figure - Database server architect

Central Database

The database server is located on a central server. see Figure 4- . It is used to store all the information associated with the system. This includes, but is not limited to

- Documents information
- Historical Data (asset class history)
- Static Data

The information includes the document ID number, type, name and date of birth of owner, etc. This is important data for the implementing allocation applications. The static data here are mainly the measurements of the target building, such as its height, width, depth, wall depth, number of rooms and their size, number of floors and height of each floor, etc. This information is used to plot the layout of the target building.

The database can be built by many means, such as EAPl, Micro SQL and so on. In this project, the SQL server is chosen to store the data because this software is a Microsoft product.

Application Server

The application server is used to run the calculation models. It will aggregate the historical data and provide projections on future growth potential. It acts as a data service provider for the front-end charts.

Internet/Web

The application is accessed using a standard browser front end, deployed as an internet application. Performance should be optimal. See Figure 4-

Some of the key objectives to implement RFID enabled-tracking System are as follows.

- Reduce the number of lost and misfiled documents.
- Provide faster search and retrieval of documents.

. Reduce the amount of physical space used to store documents, such as file cabinets, boxes and shelving.

. Organize existing documents better.

. Streamline information and workflow.

. Allow instant access to documents.

. Control the quantity and quality of records.

. Simplify the activities, systems, and processes of records maintenance and use. .

. Apply required retention periods to stored items.

. Develop and administer policies and procedures.

. Preserve records throughout their life cycle. A technical and also cost comparison of two different vendors see Figure 4- and see Figure 4- Considered as an RFID Technical Comparison between two different vendors is shown in the table below (Sunpai & SPV)

Table - RFID Technical Comparison between 2 vendors

Feature	American Brands	Chinese Brands
Durability	The life of the American hardware is expected to be around 10 to 15 years	The life of the Chinese hardware is expected to be between 2 and 3 years
Security	Safer using Trojans and other malware	not much prone to viruses, using Trojans
Compatibility	100% compatibility is guaranteed with relevant hardware and software	100% compatibility with relevant hardware and software is not guaranteed only software and hardware from the same company is compatible
Future Support	Annual feature updates in ROMS and regular bug fixes are available from the vendors	Only severe bugs and issues can be expected to be fixed by the vendor

Language programming and support	SDK are available in common programming languages with well written documentation in English	Some SDKs use only Chinese versions of popular programming languages support may not be available in English
Firmware Upgrades	Regular	None
App Performance	100% performance guaranteed	100% performance cannot be guaranteed

After the technical details, this section goes on to compare the same vendors in terms of cost under two assumption; having half quantity and full quantity.

Table - Commercials Approach Two, HALF QTY

	Product	Unit (No)	Unit Price SAR	Total SAR
	RFID (GT127A) wet inlay (no printing with adhesive) Disposable		.	
	RFID Reusable Tags with PVC Coating		.	
	M6 Reader with POE – Four Antennas Slots		.	
	M6 Reader with WiFi – Four Antennas Slots		.	
	External 12" Monostatic Antenna for M6		.	
	Juno Handheld Reader (Juno T41 CR) 3-4 ft range			
	USB+ RFID Desktop Reader/Writer		.	.
	Power Adapter for M6		.	
	(File Management System) Customized Application			
	Customized Android App for			

	Juno Handheld			
	Cabling (Coaxial+LAN+Power) as per actual based on RFT		.	
Total				
	NETWORK for RFID location		LOT	
	Server hosting of Application			
	Implementation			
TOTAL in Saudi Riyals				

Table - Commercials Approach Two, HALF QTY

Estimate SLA with RFID service RFID Assumptions	quantity	SLA	probability failure
Approach 1 with half qty	half		

Note: probability failure depends on such variables as natural disasters, building, electricity, equipment, etc.

Assumption 1:

In this approach the high frequency RFID devices are used for the purpose of managing and tracking the documents, with 4 x RFID Antennas and 1 x reader used in each room. This approach will enable the management to track the documents in real time and the software will inform the management which antenna the document is nearest to see Table 4- . The 4 x antennas will cover the entire area of all the rooms and the 1 reader will receive signals from them. A software based controller is used to allow communication between the devices

Table - Commercials Approach One FULL QTY

	Product	Unit (No)	Unit Price SAR	Total SAR
	RFID (GT127A) wet inlay (no printing with adhesive) Disposable		.	
	RFID Reusable Tags with PVC Coating		.	
	M6 Reader with POE – Four Antennas Slots		.	
	M6 Reader with Wi-Fi – Four Antennas Slots		.	
	External 12" Monostatic Antenna for M6		.	
	Juno Handheld Reader (Juno T41 CR) 3-4 ft range			
	USB+ RFID Desktop Reader/Writer		.	
	Power Adapter for M6		.	
	(File Management System) Customized Application			
	Customized Android App for Juno Handheld			
	Cabling (Coaxial+LAN+Power) as per actual based on RFT		.	
Total				
	NETWORK for RFID 1 location		LOT	
	Server hosting of Application			
	Implementation			
GRAND TOTAL		4,887,575 SAR		

Estimate SLA with RFID service RFID Assumptions	quantity	SLA	probability failure
Approach 1 with full qty	full		

Note: probability failure depends on such variables as natural disaster, building, electricity, equipment, etc.

Assumption 2

In this approach the high frequency RFID devices are used to manage and track the documents.8 x RFID antennas and 2 x readers are used in each room. This approach will enable the management to track the documents in real time and the software will inform the management which antenna the document is located nearest to see Table 4- . The 8 x antennas will cover the entire area of all the rooms and 2 readers will receive signals from them. A software based controller is used to allow communication between the devices.

Table - Approach One FULL QTY:

Vendor	The American	The Chinese
Total cost of half qty	3,644,823 SAR	1638497 SAR
Total cost of full qty	4,887,575 SAR	2622353 SAR

Finally, a technical and cost comparison between two vendors from different countries was made, taking account of all the relevant information to increase the amount of knowledge and vision available to the people concerned. However, a standard static comparison is not sufficient; while decision makers can select one vendor easily, they are not always sure which the better for the organisation is. In chapter 6 a vendor selection tool is deployed to find the best vendor in relation to the organisation‟s criteria.

Summary

The fourth chapter presented technical architecture and a system overview to clarify the RFID passport tracking system from installing the reader to the end user .Moreover a comparison was made between two vendors from different countries. Moreover for the better understanding of the project and study in technical and financial terms by understanding the business requirements and search and request vendors‟ proposal to be submitted, finally to evaluate the submitted proposals, In Chapter 7, a vendor selection tool is proposed for finding the best vendor under the organisation‟s criteria.

. Chapter 5

Multi-Criteria Decision-Making Algorithm

Introduction

The purpose of this present chapter is to give several model-based approaches by which a range of decisions can be made in solving the proposed problem in effective way. At the outset, the fundamental aspects of the multi-criteria decision-making algorithm are given, which are the multi-objective and multi-attribute factors.

Criteria, Objectives, Attributes

In contemporary society, managerial systems within firms are characterised by greater levels of complexity than has ever been the case. In many situations, managerial personnel seek to achieve several goals in simultaneous fashion, but it is important to recognise that such goals can often contradict one another. In view of this, the present author emphasises that capitalisation on a multi-criteria decision-making algorithm can promote numerous positive benefits for the firm, ranging from profitability, employee satisfaction, and shareholder satisfaction, to employee loyalty, higher incomes, and enhanced systems of product development.

Multi-Objective Group Decision-Making

Every project manager has an assortment of goals when beginning a new task, some of which are complementary, whereas others are conflicting. In view of this, multi-criteria decision-making (MCDM) offers a noteworthy strategy which, when applied, can aid managerial personnel in handling a collection of criteria which are not in line with one another. Practical issues to which MCDM can be applied are far-reaching, including the allocation of public funds to the national security budget, or the acquisition of a new house. Nevertheless, despite the differences that exist in terms of where MCDM can be applied, unifying strands exist across each(De León Almaraz, 2014) .These are given below:

- Multiple Criteria: As indicated by the name, MCDM is chiefly concerned with decision-making in the context of multiple objective or attributes.
- Conflicting Criteria: The objectives or attributes involved in MCDM are conflicting.
- Incompatible Units: Measurements for each objective or attribute occur in diverse ways.

. Design/Selection: Solving MCDM problems involve either designing the optimal alternatives, or the selection of the optimal solution based on a list of other options.

. In addition, MCDM problems can be categorised in the following:

Multi-objective decision-making (MODM).

Multi-attribute decision-making (MADM).

Multi-Objective Optimisation

The uncontrollable factors which have an impact on a dependent variable can be conceptualised as parameters or variables, where the former factors are fixed (crisp) factors, while the latter vary (i.e., are fuzzy). In this context, the uncontrollability stems from the way in which each factor emerges as a result of aspects of the system environment.

Decision variables can be conceptualised as outputs, and they provide an indication of the degree to which a system is efficacious in achieving its aim. Those who make the decisions establish values for the decision variables, thereby influencing the outcomes of the decisions, but these outcomes are simultaneously impacted by uncontrollable factors, as well as the ways in which the variables are interrelated.

In almost all cases, adequate problem-solving relies on the imposition of constraints, which specify the group of viable solutions to the decision problem.

One ideal solution is not possible when attempting to address a problem with multiple objectives, which stems from the fact that contradictions exist between certain antagonist objectives (Almaraz, 2014). Here, multi-objective optimisation is regarded as the systematic way in which problem-solving takes place when a range of contradictory design goals are sought after at the same time (Messac, 2015). As outlined in the studies conducted by Coello et al. (2007), Collette and Siarry (2011), and Rangaiah and Bonilla-Petriciolet (2013), the prioritisation of objectives is an unavoidable consequence of attempting to solve multi-objective problems.

It is possible to express the compact multi-objective optimisation in the following way:

$$\max/\min O(x)=(O_1(x),O_2(x),...,O_f\,(x))^T$$

subject to

$$g_i\,(x) \leq 0, i = 1,\, 2,3,...,\Big|\, a\; hj(x) = 0,\; j = 1,\, 2,3,...,b.$$

where O is number of objective functions; a and b are the number of constraints; is the decision variable vector; and z is the number of independent variables xi.

Dissimilar to the single objective optimization, the multi-objective optimization is characterised by the lack of a mono-dominant solution and – instead – the presence of a group of non-dominant solutions: namely, non-dominant (also referred to as non-inferior or Pareto) solutions. Noteworthily, non-dominant solutions are members of a certain group in which membership is defined by the solution‟s status as a compromise between several conflicting objectives. In the context of multi-objective optimisation, the derived solution is regarded as a non-dominant solution in the event that it enhances one objective while negatively impacting the performance of another.

Pareto solutions are regarded as groups of points that conform to a predetermined account of an optimum. The predetermined account for the optimal point is referred to as Pareto optimality (Pareto, 1906). This is given as a certain point, where an element x∗ ∈ X is Pareto optimal if it is not the case that an element x ∈ X exists such that O (x ≤ O (x∗), and Oi (x)<Oi (x∗) for at least one objective function. Best Pareto solution. In order to examine feasibility and applicability of the developed approaches.The Pareto frontier is the name given to the plot of all Pareto solutions in an objective space. (Mohammed and Wang, 2017) presented A solution approach was applied to obtain Pareto solutions and a decision-making algorithm was employed to reveal the best Pareto solution.

Methods for Multi-Objective Optimisation

The first step required to find a solution to a multi-objective optimisation issue is to identify those Pareto solutions situated on the Pareto frontier that it is not possible to determine in a direct way. With respect to genuine optimisation issues, the optimisation objectives constitute functions of several variables. As a result, the approaches adopted to find solutions are applied for the purpose of combining the multi-objective functions into a mono-objective function, which is regarded as the aggregate objective function (AOF). When the AOF is optimised, this results in Pareto solutions. Noteworthily, these approaches target the following issues: firstly, to give a group of solutions for linear multi-objective issues; secondly, to estimate the Pareto solutions pertaining to non-linear multi-objective issues (where certain Pareto points are not known); and thirdly, to estimate the Pareto solutions for non-continuous multi-objective issues (where every Pareto point is not known) (Caramia and Dell‟Olmo .

Multi-objective optimisation can be conducted in several ways, as noted by Ruzica and Wiecek (2003) and Ehrgott (2005). Furthermore, it is noteworthy that these approaches can be divided into the classical and metaheuristic areas (Donoso and Fabregat, 20). For the purposes of the present study, the classical methods have been examined, which are characterised by the way in which they translate the multi-objective problem into a mono-objective issue.

ε-Constraint (Compromise Programming)

Compromise programming was proposed by Haimes et al. (1971) as a way to facilitate the achievement of the efficient points that lie along a Pareto curve (Chankong and Haimes,). One of the defining features of this approach is the maintenance of the key objective as an objective function, and the movement of the other objectives to the constraint group, which is covered under a given value (ε The compact solution expression (O) is given in the following way:

$$\max/\min O_1(x) \qquad (.$$

Subject to

$$O_2(x) \le \varepsilon_1$$ (.

$$O_3(x) \le \varepsilon_2$$ (.

$$O_f(x) \le \varepsilon_f$$ (.

$$x \in S$$ (.

where S denotes a set of constraints, and represents the satisfaction level of the objective function Of. It is important to note that a parametric variation of values results in Pareto solutions. In the event that the objective function must be maximized, it is possible to reformulate the relevant constraint to Of (x ≥ εf.

Weighted Sum

The most straightforward way in which to solve multi-objective optimization problems, as well as to solve the issues with the approach characterized by the greatest level of intuition, is to apply the weighted sum (WS) approach. Noteworthily, this approach is frequently employed in the scholarly literature. The WS approach is characterized by the way in which it facilitates the aggregation of the multi-objective functions into a mono scalar function (O), which is multiplied against a suitable weight (w w … wf for each objective (Ruzika and Wiecek, 200 ; Ehrgott 2005). It is possible for the decision makers to determine the weight, or this can be conducted using methods such as the analytical hierarchy process (AHP). The compact solution formula (O) is given below:

$$\min O(x) = \sum_{f \in F} w_f O_i(x)$$ (.

Subject to

$$\sum_{f \in F} w_f = 1,\ w_f \ge 0,\ f = 1, 2, \ldots, F$$ (.

$$x \in S$$ (.

Goal Programming

This approach involves the minimisation of the unfavourable variances defined in relation to a certain goal. In view of this, the objectives are approached on a case by case basis, and the value is assigned as a goal regarding the approaching function (Charnes et al., 1955; Colapinto et al., 2015). The compact solution formula (O) is given below:

$$Max\ /\ Min\ O \qquad (.$$

$$\frac{\varsigma^{1}}{\mathrm{G}^{1}} \leq O_{1} \qquad (.$$

$$\frac{v^{2}}{G^{2}} \leq O_{2} \qquad (.$$

$$\frac{v^{f}}{G^{f}} \leq O_{f} \qquad (.$$

It is possible to express the equivalent objective functions in the following way:

$$Max\ /\ Min\ O_{1} = O_{1} + \varsigma^{1} - \upsilon^{1} = G^{1} \qquad (.$$

$$Max\ /\ Min\ O_{2} = O_{2} + \varsigma^{2} - \upsilon^{2} = \mathrm{G}^{2} \qquad (.$$

$$Max\ /\ Min\ O_{f} = O_{f} + \varsigma_{3} - \upsilon_{3} = \mathrm{G}_{3} \qquad (.$$

where

G^{1}	goal of objective 1
G^{2}	goal of objective 2
G^{f}	goal of objective *f*
ς^{1}	negative deviation variable of objective 1

ς^{2}	negative deviation variable of objective 2
ς^{f}	negative deviation variable of objective *f*
υ^{1}	positive deviation variable of objective 1
υ^{2}	positive deviation variable of objective 2
υ^{f}	positive deviation variable of objective *f*

Subject to

$x \in S$ (.

$\varsigma, v \geq 0$ (.

Weighted Tchebycheff

This approach is characterised by the transformation of the multi-objective model into a single-objective model (O). Subsequently, the single-objective model seeks to facilitate the minimisation of the distance between the optimal objective vector (O*) and the obtained feasible objective surface (Ehrgott 2005).

Global Criterion Approach

The purpose of this approach is to underpin the aggregation of the multi-objective function into a single objective function, thereby minimising the distance from the optimal objective value ( ) (Pandu, 2009). The compact solution formula (O) can be expressed in the following way:

$$Min\ F = \left(\sum_{f \in F} \left| O_f - O_f^{*} \right|^{\rho} \right)^{1/\rho} \ ; 1 \leq \rho \leq \infty \qquad (\ . \ )$$

Subject to

$x \in S$ (.)

Generally, ρ is 1. Nevertheless, it should be noted that it is possible to use different values of ρ.

LP-Metrics

Based on the LP-metrics method, the solution of every objective function takes place at the individual level, thereby attempting to derive the optimal objective values ( ) (Al-e-Hashem et al., 2011). The compact solution formula (O) can be expressed in the following way:

$$Min\ \mathrm{O} = \left[w_1 \frac{O_1 - O_1^*}{O_1^*} + w_2 \frac{O_2 - O_2^*}{O_2^*} + \ldots, w_f \frac{O_f - O_f^*}{O_f^*} \right] \qquad (.)$$

Subject to

$$\sum_{f \in F} w_f = 1, w_f \geq 0, f = 1, 2, \ldots, F \qquad (.)$$

$$x \in S \qquad (.)$$

Multi-Attribute Decision-Making (MADM)

MADM is characterised by the establishment of priority decision-making regarding supply selection, specifically with respect to the existing alternatives that reflect a range of (often contradictory) attributes. The key aspect of MADM is that there typically exists a finite number of preestablished alternatives, and these are linked to a level of the achievement of the attributes. In view of the attributes, the final decision can be made. Furthermore, the last choice of the alternative is established using inter- and intra-attribute comparative examinations. Noteworthily, this comparative examination can involve either explicit or implicit compromises.

MADM Methods

Several MADM methods exist, most of which have been designed as ways in which to ascertain the completing alternative as established in regard to different attributes. For the most part, the viability of one MADM method over another relies on the data given by decision makers, which can be categorised as insufficient (dominate method) or sufficient, and the expectations as pessimistic or optimistic. Several MADM methods, particularly those employed in the present research, are detailed below.

Decision-Making Trial and Evaluation Laboratory (DEMATEL)

This method is conceptualised as a multi-risk attribute decision-making algorithm, which can be applied to ascertain the weights of attributes. At the same time, DEMATEL allows evaluations of the interaction relationship between the variables that operate within a complex system, thereby illuminating the nature of the causal pathways in both a direct and indirect way. In addition, it can outline the degree to which certain variables have greater causal power when compared against others.

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Elimination and Choice Expressing Reality (ELECTRE)

The purpose of Roy"s ELECTRE MCDM algorithm is to rank-order potential choices in terms of viability and unviability. The algorithm achieves this by implementing a pairwise comparative examination of options against weights of certain criteria, intending to calculate a concordance set as well as a discordant set. Regarding this algorithm, various types of matrix are established based on the concordance and discordance sets, and this is followed by the utilisation of the threshold values as a way to facilitate the filtration of the less preferable options (in favour of the optimal ones) (Figueira et al., 2005). In recent years, ELECTRE has emerged as a critical MCDM evaluation algorithm for practical MCDM issues, which stems from the way in which it revolves around an outranking relation (Hwang and Yoon, 1981). As indicated in Table 2, linguistic variables and correspondent numbers were applied for the purpose of evaluating the vendors" performance with respect to the criteria. The evaluation was founded in relation to the decision-makers specialism when interpreting the level at which the suppliers performed regarding the trasilience criteria.

TOPSIS

The development of the Technique for Order Performance by Similarity to Idea Solution (TOPSIS) took place by Hwang and Yoon (1981). The researchers proposed the algorithm in order to establish a way in which to select an option based on its proximity to the optimal solution and the least favourable solution. In the present study, TOPSIS was implemented for the purpose of evaluating and rank-ordering the suppliers in view of their TGR (terminal growth rate) performance.

Analytic Hierarchy Process (AHP)

The AHP is characterised by the way in which it formalises complicated issues by way of a hierarchical structure. At the centre of the AHP is an approach by which those in decision-making positions can be aided in structuring a MADM issue by way of an attribute hierarchy, which is composed of the following three levels: (i) the focal point (namely, the overarching objective) at the pinnacle; (ii) several attributes criteria) which define alternatives in the middle; and (iii) alternatives (which are in competition) at the bottom. In contexts characterised by abstract attributes, sub-attributes can be produced in a sequential manner by employing multi-level hierarchies.

Summary

This chapter presented a fundamental concept of the multi-criteria decision-making algorithm which consist of (Multi objective optimisation and Multi multi-criteria decision-making algorithm, this chapter presents an overview of the multi-objective optimization including its definitions, solution methods and applications to solve several problems. The chapter also presents a study in identifying three approaches (e.g. fuzzy programming, robust programming, and stochastic programming) that used to handle the uncertainty in mathematical formulation of the supply chains. The above chapters also form the background and foundation of this research work subsequently in chapters 6 and chapter 7.

. CHAPTER 6

Cost effective design for an RFID multi objective optimisation

Introduction

This chapter presents the development of a multi-objective model for a cost-effective design. It concerns proposed RFID-enabled passport tracking system that would allocate the optimum number of related facilities to establish. The model would also help to obtain a trade-off between minimizing the implementation and operational costs, minimizing the RFID reader interference and maximizing the career opportunities. To this end, it was developed as a multi-objective optimization model. The objectives are to minimize the implementation and operational costs, minimize the RFID reader interference and maximise the social impact. To reveal the Pareto solutions, two solution methods, namely the ε-constraint method and the LP-metrics method were applied. The best solution was determined by comparing the obtained Pareto solutions using the Max-Min method .To determine the final trade-off solution, a decision making algorithm was applied.

Model development

This work presented a fuzzy multi-objective model for a passport tracking system, consisting of a set of three stages, called in turn office 1, office 2 and office 3. Figure - depicts the structure of a three-stage passport tracking network. Office 1 receives the request for new or renewed passports from clients. It is also responsible for checking whether the required documents are correct before sending them to office 2. Office 2 is responsible for issuing new passports and checking whether the information on former passports is correct (when due for renewal). Then it sends them to office 3 to be completed, and sent to the clients. The RFID is proposed as a device to improve system performance in terms of information accuracy, passport tracking for security purposes and easier issuing and renewing processes for clients. However, investing in such a system incurs extra costs that should be considered. The developed FMOM is used for obtaining a cost-effective design with regard to the number of stages that should be established. The overall aim is to obtain an optimal trade-off between the objectives previously described.

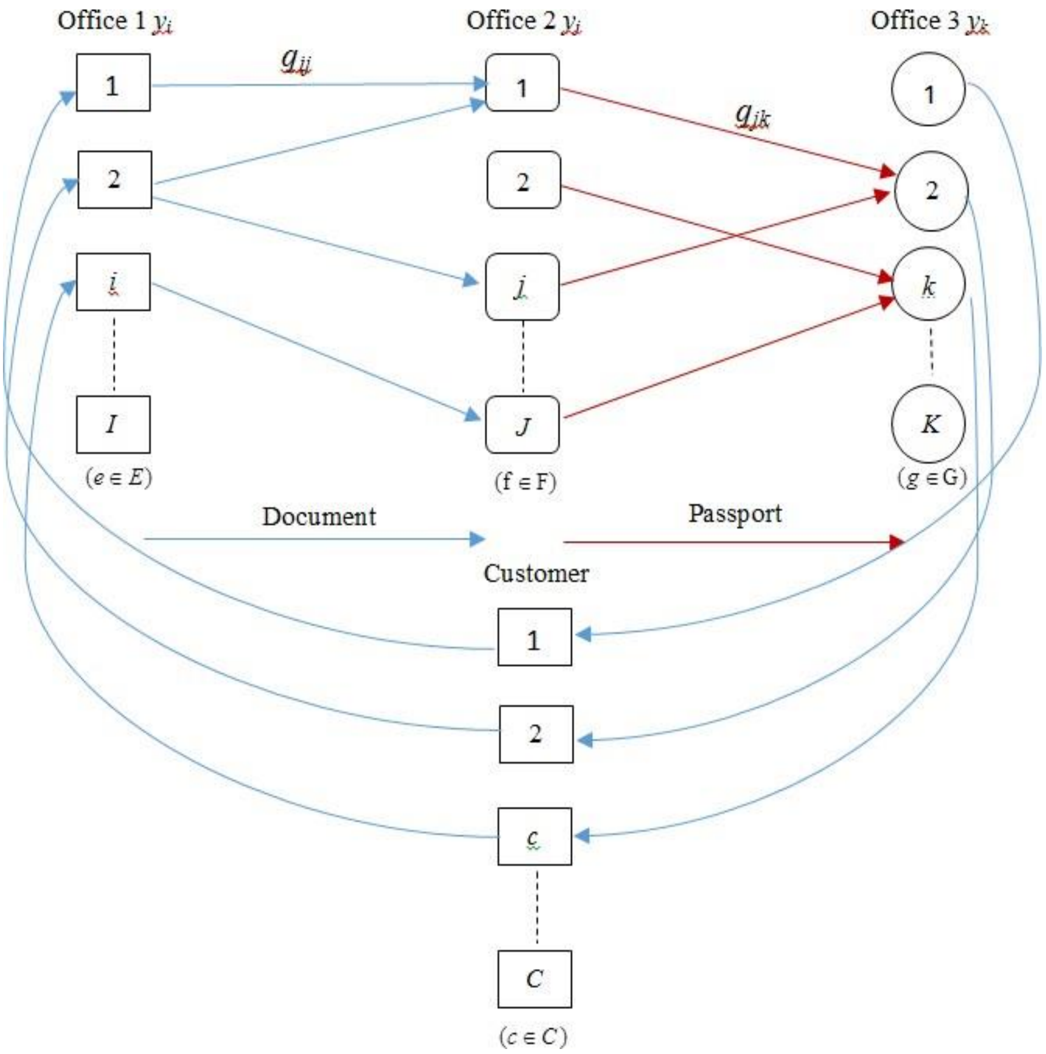

Figure 6- : Structure of the document-tracking network

The aims of the fuzzy multi-objective model are to:

- Minimise the costs required for implementing and operating the proposed RFID-enabled passport location tracking system;
- Minimise the interference that may occur among the RFID readers;
- Maximise the social impact in terms of the value generated due to establishing such a system and the creation of career opportunities.

The model is also aimed at determining a strategic design decision regarding the numbers of office 1s, 2s and 3s that should be established.

Notation

The following sets, parameters and decision variables were used in formulating the model:

Table - Sets of Parameters

I	set of nominated office 1 $i \in I$
J	set of nominated office 2 $j \in J$
K	set of nominated office 3 $k \in K$
C	set of customers $c \in C$

C_{ij}^{g} FID tag cost (GBP) per item

transported from office i to office j

C_i^r RFID reader cost (GBP) required per office 1 i

C_j^r RFID reader cost (GBP) required per office 2 j

C_k^r RFID reader cost (GBP) required per office 3 k

C_i^s fixed cost (GBP) required for the RFID management system

C_i^t training cost (GBP) per labour at i

C_j^t training cost (GBP) per labour at office 2 j

C_k^t training cost (GBP) for labour (s) at office 3 k

C_i^l labour cost per hour (GBP) at office 1 i

C_j^l labour cost per hour (GBP) at office 2 j

C_k^l labour cost per hour (GBP) at office 3 k

C_{ij}^l cost (GBP) required for labour for transporting document from office 1 i to office 2 j

C_{jk}^l cost (GBP) required for labour for transporting document from office 2 j to office 3 k

R_i working rate (items) per worker at office 1 i

R_j working rate (items) per worker at office 2 j

R_k working rate (items) per worker at office 3 k

R_{ij} working rate (items) per worker required to transport document from office 1 i to office j

R_{jk} Working rate (items) per worker required to transport document from office 2 j to office 3 k

H_i minimum required number of working hours (h) for labour at office 1 i

H_j minimum required number of working hours (h) for labour at office 2 j

H_k minimum required number of working hours (h) for labour at office 3 k

H_{ij} minimum required number of working hours (h) for labour transporting document from office 1 i to office 2 j

H_{jk} minimum required number of working hours (h) for labour transporting document from office 2 j to office 3 k

C_i maximum handling capacity (items) of office 1 i

C_j maximum handling capacity (items) of office 2 j

C_k maximum handling capacity (items) of office 3 k

D_j demand (in units) of office 2 j

D_k demand (in units) of office 3 k

D_c demand (in units) of customer c

ac_i number of available career opportunities if office 1 i is opened

ac_j number of available career opportunities if office 2 j is opened

ac_k number of available career opportunities if office 3 k is opened

Table - Decision variables

q_{ij}	quantity of units dispatched from office i to office j
q_{jk}	quantity of units dispatched from office j to office 3 k
q_{kc}	quantity of units handed to client c from office 3 k
x_i	required number of workers at office i
x_j	required number of workers at office j
x_k	required number of workers at office 3 k

x_{ij}	required number of workers to transfer document from office *i* to office *j*
x_{jk}	required number of workers to transfer passports from office *j* to office 3 *k*
y_i	1: if office *i* is opened 0: otherwise
y_j	1: if office *j* is opened 0: otherwise
y_k	1: if office 3 *k* is opened 0: otherwise

The model development was based on the following assumption:

- There are no restrictions for sharing network resources, whereby any office 1 may serve any office 2 and any office 2 may serve any office ;
- The numbers of input parameters are considered as uncertain parameters, which include costs, demand and value generated due to implementing the proposed system;
- Each office is equipped with an RFID reader;
- Each document is attached with an RFID tag;
- All demands from customers should be fulfilled;
- There is a certain capacity level for offices 1, 2 and 3;
- The quantity of flow of documents from customer *c* to office 1 *i* is neglected;
- Office 2 *j* and office 3 *k* *are* aware the number of documents submitted to office 1 *i* and their demand is determined accordingly.

The three objectives (i.e. minimisation of implementation and operational costs, minimisation of RFID reader interference and maximisation of the social impact**)** are formulated as follows.

. Objective function 1 (F1)

Minimisation of the implementation and operational cost for the RFID-enabled passport location tracking system = RFID tag cost for each item + RFID reader cost required for office *i,* office *j* and office *k* + labour costs at office *i,* office *j* and office *k* + labour costs required to transport document from office *i* to office *j* and from office *j* to office *k* + training cost for labour (s) at office *i,* office *j* and office *k.* Thus, the minimum F is formulated as follows:

Objective function 2 (F2)

$$Min\ F_1 = \sum_{i\in I}\sum_{j\in J} C^g_{ij} q_{ij} + \sum_{i\in I} C^r_i y_i + \sum_{j\in j} C^r_j y_j + \sum_{k\in K} C^r_k y_k + C^s_i + \sum_{i\in I} C^l_i x_i H_i \qquad (.$$
$$+\sum_{j\in J} C^l_j x_j H_j + \sum_{k\in K} C^l_k x_k H_k + \sum_{i\in I}\sum_{j\in J} C^l_{ij} x_{ij} H_{ij} + \sum_{j\in J}\sum_{k\in K} C^l_{jk} x_{jk} H_{jk} + \sum_{i\in I} C^t_i x_i$$
$$+\sum_{j\in J} C^t_j x_j + \sum_{k\in K} C^t_k x_k$$

The minimisation of RFID reader interference is formulated
 (Ma et al., 2014):

$$Min\ F_2 = \sum_{m_i\in RS_i}\sum_{n_i\in TS_{m_i}} \left(\delta - \left(P^{m_i}_{n} - \sum_{l_i\in RS}^{l_i\neq m_i} P^{l_i}_{m_i} y_i\right)\right) + \sum_{m_j\in RS_j}\sum_{n_j\in TS_{mj}} \left(\delta - \left(P^{m_j}_{n_j} - \sum_{l_j\in RS}^{l_j\neq m_j} P^{l_j}_{m_j} y_j\right)\right)$$
$$+ \sum_{m_k\in RS_k}\sum_{n_k\in TS_{m_k}} \left(\delta - \left(P^{m_k}_{n_k} - \sum_{l_k\in RS}^{l_k\neq m_k} P^{l_k}_{m_k} y_k\right)\right) \qquad (.$$

where $TS_{m_{i,\,j\text{ or }k}}$ is three sets of tags in the interrogation area of reader *m* at offices 1, 2 and 3, respectively. $RS_{i,\,j\ or\ k}$ is three sets of readers, which have tag *n* in their interrogation area at offices 1, 2 and 3, respectively. δ is the preferred power level; $P^{m_{i,jandk}}_{n_{i,jandk}}$ is the actual power level received by tag *n* in the interrogation area of reader *m* in office 1 *i*, office 2 *j and* office *k;* $P^{l_{i,jandk}}_{n_{i,jandk}}$ is the received power by tag *n* in the interrogation area of reader *l* in office 1 *i*, office 2 *j and* office 3 *k* (Ma et al., 2014). It should be noted that the number of readers is equal to the number of offices that need to be established. In addition, the number of tags is equal to the quantity of items transported from office 1 to office 2, where each document is attached with a tag. This objective is aimed at taking into account all the readers, excluding the best, as sources of interference.

. Objective function 3 (F3)

Maximisation of career opportunities = Career opportunities created at office 1 *i* + career opportunities created at office 2 *j* + career opportunities created at office 3 *k*. Thus, maximum F is formulated :

$$Max\,F_3 = \sum_{i\in I} ac_i y_i + \sum_{j\in j} ac_j y_j + \sum_{k\in K} ac_k y_k \qquad \text{(.}$$

It should be noted that the decision makers for each potential RFID-based system should quantify the value of ac, i.e. the number of created careers. In the study, the existing passport-issuing centre quantified the values of ac at the three offices.

Constraints

There are a number of constraints that need to be included in the optimisation. The constraints are given as:

$$\sum_{i\in I} q_{ij} \le C_i \; y_i \qquad \forall\, j \in J \qquad \text{(.}$$

$$\sum_{j\in J} q_{jk} \le C_j \; y_j \qquad \forall\, k \in K \qquad \text{(.}$$

$$\sum_{k\in K} q_{kc} \le C_k \; y_k \qquad \forall\, c \in C \qquad \text{(.}$$

$$\sum_{i\in I} q_{ij} \ge D_j \qquad \forall\, j \in J \qquad \text{(.}$$

$$D_j \ge \sum_{k\in K} q_{jk} \qquad \forall\, j \in J \qquad \text{(.}$$

$$\sum_{k\in K} q_{kc} \ge D_c \qquad \forall\, j \in J \qquad \text{(.}$$

$$\sum_{c\in C} q_{kc} \le D_k \qquad \forall\, k \in K \qquad \text{(.}$$

$$\sum_{j\in J} q_{jk} \ge D_k \qquad \forall\, k \in K \qquad \text{(.}$$

$$\sum_{i\in I} q_{ij} \le x_i \; \mathrm{R}_i \qquad \forall\, \mathrm{j} \in J \qquad \text{(.}$$

$$\sum_{j\in J} q_{jk} \le x_j \; \mathrm{R}_j \qquad \forall\, \mathrm{k} \in K \qquad \text{(.}$$

$$\sum_{k\in K} q_{kc} \le x_k \; \mathrm{R}_k \qquad \forall\, \mathrm{c} \in C \qquad \text{(.}$$

$$\sum_{i\in I} q_{ij} \le x_{ij} \; \mathrm{R}_i \qquad \forall\, \mathrm{j} \in J \qquad \text{(.}$$

$$\sum_{j\in J} q_{jk} \le x_{jk} \; \mathrm{R}_j \qquad \forall\, \mathrm{k} \in K \qquad \text{(.}$$

$$q_{ij}, q_{jk}, q_{kc}, x_i, x_j, x_k, x_{ij}, x_{ij} \geq 0, \ \forall i, j, k; \qquad (.$$

$$y_i, y_j, y_k \in \{0,1\}, \forall i, j, k; \qquad (.$$

Equations 4-6 ensure the flow balance of the document from office 1 to office 2 and from office 2 to office 3 with respect to their capacity. Equations 7-11 ensure that all demands are satisfied. Equations 12-16 determine the required number of workers at office office 2, and office 3 and between office 1 and office 2 and also between office 2 and office 3. Equations 17 and 18 limit the decision variables to being binary and non-negative.

Modelling the uncertainty

To come closer to reality, the multi-objective model needs to handle the uncertainty of some parameters, such as costs, demand and the value generated from implementing the proposed system. This allows the solution space to be flexible when the model contains some uncertain parameters. Consequently, the model is converted into an equivalent crisp model using the Jiménez method (Jiménez et al., 2007). Accordingly, the equivalent crisp model can be formulated as shown below.

The minimisation of the implementation and operational costs for the RFID-enabled passport tracking system under uncertain costs is formulated as follows:

$$\begin{aligned}
Min\ F_1 = & \sum_{i \in I} \sum_{j \in J} \left(\frac{C_{ij}^{gpes} + 2C_{ij}^{gmos} + C_{ij}^{gopt}}{4} \right) q_{ij} + \sum_{i \in I} \left(\frac{C_i^{rpes} + 2C_i^{rmos} + C_i^{ropt}}{4} \right) y_i \qquad (. \ ) \\
& + \sum_{j \in j} \left(\frac{C_j^{rpes} + 2C_j^{rmos} + C_j^{ropt}}{4} \right) y_j + \sum_{k \in K} \left(\frac{C_k^{rpes} + 2C_k^{rmos} + C_k^{ropt}}{4} \right) y_k + C_i^s + \sum_{i \in I} \left(\frac{C_i^{lpes} + 2C_i^{lmos} + C_i^{lopt}}{4} \right) x_i H_i \\
& + \sum_{j \in J} \left(\frac{C_j^{lpes} + 2C_j^{lmos} + C_j^{lopt}}{4} \right) x^j H^j + \sum_{k \in K} \left(\frac{C^{kpes} + 2C^{klmos} + C^{klopt}}{4} \right) x^k H^k + \sum_{i \in I} \sum_{j \in J} \left(\frac{C_{ij}^{lpes} + 2C_{ij}^{lmos} + C_{ij}^{lopt}}{4} \right) x_{ij} H_{ij} \\
& + \sum_{j \in J} \sum_{k \in K} \left(\frac{C_{jk}^{lpes} + 2C_{jk}^{lmos} + C_{jk}^{lopt}}{4} \right) x_{jk} H_{jk} + \sum_{i \in I} \left(\frac{C_i^{tpes} + 2C_i^{tmos} + C_i^{topt}}{4} \right) x_i + \sum_{j \in J} \left(\frac{C_j^{tpes} + 2C_j^{tmos} + C_j^{topt}}{4} \right) x_j \\
& + \sum_{k \in K} \left(\frac{C_k^{tpes} + 2C_k^{tmos} + C_k^{topt}}{4} \right) x_k
\end{aligned}$$

The formulae for minimising the reader interference and maximising the **career opportunities** of the RFID-enabled passport tracking system set out in Equations 2 and 3 are not changed, since they do not include any uncertain parameters.

$$Min\ F_2 = \sum_{m_i \in RS_i} \sum_{n_i \in TS_{m_i}} \left(\delta - \left(P^{m_i}_{n_i} - \sum_{l_i \in RS}^{l_i \neq m_i} P^{l_i}_{m_i} y_i \right) \right) + \sum_{m_j \in RS_j} \sum_{n_j \in TS_{mj}} \left(\delta - \left(P^{m_j}_{n_j} - \sum_{l_j \in RS}^{l_j \neq m_j} P^{l_j}_{m_j} y_j \right) \right)$$

$$+ \sum_{m_k \in RS_k} \sum_{n_k \in TS_{m_k}} \left(\delta - \left(P^{m_k}_{n_k} - \sum_{l_k \in RS}^{l_k \neq m_k} P^{l_k}_{m_k} y_k \right) \right) \qquad (.)$$

$$Max\ F_3 = \sum_{i \in I} ac_i y_i + \sum_{j \in j} ac_j y_j + \sum_{k \in K} ac_k y_k \qquad (.)$$

Subject to Equations 4-18,however, Equations 7-11 are reformulated to cope with uncertain demands, as shown in Equations 25- .

$$\sum_{i \in I} q_{ij} \leq C_i\ y_i \qquad \forall j \in J \qquad (.$$

$$\sum_{j \in J} q_{jk} \leq C_j\ y_j \qquad \forall k \in K \qquad (.$$

$$\sum_{k \in K} q_{kc} \leq C_k\ y_k \qquad \forall c \in C \qquad (.$$

$$\sum_{i \in I} q_{ij} \geq \frac{\lambda}{2} \frac{D_{j1} + D_{j2}}{2} + \left(1 - \frac{\lambda}{2} \right) \frac{D_{j3} + D_{j4}}{2} \qquad \forall j \in J \qquad (.$$

$$\frac{\lambda}{2} \frac{D_{j1} + D_{j2}}{2} + \left(1 - \frac{\lambda}{2} \right) \frac{D_{j3} + D_{j4}}{2} \geq \sum_{k \in K} q_{jk} \qquad \forall j \in J \qquad (.$$

$$\sum_{k \in K} q_{kc} \geq \frac{\lambda}{2} \frac{D_{c1} + D_{c2}}{2} + \left(1 - \frac{\lambda}{2} \right) \frac{D_{c3} + D_{c4}}{2} \qquad \forall j \in J \qquad (.$$

$$\sum_{c \in C} q_{kc} \leq \frac{\lambda}{2} \frac{D_{k1} + D_{k2}}{2} + \left(1 - \frac{\lambda}{2} \right) \frac{D_{k3} + D_{k4}}{2} \qquad \forall k \in K \qquad (.$$

$$\sum_{j \in J} q_{jk} \geq \frac{\lambda}{2} \frac{D_{k1} + D_{k2}}{2} + \left(1 - \frac{\lambda}{2} \right) \frac{D_{k3} + D_{k4}}{2} \qquad \forall k \in K \qquad (.$$

$$\sum_{i \in I} q_{ij} \leq x_i\ \mathrm{R}_i \qquad \forall\ \mathrm{j} \in J \qquad (.$$

$$\sum_{j \in J} q_{jk} \leq x_j\ \mathrm{R}_j \qquad \forall\ \mathrm{k} \in K \qquad (.$$

$$\sum_{k \in K} q_{kc} \leq x_k\ \mathrm{R}_k \qquad \forall\ \mathrm{c} \in C \qquad (.$$

$$\sum_{i\in I} q_{ij} \le x_{ij}\ \mathrm{R}_i \qquad \forall\ \mathrm{j}\in J$$ (.

$$\sum_{j\in J} q_{jk} \le x_{jk}\ \mathrm{R}_j \qquad \forall\ \mathrm{k}\in K$$ (.

$$q_{ij}, q_{jk}, q_{kc}, x_i, x_j, x_k, x_{ij}, x_{ij}\ \ \ge 0,\ \ \forall i, j, k;$$ (.

$$y_i, y_j, y_k\ \ \in \{0,1\},\ \ \forall i, j, k;$$ (.

In accordance with the approach of Jiménez, it is assumed that the constraints in the model should be fulfilled using a confidence value which is denoted as λ and this is normally determined by the decision makers. Moreover, mos, pes and opt are the three prominent points (the most likely, the most pessimistic and the most optimistic values), respectively (Jiménez et al., 2007).

Optimisation methodology

To solve the developed fuzzy tri-objective optimisation problem, the solution procedures are described as follows:

1. Find the upper and lower bound (U, L) solution for each objective function.

Upper bound solution of objective function 1 is obtained (6.37):

$$\begin{aligned} Max\ F_1(U_1) = {} & \sum_{i\in I}\sum_{j\in J} C^g_{ij} q_{ij} + \sum_{i\in I} C^r_i y_i + \sum_{j\in j} C^r_j y_j + \sum_{k\in K} C^r_k y_k + C^s_i + \sum_{i\in I} C^l_i x_i H_i \\ & + \sum_{j\in J} C^l_j x_j H_j + \sum_{k\in K} C^l_k x_k H_k + \sum_{i\in I}\sum_{j\in J} C^l_{ij} x_{ij} H_{ij} + \sum_{j\in J}\sum_{k\in K} C^l_{jk} x_{jk} H_{jk} + \sum_{i\in I} C^t_i x_i \\ & + \sum_{j\in J} C^t_j x_j + \sum_{k\in K} C^t_k x_k \end{aligned}$$ (.)

Upper bound solution of objective function 2 is obtained(. :

$$\begin{aligned} Max\ F_2(U_2) = {} & \sum_{m_i\in RS_i}\sum_{n_i\in TS_{m}} \left(\delta - \left(P^{m_i}_{n_i} - \sum_{l_i\in RS}^{l_i\ne \mathrm{m}_i} P^{l_i} y_{m_i i}\right)\right) + \sum_{m_j\in RS_j}\sum_{n_j\in TS_{mj}} \left(\delta - \left(P^{m_j}_{n_j} - \sum_{l_j\in RS}^{l_j\ne \mathrm{m}_j} P^{l_j} y_{m_j j}\right)\right) \\ & + \sum_{m_k\in RS_k}\sum_{n_k\in TS_{m_k}} \left(\delta - \left(P^{m_k}_{n_k} - \sum_{l_k\in RS}^{l_k\ne \mathrm{m}_k} P^{l_k} y_{m_k k}\right)\right) \end{aligned}$$

Upper bound solution of objective function 3 is obtained (. :

$$Max\, F_3(U_3) = \sum_{i \in I} ac_i y_i + \sum_{j \in j} ac_j y_j + \sum_{k \in K} ac_k y_k \qquad (.)$$

Lower bound solution of objective function 1 is obtained:

$$Min\, F_1(L_1) = \sum_{i \in I} \sum_{j \in J} C^g_{ij} q_{ij} + \sum_{i \in I} C^r_i y_i + \sum_{j \in j} C^r_j y_j + \sum_{k \in K} C^r_k y_k + C^s_i + \sum_{i \in I} C^l_i x_i H_i \qquad (.$$

$$+ \sum_{j \in J} C^l_j x_j H_j + \sum_{k \in K} C^l_k x_k H_k + \sum_{i \in I} \sum_{j \in J} C^l_{ij} x_{ij} H_{ij} + \sum_{j \in J} \sum_{k \in K} C^l_{jk} x_{jk} H_{jk} + \sum_{i \in I} C^t_i x_i$$

$$+ \sum_{j \in J} C^t_j x_j + \sum_{k \in K} C^t_k x_k$$

Lower bound solution of objective function 2 is obtained (. :

$$Min\, F_2(L_2) = \sum_{m_i \in RS_i} \sum_{n_i \in TS_{m_i}} \left(\delta - \left(P^{m_i}_{n} - \sum_{l_i \in RS}^{l_i \neq m_i} P^{l_i}_{m_i} y_i \right) \right) + \sum_{m_j \in RS_j} \sum_{n_j \in TS_{mj}} \left(\delta - \left(P^{m_j}_{n_j} - \sum_{l_j \in RS}^{l_j \neq m_j} P^{l_j}_{m_j} y_j \right) \right)$$

$$+ \sum_{m_k \in RS_k} \sum_{n_k \in TS_{m_k}} \left(\delta - \left(P^{m_k}_{n_k} - \sum_{l_k \in RS}^{l_k \neq m_k} P^{l_k}_{m_k} y_k \right) \right) \qquad (. \quad)$$

Lower bound solution of objective function 3 is obtained(.

$$Min\, F_3(U_3) = \sum_{i \in I} ac_i y_i + \sum_{j \in j} ac_j y_j + \sum_{k \in K} ac_k y_k \qquad (.$$

Find the respective satisfaction degree μ(x_i) for each criterion (.

$$\mu_1(F_1(x)) = \begin{cases} 1 & if\, F_1(x) \geq U_1 \\ \dfrac{F_1(x) - L_1}{U_1 - L_1} & if\, L_1 \leq F_1(x) \leq U_1 \\ 0 & if\;\; F_1(x) \leq L_1 \end{cases} \qquad (.$$

$$\mu_2(F_2(x)) = \begin{cases} 1 & if\, F_2(x) \geq U_2 \\ \dfrac{F_2(x) - L_2}{U_2 - L_2} & if\, L_2 \leq F_2(x) \leq U_2 \\ 0 & if\;\; F_2(x) \leq L_2 \end{cases} \qquad (.$$

$$\mu_3(F_3(x)) = \begin{cases} 1 & if\, F_3(x) \geq U_3 \\ \dfrac{F_3(x) - L_3}{U_3 - L_3} & if\, L_3 \leq F_3(x) \leq U_3 \\ 0 & if\;\; F_3(x) \leq L_3 \end{cases} \qquad (.$$

where equations 43-45 indicate the satisfaction degree of the three objective functions, respectively. Further illustration of these membership functions is depicted in Figure

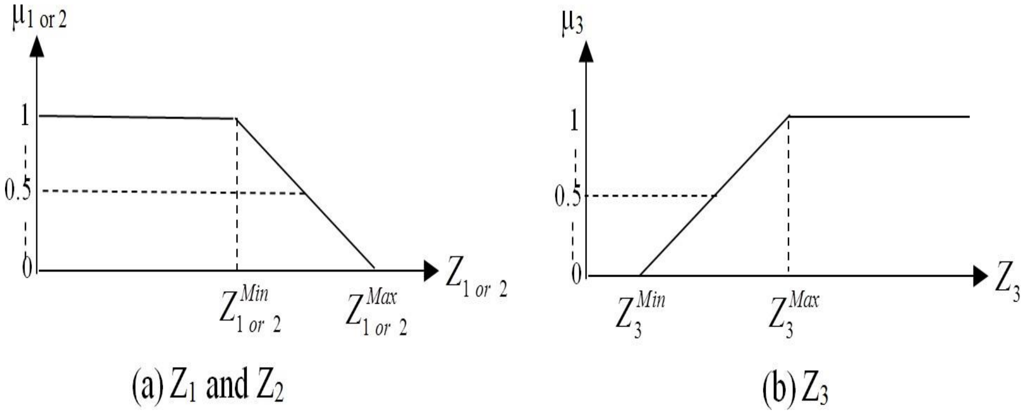

Figure - membership function of the objectivesan

Optimise the crisp model obtained from section 2.4 using the proposed solution methods (section 3.1).

Select the best Pareto-optimal solution using the developed decision making algorithm (section 3.2).

Solution approaches

ε-constraint

In order to obtain non-inferior solutions based on a multi-objective model, a number of solution approaches were found through a literature review. In this work, the ε-constraint method and the developed approach were utilized as described below.

In the ε-constraint method, the fuzzy multi-objective model turns into a single-objective model by keeping the most important function as an objective function, and considering other functions as ε-based constraints . Thus, the equivalent solution formula (F) is given by:

$$Min\ F = Min\ F_1 \qquad (.$$

Subject to:

$$F_2 \le \varepsilon_1 \tag*{(.}$$

$$[F_2]^{\min} \le \varepsilon_1 \le [F_2]^{\max} \tag*{(.}$$

$$F_3 \ge \varepsilon_2 \tag*{(.}$$

$$[F_3]^{\min} \le \varepsilon_2 \le [F_3]^{\max} \tag*{(.}$$

and Equations (22- .

In this work, the minimisation of the implementation and operational costs is kept as the objective function (Equation 46) and the minimisation of reader interference and maximisation of career opportunities are shifted to constraints (Equations 47 and 49, respectively). Pareto solutions can be obtained by varying the ε value (Equations 48 and 50). It should be noted that the selection of any objective to be an objective function or a constraint is not limited.

LP-metrics

In this work, two sets of Pareto-optimal solutions were obtained using the two solution methods, which are the LP-metrics method the ε-constraint method.

In the LP-metrics method, each objective function needs to be solved individually to obtain its ideal value (F_1^*, F_2^* and F_3^*). Subsequently, the model is solved as a single objective model using the following formula (Mohammed and Wang, 2017):

$$Min\ \mathrm{F} = \left[w_1 \frac{F_1 - F_1^*}{F_1^*} + w_2 \frac{F_2 - F_2^*}{F_2^*} + w_3 \frac{F_3 - F_3^*}{F_3^*} \right] \tag*{(.}$$

Subject to Equations (22- .

The decision-making method

The next step after revealing the Pareto solutions is to determine the final trade-off solution. The final Pareto optimal solution can be determined on the basis of the decision maker‟s preferences or by using a decision-making algorithm. Thus far, a number of approaches have been used to determine the best final solution of multi-objective problems. In this study, a new approach is developed to select the Final Trade-off (FT) solution. The idea of a technique developed for selecting the best approach is based on selecting whichever solution approach is closest to the ideal solution. For this technique: (i) determine the average mean value for the three criterion functions; (ii) sum the three average mean values, and (iii) select the approach with the lowest BC value. The selection technique formula is presented:

$$FI = \sum_{i=1}^{3} \overline{F_i^{*}} \qquad (.$$

Another way to find the Pareto optimal solutions by calculation the closest to the ideal solution, it also needs to determine one optimal solution used for implementation. The selected solution can be made by decision makers with the highest degree of preference of the related objectives. So far, several approaches have been employed aiming to select the best trade-off decision in a multi-objective problem. In this study to validate, the previous making approach, a decision-making algorithm used to select the best solution from the derived Pareto set. The selected solution is subject to the highest superiority value S which is determined by a subtraction of the minimum distance to the ideal solution Z+ and the maximum distance to the worst solution Z-. The selection formula can be expressed:

$$S = \sum_{i=1}^{I} \left| Z_i^{+} - Z_i \right| - \sum_{i=1}^{I} \left| Z_i - Z_i^{-} \right| \qquad (-$$

The development and optimization of the FMOOM can be concluded as follows:

. Identify elements required for formulating the model which include objectives, parameters, output variables and constraint.

. Formulate the MOPM using the identified elements.

. Handle the uncertainty in the input data by transforming the fuzzy model to a crisp model.

. Solve the three objective functions individually to obtain the best and worst solutions for each objective.

. Determine the membership function and solve the multi-objective optimization problem using the three solution approaches (i.e., LP-metrics, ε-constraint and goal programming).

. Apply the Max-Min approach to select the final Pareto solution from three sets of Pareto solutions obtained by using the three solution approaches. Figure .22 shows the procedure in developing and optimizing the FMOPM.

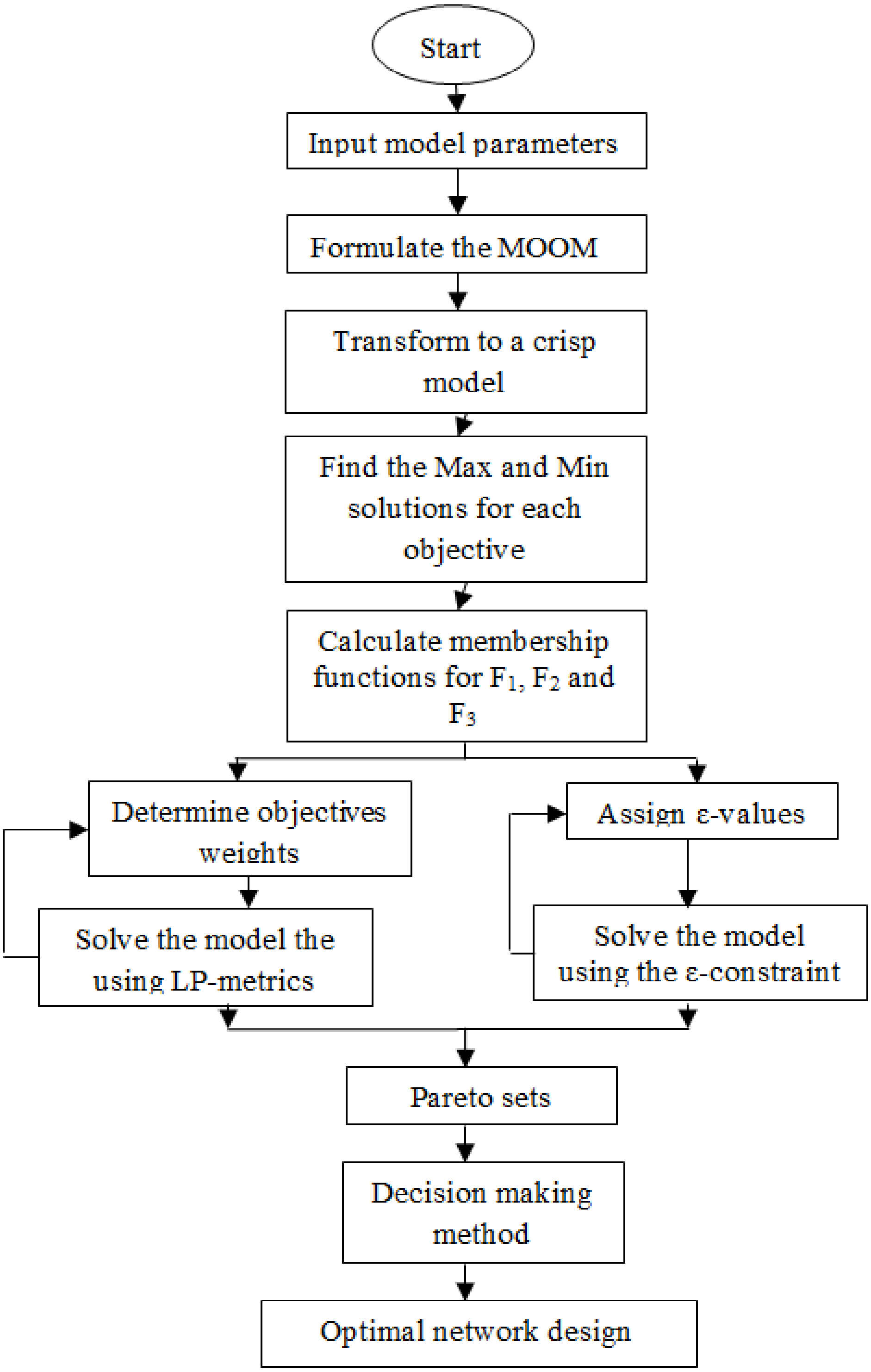

Figure - flowchart of the FMOM

Application and evaluation

With the aim of quantifying the applicability of the developed mathematical model and the proposed optimisation methodology, a case study was applied. Table - shows the data related to the investigated case study, which were collected from the Ministry of the Interior in Saudi Arabia. The demand reported in Table 1 is the total demand over a year horizon received from clients to renew or issue passports. Using the case study data, the proposed optimisation strategy described in section 3 was applied to obtain the solution of the FMOM described in section 3.4. In this study, the model was coded and solved using LINGO software on a personal laptop with Core i5 2.6 Ghz and GB of RAM.

Table - Values of the parameters

Parameter	Value	Parameter	Value
C_{ij}^{l}	(	D_c	(
C_{jk}^{l}	(	D_j	(
C_{ij}^{g}	(. .	D_k	(
C_{jk}^{l}	(. .	R_i	(
C_{i}^{r}	(	R_j	(
C_{j}^{r}	(	R_k	(
C_{k}^{r}	(	R_{ij}	(
C_{i}^{t}	(	R_{jk}	(
C_{j}^{t}	~ (	H_i	(
C_{i}^{l}	(.	H_j	(
C_{i}^{l}	(.	H_k	(
C_{i}^{l}	(.	H_{ij}	(
C_{j}^{l}	(.	H_{jk}	(
C_{k}^{l}	(.	C_i	(
D_f	(	C_j	(
ac_i	~ (,)	C_k	(
ac_j	~ (,)	ac_k	~ ( )

Results

This section presents the computational results of the FMOM using the proposed optimisation methodology for the problem previously defined. The solution procedures of the model can be expressed as follows.

Apply Equations -(-) to determine the upper and lower values for each objective function via their independent optimisation. The values are $(\{U_{F_i}, L_{F_i}$ (\{ \{ . . \{ . Apply Equations 43-45 to determine the satisfaction degree μ(x_i) for each objective function.

Optimise the FMOM model employing two methods as follows: (i) for the ε-constraint method, as illustrated in procedure 1, maximum and minimum values for each objective are obtained. The range between the maximum and minimum values is segmented into ten parts and the ε-points in between are assigned as ε values see Table - in Equations -(47 and 49). Then Pareto solutions are obtained by implementing Equation -(46). The objective function related to the implementation and operational costs is minimised while the reader interference and social impact as considered as constraints. Table - illustrates the results for eight ε-iterations. For (ii) the LP-metrics method: each objective function is optimised independently under the problem constraints and the results are shown in Table - . For example, optimising the second objective (F) independently, the solutions of the three objective functions are determined as F = 498,101, F = 0.137, and F = 63. As shown in Table 6- , the ideal solutions for the three objectives are in bold, these being: F = 498,101; F = 0.128; and F = 194. Then weights are assigned in different combinations (see Table -) for the three objectives to obtain Pareto solutions of the FMOM. Table 6- shows the computation results obtained by determining eight different weights for the three objectives. These solutions are associated with the number of offices 1, 2 and 3 that should be established.

Choose the best Pareto solution using the developed decision making method; the calculated score values of the obtained solutions are shown in Table - .

It should be noted that the three methods were respectively implemented with eight λ levels (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 and 0.8). Table 6- shows the setting of these eight levels to the λ with steps 0.1 and implementing it to the model, eight Pareto solutions were obtained. Consequently, the model should be frequently solved for each λ level.

Table - ε–value assigned for objective functions two and three

	Assigned ε –value	
#	ε	ε
	.	
	.	
	.	
	.	
	.	
	.	
	.	
	.	

Table - Results related to F1, F2 and F3 using the ε-constraint based on different λ values

	λ-level	μ (F)	μ (F)	μ (F)	Min F	Min F	MaxF	Open office	Open office	Open office
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				

Table - Solutions relating to F1, F2 and F3 when optimising them independently

Objective functions	Min F	Min F	Max F
F		.	
F			
F		.	

Table - Assigned combination of weights relating to the LP-metrics method

#	w	w	w
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	.	.	.

Table - Results relating to F1, F2 and F3 using the LP-metrics method based on different λ values

#	λ-level	μ (F)	μ (F)	μ (F)	Min F	Min F	MaxF	Open office	Open office	Open office
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				
	.	.	.	.		.				

Table - Score values of Pareto solutions using the developed decision making method

ε-constraint method								
Solution								
Score	.	.	.	.	.	.	.	
LP-metrics method								
Solution								
Score	.	.	.	.	.	.	.	.

As previously mentioned, Tables 6- and 6- illustrate, respectively, the results for simultaneously optimising the three objective functions and the numbers of office office 2 and office 3 that should be established. For example, solution#2 in Table 6- yields minimum implementation and operational costs equal to 517,118 GBP, minimum reader interference equals 0.138 and maximum social impact equals 76. This solution was obtained by an assignment of w . w and w = 0.05. As shown in Table 6- , this solution suggests an establishment of three office 1s, three office 2s and three office 3s. It is notable in these results that trade-offs between the three conflicting objectives can be achieved. It should also be noted, as can be seen in Tables - and 6- , that increasing the satisfaction level (λ -level) yields an increase in the undesired value of the first and second objective functions, while, in contrast, it gives an increase in the desired value of the third objective function. This means that the decision makers will have to spend more money to cope with the uncertainties. However, decision makers can vary the importance of the three objective functions (w ε values and the satisfaction level (λ -level), according to their preferences, to obtain another compromised solution.

To compare the three Pareto sets obtained by using two different methods, Figures ------- - . Illustrates Pareto fronts corresponding to the concurrent optimisation of the three objectives, using the two solution methods. The two methods performed well in presenting the alternative Pareto solution. However the results obtained by using the ε-constraint method are closer to the ideal values of the three objectives compared to those from using the LP-metrics method. As shown in Figures - - - , the objectives (i.e. implementation and operational costs, reader interference and social impact) are conflicting, since it is impossible to obtain an ideal value for all the objectives simultaneously. In other words, the Pareto solutions cannot be improved in relation to one objective without impairing the performance of the others. It is worth mentioning that all the Pareto-optimal solutions are feasible.

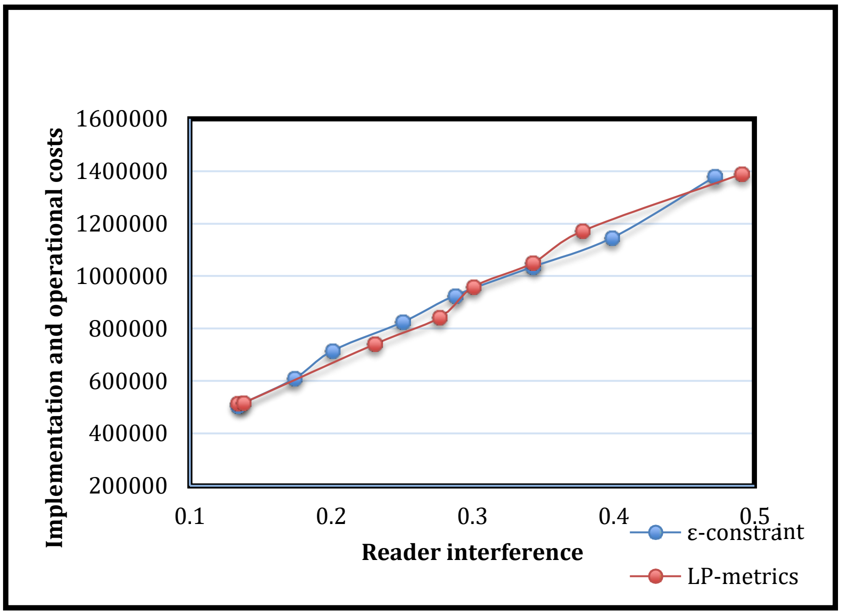

Figure 6-3Pareto fronts for the reader interferences over the social impact using the two approaches

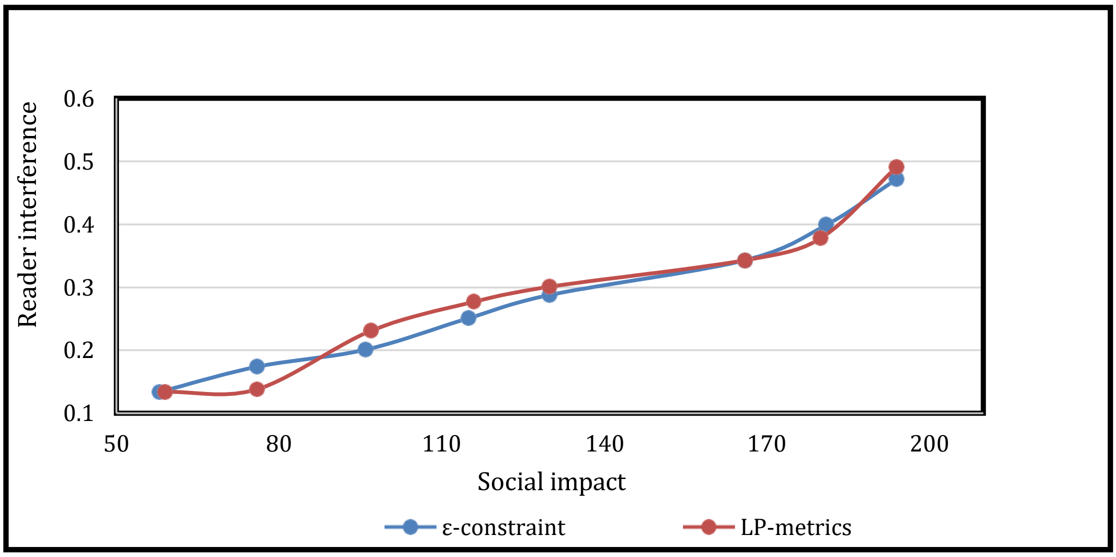

Figure 6-4Pareto fronts for the reader interferences over the social impact using the two approaches

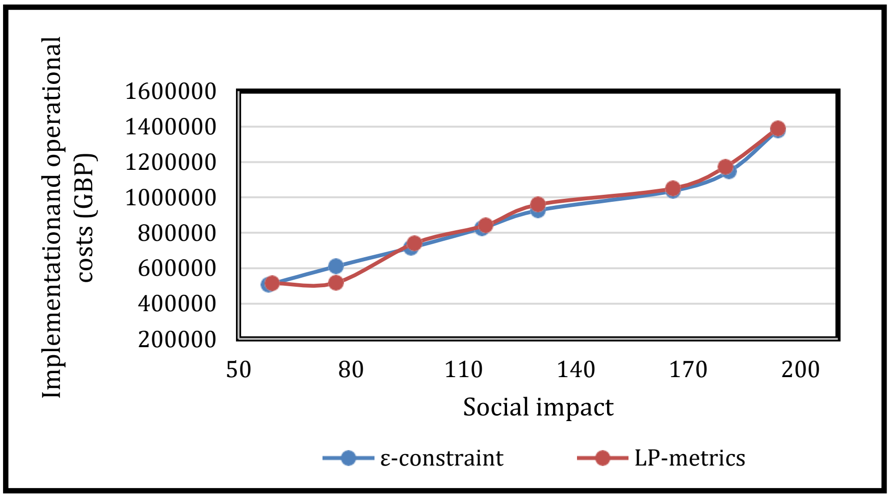

Figure 6- : Pareto fronts for operational cost over the social interference using the two approaches

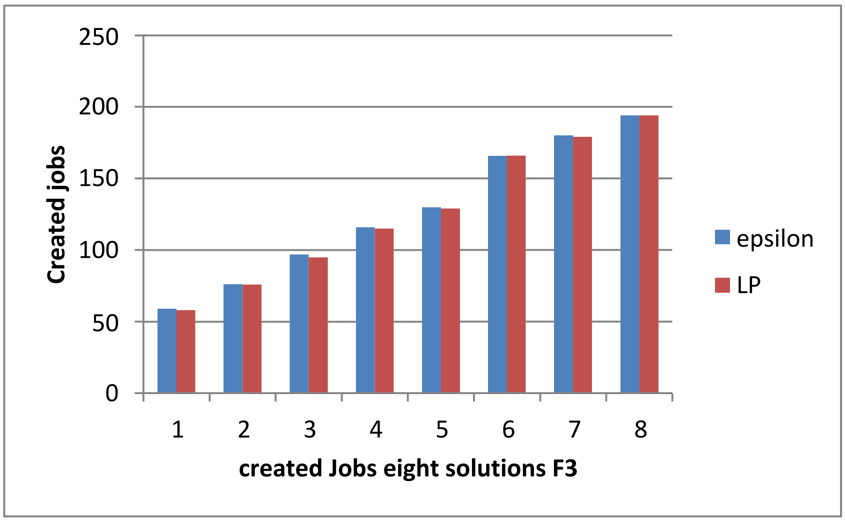

Figure 6- created job pareto set solved by LP and Epsilon

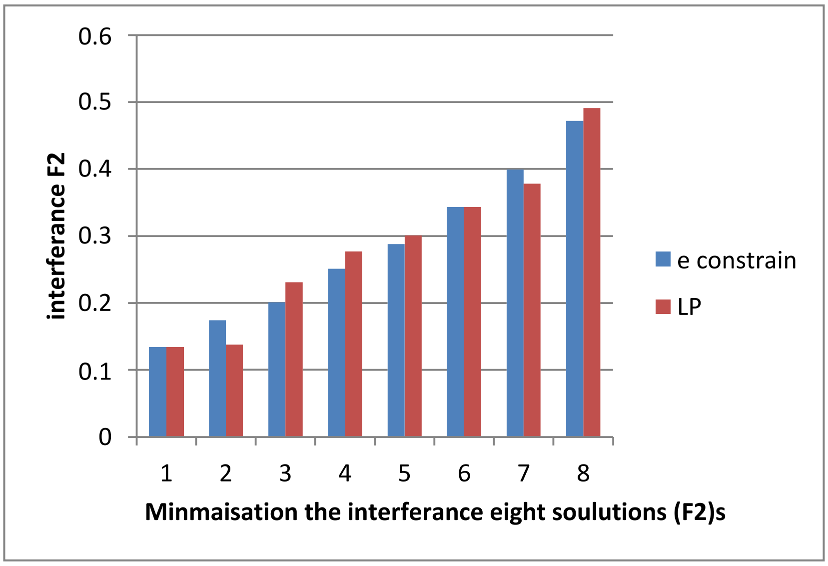

Figure - interface solutions by LP and e

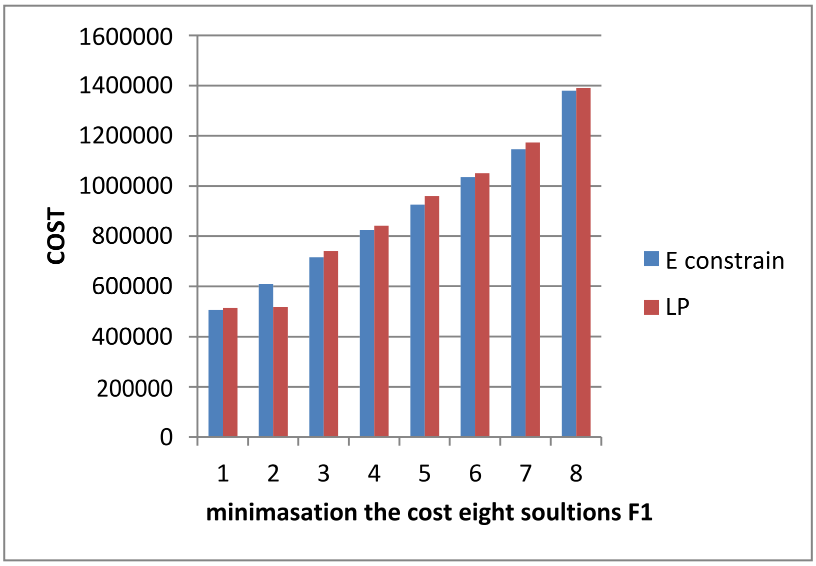

Figure - cost LP and Epsilon soultions

Nonetheless, after obtaining Pareto solutions, stakeholders should choose one solution to design their system. As shown in Figure 6- , the values of minimum implementation and operational costs along with those for minimum reader interference and maximum social impact are not very different for the two methods. This makes any direct selection of the final solution a challenge. Consequently, the developed decision making method was employed to reveal the final solution. As revealed in Table 6- , solution#5, obtained by using the ε-constraint method is the best solution, since its score is the lowest ($FT = 0.19$). This solution is obtained by an assignment of $\varepsilon = 0.291$ and $\varepsilon = 0.725$. The solution requires 926,106 GBP as its minimum implementation and operational cost, minimum reader interference equalling 0.288 and maximum social impact equalling 130. It also needs the establishment of five office 1s, six office 2s and five office 3s.

Summary

The chapter presented a cost-effective design for a proposed RFID-enabled passport tracking system by allocating the optimum number of related facilities that should be opened; furthermore, it took account of the development of the model by obtaining a trade-off between minimising the implementation and operational costs, minimizing the RFID reader interference and maximizing the social impact. It includes the setting of parameters and the uncertainty modelling. Moreover, it includes the optimization methodology where the solution approaches are defined, the LP metrics and epsilon constraint are explained and the Pareto solution found. It presents the method of using decision-making algorithms to find the best solution.

. Chapter 7

A trasilient decision making tool for vendor selection: A hybrid-MCDM algorithm

This chapter sets out to solve a real life problem and aims to provide a user-friendly decision making tool for selecting the best vendor from a group of vendors who have submitted their project proposals for implementing an RFID-based passport tracking system. The main traditional and resilience (trasilience henceforth) selection criteria are identified in a unified framework in collaboration with experts in the institution. Then a decision-making trial and evaluation laboratory (DEMATEL) algorithm is proposed to determine the importance (relative weight) of all the criteria. The obtained weights are to be integrated into the ELimination Et Choix Traduisant la REalité (ELECTRE) algorithm proposed to evaluate the performance of vendors and select the best. The qualitative evaluation of criteria and vendors is based on 5 decision makers. The efficiency of the proposed decision making tool is to be evident from the real case study of 7 tenders submitted to implement a radio frequency identification (RFID)-based passport tracking system.

Trasilient vendor selection tool

It was proposed to implement the RFID technology in a current traditional passport tracking system in an institution to improve the information accuracy, the tracking for security purposes and the issuing and renewing processes of passports for the clients of this institution. Recently, the institution approved the system design and wrote a project proposal for the vendors who wanted to submit their tenders. The institution is interested in seeking the best vender to implement the project because it is a strategic project handling sensitive data and needs high quality implementation.

This chapter aims to develop a user-friendly decision making tool to help the decision makers at the institution to select the best tender out of the 7 submitted. The tender should take account of both traditional criteria and resilience criteria. The decision making tool should be developed as follows:

Develop a unified trasilience framework as shown in Figure - to meet two main sets of evaluation criteria, the traditional and the resilience kind. The two main sets of criteria have their own sub-criteria. Use the linguistic evaluation of decision makers to determine the qualitative relative importance of the criteria and sub-criteria by means of the evaluation scale presented in Table - .

Using the decision makers" opinions from the previous step deploy the DEMATEL algorithm to determine the quantitative relative importance of the criteria and sub-criteria.

Using the linguistic evaluation of the decision makers, determine the qualitative ranking of the vendors vis-à-vis the identified criteria and sub-criteria by means of the evaluation scale presented in Table - .

Use the ELECTRE algorithm to determine the quantitative importance and ranking of vendors according to their trasilience performance.

Validate the obtained vendor ranking via re-ranking them according to the TOPSIS algorithm.

Determine the SRCC value to calculate the relationship between TOPSIS and ELECTRE.

Figure - presents a schematic illustration of the processes followed for developing the trasilient vendor evaluation tool.

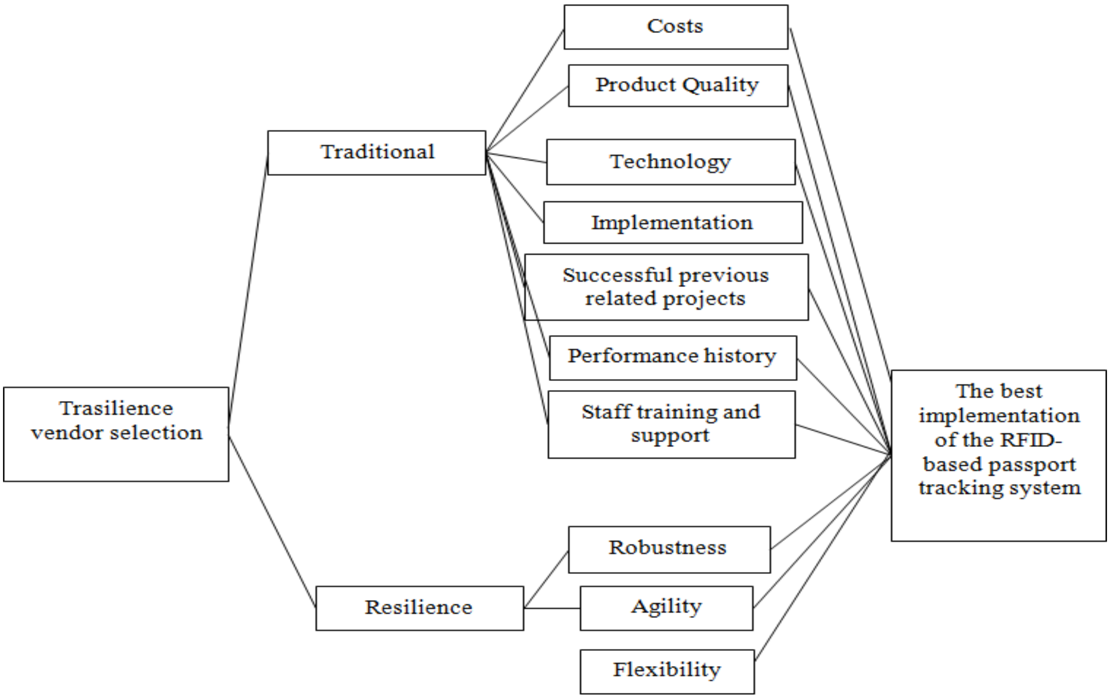

Figure 7-1:A hierarchal framework for the unified trasilient vendor selection.

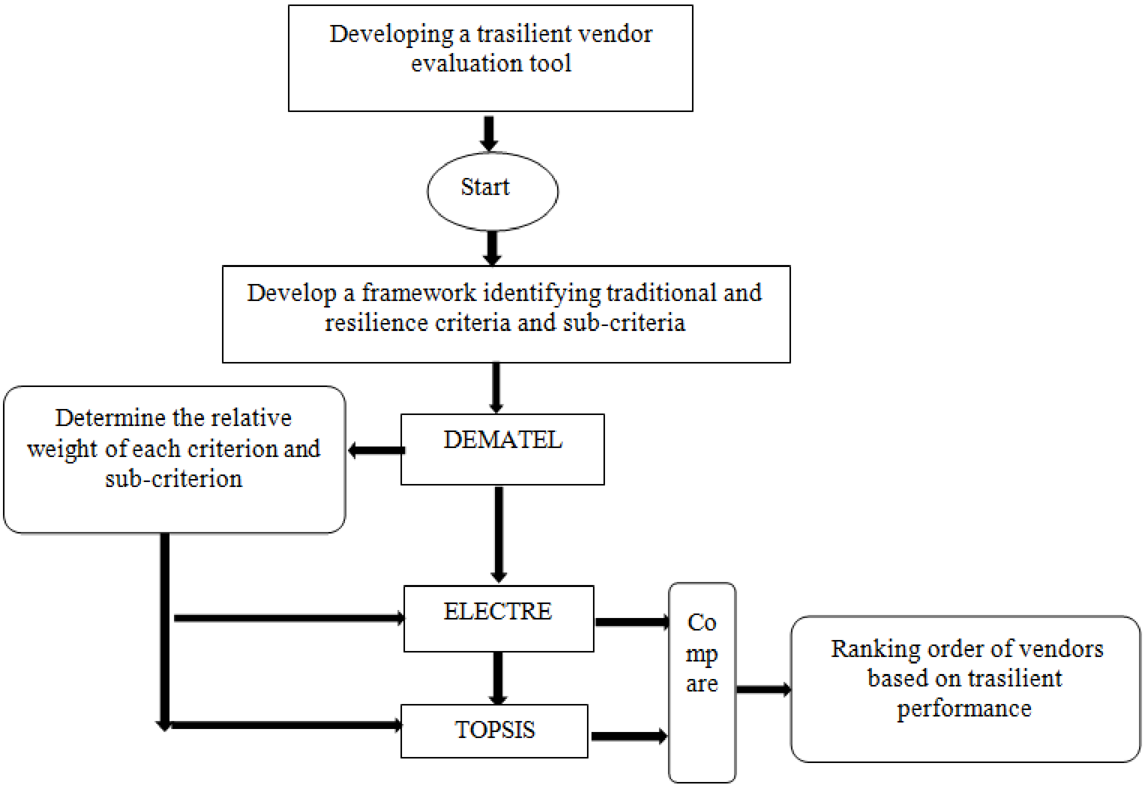

Figure - Schematic representation of the trasilient vendor evaluation tool.

Table - Linguistic variables and correspondence scales used for evaluating the trasilience criteria and sub-criteria

Linguistic Variable	Scale
No influence (NI)	
Lo influence (LI)	
Medium influence (MI)	
High influence (HI)	
Very high influence (VHI)	

Table - Linguistic variables used for evaluating vendors

Linguistic Variable	**Scale**
Very Low (VL)	
Low (L)	
Medium (M)	
High (H)	
Very High (VH)	

DEMATEL (as presented in 5.5.......)

. The implementation of DEMATEL consists of the following steps

Step : Generate the linguistic evolution decision matrix based on decision makers‟ expertise. In this research the linguistic evaluation and its correspondence quantitative scale are shown in Table - .

Step 2: The linguistic evolution obtained from step 1 was converted using the quantitative scale shown in Table -1 to the correspondence scale to generate a pairwise comparison decision matrix for the three objectives.

$$A_{ij} = \begin{bmatrix} r_{11} & r_{12} & r_{1j} \\ r_{21} & r_{22} & r_{2j} \\ . & . & . \\ . & . & . \\ r_{i1} & r_{i2} & r_{ij} \end{bmatrix}$$

where A_{ij} represents a pairwise decision matrix, in which the element a_{ij} denotes the level to which the ith attribute influences the jth attribute.

Step 3: The aggregated normalized decision matrix N was built according to the decision matrix generated in step 2 using Equation - .

$$N = A.K \qquad (.$$

.Where

$$K = \frac{1}{\max\limits_{1<i<n}\left(\sum\limits_{j\in n} r_{ij}\right)} ; i, j = 1,\ldots,n \qquad (.$$

Step 4: Generate the total-relation matrix *T* using Equation7-3, in which I denotes the identity matrix. The matrix *T* reveals the total relationship between each pair of decision attributes.

$$T = N\left(I - N\right)^{-1}$$

(.

Step 5: Sum the rows and columns of matrix *T* using Equations -4 and -5. These two summations are presented by the D and R vectors.

$$D_i = \left[\sum_{j\in n} t_{ij}\right]_{nx1} ;i = 1,2,...,n$$

(.

$$R_j = \left[\sum_{i\in n} t_{ij}\right]_{1xn} ; j = 1,2,...,n$$

(.

Step 6: Define a threshold value *a*. Matrix *T* shows how one attribute influences another, it thus becomes necessary for the decision makers to define a threshold value *a* for elucidating the structural relationship between attributes while simultaneously keeping the intricacy of the entire system to a convenient level. An relationship of influence between two attributes is excluded from the evaluation if their correlation value in matrix *T* is smaller than *a* and only effects greater than the set *a* value are chosen and shown in the digraph. In this work, the threshold value *a* is determined from the average of the values in matrix *T* using Equation (-6), where *N* is the total number of values in matrix *T*.

$$a = \frac{\sum_{i\in n}\sum_{j\in n} t_{ij}}{N}$$

(.

Step 7: Build the relationship table by summing *D* and *R* and subtracting *D* from *R,* where the *D+R* vector reveals how much importance the criterion has. The *D-R* vector divides the attributes into causal and effect groups. Generally, a positive value of *D-R* refers to the attributes that belong to the causal group and shows whether the *a* negative value *D-R* refers to the attributes that belong to the effect group.

Step 8: Use Equation. (-7) to determine the importance (weight) for each attribute by normalizing the *D+R* vector in which the sum of normalized weights equals 1.

$$w_i = \frac{(D+R)_i}{\left(\sum_{i \in n} (D+R)_i\right)} ; i = 1, 2, \ldots, n \qquad (.$$

Rankine Vendors

ELECTRE (as presented in............)

Procedures for applying ELECTRE to evaluate and rank vendors can be described as follows:

. Construct the basic decision matrix A_{ij} s that the numbers of matrix rows (i) and matrix columns (j) refer to the options and the criteria respectively.

$$A_{ij} = \begin{bmatrix} r_{11} & r_{12} & r_{1j} \\ r_{21} & r_{22} & r_{2j} \\ . & . & . \\ . & . & . \\ r_{i1} & r_{i2} & r_{ij} \end{bmatrix}$$

2. the decision matrix should be normalized as follows:

$$v_{ij} = \frac{r_{ij}}{\left(\sqrt{\sum_i r_{ij}^2}\right)} \qquad (.$$

Where the normalized decision matrix V_{ij} is presented as follows

$$V_{ij} = \begin{bmatrix} v_{11} & \mathrm{v}_{12} & v_{1j} \\ v_{21} & v_{22} & v_{2j} \\ . & . & . \\ . & . & . \\ v_{i1} & v_{i2} & v_{ij} \end{bmatrix}$$

3. The normalized weighted decision matrix W_{ij} should be constructed by multiplying the normalized decision matrix by the criteria weight (w_i) revealed via DEMATEL.

$$W_{ij} = V_{ij} \, x \, w_j$$

(.

4. Equations. - and -11 should be applied to determine the concordance and discordance sets, respectively. The concordance matrix should be constructed by adding the values of weights of the concordance elements. The discordance matrix should be constructed by dividing the total value of set by the values of the discordant members.

$$C_{lm} = \sum_{j^*} w_{j^*}$$

(.

$$D_{ab} = \frac{\left(\sum \left| W_{aj^*} - W_{bj^*} \right| \right)}{\left(\sum \left| W_{aj} - W_{bj} \right| \right)}$$

(.

where $C(a,b) = \left\{ j,\ W_{aj} \geq W_{bj} \right\}$ **and** $D(a,b) = \left\{ j,\ W_{aj} < W_{bj} \right\}$.

5. The binary concordance and discordance matrices should be constructed on the basis of the sets obtained in step 5.

6. The alternatives should be ranked by constructing the aggregated binary concordance and discordance matrices via the binary multiplication of the concordance and discordance matrices.

TOPSIS (As presented on (5.5.1.3)

As previously presented TOPSIS as a way to select an alternative based on its distance from the ideal solution and the negative ideal solution. TOPSIS was implemented as follows:

Equation. (. .) is used to normalize the decision matrix to get the normalized decision matrix ($\tilde{R}$):

$$\tilde{R} = \left[\tilde{r}_{ij} \right]_{nxm}$$

(.

where

$$r_{ij} = \left(\frac{a_{ij}}{\sqrt{\sum_i a_{ij}^2}} \right)$$ (.

The weights of the criteria (w_j) obtained from the AHP approach should be multiplied by the elements of the normalized decision matrix ($\tilde{R}$) to form the weighted normalized decision matrix ($\tilde{V}$).

$$\tilde{V} = \left[\tilde{v}_{ij} \right]_{nxm}$$ (.

where $\tilde{v}_{ij}$ is obtained using the following equation:

$$\tilde{v}_{ij} = \tilde{r}_{ij}\, x\, w_j$$ (.

The positive and negative ideal solutions are determined by means of Equations -16 and - , respectively (Roy et al., 2004).

$$\tilde{A}^{+} = \left\{ \tilde{v}_1^{+}, \tilde{v}_2^{+}, ..., \tilde{v}_n^{+} \right\}$$ (.

$$\tilde{A}^{-} = \left\{ \tilde{v}_1^{-}, \tilde{v}_2^{-}, ..., \tilde{v}_n^{-} \right\}$$ (.

The distance of supplier „I" from the positive ideal solution (d_i^{+}) and the negative ideal solution (d_i^{-}) are calculated as follows:

$$d_i^{+} = \sum_{j\in n} d_v\left(v_{ij}, v_j^{+} \right); \; d_i^{-} = \sum_{j\in n} d_v\left(v_{ij}, v_j^{-} \right);$$ (.

where v_j^{+} and v_j^{-} are respectively the positive and negative ideal points for criterion „j"

Based on d_i^{+} and d_i^{-}, the closeness coefficient (CC) for each supplier is then determined, using Equation ....The supplier with the highest CC (varying between 0 and 1) is selected as the most green and most resilient supplier.

$$CC = \frac{\square_i\, d^{-}}{d_i^{+} + d_i^{-}}$$ (.

Measuring the association: Spearman rank correlation coefficient

The Spearman rank correlation coefficient is a statistical measure of the association of a monotonic relationship between paired data revealed via two different algorithms (Chamodrakas et al., 2011; Raju & Kumar, 1999; Kannan et al., 2013). In the present work, the SRCC measure was applied to obtain the statistical importance of the difference in the ranking orders revealed via TOPSIS and ELECTRE. The SRCC between the two algorithms was determined as follows (Raju & Kumar, 1999):

$$SRCC = 1 - \frac{6\sum_{v \in V} d^{2}}{V^{3} - V}; \quad -1 \leq SRCC \leq 1$$

(.

where *SRCC* is the absolute association value between ranking orders revealed via TOPSIS and ELECTRE

v number of vendors

V total number of vendors

d difference between ranking orders revealed via TOPSIS and ELCTRE

The SRCC value varies between -1 and 1.0 (a perfect positive association) Possible SRCC values can be verbally described in bands as follows:

- 00-. “very weak”
- 20-. “weak”
- 40-. “moderate”
- 60-. “strong”
- 80- . “very strong”

Application: A case study

To validate the applicability and effectiveness of the developed vendor selection decision making tool, it was applied on an institution that belongs to the Ministry of the Interior. Institution A is responsible for issuing and renewing passports for citizens of the country. An RFID-based passport tracking system design was proposed to replace the current traditional passport tracking system with the aim of improving system performance in terms of information accuracy, passport tracking for security purposes and easing the issuing and renewing processes (Dukyil et al., 2017). Recently, Institution A approved the system design and invited 7 vendors to submit their tenders for implementing the RFID-based passport tracking system. At the same time, the institution was interested in acquiring an accurate selection tool that would help to thoroughly evaluate the submitted tenders and find the best vender to implement the project. It is a strategic project and the sensitive data that the system handles need high quality implementation. To this end, the vendor selection decision making tool, when developed, was applied to help the decision makers at institution A to (1) develop a unified trasilient selection strategy and (2) evaluate the 7 vendors on the basis of the performance of their tenders with reference to the above trasilience criteria see Figure - .

The evaluation and selection panel at institution A consists of 4 employees (E1, E2, E3 and E4) who were responsible for reading and evaluating the 7submitted tenders and then selecting and recommending the vendor who would finally implement the project. The four employees have an average 12 years of work experience. Two detailed interviews, each lasting about 3 hours, with the selection panel were held to explain, discuss and evaluate the trasilience criteria and sub criteria and the performance of the 7 vendors (V). For the purpose of the evaluation, the following terms were used in discussions with the buyers:

Robustness measures the ability to withstand disruptions to elements within the supply network, either through the immediate availability of alternative vendors or capacity to quickly plan the incorporation of new vendors.

Agility evaluates the ability to respond in a quick and well-coordinated manner to comparatively small market opportunities, through having a partner able to handle unexpected/volatile demand. For instance, institution A might want to slightly change one of the RFID reader‟s specifications.

Flexibility gauges the ability to respond with ease to disturbances in the supply network, whilst maintaining control of costs and lead-times. This involves having processes in place that allow effective response when disturbances in the supply are sensed.

Revealing the weight of trasilience criteria: DEMATEL

First, the DEMATEL algorithm was applied to determine the relative importance (weight) of the criteria and sub-criteria according to the qualitative evaluation of the criteria performed by the four employees. The pairwise comparison among criteria was generated using a scale of 0-4, as illustrated previously in Table -1. Tables -3 and -4 show the Equivalent quantitative evaluation for the traditional and resilience criteria respectively, based on the expertise of decision makers.

Table - Decision matrix among traditional criteria

Criteria	**C1**	**TC2**	**TC3**	**TC4**	**TC5**	**TC6**	**TC7**
E1							
TC1							
TC2							
TC3							
TC4							
TC5							
TC6							
TC7							
E2							
TC1							
TC2							
TC3							
TC4							
TC5							
TC6							
TC7							
E3							
TC1							
TC2							
TC3							
TC4							
TC5							
TC6							
TC7							
E4							
TC1							
TC2							
TC3							

TC4							
TC5							
TC6							
TC7							

Table - Decision matrix among resilience criteria

Criteria	RC1	RC2	RC3
E1			
RC1			
RC2			
RC3			
E2			
RC1			
RC2			
RC3			
E3			
RC1			
RC2			
RC3			
E4			
RC1			
RC2			
RC3			

The aggregated normalized decision matrix for traditional and resilience criteria was then built. Its design was based on the decision matrix using Equation - 2 as shown in Tables -5 and - 6. The total-influence matrix (T) for the traditional and resilience criteria is generated by using Equation -3, as shown in Tables -7 and - . The sums of the rows and columns as represented by vectors D and R respectively are computed and are shown in Tables -9 and 10. Now, the summation and subtraction of D and R (D + R) and (D-R) are listed in Tables -9 and - 10. These values show in turn the total influence levels and net influence levels, where the positive values indicate that it will influence other objectives more than any other objectives influence it. As shown in Table -9, the traditional criterion of cost revealed the highest net influence level in relation to the criterion of successful previous related projects, which revealed the lowest net influence level. In addition, as shown in Table -10, the resilience criterion of agility revealed the highest net influence level in relation to the criterion of flexibility which revealed the lowest net influence level. Table -11 lists the importance (weight) of all the criteria that were determined by normalizing the total influence vector (D+R) shown in Tables - 9 and -10. As shown in Table -11, the traditional criterion of cost has the highest importance (0.302215). The resilience criteria of agility revealed the highest importance (0.658428). All weights were then used to evaluate the performance of the vendors by applying ELECTRE and TOPSIS, as the next sub-section illustrates.

Table - The aggregated normalized decision matrix among resilience criteria

Criteria	TC1	TC2	TC3	TC4	TC5	TC6	TC7
TC1		.	.	.	.	.	.
TC2	.		.	.	.	.	.
TC3	.	.		.	.	.	.
TC4	.	.	.		.	.	.
TC5	.	.	.	.		.	.
TC6	.	.	.	.	.		.
TC7	.	.	.	.	.	.	

Table - The total-influence matrix (T) among traditional criteria

Criteria	RC1	RC2	RC3
RC1		.	.
RC2	.		.
RC3	.	.	

Table - The total-influence matrix (T) among resilience criteria

Criteria	TC1	TC2	TC3	TC4	TC5	TC6	TC7
TC1	-	-	-	-	-	-	-
TC2	-	-	-	-	-	-	-
TC3	-	-	-	-	-	-	-
TC4	-	-	-	-	-	-	-
TC5	-	-	-	-	-	-	-
TC6	-	-	-	-	-	-	-
TC7	-	-	-	-	-	-	-

Table - Total influence and net influence levels related to traditional criteria

Criteria	RC1	RC2	RC3
RC1	-	-	-
RC2	-	-	-
RC3	-	-	-

Table - Total influence and net influence levels related to resilience criteria

Objective	D	R	D+R	D-R
TC1	.	.	.	.
TC2	.	.	.	.
TC3	.	.	.	- .
TC4	.	.	.	.
TC5	.	.	.	.
TC6	.	.	.	- .
TC7	.	.	.	- .

Table - Weights of trasilience criteria and sub-criteria obtained by DEMATEL

Objective	D	R	D+R	D-R
TC1	.	.	.	.
TC2	.	.	.	.
TC3	.	.	.	- .

Table - Weights of the trasilience criteria and sub-criteria obtained by DEMATEL

Criteria	Sub-criteria	IW	Ranking
Traditional	TC1		
	TC2	.	
	TC3	.	
	TC4	.	
	TC5	.	
	TC6	.	
	TC7	.	
Resilience	RC1	.	
	RC2	.	
	RC3	.	

Ranking suppliers: ELECTRE and TOPSIS

After revealing the relative weight of each trasilience criterion via DEMATEL, ELECTRE and TOPSIS were implemented to reveal the ranking of the vendors on the basis of their trasilience performance. The four employees were invited individually to evaluate the performance of the 7 vendors with respect to each sub-criterion using the evaluation scale presented in Table - . Table -12 shows the performance evaluation based on the 4 employees‟ opinions and the aggregated decision matrix presented in Table -13. Following this, ELECTRE and TOPSIS were applied as follows.

Table - Evaluation of suppliers based on their trasilience performance

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	RC1	RC2	RC3
	E1									
V1										
V2										
V3										
V4										
V5										
V6										
	E2									
V1										
V2										
V3										
V4										
V5										
V6										
	E3									
V1										
V2										
V3										
V4										
V5										
V6										
	E4									
V1										
V2										

V3	
V4	
V5	
V6	

Table - The aggregated decision matrix

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	RC1	RC2	RC3
V1			.			.		.		.
V2	.		.			.				
V3		.			.	.			.	
V4	.			.	.					.
V5			.	.	.			.		.
V6			.		.		.	.	.	.

ELECTRE

Based on the aggregated matrix presented in Table .13, the ELECTRE algorithm was applied as follows:

Step 1: Tables . and . show the normalized decision matrix and the weighted normalized decision matrix which was obtained by multiplying the sub-criteria weights obtained by DEMATEL see Table .

Step 2: The concordance set was built using Equation 10. as shown in Table..........Table .17 shows a pairwise comparison of vendors with respect to the weighted normalized decision matrix presented in Table ..

Step 3: The discordance set was built using Equation -11, as shown in Table . .

Step 4: The aggregated concordance and discordance binary matrix was built by binary multiplication between the concordance and discordance sets, as shown in Table .

Table - Normalized decision matrix related to ELECTRE

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	RC1	RC2	RC3
V1	.	.	.	.	.	.	.	.	.	.
V2	.	.	.	.	.	.	.	.	.	.
V3	.	.	.	.	.	.	.	.	.	.
V4	.	.	.	.	.	.	.	.	.	.
V5	.	.	.	.	.	.	.	.	.	.
V6	.	.	.	.	.	.	.	.	.	.

Table - Weighted normalized decision matrix related to ELECTRE

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	RC1	RC2	RC3
V1	.	.	.	.	.	.	.	.	.	.
V2	.	.	.	.	.	.	.	.	.	.
V	.	.	.	.	.	.	.	.	.	.
V4	.	.	.	.	.	.	.	.	.	.
V5	.	.	.	.	.	.	.	.	.	.
V6	.	.	.	.	.	.	.	.	.	.

Table - Concordance set

	V1	V2	V3	V4	V5	V6
V1		.	.	.	.	.
V2	.		.	.		.
V3	.	.				.
V4	.	.	.			.
V5	.	.	.	.	.	.
V6	.	.	-.	-.	-.	
C BAR =						

Table - Vendor pairwise comparison with respect to the normalized decision matrix related to ELECTRE

V1_V2	-.	-.	-.	-.	.		.	-.	-.	-.
V1_V3	-.	-.	-.	-.	.	.	.	-.	-.	-.
V1_V4	-.	.	.	-.	.	.	.	.	-.	-.
V1_V5	-.		.	-.	.	.	.	-.	-.	-.
V2_V1	.	.	.	.	-.		-.	.	.	.
V2_V3	-.	.	.	-.	-.	.	-.	.	.	
V2_V4	.	.	.	-.	-.	.	-.	.	.	.
V2_V5	.	.	.	-.	-.	.	-.	-.	.	.
V3_V1	.	.	.	.	-.	-.	-.	.	.	.
V3_V2	.	-.	-.	.	.	-.	.	-.	-.	
V3_V4	.	.	.	-.	-.	.		.	.	.
V3_V5	.	.	.	-.		-.	-.	-.	-.	.

V4_V1	.	-.	-.	.	-.	-.	-.	-.	.	.
V4_V2	- .	-.	-.	.	.	-.	.	-.	-.	-.
V4_V3	- .	-.	-.	.	.	-.		-.	-.	-.
V4_V5	- .	-.	.		.	-.	-.	-.	-.	
V5_V1	.		-.	.	-.	-.	-.	.	.	.
V5_V2	- .	-.	-.	.	.	-.	.	.	-.	-.
V5_V3	- .	-.	-.	.		.	.	.	.	-.
V5_V4	.	.	-.		-.	.	.	.	.	
	- .									
V6_V1	.		.	.	-.	-.	-.	.	.	.
V2_V2	- .	-.	-.		.	-.	-.	-.	-.	-.
V6_V3	- .	-.		-.	-.	-.	-.		-.	-.
V6_V4	.	.	.	-.	-.		-.	.		
V6_V5	- .		.	-.	-.	-.	-.	-.	-.	

Table - Discordance set

	V1	V2	V3	V4	V5	V6
V1		-.	-.		-.	-.
V2	.		-.	-.	-.	-.
V3	.	-.		-.	-.	.
V4	.	-.	-.		-.	.
V5	.	-.	-.	-.		
V6	.	-.	-.		-.	
D BAR =						

Table - The aggregated concordance and discordance binary matrix

	V1	V2	V3	V4	V5	V6
V1						
V2						
V3						
V4						
V5						
V6						
V1> V4, V3 and V2						
V2>V3						
V4>V2 and V3						
v5> V1, V2, V3 and V4						
V6> V1, V2, V3, V4 and V5						

Implementation TOPSIS

Table . shows the normalized decision matrix. Based on the aggregated matrix presented in Table 13, the TOPSIS algorithm was applied as follows:

Step 1: Table shows the normalized decision matrix.

Step 2: Table .21 shows the weighted normalized decision matrix which was obtained by multiplying the sub-criteria weights obtained by DEMATEL as shown in Table .

Step 3: The distance of each vendor from the positive ideal solution (D_i^+) and the negative ideal solution (D_i^-) were calculated. Table -22 shows the ranking order of vendors based the closeness coefficient (cc) for each vendor, which was determined by the distances (D_i^+ and D_i^-) obtained using Equation. Figure - illustrates the performance of the vendors based on their closeness coefficient.

Table - Normalized decision matrix related to TOPSIS

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	RC1	RC2	RC3
V1	.	.	.	.	.	.	.	.	.	.
V2	.	.	.	.	.	.	.	.	.	.
V3	.	.	.	.	.	.	.	.	.	.
V4	.	.	.	.	.	.	.	.	.	.
V5	.	.	.	.	.	.	.	.	.	.
V6	.	.	.	.	.	.	.	.	.	.

Table - Weighted normalized decision matrix related to TOPSIS

				T						
	C1	C2	C3	C4	C5	C	C7	C1	C2	C3
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.

Table - Ranking of vendors based on their closeness coefficient

	D_i^+	D_i^-	Cc	Rank
V1	.	.	.	
V2	.	.	.	
V3	.	.	.	
V4	.	.	.	
V5	.	.	.	
V6	.	.	.	

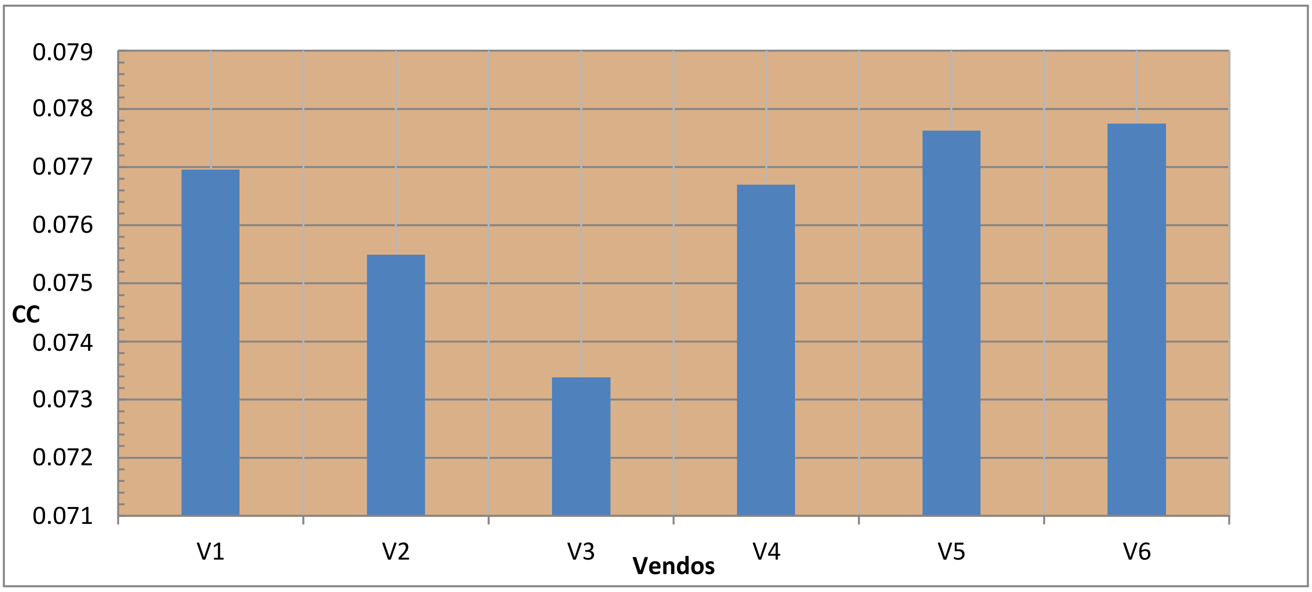

Figure - A graphical illustration of the vendors' performance revealed via TOPSIS

According to the obtained results via ELECTRE and TOPSIS, the vendors were revealed to be very close to one another in the quality of their performance, which would make the choice very difficult for an evaluation panel without the use of this decision-making tool. ELECTRE ranked the order of vendors as shown on the graphical Figure 7_3 above V6>V5>V1>V4>V2>V3 while V6>V5>V1>V2>V4>V3 was the ranking order obtained by using TOPSIS. It can be noticed that the two algorithms each revealed a ranking order that was quite similar. However, the SRCC is used to obtain the statistical difference between the ranking orders that the two algorithms obtained. The SRCC between ELECTRE and TOPSIS turns out to be 0.942857143, as follows:

$$SRCC = 1 - \frac{6*2}{(6)^3 - 6} = 0.942857$$

It can be inferred that there is an almost total or “very strong” association between the two algorithms. In other words, there is no substantial variance in the ranking orders revealed via TOPSIS and ELECTRE. The obtained evaluation revealed V6 as responsible for the highest trasilience performance, with a closeness coefficient of 0.077744 see Table 7- compared with the other vendors. The closeness coefficient of V1 was 0.076954), V2 scored 0.075494, V3 scored 0.076691, V4 scored 0.073379 and V5 scored 0.077624, all lower in rank than V6. Thus, it is recommended to allow to Vendor 6 to implement the RFID-based passport tracking system.

Survey Result

A simplified survey was conducted to capture the impressions of the decision-makers and the engineer content was presented to the decision -makers and specialists from GDP institution. The IT project manager was briefly interviewed.

The result of the survey shows that more than 87% of the respondents thought that

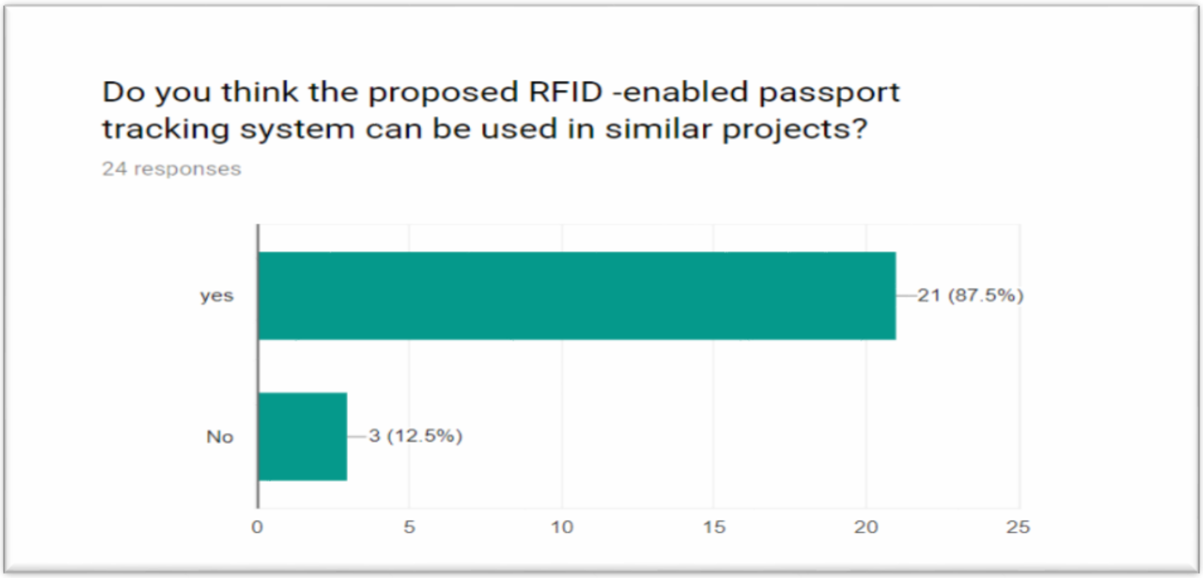

Figure 7-4 RESULT OF THE FIRST SURVEY QUESTION

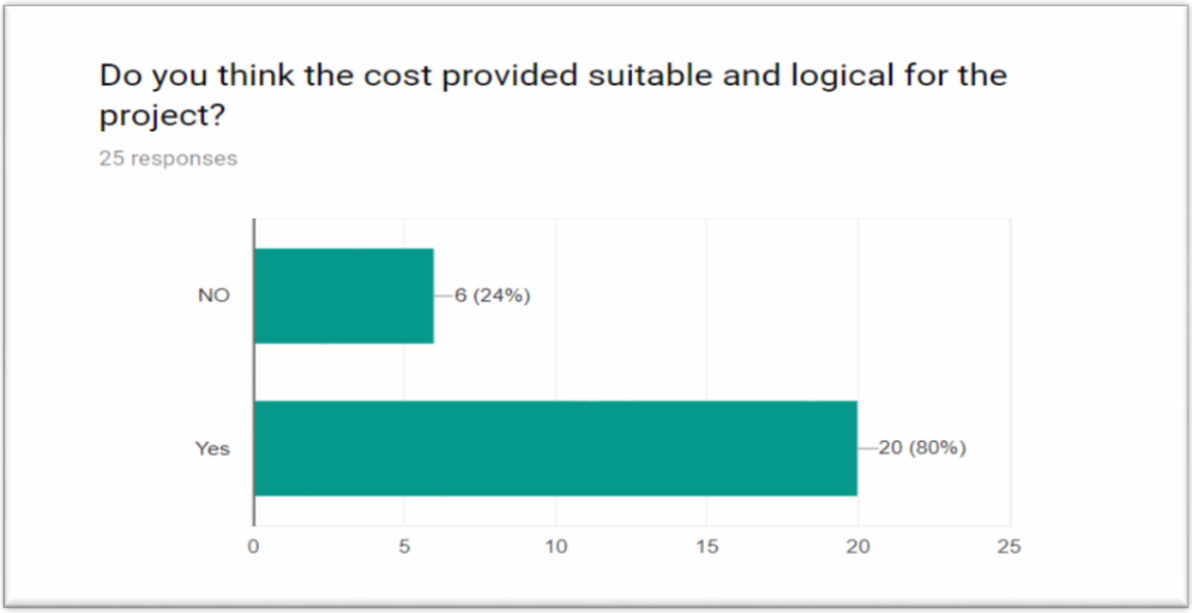

Figure 7-5 RESULT OF THE SECOUND QUESTION

According to the survey, 80% of the respondents found the proposed cost reasonable. In terms of cost reduction to incentivise the use of an RFID-based passport tracking system, 6% of the respondents indicated that it was more than they expected.

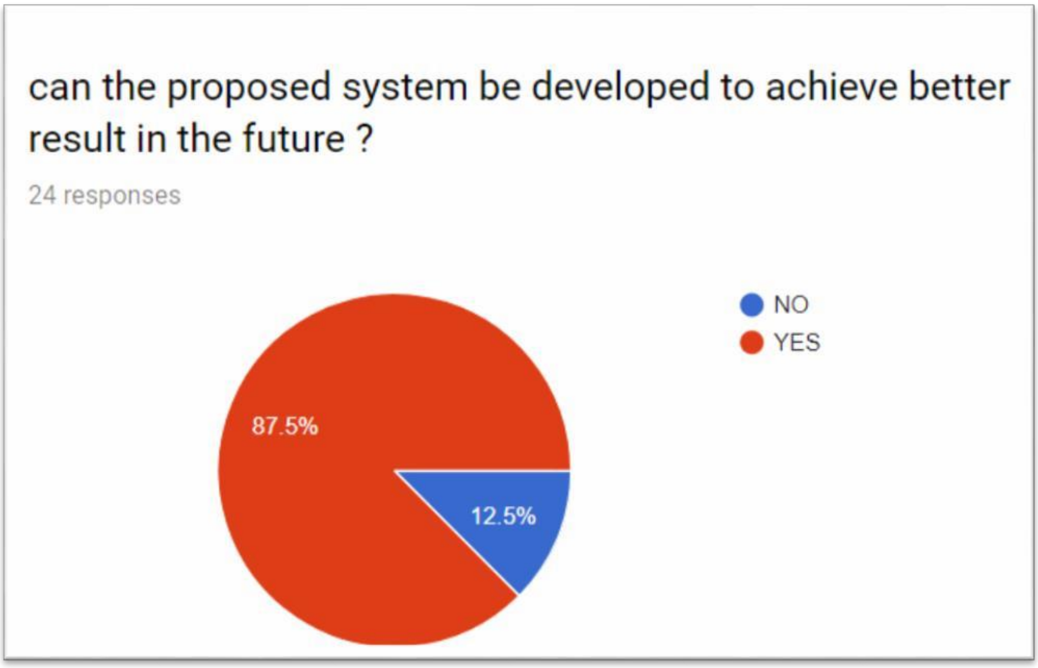

Figure - RESULT OF THE THIRED QUESTION

Only 12.5% indicated that the RFID-based passport tracking management system could not be improved, but 87.5% expected this model to achieve better results in the future

14 responses out of 25 thought the design clearly defined and had good coordination but while 5 thought that these points needed more improvement.

According to the survey, the four main questions about the design had fairly high scores.

Project manager interview

The proposed system had been implemented, the project manager at GDP institution , Dr Majid Al Roamith, was interviewed (see the appendix). Dr Majid had a generally positive response; he found the system friendly and close to designs that he had encountered in practice. He called the system friendly because it was:

- Simple to install
- Easy to use
- Easy to update
- Easy to learn
- Efficient
- Complete without third-party software
- Easy to troubleshoot
- Faithful to standards

He thought that tracking the delivery of passports is important because:

. It is a government document and is sensitive.
. It carries data which require privacy.

This system handles the last two issues by being able to track the passport. Thus this system attains its objectives and helps the decision-makers in the passport department to ensure that passports are delivered more cheaply than before. The project manager agreed that it would reduce the delivery cost to customers. He said that this was the first time he had come across such a system. In the past his office had tried to implement a commercial RFID tracking application to monitor passports in transit from head office to branch office but had found it inapplicable.

He believed that the cost analysis and comparison of two vendors from different countries had given his staff an idea about the product cost, and liked the vendor selection method because it covered the GDP criteria and could later be updated for other projects.

Summary

This chapter solves an authentic real industry vendor selection problem using the MCDM algorithm which considers traditional and resilience criteria and sub-criteria. The main trasilient sub criteria were identified in a unified hierarchical framework. The DEMATEL algorithm was used to determine the relative importance of the trasilience criteria and sub criteria based on the opinions of a panel of four employees who were nominated to select the best vendor of the group of 7. The results show that the traditional criterion of cost and the resilience criterion of agility had the highest importance. Next, the performance of each vendor vis-à-vis the defined criteria and sub criteria were determined aiming to rank them from 1 to 7. The ELECTRE and TOPSIS algorithms were used to incorporate the relative weights of the criteria and sub criteria obtained via DEMATEL.. Furthermore, the reliability of the two algorithms was validated by applying the Spearman rank correlation coefficient, which revealed a high absolute association between TOPSIS and ELECTRE. However, the evaluation panel preferred to keep the EXCEL sheet that includes the TOPSIS implementation for the upcoming evaluation of similar projects. The decision-making tool was made available to the panel so as to be readily available to solve similar upcoming vendor selection problem. However, it was recommended to re-ass the evaluation of the criteria. For instance, different problems may require higher weight to be given to quality than to cost.

. CHAPTER 8

Conclusion and Future work

Conclusions

In this study, the problem of a proposed RFID-enabled document location tracking system was investigated using a multi-objective optimisation approach. The system consisted of three stages covering office1, office 2 and office 3. The problem involved the design and optimisation of the proposed system by (i) allocating the optimal number of stages that should be opened and (2) obtaining a compromise between the incompatible solutions satisfying three objectives (namely, minimisation of the implementation and operational costs, minimisation of the RFID reader interference and maximisation of the social impact) of the proposed RFID-enabled document location tracking system. The problem was formulated as a multi-objective model that considers the objectives previously described. Moreover, to move from the theoretical to the practical, the critical parameters the demands, costs, and value generated due to implementing the proposed system – were considered imprecise. Accordingly, the model was developed in terms of a fuzzy multi-objective model, with a two-stage solution methodology being proposed to solve the problem. At the first stage, two solution approaches, that of an ε-constraint method and an LP method, were used to obtain two sets of Pareto solutions. Next, these two methods for finding solution values were evaluated and the results discussed. In general, they were both found appropriate and efficient for solving the fuzzy multi-objective problem, hence being able to reveal trade-offs between the conflicting criteria that were considered. Nevertheless, the ε-constraint has the advantage of revealing Pareto solutions that are closer to the ideal values of the three objectives. In a second stage, a developed decision-making method was employed to select the final Pareto solution, which proved the greater efficiency of the ε-constraint method over the LP-metrics method.

This thesis also solved an authentic problem in the industry, that is, vendor selection using an MCDM algorithm that considers traditional and resilience (trasilient) criteria and sub-criteria. The main trasilient sub-criteria were identified in a unified hierarchical framework. The DEMATEL algorithm was used to determine the relative weight of the resilience criteria and sub-criteria based on the opinions of four employees who were nominated as a panel to select the best vendor out of the group of 7. The results show that the traditional criterion of cost and the resilience criteria of agility have the highest level of importance. Next, the performance of each vendor vis-à-vis the defined criteria and sub-criteria, aiming to rank them from 1 to 7, were determined by using the ELECTRE and

TOPSIS algorithms which incorporated the relative weights of the criteria and sub-criteria obtained via DEMATEL. The two algorithms performed well in revealing the vendors in the same ranking order. However, the evaluation panel preferred to keep the EXCEL sheet that includes TOPSIS implementation for evaluation of similar projects in the near future. This was justified on the grounds that TOPSIS does not require difficult changes when solving other similar evaluation problems. Based on the results obtained via ELECTRE and TOPSIS, it was recommended to let vendor 6 implement the project because his performance was the closest to ideal and furthest from the worst performance.

Finally, its implementation within a case study verified the applicability of the mathematical model that had been developed as well as the effectiveness of the proposed optimisation methodology in terms of: (i) presenting an optimal design for the RFID-enabled document location tracking system; (ii) obtaining trade-offs between the three objectives; and (iii) coping with the uncertainty in the input data. Consequently, the model can be configured and used as a reference for the designers of similar RFID-enabled passport tracking systems.

- It presented the development of a fuzzy multi-objective model (FMOM) to obtain a design for a proposed RFID-enabled passport tracking system that was effective in cost and performance, including allocation of the optimum number of related facilities that should be established;
- There was a trade-off between the optimisation of three of the key factors for effective cost and performance in the design of an RFID-enabled system, namely, the minimisation of the implementation and operational costs, minimisation of RFID reader interference and maximisation of the social impact;
- As would be required in practice, the developed multi-objective model also incorporated the consideration of uncertainty of the input parameters in costs and demands.
- It presented an optimisation methodology that can be used for optimising a similar fuzzy multi-objective model;
- It presented the development of a decision-making method for selecting the final trade-off solution from a pool of solutions derived from the fuzzy multi-objective mode;
- Two different solution methods used to solve the fuzzy multi-objective optimisation problem were employed, with their solution performances subsequently being compared in terms of quality. This helped to obtain the best RFID-enabled system

design and it also reflected the fact that decision makers have different perspectives according to their different preferences

- a user-friendly decision making tool was created that identified the main trasilience criteria and then quantified them using the DEMATEL algorithm. Finally, the ELECTRE algorithm was chosen to evaluate and rank the performance of 7 vendors to implement the RFID-based passport tracking system
- An actual case study was used to investigate the applicability of the developed model and proposed methods for finding a solution.
- Finally, the decision-making tool for vendor selection was made available to the panel to make it easier to solve upcoming similar vendor selection problems. However, it was recommended to reassess the evaluation of the criteria. For instance, different problems may require higher importance to be given to quality rather than cost.

Future work

Due to the application of the developed system in the general directory for the issuing of passports which is a security matter and viewed as highly secure government sector, the research experienced difficulties in obtaining some data from its central database and middle ware.

Applying the RFID system in practice will lead to collision which needs further study. It is a very complicated subject and although the cover is improved the interference is still high, by using interference management technology such as power control and a cluster head between the RFID devices, in order to make the tags send their own ID spontaneously under certain trigger conditions.

It is certainly worth considering an investigation, with a cost-effective analysis, of the RFID-enabled passport tracking system and non-RFID-enabled tracking system to determine the impact of the costs of RFID implementation on the tracking system. A number of other directions may be recommended of solving the developed model; deploying meta-heuristic algorithms such as MOPSO, and NSGA-II would be useful for handling complicated problems in a reasonable timeframe. Minimising unstable RFID power consumption or maximising the quality of the RFID passport would enabled the system to fulfil an objective function.

The following are recommended as possible areas of research on the same topic

- Deploying a metaheuristic algorithm for complicated problems.
- Objective functions could be added to the system, such as minimising the tag coverage or minimising unstable RFID power consumption or maximising the quality of the RFID system.
- Interference management technology such as power control and cluster head between the RFID units could be used to control the interference and achieve better results.
- Compare between RFID tracking system and the non-RFID systems based on three criteria (cost, capacity and time).
- Support smart devises by Deployment of IOT (Internet of things) for sharing and integrate all information.
- Implement the developed multi-criteria decision making-fuzzy multi-objective approach to obtain a sustainable supplier selection.

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. Appendix

***Project manager interview** As the The proposed system has been implemented in case study and the project manager at GDP Majid Al Roamith the is interviewed (contact on the appendix). Dr. Majid respond generally with positive response he found the system friendly was desined close to real design he seen the system is friendly for some reason that are:*

- Simple to install
- Easy to use
- Easy to update
- Easy to learn
- Efficient
- Doesn't need third-party software
- Easy to troubleshoot
- Adheres to standards

he thinks that the tracking delivery of the passport is important for much response:

. It is a government document and its sensitivity.
. Data Privacy.

Based on these reasons this system touches these issues by tracking the passport, thus this system is efficiently to its objectives and help the decision makers in the passport department to make sure the passport will be delivered by lower cost and saving. I suggest to applied that in real world because that will reduce the delivery cost from office until customer. He answerd a question of (Have you come across similar proposed design in past if yes? How you compare with our system?

No, this the first time, but before we tried to implement commerce RFID tracking application to monitor passport when moving from head office to branch office but that was not applicable.

In the cost analysis he added The study compared two vendors from different country which gave us an idea about the cost, also I really like the vendor selection method which covers the GDP criteria and it can be updated in the future for other project. Also we can use it for a similar project in the future.

To contact <mrowathi@gmail.com

An optimization of the reader network

If the network is to be optimised, the placement readers should be considered (see also Chapter One). The second objective of the multi objective model is minimising the interference between the RFID devices. Understanding such problems in the placement of the RFID readers is basic. An example of a test would be to apply one reader to one office. In this case, multiple radars, or to be more precise, radar networks, would be required to cover the whole building. This is because the target can be anywhere inside the office.

Methods of placing the readers

In order to guarantee the accuracy and efficiency of the radar network, the design can normally be divided into two types, which we call hexagon and square. A detailed analysis of each type is shown below.

Hexagon Distribution

The hexagon distribution shapes the outlook of the radar network hexagonally. Typically, three cases are included in the radar network distribution based on the cut-off point, where the distance between two radars is equal to √ Here is the radius of the range of the radar scan. The three cases are discussed individually below.

Case 2: is larger than √

When √ , it means that not every area can be efficiently scanned by the radar network. See the illustration in Fig. 11 in which............. The shadow area (*) is the area where there is a gap in the scanning and the dots are the points where the radar is located. Academically, the un-scanned area (*) beyond the coverage of the radar network is called the “blind area “If the item of interest is accidentally within this area, the radar will not sense it This will cause errors, e.g. the tracking function will not be available. Applications must avoid this problem.

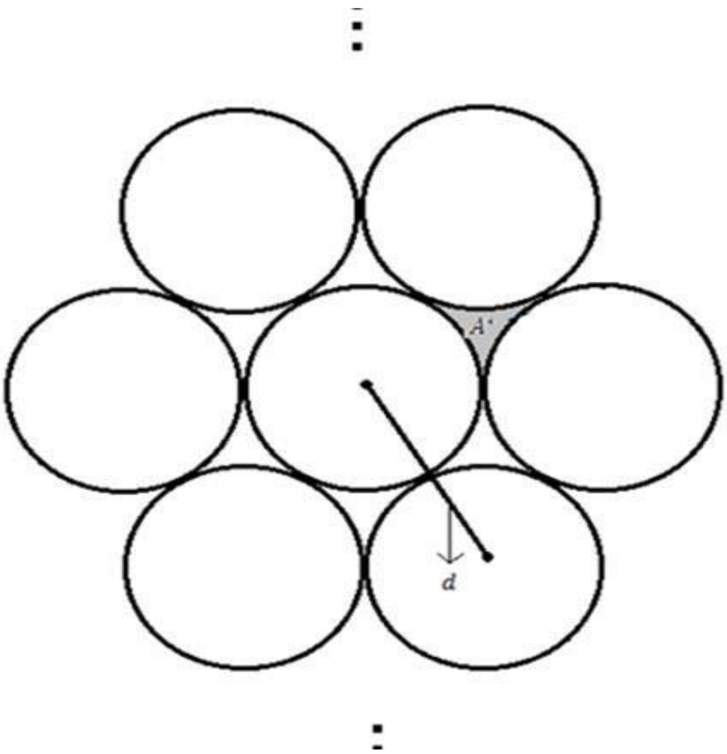


Figure ---- Radar network coverage when d=2r.

Case 2: *is equal to*

$\sqrt{\ }$

When $\sqrt{\ }$*, the radar scan ranges will overlap each other. In this situation, the radar distribution is the most efficient and economical because the same area can be covered by the fewest radars. However, it may be difficult to achieve in practice due to many factors, such as the structure of the building and the settings inside it.*

Figure 12 illustrates part of the radar networks when $\sqrt{\ }$*. The dots are where the radars are located and the circle is the radar scan range. It is clear that the distribution that gives a* *hexagon with the radar in the middle will have a scan area that overlaps with the 6 other neighbouring radars. The notation used for the design of the mathematical model is as follows:*

: arc length of overlapped area

: radian of overlapped area

: radius of radar scan range

: distance between any two radars

: area of overlapped portion

: area of sector with radian

: part of overlapped area

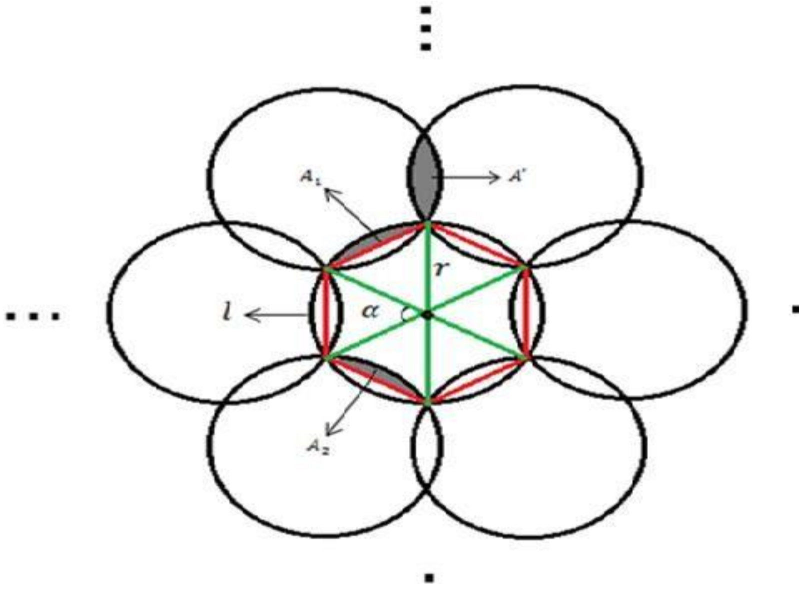


Figure ----Illustration of radar network distribution when d √ r

For this case, the radar scan area has been evenly divided into six sectors, hence the radian for each sector is , and has an angle of .

Case 3: is smaller than √

When √ , it means that the whole area can be scanned but the efficiency is low as radar scan range has wide overlaps. More radar than necessary is involved to cover the whole area. This will probably be closer to reality in most cases, because an ideal situation is hard to be achieved for many reasons such as the structure of the building and setting inside the building. However, it should be noted that not only because it will involve more radar to enable the whole space to be scanned of but it also avoids interaction between two radars.

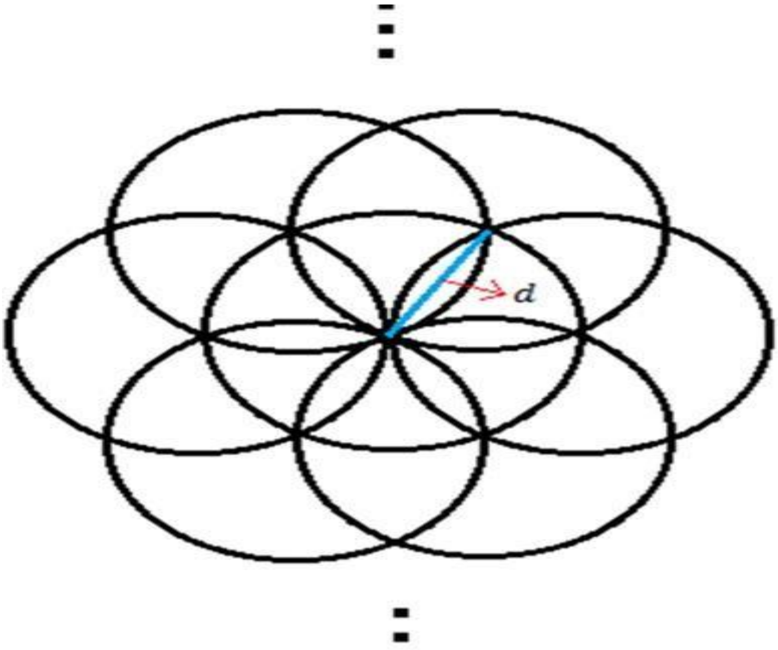


Figure-----Illustration of hexagonal radar network distribution when d=r.

Usually, scanning by radar is used for assigning a location to every item that is tagged accurately. Furthermore, this also serves all the various type of application, including the tracking of documents. In particular, a database that is radar-derived is usually integrated with the help of software for the process or function of the tracking and allocation of documents. Furthermore, in order to provide a clear and exact picture of the way that the suggested method works with the MAT LAB, the explanation begins with 2 dimensions on the horizontal and extends to 3 dimensions in space. These features are discussed further below.

Square Distribution

In square distribution the arrangement of the radar network is square. According to the analysis given in Section 2.2.2, one can note that the distance is an important factor which significantly affects the distribution of the radar network. Depending on the cut-off point, the square radar network distribution should be considered in three different cases, based on the cut-off point (the distance between two radars), but different values. Details are as follows.

Case 2: d is larger than$\sqrt{\ }$

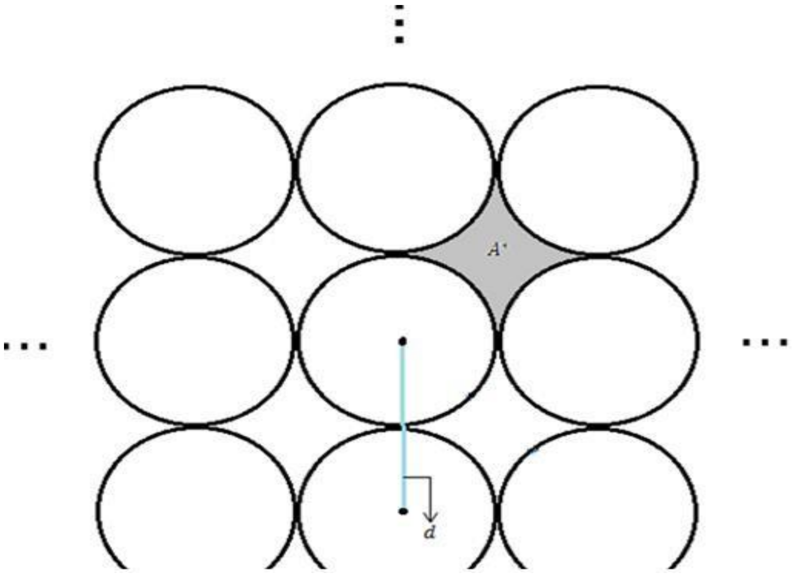


Figure----- Illustration of square radar network distribution when d=2r.

Case 2: is equal $\sqrt{}$

The distribution will be the most efficient and economical when $\sqrt{}$**.......** *This is because the same area can be covered by the fewest types of radar.*

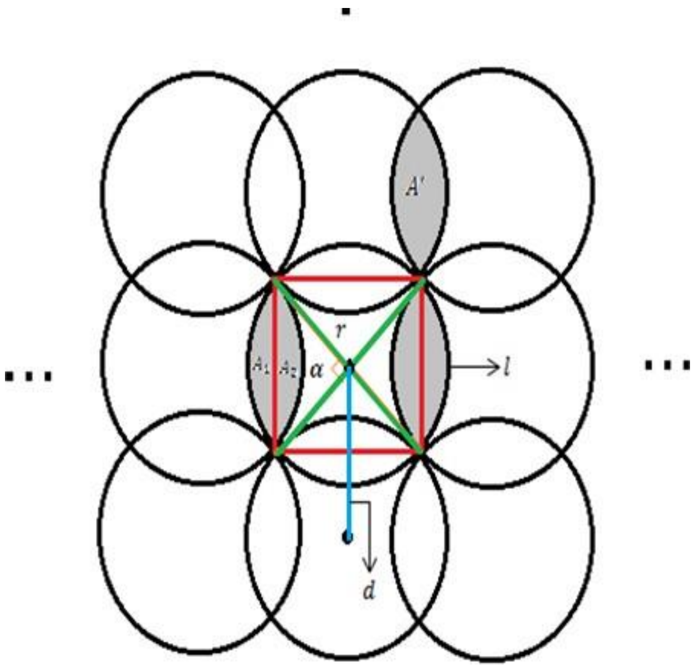


Figure---- Illustration of square radar network distribution when d √ r

The notations used for the design of the mathematical model are as follows:

: arc length of overlapped area

: radian of overlapped area

: radius of radar scan range

: distance between any two radars

: area of overlapped portion

: area of sector with radian

: part of overlapped area

For this case, the radar scan area has been evenly divided into four sectors; hence the radian for each sector is_, and the angle is .

Case 3: is smaller than √

When √ , more radars are required to cover the same size of area. This probably indicates that the scan range of the radar is not being fully used (Chen & Zhu, 2011). The overlap area between any two radars is bigger; see the example presented in the figure. below

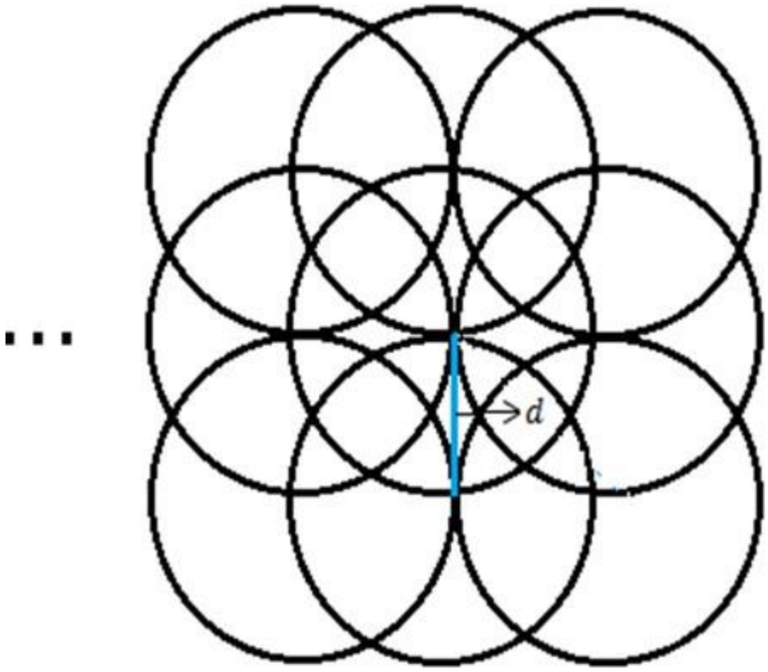


Figure-----Illustration of a square radar network distribution when d=r.

THEORETICAL Mathematical Model

From the previous discussion, it is clear that the distance between readers and tags is important when assigning locations.

Several approaches can be to find the distance between the tag and the reader. For example implementation of the Frris Model (see Equation 3_4), or by using the time interval or by using a minimum number of referencing tags or a minimum number of referencing tags. The simple Friris model proposed by Balanis in 1997 as adopted to carry out the study; it is given as follows:

Here is the power received by the tag, and is the original transmitted power. and are the gain of the transmitter and receiver, respectively. is the coefficient that needs to be defined, and is the distance between tag and reader.

Hence, the distance between tag and each reader can then be calculated by Equation (23). Combined with Equation (1-4), the size of the angle of each triangle can be calculated.(For more details see Appendix a)

Case 2: 2-Dimentional

For information, the target tag (point C) and any two readers (points A and B) will form a triangle (see Figure 17).

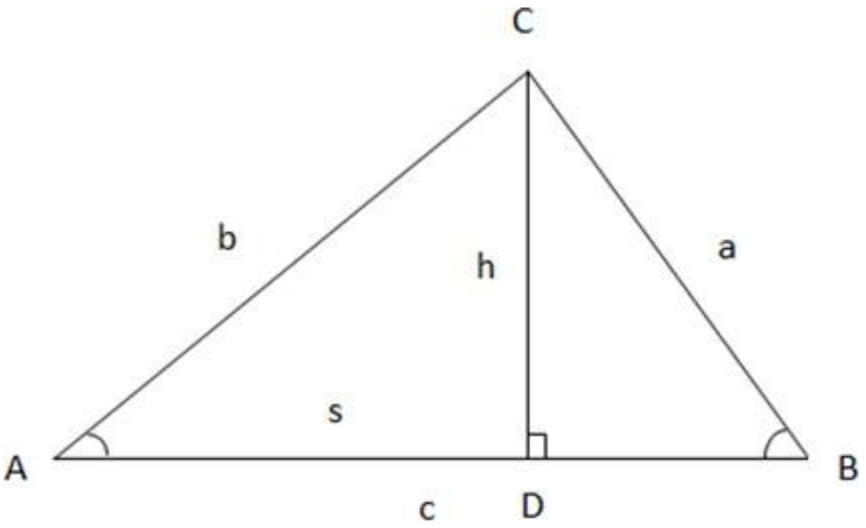


Figure 18- Illustration of the triangle formed by tag and readers.

In Figure 18, point C is where the target tag is located and points A and B are the readers that can receive the signal from it. and are the side length of each side, which can be calculated by Equation (23). Based on these the size of angle A can be worked out.

Then

-

and

-

Here is the distance between point A and point D, and is the height of the triangle. Bearing in mind that the coordinate of each reader will be pre-set as a reference location, let the coordinate of point A be

Therefore, the coordinate of the target tag and for more information see appendix b.

Case 2: 3-Dimentional

To calculate the 3D allocation, it is essential to have the reference coordinate of the pre-set readers.

.

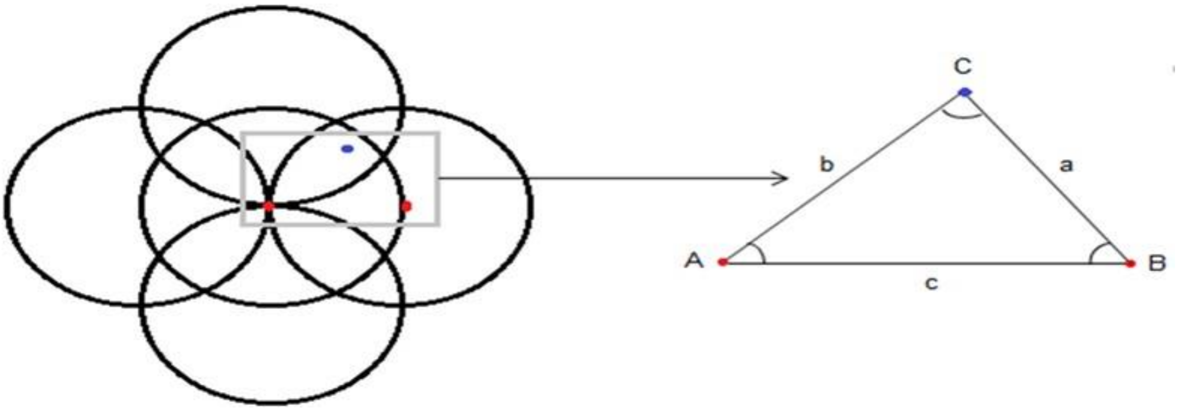


Figure ----- a two readers and one tag ,b allocation the objective tri methood

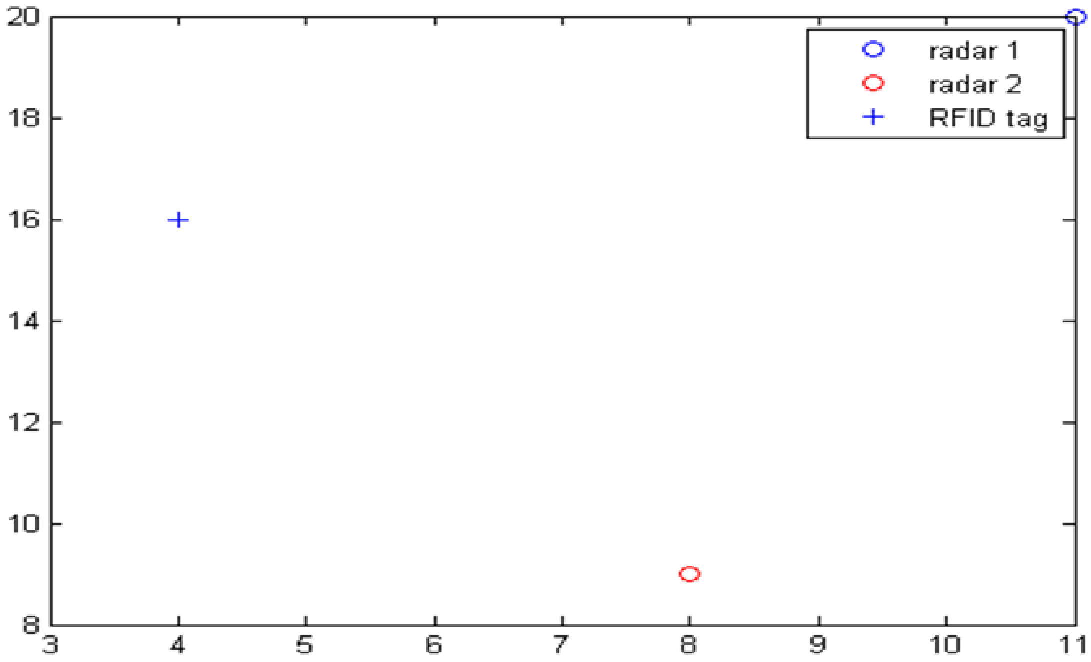
Theoretical method

Furthermore, one of the methods used to calculate the size of the angles in the random triangle is presented in Figure 19. In Figure 19 a), the red dots show the location of the readers. The distance between them is the radius of the radar scan with range r.

Since the radar system can provide the time interval that signal needs to go from the radar to the tagged time, the distance (D) between them can be calculated by:

D=ct/2, Where c is speed of light, t is time interval needed by the signal from radar to item then its return to radar. Based on this, the side lengths a, b and c can be easily worked out according to cosine theorem.

To continue the illustration, MATLAB is applied to the mathematical model discussed in this chapter to define the coordinate of the RFID tag In fact; the coordinate of the RFID tag is unknown to begin with and needs a proper method for its solution. This code needs information about the distance between radar and tag. Of the methods that can be considered, for example, we can assume that the time needed to transmit the signal between reader and tag can be measured. However, as this code is just for a case study, we may assume the distance between radar and tag is already known ().


20
18
16
14
12
10
8
3
4
5
6
7
8
9
10
11
○ radar 1
○ radar 2
+ RFID tag

```
      % University of brunel
      % Abdulsalam Dukyil
      % This programme is developed for allocate the item of interested
      clear
      clc

      % C=299792458;
      %---------------------------------------------------------------------
------
      % define the coordinate of radar 1
      a=20;
      b=11;
      %---------------------------------------------------------------------
------
      % define the coordinate of radar 2
      c=9;
      d=8;
      %---------------------------------------------------------------------
------
      % define the coordinate of RFID tag
      % In fact, the coordinate of RFID tag is unknown at beginning, a
proper
      % method is needed to solve this issue. This code needs the
information of
      % the distance between radar and tag. Some methods can be considered,
for
      % example, we can assume the time interval of signal transimission
between
      % radar and tag can be meausred. However, as this code is just a case
      % study, we assume the distance between radars and tag is already
known

      %---------------------------------------------------------------------
------
      % the coordinate of RFID tag, this is supposed to be unknown at
beginning,
      % however, as example, we define it here to make the code work
      e=4;
      f=16;
      % T1=; % Time interval between radar 1 and item of interested
      % T2=; % Time interval between radar 2 and item of interested
      % D1=T1*C;
      % D2=T2*C;
      D1=sqrt((a-e)^2+(b-f)^2);
      D2=sqrt((c-e)^2+(d-f)^2);
      % D1=18.3848; % distance between radar 1 and tag
      % D2=11.6619; % distance between radar 1 and tag
      D3=sqrt((a-c)^2+(b-d)^2); % distance between radar 1 and radar 2
      % unilogo=imread('LogoUni.jpg');
      % unilogo=imread('LLogo.jpg');
      % D1=15; % Distance between reader1 and item
      % D2=13; % Distance between reader2 and item
      % D3=12; % Distance between two readers
      %=====================================================================
======
      % the radar network distribution can be divided into two groups:
regular
      % distribution and irregular distribution. The regular distribution
means
      % the radar network regularly distributed in horizontal or vertical
```

```
      %======================================================================
======

      %======================================================================
======
      % Senario 1: regular distribution
      % case 1: a=c and b~=d
      if (isequal(a,c)==1 | isequal(b,d)==1)==1
          if D1+D2==D3
             [x,y]=ItemAllocation1(a,b,c,d,D1);
      %        disp('The coordinate of the wanted item is:')
      %        disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row  (x):  ', num2str(x)]; ['Colum  (y):  ',
num2str(y)]}, 'Item Information','custom',unilogo);
          end
          if D1+D3==D2
             [x,y]=ItemAllocation2(a,b,c,d,D1);
      %        disp('The coordinate of the wanted item is:')
      %        disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row  (x):  ', num2str(x)]; ['Colum  (y):  ',
num2str(y)]}, 'Item Information','custom',unilogo);
          end
          if D2+D3==D1
             [x,y]=ItemAllocation3(a,b,c,d,D1);
      %        disp('The coordinate of the wanted item is:')
      %        disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row  (x):  ', num2str(x)]; ['Colum  (y):  ',
num2str(y)]}, 'Item Information','custom',unilogo);
          end
          if (D1+D2~=D3 | D1+D3~=D2 | D2+D3~=D1)==1
              Cos_A=(D1^2+D3^2-D2^2)/(2*D1*D3);
              Sin_A=sqrt(1-Cos_A^2);
              [x,y]=ItemAllocation4(a,b,c,d,e,f,Cos_A,Sin_A,D1);
      %         disp('The coordinate of the wanted item is:')
      %         disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row  (x):  ', num2str(x)]; ['Colum  (y):  ',
num2str(y)]}, 'Item Information','custom',unilogo);
          end
      else
          Tan=abs((b-d)/(a-c));
          Angle=atan(Tan);
          if D1+D2-D3<0.01
             [x,y]=ItemAllocation5(a,b,c,d,D1,Angle);
      %        disp('The coordinate of the wanted item is:')
      %        disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row  (x):  ', num2str(x)]; ['Colum  (y):  ',
num2str(y)]}, 'Item Information','custom',unilogo);
          end
          if D1+D3-D2<0.01
             [x,y]=ItemAllocation6(a,b,c,d,D1,Angle);
      %        disp('The coordinate of the wanted item is:')
      %        disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row  (x):  ', num2str(x)]; ['Colum  (y):  ',
num2str(y)]}, 'Item Information','custom',unilogo);
```

```
          end
          if D2+D3-D1<0.01
             [x,y]=ItemAllocation7(a,b,c,d,D1,Angle);
      %        disp('The coordinate of the wanted item is:')
      %        disp([x,y])
      %          msgbox({'The coordinate of the scanned item is:'; ...
      %                      ['Row (x): ', num2str(x)]; ['Colum (y): ',
num2str(y)]}, 'Item Information','custom',unilogo);
          end
          if (D1+D2-D3<0.01 | D1+D3-D2<0.01 | D2+D3-D1<0.01)~=1
              Cos_A=(D1^2+D3^2-D2^2)/(2*D1*D3);
              Sin_A=sqrt(1-Cos_A^2);
              Angle_A=acos(Cos_A)*180/pi;
              Angle_T=Angle*180/pi;
              [x,y]=ItemAllocation8(a,b,c,d,e,f,Angle_A,Angle_T,D1);
      %         disp('The coordinate of the wanted item is:')
      %         disp([x,y])
```