END-OF-LIFE VEHICLE MANAGEMENT: A SURVEY OF LOGISTICS NETWORK DESIGN MODELS

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Abstract: *End-of-life vehicles are classified as hazardous waste and may cause serious environmental pollution and transportation safety problems with improper management. The end-of-life vehicle management is of vital importance for environment conservation, circular economy and sustainable development. This process is not only profit-oriented, but also dependent on legislations and aimed at reducing health hazards. This paper investigates the current research within the area of end-of-life vehicle management through a brief survey of logistics network design models. The purpose of this paper is to provide a content analysis overview of exclusively peer-reviewed international journal papers published in the period 2013-2019. The distribution list is created to identify primary publication outlets. Finally, on the basis of the performed review, several important avenues for future research are highlighted. This review could provide a source of references for researchers interested toward the optimization modeling of green logistics systems and inspire their additional attention.*

Keywords*: End-of-life vehicle, Network design, Logistics, Content analysis.*

1. INTRODUCTION

End-of-life vehicles (ELVs) are classified as hazardous waste and have the potential for polluting the environment if they are not managed properly (Simic, 2016). ELVs are the single largest hazardous waste category from households (Raja Mamat et al., 2018). They represent a category of waste whose processing is especially difficult because of their complex structure and varied composition. ELVs also contain important renewable resources which are considered as urban minerals. As the number of ELVs is estimated to increase to approximately 80 million units per year by 2020 (WRME, 2014), there is strong motivation to effectively manage this fast-growing waste flow.

ELV management is of vital importance for environment conservation, circular economy and sustainable development. This process is not only profit-oriented. The management of ELVs is significantly dependent on legislations, like Directive 2000/53/EC (EU, 2000) in the European Union, Law on recycling of ELVs (MOE, 2002) in Japan, Technical policy

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for the recovery and utilization of automobile products (NDRC, 2006) in China, Act on the resource circulation of electrical and electronic equipment and vehicles (ME, 2010) in Korea, etc. Sound management of ELVs has become the principal sustainability issue in most countries worldwide and therefore requires sophisticated decision-making tools for optimizing its efficiency (Simic and Dimitrijevic, 2015).

Today, the ELV management is a well positioned and emergent research area. Recently, several review papers have been published (Table 1). Simic (2013) reviewed the environmental engineering issues of the ELV recycling by covering a wide range of peer-reviewed journal papers published in the period 2003–2012. A review of the literature published in year 2012 on topics relating to automotive wastes is presented in Kindzierski et al. (2013). Lashlem et al. (2013) presented a brief review of ELV management practices world-wide. Li et al. (2014) provided an overview of present ELV management practices in China. Guigard et al. (2014) presented a review of the literature published in year 2013 on topics relating to automotive wastes. Topics include solid wastes from autobodies and tires, and vehicle emissions to soil. Sakai et al. (2014) provided a comparative analysis of ELV management practices in several countries. Cossu and Lai (2015) presented a general overview of post shredder technologies for treatment of ASR. Cucchiella et al. (2016) provided a mini-review on the automotive electronics recycling topic in the period 2000-2014.

Table 1. Summary of recent review papers

References	Topic	Analysed period
Kindzierski et al., 2013	Automotive waste	2012
Guigard et al., 2014		2013
Cossu and Lai, 2015	Automotive shredder residue treatment	2005-2014
Simic, 2013	Environmental engineering issues	2003-2012
Lashlem et at., 2013	Management practices	-2012
Sakai et al., 2014		-2012
Li et al., 2014		2005-2012
Cucchiella et al., 2016	Automotive electronics recycling	2000-2014

The most recent and relevant review papers are limited to some specific area of ELV management. Moreover, a holistic view of state–of–the–art logistics network design models is still missing from the available reviews. Hence, additional research effort to address this important topic is needed.

This paper investigates the current research within the area of ELV management through a survey of logistics network design models. The purpose of this paper is to provide an extensive content analysis overview of exclusively peer-reviewed international journal papers published in the period 2013-2019. Grey literature is excluded from this review.

All collected original research papers are analyzed and classified based on their modeling technique, solution approach and type of supply chain. Finally, the distribution list is created to identify primary publication outlets.

The remaining part of the paper is organized as follows: Section 2 provides a review methodology. Section 3 presents the obtained results of the review. The last section presents the paper's main conclusions and recommendations.

2. METHODOLOGY

In this paper, content analysis method is adopted for literature review. Content analysis is an observational research method that is used to systematically evaluate the symbolic content of all forms of recorded communication and also helps to identify the literature in terms of various categories (Pokharel and Mutha, 2009).

Search engines were used to explore ACS Publications, ASCE Library, ASME Digital Library, Cambridge JOURNALS, EBSCOhost, EmeraldInsight, Google Scholar, IEEE Xplore, Inderscience, IntegraConnect, IOPScience, J-STAGE, JSTOR, ProQuest, RSCPublishing, SAGE journals, ScienceDirect, SciVerse, SpringerLink, and WILEY databases for literature. In addition, the references cited in each relevant literature were examined to find out additional sources of information.

3. RESULTS

Farel et al. (2013) used a mixed integer linear programming modeling technique to determine the optimal topology and material flows in future ELV glazing recycling network. Gołębiewski et al. (2013) proposed a simulation approach that could be used to determine optimum locations for dismantling facilities in Poland. Mahmoudzadeh et al. (2013) used a mixed integer linear programming formulation to solve the location-allocation problem of ELVs scrap yards in Iran. Merkisz-Guranowska (2013) proposed a bi-objective mixed integer linear programming model aiming at the reorganization and construction of the ELV recycling network in Poland.

Mora et al. (2014) proposed a mixed integer linear programming model for ELV closed-loop network design. Ene and Öztürk (2015) formulated a mixed integer linear programming model for managing reverse flows of ELVs within the framework of a multi-period, multi-stage, capacity-constrained network design problem.

Chen et al. (2016) investigated coordination in the green supply chain and applied cooperative game theory to analyze economic benefits of two different pricing strategies. Demirel et al. (2016) proposed a mixed integer linear programming model for reverse logistics network design including different actors taking part in ELV recycling system.

Balcı and Ayvaz (2017) provided a mixed integer linear programming model to design ELV recycling network in Istanbul, Turkey. Özceylan et al. (2017) presented a mixed integer linear programming model to optimize a closed-loop supply chain for ELV treatment in Turkey. Phuc et al. (2017) formulated a fuzzy mixed integer linear programming model for designing multi-echelon, multi-product reverse logistic network. The economic parameters and ELV supply were considered as fuzzy values.

Lin et al. (2018) proposed a mixed integer linear programming model for the facility location-allocation problem of ELV recovery network. An improved artificial bee colony metaheuristics was applied to solve the model. Shankar et al. (2018) formulated a mixed integer linear programming model to meet the requirements of the strategic closed-loop supply chain network design in the context of India. A cooperative game was played to compute the best possible combination of strategies. Sun et al. (2018) developed a mixed-integer bilevel linear programming model to locate distribution centers for collecting parts of ELVs. The outer and inner optimization tasks were minimizing location costs and transportation cost respectively. Yildizbaşi et al. (2018) proposed a fuzzy mixed integer linear programming model to optimize the production and distribution planning for a closed-loop supply chain network inspired by the Turkish automotive industry. The authors used four different interactive fuzzy programming approaches to tackle the trade-offs among three objective functions.

Kuşakcı et al. (2019) modeled the problem of designing ELV reverse logistic network for Istanbul Metropolitan area as a fuzzy mixed integer linear program. The authors assumed that ELV supply could be presented as a fuzzy parameter. Xiao et al. (2019) developed a mixed integer linear programming model for constructing a four-tier reverse logistics network model, which includes ELV sources, collection centers, remanufacturing centers and dismantlers.

As a first step, all collected original research papers are classified based on their modeling technique (Table 2). The reviewed papers are classified into three categories: (1) mathematical programming, (2) simulation and (3) game theory. For the sake of clarity, the first category is further divided into four sub-categories: (1) mixed integer linear programming, (2) fuzzy mixed integer linear programming, (3) bi-objective mixed integer linear programming and (4) mixed integer bilevel linear programming. The mathematical programming is by far the most popular modeling technique. Also, ten papers (58.8%) utilized the mixed integer linear programming as modeling technique for designing logistics network for ELVs.

In the second step, reviewed research papers are classified based on solution approach in three categories (Table 2): (1) exact, (2) heuristic and (3) meta-heuristic. Almost all researchers (88.2%) solved logistics network design problems with exact methods, mostly applying solvers like Lingo, GAMS or CPLEX.

Afterward, the surveyed research papers are classified based on supply chain type in two following categories (Table 2): (1) open loop and (2) closed-loop supply chains. The analysis showed that traditional and novel closed-loop supply chain design, which simultaneously considers forward and reverse supply chains, have attracted almost equal attention among researchers.

Finally, the distribution list of peer-reviewed international journal papers published in the period 2013-2019 is created in Table 3. From the distribution list of journal papers (Table 3) it can be concluded that the primary publication outlets for the highlighted research area of ELV management are: Journal of Cleaner Production (23.5% share), Computers and Industrial Engineering (17.6% share) and Resources, Conservation and Recycling (11.8% share), jointly publishing 52.9% of the total number of identified peer-reviewed international journal papers printed in the period 2013-2019.

Table 2. Classification of logistics network design models by modeling technique, solution approach and type of supply chain

References	Modeling technique		Solution approach	Supply chain
Farel et al., 2013	Mathematical programming	Mixed integer linear programming	Exact	Open loop
Mahmoudzadeh et al., 2013			Exact	Closed-loop
Mora et al., 2014			Exact	Closed-loop
Ene and Öztürk, 2015			Exact	Open loop
Demirel et al., 2016			Exact	Open loop
Balcı and Ayvaz, 2017			Exact	Closed-loop
Özceylan et al., 2017			Exact	Closed-loop
Lin et al., 2018			Meta-heuristic	Open loop
Shankar et al., 2018			Exact	Closed-loop
Xiao et al., 2019			Exact	Open loop
Phuc et al., 2017		Fuzzy mixed integer linear programming	Exact	Closed-loop
Yildizbaşi et al., 2018			Exact	Closed-loop
Kuşakcı et al., 2019			Exact	Open loop
Merkisz-Guranowska, 2013		Bi-objective mixed integer LP	Exact	Open loop
Sun et al., 2018		Mixed integer bilevel linear programming	Exact	Open loop
Gołębiewski et al., 2013	Simulation		Heuristic	Open loop
Chen et al., 2016	Game theory		Exact	Closed-loop
Shankar et al., 2018			Exact	Closed-loop

Table 3. Distribution of journal papers published in the period 2013-2019.

Journal	Year of publication							Share [%]	Total
	2013	2014	2015	2016	2017	2018	2019		
Journal of Cleaner Production	1	–	–	1	–	1	1	23.5	4
Computers and Industrial Engineering	–	–	–	–	2	–	1	17.6	3
Resources, Conservation and Recycling	2	–	–	–	–	–	–	11.8	2
Others (8 journals)	1	1	1	1	1	3	–	47.1	8
Total (11 journals)	4	1	1	2	3	4	2	100	17

Note: Others (8 journals): Waste Management; International Journal of Production Economics; Journal of Sustainable Development and Planning; International Journal of Logistics Systems and Management; International Journal of Material Science; Southeast Europe Journal of Soft Computing; Simulation; Technological and Economic Development of Economy.

4. CONCLUSION

This paper investigates the research within the area of ELV management through a brief survey of logistics network design models proposed from 2013 to 2019. The review has showed that the most widely used modeling technique in the investigated period is the mixed integer linear programming. Exact solution methods are mostly provided. However, vast majority of surveyed logistics network design models were illustrated on either small or medium size cases studies or numerical examples. It should be outlined that when solving real-life large-scale problems this solution approach is significantly limited due to thousands of integer variables. It is found that Journal of Cleaner Production, Computers and Industrial Engineering and Resources, Conservation and Recycling represent primary publication outlets for the investigated research area.

According to the literature review of logistics network design models for ELV management, the following gaps and potential research fields for their improvements are noticed:

- Resource scarcity and volatile quantities of ELVs introduce risk in management systems. The available models can hardly provide network designs appealing to risk-averse waste managers. In fact, they can generate less reliable and inferior solutions. Thus, risk measurement methods integration into future optimization frameworks is one of possible improvements;
- Uncertainty is the key factor influencing the management of ELVs. However, uncertainty analysis is mainly ignored in the latest logistics network design models. Uncertainty analysis methods incorporated into future modeling frameworks could help avoiding erroneous strategic decisions;
- Researches of environmental and social consequences of introducing or extending ELV logistics network are also missing.

This review could provide a source of references for researchers interested toward the optimization modeling of green logistics systems and inspire their additional attention.

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