

## **RFID technology in supply chain management: a review of the literature and prospective adoption to the Greek market**

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**ABSTRACT:** This literature review gathers information regarding the latest trends of radio frequency identification (RFID) technology in supply chain management (SCM). This article explores and examines a number of papers, journals and publications written about RFID technology in the area of SCM. Extended research has been carried out by examining the adoption of RFID technology in the Greek environment. Case studies have also been collected from the publications to point out the industries and/or organisations that RFID technology was adopted by. A comprehensive critical evaluation also takes place to examine the impact and the results found in RFID technology in these case studies.

**Keywords:** Radio frequency identification, RFID, supply chain management, (SCM), efficiency, competitive advantage

### INTRODUCTION

It is true that the field of radio frequency identification (RFID) technology in supply chain management is one of the most innovative and challenging, since information technology (IT) is a constantly changing and evolving area [1]. Companies seek to gain competitive advantage through the extended use of IT. Sometimes this promising approach to company development turns out to be a disaster. RFID technology is not a particularly new technology. It was first developed just after World War II. Germany, Japan, America and Britain were all using radar (which had been discovered in 1935 by Scottish physicist Sir Robert Alexander Watson-Watt) to warn of approaching planes while they were still miles away.

The problem was there was no way to identify, which planes belonged to the enemy and which were a country's own pilots returning from a mission. The work in radar during World War II was a significant technical development. Radio frequency identification (RFID) was invented in 1948 [2]. RFID is a technology that automatically identifies goods. Information systems are the means that can be used to capture data and keep those data up-to-date and accurate. RFID is already being used in industries, such as warehousing, maintenance, pharmaceuticals, medical devices, agriculture, food, retailing and defence [3].

The basic functionality of an RFID system is asset management. The core ingredients are: identification, alerting, monitoring and authentication. The proper asset visibility can prevent losses due to spoiling of perishables, theft and counterfeiting. Today most organisations see whether RFID can add value to their business operations, supply chain partnerships and customer service relationships.

### RFID Technology in the Supply Chain Management Area

According to the literature and research by academics, many organisations are adopting new technologies and innovations in order to achieve a competitive advantage, and to automate the processes inside and outside their organisations. These implementations act as a strong tool for an organisation's benefit and to give value. Data synchronisation, real-time tracking, planning, scheduling and reporting are some of supply chain management issues that organisations are trying to automate and solve problems that might exist.

Radio frequency identification technology is becoming the innovative technology to provide answers and solve most of the problems. RFID is the latest magic bullet in the technological scope that has the potential to make sweeping changes to the way organisations approach their supply chain [4]. This specific technology uses tags, readers and radio waves to communicate between two entities. RFID technology is combined with the Electronic Product Code (EPC). This combination helps to overcome an organisation's challenges in the area of manufacturing, distribution, retail, logistics and security.

Nowadays, RFID has generated a great deal of interest in the academic area, and researchers focus on the technology specifics and their impact on supply chain issues, as well as cost and time savings [5]. Most organisations are trying to achieve a competitive advantage through innovations and new technologies. Porter depicts this as one of the new ways of doing things [6]. The implementation of RFID technology is in its infancy in most organisations. As a result, they must adopt the technology as an innovative process [7].

## RESEARCH METHODOLOGY

To undertake research in the use of RFID technology in the supply chain management area, the authors used Internet-based libraries to search and evaluate papers issued over the last five years. An extended literature review was undertaken initially to create the categories considered necessary to be studied in more detail. The authors explored, identified and finally classified major journal articles on this technology. The preliminary results of this classification were used to form RFID key areas of interest from this broad area, and finally to reveal its use in the supply chain management field.

## RESULTS

As an outcome, the authors selected 252 articles as primary data. The review of the literature showed that most of publications referred to the areas such as computer science, engineering, business management and accounting. It is clear that RFID technology is increasing, promising and controversial, and is an area that researchers want to study in order to overcome new challenges. Furthermore, many organisations have already adopted this technology in order to gain a competitive advantage.

The research continued in an attempt to find and select publications written in the Greek environment. Greece is a country that faces serious economic crisis and most organisations try to find ways in order to survive in such a critical environment. Publications written for Greece are minimal, but they might increase rapidly. The table below shows the number of publications written about RFID adoption in the Greek environment.

Table 1: Journals (RFID in Greece).

Journals/sources of collected articles RFID in SCM adopted in Greece	
Source title	Number of publications
Information Systems Management	1
European Journal of Information Systems	1
Computers and Electronics in Agriculture	1
International Journal of Electronic Customer Relationship Management	1
Proceedings of the ACM Conference on Computer and Communications Security	1

It is clear that publications written for the Greek area of interest are few in number but suggest a promising future. An extended search showed that Greek organisations in the area of supply chain seek to adopt RFID technology to their operations.

Due to economic crisis, Greek organisations are trying to find ways to boost their competitive advantage and become strong market players. In this situation, RFID technology can be regarded as the tool for success and growth. Competitive pressure is increasing and Greek organisations seek ways of adopting new and innovative technologies in order to increase the efficiency of their business processes.

The competition in mature markets is strong, so organisations require not only to optimise cost structures, efficiency and products of excellent quality, but also to communicate and cooperate with business partners and potential customers. RFID is a promising technology for the Greek market and soon organisations will take advantage of this technology and adopt it.

## PROCESSING RESULTS

As it is revealed through this research, the articles that are referring to RFID technology in the area of supply chain management according to different categories are shown in Table 2. Conference papers, articles and articles in press were collected in order to depict the results and categorise them.

Table 2: Articles' statistical elaboration (RFID SCM).

Categories by year	2008	2009	2010	2011	2012	Grand total
Conference Papers	23	29	34	36	07	129
Articles	17	28	32	21	22	120
Articles in Press	0	0	1	0	2	3
TOTAL	40	57	67	57	31	252

As demonstrated in the above table, more publications were written in 2010 than in other years. From the 67 publications that year, 34 were conference papers that depicted the importance of RFID technology in the supply chain management area. Case studies also appeared to be of high importance. Studies in a range of industries showed that there is high interest in RFID technology. There is no doubt that RFID is the key to success in most organisations. A number of case studies were collected for 2010 in order to depict the interest area of RFID technology in specific industries.

Some specific levels of security were defined and improved customers' privacy through a case study of the pharmaceutical industry [8]. Another case study was an experiment in the Hub Express business in a famous logistics company in China [9]. Their research resulted in higher throughput, better information sharing, saving labour and time and more transparency in the supply chain. A novel service-oriented architecture (SOA) that was applicable to a supply chain logistics management system was proposed [10]. Results were of remarkable performance as far as flexibility and scalability concerns. A generic FlexRFID middleware was developed for better supply chain results [11].

The authors worked in their own computing laboratory and, thus far, they have been in a position to offer to organisations the FlexRFID technology in order to improve inventory control, asset management, work in process and tracking shipments. Two major components in the implementation of RFID were introduced. These were based on the analysis of differences between actual and potential key benefits and the performance of a two-dimensional expectation perception analysis (EPA) [12]. Empirical data for that research were collected from selected companies in Taiwan. Taiwan also appeared in research that involved an experiment that was conducted about 640 times [13]. The experiment included key performance indicators that were the total inventory cost, turnover rate and the bullwhip effect. The result was that RFID-enabled R-SCIARIMA supply chain model was the best in practice, reducing the total inventory cost by 35.43% and increasing the inventory turnover rate by 61.36%.

Other interesting pieces of research outlining the possibility of adopting RFID technology in pharmaceutical supply chain information transmission was also found [14]. Moreover, a similar case study that identifies key performance indicators in order to trace the impacts of standards like RFID, EPCglobal and ebXML on the pharmaceutical industry supply chain was written up [15]. Post-consumer monitoring and ordering of medical supplies with the use of RFID technology were also investigated [16]. Practical experiences have been undertaken on the item level traceability in the pharmaceutical supply chain.

Another case study that used RFID technology in a perishable commodity environment on flowers at Daniel's Flowers in Manhattan, New York, was also found [17]. As a result, the company saved money through better control of inventory by applying RFID technology.

Similar research suggested that there could be substantial cost benefits to grocery retailers [18]. Grocery retailers were also featured by Wang et al, reporting on a methodology that was developed to model food quality degradation [13]. The result was to maximise food retailers' profits through a pricing approach based on identified food quality features. Furthermore, another case study focused on an Italian silk textile cluster in Como [19]. Quetti and Pigni depicted RFID technology as a tool to improve product traceability along the supply chain and to certify products' origins safeguarding the *Made in Italy* value. Another assessment was carried out in Italy at Italian fast moving consumer goods (FMCG). The assessment included both quantitative and qualitative data that resulted in the reduction of the bullwhip effect affecting the economic profitability of the whole FMCG supply chain [20].

An interesting analysis and combination of the requirements of energy-related products legislation (ERP) to the automotive supply chain and the tracking system was also valuable [21]. The scope of the case study was to show the benefits of RFID technology in the green supply chain (GSC) area in the automotive industry. An investigation of South Korean retailers appeared in another case study that identified the organisational characteristics that result from the RFID adoption [22]. Furthermore, Kim and Garrison collected and analysed results from 278 adopting organisations in order to show the organisational needs, perceived factors and organisational readiness.

#### Case Studies Selection

The research meant that a collection of case studies on RFID technology was selected, in order to separate the different industries that adopt and evaluate the introduction of RFID technology to organisations. Sixty-one case studies on a range of industries were collected.

Table 3: Case studies collected in each industry.

Industry	No of publications
Technology Industry	13
Food Industry	6
Retail Industry	5
Fashion and Textile Industry	6
Pharmaceutical and Hospital Industry	6
Forest Industry	2
Fish and Sea Industry	2
Construction Industry	1
Transportation and Shipping Industry	7
Military Industry	1
Energy Industry	1
Separate Organisations	11
Total	61

It is worth pointing out that the food industry, the fashion and textile industry and the pharmaceutical and hospital industry show interest in RFID technology. The food industry needs to handle the raw materials and finished products better. Technology is being applied to improve the traceability of food in a supply chain [23]. A lot of applications of RFID exist in the food industry, including those for supply chain management, temperature monitoring of foods and ensuring food safety [24]. Uniform standards need to be established and cost effectiveness requirements could lead to the adoption of RFID technology in the food industry.

The fashion and textile industry is an increasing area of study. The competition is high and suppliers try to provide fast responses to a customer's requests. In such a growing market, suppliers encounter issues of long production lead time, fast response to market needs and product innovation. Customers making decisions benefit from the technology provided as they demand the ability to mix and match various items of clothing within a short period of time. Some authors believe that the fashion and textile industry will benefit from RFID technology; however, issues of security in information sharing are still a big challenge [25]. RFID is an effective method for identification of counterfeit apparel products by tag authentication to differentiate genuine products, where lightweight cryptography is involved [26]. The products can be also protected from shoplifting by the use of RFID tagging [27].

The pharmaceutical industry is one of the most important industries as it is related to people's health and life. A great number of case studies were founded that examined the pharmaceutical production management system based on RFID technology. They managed to trace the whole pharmaceutical life cycle system including raw materials, production, transportation and storage. The pharmaceutical industry and healthcare world is a large, complex and fast growing area.

#### RFID in Greece

As far as the Greek environment is concerned, the authors divided the publications according to the year in which they were published. It can be observed that 2009 was the year in which most publications were issued on RFID technology. Table 4 shows the number of academic publications in each year.

Table 4: Articles' statistical elaboration (RFID SCM in Greece).

Count of year	2008	2009	2010	2011	2012	Grand Total
Labels						
Information Systems Management					1	1
European Journal of Information Management		1				1
Computers and Electronic in Agriculture		1				1
International Journal of Electronic Customer Relationship Management			1			1
Total journals/articles by year	0	2	1	0	1	4

It is worth noting that in 2011 there were no publications on RFID technology in the area of supply chain management in Greece. The economic crisis in Greece was a huge drawback to organisations and of course to the country's growth. The downgrading of Greek government bonds to junk status in April 2010 created alarm in all financial markets. Most of the publications referring to Greece related to the retail industry.

A model was developed and empirically tested that focused on consumer attitudes towards technology-based services [28]. Analysis of 575 questionnaire responses took place, being consumer surveys from Greece (173) and Ireland (402). Results of the study showed that consumer attitudes towards RFID-enabled services in retailing can be modelled as a confluence of multiple attitudes. Lessons learned due to the deployment of two RFID retail applications also appeared. These applications referred to dynamic pricing of fresh products and management of on-floor promotions in a supermarket.

Two methods were proposed for automatically matching bins containing harvested fruits with corresponding trees, during harvesting in orchards, where GPS data might be unavailable due to foliage [29]. These methods used an RFID antenna located on the harvesting platform for tree identification. A digital scale was also used to measure the yield distribution in the field, during the loading of the bins. The evaluation of methods used was performed during peach and kiwi harvesting in two fields in Northern Greece. The results suggested that barcode technology can be used reliably for bin registration, without delaying the harvesting. Tree detection with long-range RFID technology was also reliable.

A framework was developed for the preparation of an RFID based application at several established grocery retailers for short life products in Ireland and in Greece [30]. Findings showed that low individualism and high uncertainty avoidance are conducive to greater customers' acceptance of new service technologies.

Simple SQL queries are found in a case study that shows the efficiency of RFID [31]. Chatziantoniou et al discussed a prototype called COSTES (COntinuous SpreadsheeT-like computations), that implements SQL extensions and evaluation algorithms. RFID applications were also presented in an in-store sales promotion.

The use of IT systems in logistics and supply chain in South East Europe can lead to information related to RFID's current and future implementation in this region, including Greece. In relation to Albania, Bulgaria, FYROM, Romania, Serbia and Montenegro, the challenges are similar; however, they differ in the stage of development of logistics and supply chain management (LSCM).

Greece has been a member of the European Union (EU) since 1980. Its geographical position is advantageous as it facilitates communication with the rest of south-eastern Europe, a fact that leads to increased competitiveness as EU policy is to provide significant advantages to EU countries-members. In addition, from a macro perspective, the EU is one of the competitive forces in the global market.

In contrast to the publications, the private sector in Greece seems to have a great interest in adopting RFID technology. Some organisations provide integrated systems and solutions in order to automate the business processes through the supply chain.

Some of the major solutions that are offered to supply chain operators in Greece cover the following areas: distribution centre, asset tracking and management, retail and apparel, laundry tracking, personnel management, waste collection management, library management, patient safety, document tracking and automatic vehicle identification.

Greek organisations/businesses that have already adopted or are planning to adopt RFID technology in their operations are shown in Table 5.

The first organisation that appears, Diakinisis, belongs to the distribution sector and is one of the largest third-party logistics operators in Greece. Diakinisis has already implemented readers and alien tags that have been tested on-site for a range of RFID applications. Vlasios Tsezos, engineering manager at Business Effectiveness, points out that the adoption of RFID was a piece of strategic thinking with regard to competition and also this system will save labour and time.

Employees will no longer scan the bar codes used to identify the pallets manually. RFID technology will provide Diakinisis customers with accurate visibility of their shipped goods. The other organisations are planning to adopt RFID technology and they are either participating in a pilot project or willing to participate in such a project.

Due to the economic crisis, Greece cannot expect private investments to lift its economy. The Greek private sector is shrinking, production is declining and unemployment is increasing. Business performance is at a low ebb because of social, political and cultural factors. Capital equipment, machinery, resources growth and technology are very slow and research and innovations face serious shortages.

Table 5: Adoption of RFID in Greece.

Organisation Name	Industry	Level of RFID
Diakinisis	Distribution	Storage and shipment
Plaisio Computers	Distribution - retail	Warehouse management
Colgate - Palmolive	Consumer goods - personal products	Point-of-purchase promotional management and item level packaging
Olympos Dairy	Dairy	Logistics
Technological Educational Institution of Kalamata Greece	Education	Library services
Municipality of Korinthos - Waste Collection Management	Public sector - waste management	Waste chain
Ioakeimedes Textiles SA	Textile and fashion	Warehouse management
Vianox Svolos SA	Third party logistics	Storage and shipment

Even though Greece is in a very difficult position, both the private and public sectors are trying to overcome the obstacles and become strong market players despite the circumstances. RFID technology has already been adopted by a few organisations and over time will show improved results. Future promotions will become efficient and maximise organisations' profits. Customers will enjoy products and services through the supply chain. Organisations need and want to follow technology and innovations.

The cost of RFID technology implementation is high. Organisations need to know the return on investment (ROI) in order to organise their operations and strategies. The economic crisis will not help organisations to grow. Users and all the participants need training and to know how to use competency. The waterfall effect will become an opportunity for the Greek market. Some organisations have already adopted RFID technology and others will follow up.

Technological revolutions will help the growth of organisations. Integration systems will help the implementation of RFID. Some people believe that traditional ways of doing things are better. Suppliers could not afford the cost of implementation and training. The result will be that small organisations will go out of business. The loss of jobs will increase Greece's unemployment. More devices will need support which means more trained employees.

#### IMPLICATIONS FOR ENGINEERING EDUCATION

Engineering education can follow up innovations, such as RFID technology and the adoption of supply chain management. Engineering academics will be able to focus on such technologies and create new problem-solving methods that will help all businesses to stay competitive in the global market.

The development of engineers could include an extensive analysis of the requirements and choosing the best selection criteria and concepts in RFID and supply chain management. Models, process models or meta-models could be developed in order to produce a comprehensive analysis of the framework of RFID technology and supply chain management. Furthermore, new and innovative applications could be also developed for better integration between RFID technology and supply chain applications. New implementations, skills and methods could be also produced in order to act as a strong weapon for all businesses to gain a competitive advantage.

On the other hand, academics should follow all of the above technologies and provide their valuable knowledge and skills to students in order to increase their professional potential. Engineering curricula could include a comprehensive analysis with real life examples from companies, which have adopted RFID technology and led to high vocational education. Successful training processes could be achieved by arranging for engineering professionals to visit universities that would provide students with the capacity to work on RFID technology practical activities and, therefore, realise the professional work.

Engineering education could add valuable knowledge and skills to future engineering professionals and as a result contribute to the growth of small countries like Greece and help them to overcome all obstacles and get over the economic crisis.

#### FUTURE WORK

Future research could focus on Greek organisations that have already adopted the technology and to measure the results inside and outside the organisation. Implementing of such a system on this large scale would provoke interesting issues (feasibility, cost, acceptance by the employees, bureaucracy matters, etc), which could be also examined in further research.

## CONCLUSIONS

The volume of articles, journals and books concerning RFID technology in supply chain management denotes the strong interest in the specific field. It seems that the adoption of RFID technology in supply chain management has penetrated into the IT industry, having as a goal the provision of solutions that will help its expansion and excellence.

Greek academics have shown interest in researching the technology of RFID, but Greek organisations with vision have already adopted such technology or are participating in a pilot project in order to gain competitive advantage. The above research leads to the assumption that the integration of RFID systems has many advantages.

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