RFID in Green Supply Chain: Proposal of a multicriteria decision model based on AHP

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Abstract—Due to increasing competitive pressure, shortened life cycle and environmental consciousness, more attention has been paid to resource usage reduction and ecology protection. Green product design has received much attention recently, because product design significantly influences the cost of disassembly, component inspection and repair, remanufacturing and recycling. The paper's aim is to theorize and assess a structural model that incorporates radio frequency identification (RFID) technology utilization and supply chain information sharing as antecedents to supply chain performance. In detail, the present paper intends to designate the best combination of strategic and control criteria to form a robust performance indicator system for manufacturing industry via the utilization of Analytic Hierarchy Process (AHP) - a well-known structured technique for organizing and analyzing complex decisions - and RFID technology. The paper concludes with a proposed model which can be used to comprehend the complex decision system of the sustainability assessment.

Keywords: Green supply chain; RFID; AHP; sustainability

I. INTRODUCTION

Supply chains are articulated organisms involving organizations aimed at transferring either products or services from a supplier to a customer. In particular with increase in environmental concerns during the past decade, Green Supply Chain Management (GSCM) has emerged as a proactive approach for improving environmental performance of processes and products in accordance with the requirements of environmental regulations [1].

Nowadays, a successful green supply chain should more and more rely on an extended collaboration and integration among component actors belonging to the productive and/or logistic network [2]. A number of approaches for implementing GSCM practice have been proposed in previous literature, in which they are aimed at mitigating the risks associated with green supply chain interruptions. Although the literature on GSCM has been growing during the last decade, there are still some areas that need further research. The next frontier for gaining competitive advantage is responding to sustainability responsibility is, in our opinion, Radio Frequency Identification (RFID).

RFID is seen as a perspective key technology that helps companies practice the “three R’s” of sustainability: reducing the number of logistics assets needed to operate the supply chain; reusing those assets as frequently as possible; and enabling new types of recycling programs. Benefits of RFID technology in supply chain management include timeliness, accuracy and completeness [3]. Various RFID systems can be obtained by combining different tags, readers, frequencies and levels of tagging, etc. [4].

In the present paper we present the best combination of strategic and control criteria to form a robust performance indicator system for manufacturing industry via the utilization of Analytic Hierarchy Process (AHP) - a well-known structured technique for organizing and analyzing complex decisions - and RFID technology.

The paper is structured as follows. In the next section relevant related work is surveyed. Section 3 illustrates the main features of Analytic Hierarchy Process, a multicriteria structured technique followed in the methodological approach. Section 4 outlines the framework, explaining the followed approach, Finally conclusion and future work is presented.

II. LITERATURE REVIEW

Literature review gathers information regarding the latest trends of radio frequency identification (RFID) technology in supply chain management.

According to the literature and research by academics, many organizations are adopting new technologies and innovations in order to achieve a competitive advantage, and to automate the processes inside and outside their organizations [5]. Radio frequency identification technology is becoming the innovative technology to provide answers and solve most of the problems.

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 [6].

However, RFID is not a new technology. According to AIM (Association for Automatic Identification and Data Capture Technologies) , the first applications marked during the Second World War were created to differentiate friendly planes from enemy planes (IFF System, Identification Friend or Foe) [7].

The US Department of Defense, Wal-Mart, the Food & Drug Administration, Mark and Spencer, Tesco, Gillette are some of the pioneers of RFID technologies users [8].

Current applications of RFID focus on inventory management, logistics and transportation, assembly and
manufacturing, asset tracking and object location, environment sensors, etc [9]. The literature on RFID applications in supply chains is limited. Here below we reported a brief report on the main publications (in our opinion) about RFID and supply chain.

Gunesekaran and Ngai [10] highlight RFID technology as one of the important information technologies for Build-to-Order Supply Chain (BOSC) that increases efficiency and accuracy. Nmeth et al. [11] present a state-of-the-art on RFID systems and the challenges and possibilities of the integration to supply chains. Delaunay et al. [12] present a survey on the causes of inventory inaccuracy in supply chain management. Dolgui and Proth [13] also present a literature review on RFID technology in supply chain. They focus on the advantages of RFID technologies in inventory management. They also analyze some problems and present perspectives dealing with privacy and authentication properties of RFID technologies.

RFID technologies offer several contributions to supply chain through their advanced properties such as unique identification of products, easiness of communication and real time information [14].

There are different approaches to evaluate the benefits of RFID technologies in supply chains. For example Kok et al. [15] propose an analytic model to study the impact of RFID technology on inventory management with shrinkage errors; Gaukler et al. [16] propose a model about the impact of RFID on supply visibility in the (Q, R) policy; Rekik et al. [17] analyze a single manufacturer, single retailer, single product vendor model subject to execution problems such as losses in the backroom and misplacements in the store; Sounnderpandian et al. [18] are interested in the costs and benefits of implementations of RFID technologies in a supply chain that contains a manufacturer, a distributor, a retailer and consumers; DeHoratius et al. [19] analyze a multi-period inventory system for a single item with periodic review. They consider an intelligent inventory management tool using a Bayesian analysis of the physical inventory level.

Concerning integration on AHP and RFID literature is much more limited. For example Cebeci and Kiling [20] propose a fuzzy analytic hierarchy process (AHP) method in a glass industry company; Lin presents [21] an integrated framework for the development of RFID technology, which includes the hierarchy of factors, structural procedure, and sequence of adoption; Vanany [22] presents the priority of RFID application area using the AHP technique; Adhiarina et al. [23] present a framework to identify dynamic RFID adoption and diffusion from three different perspectives using AHP; Kong [24] introduce a model that takes both the shareholder requirements and the RFID reliability to demonstrate a multiple decision approach based upon Analytic Hierarchy Process (AHP).

In the present paper we present a multicriteria model based on AHP and RFID in Green Supply Chain.

In fact, the pursuit of sustainable supply chains is also a new experience for most firms, with the exception of world-class corporations that have strategically planned for this decades [25]. Some authors like Zhang et al. [26], analyze automotive green supply chain management based on the RFID technology; while Dukovska-Popovska et al. [27], analyze RFID technology to support environmentally sustainable supply chain management.

Differently from other works our paper presents a robust performance indicator system for manufacturing industry via the utilization of Analytic Hierarchy Process (AHP) and RFID technology. In this research, AHP is being employed to find weights of each RFID success factor within the proposed framework and then the most important success factors (the highest weights) can be recognized.

III. ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process is a multicriteria decision method, developed by T. L. Saaty at the end of the 70s, which uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgments of experts [28]; [29]. The AHP includes experience in the method to analyze a complex decision problem by combining both qualitative and quantitative aspects in a single framework and generating a set of priorities for alternatives. This method is currently regarded as one of the most robust methods for multi-criteria decision making. It can be applied to evaluate various problems.

Many outstanding works have been published based on AHP; they include applications of AHP in different fields such as planning, selecting a best alternative, resource allocation, resolving conflict, optimization, and numerical extensions of AHP. The strength of the AHP method lies in its ability to structure a complex technological, economic, and socio-political problems with multiperson, multiattribute, and multiperiod hierarchically. The mathematical foundations are simple, and its purpose is to make a contribution towards unity in modeling real-world problems. The major assumptions in this methodology are the methods to pursue knowledge, to predict, and to control the world are relative, and the goal to use the methodology is itself relative [30].

The first step of the method is to define the decision problem and split into a hierarchy of elements identifying the objective, the criteria and the alternatives. Once the decision problem is structured, the next step is the determination of relative weights, which reflect the relative importance of the elements belonging to each hierarchical level considered with respect to the elements of the immediately higher level. For determining the relative weights, in the AHP context, Saaty uses pairwise comparisons between the elements of each level with respect to a given criterion. To each pair of elements \( x_i, x_j \) of a fixed level, a positive number \( r_{ij} \) is assigned expressing how much \( x_i \) is preferred to \( x_j \) as regards a given criterion; by comparing all \( n \) elements of a level a positive square matrix of order \( n \) is obtained. The comparisons are made using a scale of absolute judgments. In Table 1 is shown Saaty’s fundamental scale usually used in the AHP context.

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>1</td>
<td>Strong</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>50%</td>
</tr>
<tr>
<td>5</td>
<td>Weak</td>
<td>20%</td>
</tr>
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The aim of the approach is to:
- Coordinate with top management in pursuing sustainability;
- Create a strong business case for green supply chains;
- Create a solid plan for pursuing the green initiative;
- Identify opportunities for green supply chain applications using RFID and analyze relevant business processes.

A. RFID system: Selecting the performance factors
This section presents an experimental approach to deriving an RFID performance indicator system. The first step is to determine main factors affecting RFID performance system. Here, the fishbone diagram shown in Figure 2 (see appendix) is used. The relevant factors are classified into 2 criteria, 2 subcriteria and 18 factors as shown in Figure 2, including: cost, product, technology, environmental sustainability, international standards and security and privacy.

B. AHP Model
In this phase we defined AHP Model according to the previous section (see Figure 3 in appendix).
For the pairwise judgments, twelve experts were selected, including one senior academician, a general manager in the RFID industry, two experts in the research and development organizations, and eight executive managers in the logistics industry. For the criteria, subcriteria, consistency index is less than 0.1, hence they fit the requirements of consistency. The weights of factors were summarized in Table 2.

<table>
<thead>
<tr>
<th>TABLE II. WEIGHTS OF FACTORS</th>
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<tr>
<td>Factors</td>
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<tr>
<td>Communication</td>
</tr>
<tr>
<td>Consistency of data format</td>
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<tr>
<td>Electromagnetic compatibility</td>
</tr>
<tr>
<td>Energy consumption</td>
</tr>
<tr>
<td>Exposure and outflow of product information</td>
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<tr>
<td>Geometry</td>
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<tr>
<td>Material</td>
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<tr>
<td>Placement on the market</td>
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<tr>
<td>Prevention of stealing and loss</td>
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<tr>
<td>Relevant legal regulation</td>
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<tr>
<td>Reusability of tags</td>
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<tr>
<td>Sensitivity</td>
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<tr>
<td>Standardization of frequency used</td>
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<tr>
<td>System compatibility in the supply chain</td>
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<tr>
<td>System integration cost</td>
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<tr>
<td>System maintenance cost</td>
</tr>
</tbody>
</table>

The result of the comparison is the so-called dominance coefficient that represents the relative importance of the component on row (i) over the component on column (j). To more accurately represent judgments the comparisons need not be entirely consistent. However, if a set of comparisons are too inconsistent one could just as well have used random entries and the information from the comparisons would not be useful. In order to provide a balance the consistency index (CI) of the derived weights can then be calculated by: CI = (λmax–n) n−1. In general, if CI is less than 0.10, one may be satisfied with the judgments that were derived [31]; [32]. In the case of perfect consistency CI is equal to zero and the principal eigenvalue is equal to n. The CI index measures how much judgments expressed by the decision maker differ from the case of perfect consistency.

IV. EXPERIMENTAL APPROACH
In the present section we present the experimental approach. In figure 1 is shown the experimental approach.

![Figure 1. Experimental approach.](image-url)
C. Analysis of results

After obtaining the ranking of weight values, the five most important factors are: WEEE disposal (0.0653); Reusability of tags (0.0612); Transit power (0.0583); System maintenance cost (0.0574) and System integration cost (0.0566). Several insights could be obtained from these results. First, it is important to develop a new technology in order to ensure RFID more sustainable. Secondly, it is important to select a specific industry and integrate its supply chain members to implement the RFID technology together; otherwise, the synergies of RFID technology would be sacrificed. Thirdly, 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.

V. CONCLUSIONS

The RFID applications may generate solid benefits and advantages on logistics and supply chain management although the cost is high currently.

This study has identified a complete and comprehensive set of dimensions and factors for RFID system development. The weights and rankings of these factors are provided.

The research did not clearly demonstrate the RFID application procedures to industries, and the procedures were not integrated with the key factors, neither. Thus, this research would propose a structural procedure of RFID system establishment and integrate the procedure with key dimensions and factors identified from previous section.

This study proposed an integrated and comprehensive framework to identify dynamic RFID adoption and diffusion. To establish the framework we provide a new perspective of RFID stages of adoption and diffusion, which we classify into: Development phase, Trial phase, Implementation phase. This study also involves different levels of analysis including industry and customers level, which is lacking in the current literature. Future work will include a real case study and more factors will be considered under study.

REFERENCES


Appendix:

Figure 2. Selected factors.

Figure 3. AHP Model.