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Supply Chain RFID Solution Evaluation Applying AHP and FAHP Methods: A Case Study of the Serbian Market

Milorad KILIBARDA, Milan ANDREJIC, Vukasin PAJIC*

Abstract: There has been a recent years tendency for replacing traditional supply chain data identifying and collecting systems with RFID (Radio Frequency Identification) technologies. There are different RFID solutions on the market and it is crucial to choose the solution that best suits the set of goals and desired scenarios. The choice of solution depends on a whole range of different factors and criteria. The present paper develops multi-criteria evaluation models based on the AHP (Analytic Hierarchy Process) and FAHP (Fuzzy Analytic Hierarchy Process) approach. There are no papers in the literature that solve the mentioned problem in this way, on a real example. Three RFID solutions are defined referring to different data identification levels in supply chains, namely: product level, level of packaging and the level of the pallet. Solutions are evaluated, and rated in relation to four criteria: investments, costs, participants' visibility and participants' privacy protection in supply chains. Developed models are tested and applied via a case study conducted in the Serbian market. The model is an excellent basis for decision-making in practice and for researchers in the literature, while with certain modifications, it can be used for other similar problems.

Keywords: AHP method; decision-making; FAHP method; logistics; RFID solutions; Supply Chain

1 INTRODUCTION

Efficient supply chain management requires timely, accurate and reliable information. Information can be identified, collected and transmitted in different forms. One of the exceptionally important and increasingly utilized systems for data identification and collection is RFID technology. Compared to bar code, RFID offers significant advantages with communication not requiring any physical or visual contact between tag and the reader. Automatic scanning using RFID technology allows for high-speed reading and transfer of various data, helping automate many of the supply chain processes [1]. This is especially important for high-intensive processes, such as product receipt and dispatch in warehouses and distribution centres as well as monitoring inventory, sales and delivery. There is a consensus, in both literature and practice, that RFID offers significant possibilities for the efficient supply chain management [1-3]. These capabilities affect all supply chain areas, such as warehouse and transport management, production planning, order management, inventory and assets management. The application of these technologies is not at a satisfactory level. These facts impose the requirement to explore different RFID solutions in more detail as well as to better assess the benefits and effects these technologies provide for the supply chain. Being a sufficient motive for research, the tendency was to develop procedures and form models to evaluate supply chain RFID solutions. The present paper aims to examine different supply chain RFID solutions, and, by utilizing a multi-criteria evaluation method (AHP and FAHP), determine which solutions provide the best results in terms of certain criteria. The essence here is that RFID systems can be implemented at different levels in the supply chain, and, depending on the implementation level, the effects, as well as investments in these technologies, depend as well [4]. In addition to the introduction and conclusion, the present paper is organized into four parts. The second part provides an overview of scientific literature and publications considering various aspects of supply chain RFID technology applications, defines the research problem, and variant RFID solutions, as well as the evaluation criteria, presented. The paper's third and fourth parts respectively develop AHP and FAHP models of evaluating variant solutions, with the fifth part analysing and discussing obtained results of the case study conducted in the Serbian market. In the end, final conclusions and directions of future research are presented in the sixth part.

2 PROBLEM STATEMENT

Literature review points to numerous advantages and effects of supply chain RFID technology utilization. Full effects can be considered achieved if RFID technology is introduced in the entire supply chain [5]. However, in addition to a series of empirical and analytical research results pointing to undeniable advantages of RFID system utilization, there is still a certain business world concern and reluctance of companies to invest in these technologies [6]. There is a regular question in practice regarding which supply chain RFID solution to be implemented. The answer is not easy, as it depends on a whole range of different factors [7, 8]. There is an evident lack of papers in the literature that deal with the selection and application of RFID solutions in a broader context (markets of the country, region, and continent). One of the rare papers of this kind is [9]. In this paper, field interview and panel discussion were used to explore the opportunities and challenges of RFID adoption in China, which provide valuable guidance for RFID adoption for Chinese companies and foreign companies operating in China. Vlachos explored supply chain RFID system performance impact, stating that these technologies have a special impact on supplier relationships, inventory and stock tracking, distribution, planning, sales and forecasting [10]. Certain papers in the literature dealt with the problems of provider selection. Büyüközkan et al. [11] investigated RFID service provider selection by using an integrated fuzzy MCDM approach. Obtained results were discussed through a sensitivity analysis and a comparative evaluation with a fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The criteria that were used in this paper are total cost, RFID infrastructure, RFID technology, experience and reputation, delivery lead-time, compatibility in the supply chain, service quality and problem-solving and capability.

A similar problem was solved by Sari [8] in order to provide a comprehensive framework to help managers effectively evaluate RFID solution providers and then select the most suitable one. In order to select an RFID solution provider, the author used a hybrid fuzzy MCDM approach based on the integration of Monte Carlo simulation with fuzzy AHP and fuzzy TOPSIS. The proposed approach was then tested on an illustrative case. In order to evaluate RFID solution providers, the author defined two groups of criteria. The first group of criteria measures the performance of the RFID solution provider (such as experience in RFID implementations, application specialization, customer references, technical/engineering capability, innovation capability, service and support capability and financial stability), while the second group focuses on the properties of the RFID system provided by the solution provider (such as total cost of ownership, platform flexibility and scalability).

In the paper [12] authors pointed out that timely collecting logistics information and finding anomalies of material supply plays a critical role in modern manufacturing systems. For this reason, the authors proposed a novel approach for information processing based on RFID. In order to assess the changes of logistics states, time, location, quantities, sequence and path were observed as state attributes. The results of the research showed that the proposed approach can efficiently find out more than 90% of anomalies among production logistics. Authors also pointed that manual operation faults are associated with the following: parts do not arrive at stations in the right time, either delivering late or too early; parts stay overtime at one station during the period of normal production; parts stay at warehouse beyond their set time; parts are transported overtime from warehouse to the line-side inventory shelf; parts are transmitted to the wrong working stations; part inventories of the warehouse are critical or excessive, parts at one station are inadequate or excessive; parts at stations are lost or consumed unexpectedly; produced parts are fewer or excessive in a production line.

Alfian et al. [13] also recognized the importance of traceability and monitoring of supply chains of perishable products. The authors proposed a traceability system that utilizes RFID and Internet of Things (IoT) sensors in their paper. Namely, RFID can be used to track and trace perishable food while IoT sensors can be used to measure temperature and humidity during storage and transportation. Machine-learning models were used in order to determine the direction of passive RFID tags since it is important to determine whether products are being received or shipped. Škiljo et al. [14] investigated passive RFID and IoT applicability in a retail store. The study included different types of retail layouts and materials that influence tag responsiveness. Results showed that there is a very high potential of IoT application in a retail store but with certain limitations.

Special emphasis on the application of RFID is given to the elimination of human errors [15-17]. In this respect, Giusti et al. [15] addressed the quality issues concerning the logistic processes carried out by air cargo handlers. A methodology that allows assessing the performances resulting from different RFID implementation set-ups within an air cargo handler's warehouse was also proposed. The performances have been assessed in terms of benefits related to the informatization, in order to reduce the severity of the mistakes' consequences. The authors considered that actual delivery time is a consequence of the possible occurrence of human errors, the elapsed time between the error event and the error detection, the application of mitigating actions and the stochasticity of process times.

Papers and research are mostly related to hypothetical examples or examples of specific companies and cases. This was one of the main motives for conducting research in Serbia.

3 METHODOLOGY

In this paper, a methodology for solving the problem of choosing a solution RFID solution has been developed. Based on the literature review variant solutions as well as criteria used in this paper were defined (Tab. 1). In that manner, the variants were observed, placing RFID on product level ($V1$), packaging level ($V2$), and pallet level ($V3$). On the other hand, four criteria used in this paper are investment ($C1$), costs ($C2$), visibility ($C3$) and privacy ($C4$). Previously mentioned variants and criteria were then used in the AHP and FAHP methods in order to obtain final ranking. Special emphasis in this paper is given to the analysis of applied RFID solutions on the Serbian market. This paper analyses the segment of the logistics market related to retail companies operating in the Serbian market. The methodological approach consists of a series of related steps shown in Fig. 1.

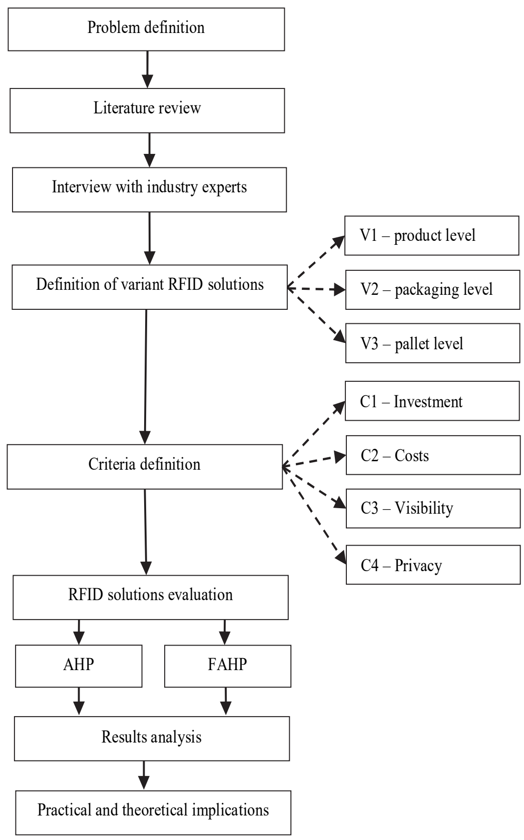

Figure 1 Proposed research methodology

Table 1 Variant solution and criteria

Variant solutions		
Variant	Description	References
*V*1	• The manufacturer places RFID tags on the product unit. • Costs of applying the tags need to be shared with other supply chain participants. • Problem with customer privacy.	[6, 25, 28]
*V*2	• Very convenient for large-scale packaging cases. • Identification of broken packages preventing customers complaints. • High benefits and low costs and risks for backend processes of storage, handling and moving to get a large variety of cases into retail stores.	[25, 27]
*V*3	• Low costs and risks. • Low benefits for suppliers.	[25]
Selection criteria		
Criteria	Description	References
*C*1	• The price for this technology has dropped significantly in recent years. • RFID charges range from USD25 for low-range passive tags up to USD10 for special long-range active tags. • Investment costs as well as the return of investment are very important parameters for companies.	[6, 19, 26]
*C*2	• Directly dependent on the selected variant solution are the operating costs associated with the engaged labor, inventory level, errors, market returned products, etc. • RFID technology implementation and data identification and collection process automation lead to required workforce reduction, in turn providing significant cost savings. • Labor costs account for 50% to 80% of the total distribution center operating costs. • This technology utilization could save labor costs by up to 36% in the ordering process and even 90% in the receiving and dispatching goods processes.	[8, 26]
*C*3	• Proposed variant solutions provide for a different degree of visibility, directly affecting the monitoring and location of products, supplies, resources, loss reductions, increased safety and product falsification protection. • Around 42% of the losses occur in stores and sales system while remaining stems from within the supply chain. • Better inventory visibility allows for a more rapid response to market and consumer demands, meaning increased ability to deliver the right product to the right place at the right time. • Improving visibility in the supply chain can help reduce distribution costs as well as reduce handling and inventory levels.	[5, 18]
*C*4	• Variant solutions provide for a different level of privacy protection for supply chain participants. • RFID tags placed on pallets and packaging are much less of a problem since these tags are not generally obtained by end consumers RFID tags placed on pallets and packaging are much less of a problem providing that these tags are not generally obtained by end consumers.	[6, 19]

Also, interview with 20 industry experts (who have years of experience in organizing international supply chains, from manufacturers, retailers, freight forwarders, up to distributors) was performed in order to define values for variants in accordance with criteria.

RFID technology can be utilized at different levels with regard to supply chains. Identification and data collection can be essentially done at the product, packaging or palette level [6, 18]. Each of the levels has numerous advantages and disadvantages in relation to different supply chain stakeholders. The present paper specifically deals with this problematic, and three variant RFID solutions defined and evaluated. Supply chain RFID solution evaluation is a very complex process requiring different valuation methods and techniques application. It is necessary to utilize integrated approaches, hybrid models, and evaluation methods in order to authentically present the problematic complexity [7, 8, 10]. It is for these reasons that the following parts of the present paper contain developed and implemented multi-criteria evaluation models based on AHP and FAHP methods.

4 AHP METHOD

In the literature AHP has mainly been used in decision making when large number of factors were involved and due to the hierarchical nature of decision-making process. This is specifically the case when selecting RFID solutions or providers. AHP, being one of the multi-criteria evaluation methods, is very suitable for solving complex problems (such as RFID solution evaluation) requiring selection of optimal solution from a set of multiple variant solutions. Also, AHP enables the delimitation of problems on several levels, which facilitates the problem of decision-making. In the paper [19] authors implemented the AHP method for determining factors affecting RFID adoption since AHP produces the most credible results [20]. With this in mind, the authors decided to apply this method in this paper. Solution choice is made possible by mutually comparing many quantitative and qualitative elements based on expert opinion. Hierarchical structure of proposed model is shown in Fig. 2.

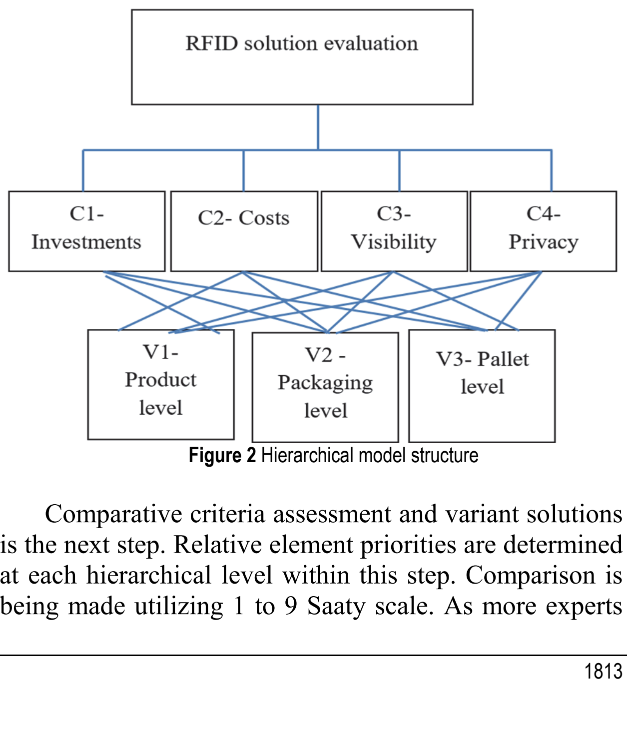

Figure 2 Hierarchical model structure

Comparative criteria assessment and variant solutions is the next step. Relative element priorities are determined at each hierarchical level within this step. Comparison is being made utilizing 1 to 9 Saaty scale. As more experts were involved in the evaluation, the geometric mean of the judgments was used in order to obtain a single assessment [21].

Tab. 2 shows comparison matrix values, set by experts and calculated value of the resulting priority vector. Vector shows each criterion's relative priority. Index and consistency ratios have been determined, and with *CR* value less than 0,10%, it means that the estimated priority vector can be accepted [22].

Table 2 Criteria comparison matrix

	*C*1	*C*2	*C*3	*C*4	*W*
*C*1	1	3	5	7	0,55
*C*2	1/3	1	3	5	0,34
*C*3	1/5	1/3	1	3	0,12
*C*4	1/7	1/5	1	1/3	0,035
	λ_{max} = 4,06; *CI* = 0,019; *CR* = 0,021				

During the next step experts, estimate each variant solution in relation to the evaluation criteria. Based on marking, a comparison of RFID variant solutions is made in relation to each criterion and the partial priority values ***W*** are being determined, as presented in Tab. 3. All comparison matrices meet the consistency condition.

Table 3 Variant solutions comparison matrices

Variant Solution →	*V*1	*V*2	*V*3	*W*
Criteria ↓				
*C*1 - *Investments*				
*V*1	0,09	0,05	0,10	0,08
*V*2	0,27	0,16	0,15	0,19
*V*3	0,64	0,79	0,75	0,72
	λ = 4,0390	*CI* = 0,0190	*CR* = 0,0330	
*C*2 - *Operational costs*				
*V*1	0,65	0,69	0,56	0,63
*V*2	0,21	0,23	0,33	0,26
*V*3	0,14	0,08	0,11	0,11
	λ = 4,001	*CI* = 0,010	*CR* = 0,002	
*C*3 - *Visibility*				
*V*1	0,65	0,69	0,56	0,63
*V*2	0,21	0,23	0,33	0,26
*V*3	0,14	0,08	0,11	0,11
	λ = 4,001	*CI* = 0,010	*CR* = 0,002	
*C*4 - *Privacy*				
*V*1	0,09	0,20	0,03	0,11
*V*2	0,27	0,60	0,72	0,53
*V*3	0,64	0,20	0,24	0,36
	λ = 4,000	*CI* = 0,000	*CR* = 0,000	

Resulting priority vector indicates *V*3 as the optimal solution, whereby the supply chain products and processes identification is being implemented via RFID tags on pallets. When it comes to evaluation criteria, the highest-rated priority is *C*1 - Investment, with 55% impact, and *C*4 - Privacy having the lowest priority with a 3,5% impact on the final variant RFID solution (Tab. 4).

Table 4 The final order of the variant RFID solution priorities, as per AHP method

Criterion →	*C*1	*C*2	*C*3	*C*4	Final priority vector ***W***
Variant solution ↓	0,55	0,34	0,12	0,035	
*V*1	0,08	0,63	0,63	0,11	0,34
*V*2	0,19	0,26	0,26	0,53	0,24
V3	0,72	0,11	0,11	0,36	0,46

5 FAHP METHOD

FAHP method is an extended version of the AHP method, with input values (comparing criteria and variant solutions) described by fuzzy numbers. Fuzzy number application can improve the expert's assessment accuracy as well as the output results quality [23]. After interviews with experts it was found that there was incomplete and unobtainable information. For this reason, the authors implemented FAHP method for this decision-making problem. Besides that, selection of RFID solution is a complex problem because it involves the interaction and dependence of higher-level elements in a hierarchy on lower level elements, which is why the FAHP was applied. Also, the FAHP method was applied in this paper in order to compare the results obtained using the AHP method with the results of the application of the FAHP method, in order to determine the difference in the results of these methods. Today there are several FAHP method formulations proposed by different authors. Chang's FAHP method is being utilized in the present model, and can be described through the following steps [24].

Step 1. Criteria pairs *i* and *j* comparison at each hierarchy level in relation to the higher level elements utilizing fuzzy numbers corresponding to 1 to 9 Saaty scale (Tab. 5). Decision maker determines a_{ij} values, for elements *i* and *j*, with a_{ij} being the triangular fuzzy numbers (k_{ij}, n_{ij}, p_{ij}).

Table 5 Fuzzy scale for criteria importance comparison

Definition	Triangular fuzzy numbers	Reciprocal triangular fuzzy number
Equal importance	(1, 1, 3)	(1/3, 1, 1)
Weak dominance	(2, 3, 4)	(1/4, 1/3, 1/2)
Strong dominance	(4, 5, 6)	(1/6, 1/5, 1/4)
Demonstrated dominance	(6, 7, 8)	(1/8, 1/7, 1/6)
Absolute dominance	(8, 9, 9)	(1/9, 1/9, 1/8)

Step 2. Summing rows of matrix $\boldsymbol{A} = (a_{ij})_{m\times m}$ in order to obtain values according to Eq. (1):

$$RS_i = \sum\nolimits_{j=1}^{m} a_{ij} = \left(\sum\nolimits_{j=1}^{m} k_{ij}, \sum\nolimits_{j=1}^{m} n_{ij}, \sum\nolimits_{j=1}^{m} p_{ij}\right) \quad (1)$$

for $i = 1, ..., n$

Value RS_i normalization value according to Eq. (2):

$$S_i = \frac{RS_i}{\sum\nolimits_{j=1}^{m} RS_j} = \left(\frac{\sum\nolimits_{j=1}^{m} k_{ij}}{\sum\nolimits_{l=1}^{m}\sum\nolimits_{j=1}^{m} p_{kj}}, \frac{\sum\nolimits_{j=1}^{m} n_{ij}}{\sum\nolimits_{l=1}^{m}\sum\nolimits_{j=1}^{m} n_{kj}}, \frac{\sum\nolimits_{j=1}^{m} p_{ij}}{\sum\nolimits_{l=1}^{m}\sum\nolimits_{j=1}^{m} k_{lj}}\right), \quad (2)$$

$i = 1, ..., m$

Determining the probability that $S_i \geq S_j$ according to Eq. (3):

$$V\left(S_i \geq S_j\right) = \begin{cases} 1 \\ \dfrac{p_i - k_j}{\left(p_i - n_i\right) + \left(n_j - k_j\right)}, \text{ if } k_j \leq p_i;\ i, j = 1, \ldots, m;\ j \neq i \\ 0, \text{ rest} \end{cases} \quad (3)$$

with $S_i = (k_i, n_i, p_i)$ and $S_j = (k_j, n_j, p_j)$.

Determining the probability that the fuzzy number S_i is greater than other fuzzy numbers, according to Eq. (4):

$$V\left(S_i \geq S_j \mid j = 1, \ldots, m; j \neq i\right) = \min V\left(S_i \geq S_j\right), \quad i = 1, \ldots, m \quad (4)$$

Step 3. Determination of priority vector $\boldsymbol{W} = (w_1, \ldots, w_n)^{\mathrm{T}}$ of the fuzzy values comparison matrix $\boldsymbol{A}$ according to Eq. (5):

$$w_i = \frac{V\left(S_i \geq S_j \mid j = 1, \ldots, m; j \neq i\right)}{\sum_{l=1}^{m} V\left(S_l \geq S_j \mid j = 1, \ldots, m; j \neq k\right)}, \ i = 1, \ldots, m \quad (5)$$

Present model outcome is the priority value significance S_i of each criterion ($C1$, …, Ci, …, Cn) and variant solutions $\boldsymbol{W} = w_1 - V1$, $w_2 - \mathrm{V2}$, $w_3 - \mathrm{V3}$.

Input values for the FAHP method being presented are the expert estimates expressed in fuzzy numbers, in accordance with Tab. 5. Tab. 6 shows the criteria comparison matrix values, set by experts and calculated value of the resulting priority vector $\boldsymbol{W}$.

Table 6 Criteria comparison matrix

	*C*1	*C*2	*C*3	*C*4	***W***
*C*1	(1, 1, 1)	(1, 3, 5)	(3, 5, 7)	(5, 7, 9)	0,44
*C*2	(1/5, 1/3, 1)	(1, 1, 1)	(1, 3, 5)	(3, 5, 7)	0,32
*C*3	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1, 1, 1)	(1, 3, 5)	0,16
*C*4	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/3, 1, 1)	(1, 1, 1)	0,09

Afterwards experts gave their variant solutions estimates, based on which, according to the previously presented procedures, the comparison of the variant solutions is made in relation to each criterion. Values of all matrix elements are expressed by the triangular fuzzy numbers. Partial priority w for each variant solution is calculated utilizing the FAHP method. The final priority of RFID variant solutions (Tab. 7) was determined on the basis of partial priorities.

Table 7 The final order of the variant RFID solution priorities, as per FAHP method

Criteria →	*C*1	*C*2	*C*3	*C*4	Resulting priority vector ***W***
Variant solutions ↓	0,44	0,32	0,16	0,09	
*V*1	0,09	0,49	0,52	0,14	0,32
*V*2	0,18	0,23	0,25	0,48	0,26
*V*3	0,84	0,09	0,10	0,25	0,42

Similar to previous model *V*3 variant RFID solution has the highest priority here as well. The highest priority as well (with 44% impact) has the *C*1 criterion - Investment, with the lowest again (with 9% impact) the *C*4 criterion - Privacy.

6 DISCUSSION AND IMPLICATIONS

Obtained results of comparative analysis suggest a great similarity in AHP and FAHP models application. Results deviations can be considered acceptable and are due to the fact that FAHP approach allows for the uncertainty and subjectivity characterizing the input values to be presented more accurately and precisely [8, 10, 23]. According to both models, the most acceptable solution in the Serbian market is the data identification via RFID tags set at the pallet level, while considerably less favourable were solutions with RFID tags placed on the product or packaging. The proposed model is validated by including all entities of a supply chain. In that matter, the model is more reliable since the values for the initial matrix were determined based on the opinion and experience of 20 experts in the supply chain.

The obtained result primarily stems from experts' assessment that the product and packaging level RFID solutions require significant investments. Investments, otherwise, are the dominantly influencing criterion when it comes to RFID solution selection, and it ranges from 44% to 55%. This fact can be fully explained by the characteristic situation of the Serbian market. As awareness of the importance of logistics and modern logistics solutions in the Serbian market is still not sufficiently developed, especially in manufacturing and trading companies, costs are still a major obstacle. At first glance, these seem like fixed costs, not fluctuating with the supply chain turnover volume change. RFID tags that are placed on products, packages, or pallets, however, are variable in nature, directly dependent on the turnover volume, i.e., the product quantity. In future research, individual RFID solutions profitability should be considered as the turnover volume function. In turn, this could lead to different results as well as orders of considered variant RFID solutions. The assumption is that it would be justified to apply product level RFID solutions for a higher product turnover volume, and for smaller turnover volumes and marginal product quantities it simply makes no sense. It is for these reasons the companies with a smaller scope of operation are being reluctant to adopt a product level RFID solution. Relatively high RFID solution investment issues will decrease over time, as RFID tag prices and readers can be expected to fall to an acceptable level. RFID solution return on investments can be significantly improved by introducing tags that can be used multiple times instead of just once. Experiences of companies that have implemented RFID solutions show that technology investments can be depreciated over several years [18].

It is necessary to keep in mind that RFID solution investment justification has to be considered differently comparing to other solutions related to scanning, and data identification and monitoring. For example, sticker prices with the bar code system are relatively low, but the operating costs of each scanning are relatively high, as this typically involves significant labour engagement, stalling the flow of the material. Initial costs (prices and investments) with RFID solutions are significant, but the scan operating costs are very low.

Apart from investments, RFID solution evaluation and selection are being significantly influenced by the certain solutions functioning costs, that is, the costs of scanning and data identification. As per results being obtained, the highest operational cost savings are achieved with product level RFID solutions. This is the logical outcome because such a system enables automatic scanning and data collection across all the supply chain phases, without significant labour engagement [2]. Labour cost reduction is a direct effect of RFID solution implementation [1]. Several indirect effects should be also considered, such as reducing inventory costs, reducing supply chain losses and downtime, streamlining the flow and product sales, and product market withdrawal. Activities going forward should necessarily include more detailed work on the research and quantification of these effects, that could significantly influence the RFID solution's ultimate selection. The same is to be applied with effects achieved through greater supply chain visibility, provided for by certain RFID solutions [5]. This is about significant effects related to better product locating and monitoring, activities, entire supply chain processes and resources, and greater safety in terms of product protection from theft, losses and counterfeits [6]. When it comes to supply chain participant's privacy protection, this mainly applies to end customers and consumers as well as product level RFID solutions. However, this danger is considered overemphasized because RFID tags do not contain any more consumer data than, for example, a loyalty card that consumers obtain from the retail stores and supermarkets [6].

Experience indicates that different supply chain stakeholders have different expectations. For example, manufacturers, logistics providers, and merchants see different advantages of utilizing RFID solutions. Manufacturers and logistics providers are usually interested in tracking products at the pallet or packaging level, via different distribution channels, while merchants generally benefit the most from product level RFID tags. Therefore, taking into account the entire supply chain, it can be noted that product level RFID solutions provide the most benefits for the seller, but are at the same time the most expensive solution for the manufacturer, being obliged to put RFID tags on each individual product at the end of the manufacturing process. The question regarding costs and benefits distribution arises between supply chain stakeholders [6]. Based on the conducted research on the Serbian market, costs and insufficient awareness of individual participants in supply chains (manufacturers and retailers) are the main obstacles to the introduction of RFID solutions [12]. A particular problem is the use of RFID at the product level where initial investments are higher. Additional utilization factors also depend on the length of supply chains, but also on whether they are domestic or international supply chains. It is necessary to share the costs among supply chain stakeholders as well as to encourage manufacturers through a certain stimulus to incorporate RFID tags on products.

On the one hand, this paper represents a kind of tool to help decision-making on the selection of appropriate RFID solutions, primarily for decision-makers and owners. The proposed approach provides an opportunity to give more importance to certain criteria depending on the needs, requirements and characteristics of individual companies and chains. At the same time, the tool is the basis for solving other problems such as the selection of a provider, the purchase of an RFID technical solution (product), etc. [8, 11]. On the other hand, the proposed methodology is an excellent basis for further research, primarily applications and measurements in other markets, with appropriate comparisons and conclusions. It is also desirable to quantify more precisely the effects that are achieved by changing certain solutions both from the theoretical aspect and from the aspect of practical application.

The obtained results partly match with the results of the research [25] where the authors came to the conclusion that placing a tag on pallet-level will result in low costs and risks but also low benefits. Placing a tag on the product level will result in high benefits but also high risks and costs. Also, another problem that arises with product-level tagging is that on some products tag cannot be placed. Finally, authors found that placing a tag on packing-level results in high benefits and low costs and risks for backend processes of storage, handling and moving to get a large variety of cases into retail stores. This may be a consequence of the fact that of the four criteria analysed in this paper, two are financial (costs related), and therefore as a better solution tagging at the pallet-level was chosen, since it was the solution with the lowest costs. In addition, the reason for obtaining the results presented in this paper may be the fact that many companies operating in the Serbian market are not ready for large investments and costs of RFID solutions.

7 CONCLUSIONS

There has been a significant recent year's tendency for increasing the implementation of such technologies in various areas of the supply chain. This, however, when the Serbian market is in question is still quite insufficient and it is necessary to systematically work on creating preconditions for greater RFID solution applications. The available literature demonstrates that this statement applies to most other markets to a large extent. The multi-criteria evaluation models developed and tested through this research will find their application both in scientific and research as well as in practical terms. Research has shown that the AHP method and fuzzy logic can be successfully utilized to evaluate and select different RFID solutions. The approach developed in this paper has undoubtedly theoretical and practical contributions. It is an excellent decision-making tool for different participants in supply chains, but also a basis for the development of new models and approaches.

Based on all of the above mentioned, this paper lays the foundations for several directions of future research. The first direction refers to the application of the proposed approach in other markets, as well as the comparison with the results obtained in this paper. The second direction refers to the development of new models based on this, primarily by combining with other methods and approaches, with a wider set of criteria and variant solutions. In this regard, it is necessary to emphasize that in future directions, special emphasis must be paid to quantifying the effects of individual RFID solutions. This research opens more potential directions for future research, which is the initial basis for researchers in the literature. With certain minimal modifications, the model can also be used for other similar problems, such as a selection of an RFID provider, selection of a technical solution for RFID (manufacturer), etc.

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Contact information:

Milorad KILIBARDA, Full Professor, PhD
University of Belgrade,
Faculty of Transport and Traffic Engineering, Logistics Department,
Vojvode Stepe 305, Belgrade, Serbia
E-mail: m.kilibarda@sf.bg.ac.rs

Milan ANDREJIC, Associate Professor, PhD
University of Belgrade,
Faculty of Transport and Traffic Engineering, Logistics Department,
Vojvode Stepe 305, Belgrade, Serbia
E-mail: m.andrejic@sf.bg.ac.rs

Vukasin PAJIC, Assistant
(Corresponding author)
University of Belgrade,
Faculty of Transport and Traffic Engineering, Logistics Department,
Vojvode Stepe 305, Belgrade, Serbia
E-mail: v.pajic@sf.bg.ac.rs