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Importance of Artificial Intelligence in Reverse Logistics: The State of the Art

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***Abstract*—The primary target in this study is to present the tendency of academicians and practitioners towards the reverse logistics (RL) issue. Hence, the literature related to the issue is examined in detail and at the end of the study some valuable information is gathered according to the distribution of artificial intelligence (AI) techniques in various segments of RL. Based on the results presented, it'll be appropriate to decide whether it is a necessity to continue considering the RL concept in managerial processes or not.**

***Keywords*—reverse logistics, artificial intelligence, meta-heuristics**

I. Introduction

RL has been defined as the movement of product or materials in the opposite direction for the purpose of creating or recapturing value, or for proper disposal [1]. Although the tendency toward RL concept is increasing nowadays, it is currently attracts less attention than needed because to deal with a cost-intensive activity does not take place among the priorities of a company. According to a survey conducted in 1997, the RL cost amounted to approximately $35 billion which is around 4% of the total logistics cost in the same year [2]. However, companies with the right RL practices can increase up to 5% of their earnings [3]. Companies have begun to realize this fact recently. Additionally, RL practices have become necessary not only for cost concerns but also for increasing level of global competition, heightened environmental regulations, improved corporate image opportunities, etc. The justification for introducing RL into organizations is not a trivial decision. Introducing RL is a strategic decision requiring evaluation of a broad set of criteria, including strategic, operational, tangible, and intangible dimensions [4]. Several reasons forming the basis of this strategic decision are *competitive reasons*, *legal disposal issues* and *Good Corporate Citizenship*.

As [5] point out, RL is not necessarily a symmetric picture of forward distribution. Table 1 summarizes the differences between reverse and forward logistics. The differences existing between the two distribution channels cause RL to be managed with great difficulty. RL problems are classified in NP-hard class of problems [6 - 12]. [13] expressed that due to the NP-hard nature of the problems, efficient solving of these problems within a reasonable time for large instances requires adoption of effective heuristic and meta-heuristic approaches.

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The remainder of this study is structured as follows. The survey methodology used in this paper is outlined and the results of the survey are presented next. Finally, conclusions and further recommendations are highlighted in the last section.

II. Survey Methodology

During the review, ScienceDirect, SpringerLinks, and Emerald databases had been investigated to search for the keywords. The keywords are classified into two categories, namely AI and RL, for the sake of the research. Thus, the literature is examined by the two groups of keywords respectively to cross-search the related journal publications. In this research, 88 papers which were published during the 2008-2013 period had been examined. The papers found from the aforementioned databases had been identified, analyzed, classified, and recorded under a classification scheme that includes the method(s) applied, application area(s).

III. Results of Literature Survey

A. *Distribution of AI Techniques in Various Segments of RL*

Based on the problems concerned in the articles, they were classified into four subcategories, namely, network design problems, vehicle routing problems, preference problems, and other issues.

- *Network design problems:* A network having both forward and reverse channels contains some of the supply chain components such as retailers, suppliers, manufacturers, customers/consumers, collection centers, repair centers, hybrid processing facilities, disposal centers, etc. [15 - 16] stated that few studies have addressed the problem of determining the number and location of repair facilities where returned products from retailers or end-customers were inspected, repaired, and refurbished for redistribution. [17] proposed a hybrid approach integrating fuzzy concept and genetic algorithm for a network design problem. [18] proposed a multi-objective optimization model in which maximization of satisfaction level of trade, maximization of satisfaction degrees of customers, and maximization of total closed-loop supply chain (CLSC) profit objectives exist. The general list of the studies concerning this subject is presented in Table 1. According to the distribution of AI techniques in this sub-category, GA and FS are the most popular techniques as shown in Fig. 1.

TABLE I. DISTRIBUTION OF AI TECHNIQUES IN NETWORK DESIGN PROBLEMS

AI Method	Summary of the Literature
FS	[17 - 18], [21], [23 - 30]
GA	[8], [15 - 16], [17], [19 - 20], [26], [31 - 38]
MA	[9], [22], [39]
AIS	[34]
NS	[13], [40]
SS	[41]
SA	[10], [42 - 43]
TS	[11 - 12], [44 - 45]
PSO	[38], [46]

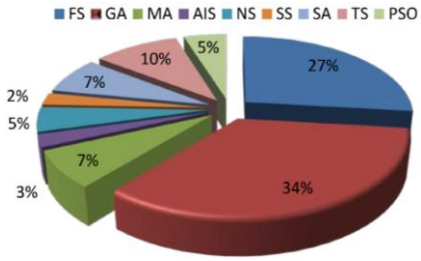

Figure 1. Frequency of AI techniques in network design problems

- *Vehicle routing problems:* Vehicle routing problem (VRP) in which the target is to minimize the cost of distributing the goods to a number of customers with a fleet of vehicles, is one of the popular issues within RL subject. For example, [47] introduced the strategy of information update via Ant Colony Systems to solve the VRPSDP problem with limited maximum distance. [48] developed a mixed integer programming model. [49] studied the VRPSDP problem having its special feature. [50] studied VRP and the inventory control decision problem simultaneously which is because they believed that the two problems affect each other and must be considered together. Table 2 summarizes the AI approaches used in this subcategory. According to the distribution of AI techniques TS is the most popular tool used in the VRPs' solution procedure as shown in Fig. 2.

TABLE II. DISTRIBUTION OF AI TECHNIQUES IN VEHICLE ROUTING PROBLEMS

AI Method	Summary of the Literature
ACO	[47], [54 - 55]
GA	[48]
DEA	[56]
TS	[49 - 50], [52], [57 - 59]
NS	[51]
PSO	[60 - 61]
SA	[62 - 63]
GRASP	[53]

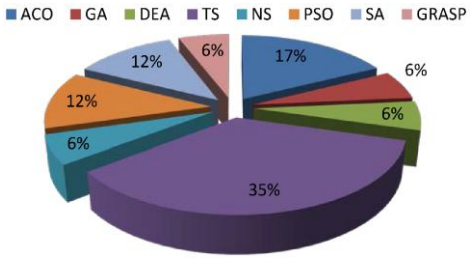

Figure 2. Frequency of AI techniques in VRP

- *Preference problems:* [64] proposed a hybrid methodology based on AHP and fuzzy TOPSIS for the evaluation and selection of RL operating channels. [65] evaluated three different collecting modes (reverse channels) in RSCM. [66] introduced green criteria into the framework of supplier selection issue. [67] investigated the consideration factors of RL implementation. Based on characteristics of electronic products' recycling and reuse. Table 3 summarizes the AI approaches used in this subcategory. Among various methodologies FS is the most popular tool used in preference problems as shown in Fig. 3.

TABLE III. DISTRIBUTION OF AI TECHNIQUES IN PREFERENCE PROBLEMS

AI Method	Summary of the Literature
FS	[34], [64 - 65], [67], [69 - 79]
CBR	[7]
ANN	[70]
GA	[66], [71]
ABC	[68]
PSO	[80]

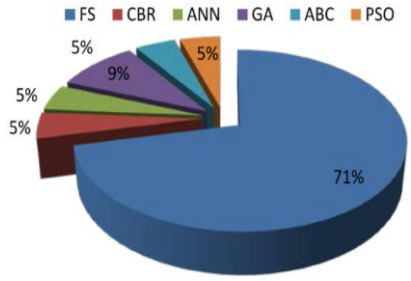

Figure 3. Frequency of AI techniques in preference problems

- *Other issues:* [81] developed two models in which one of them had a constant rate of defectiveness while the other had its fuzzy version. [82] presented a multi-criteria decision model to determine prices of reusable and recyclable components to maximize revenue and minimize product recovery costs. [83] looked for a disassembly sequence plan in two steps. [84] searched to balance a paced disassembly line considering sequence dependency. [85] considered the capacitated production planning problem within which all demands are met by production. [86] proposed a generic forecasting framework for product returns. [87] defined the reverse MRP algorithm and [88 - 90] considered the disassembly line balancing problem. Table 4 summarizes the AI approaches used in this subcategory.

TABLE IV. DISTRIBUTION OF AI TECHNIQUES IN OTHER ISSUES

AI Method	Summary of the Literature
GA	[81 - 82], [85], [91]
FS	[81], [87], [91]
GRASP	[83]
MAS	[92 - 93]
ACO	[84], [89]
BN	[86]
PSO	[88]
RL	[90]
SA	[94]

IV. Conclusions and Further Recommendations

This study has presented an extensive review consisting of 88 papers from 40 scholarly journals on the usage of AI methodologies within RL concept. During the review process, a classification scheme was developed to organize each paper into several categories. Papers were categorized based on methods used, and application areas. According to the review, the findings are given as follows:

- The three subjects used extensively within RL concept are network design problems, vehicle routing problems, and preference problems.
- GA and FS are the most popular methods used in network design problems while TS and FS are the most popular ones respectively in VRPs and preference problems.

Based on the review, the complex nature of RL problems frequently requires multi-objective optimization. Therefore, AI seems to be a promising tool for these problems. But still, there are some certain aspects in RL that have not been fully addressed and also several AI methodologies that are not employed yet. This is surely a future direction for both research subjects: AI and RL.

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