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MODELLING OF REVERSE LOGISTIC APPROACHES: A PROPOSED FRAMEWORK

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Abstract
Reverse logistics is receiving more attention because of the growing environmental and economical concern. The complex issues depending on social, technical and legislative factors are: how to prevent the environmental deterioration caused by the generation of wastes, how to minimize the generation of wastes, and finally how to re-cover the valuable material contained by the wastes. In this paper, we have done an exhaustive literature review, highlighting the application of various modelling approaches from reverse logistics perspectives. The considered modelling approaches are Linear programming, Mixed integer linear programming, Goal programming and Genetic algorithm. The reverse logistics issues are basically categorized into five categories namely distribution, Production planning and control, Information technology, business economics and integration/co-ordination. The paper proposes a framework focusing these issues and suggests an appropriate approach to model reverse logistics.

Keywords: Reverse logistics networks, Linear programming, Mixed integer linear programming, Goal programming, Genetic Algorithm

Introduction

Reverse Logistics (RL) refers to the sequence of activities required to collect the used product from the customers for the purpose of either reuse or repair or re-manufacture or recycle or dispose of it [1]. Reverse Logistics concentrates on those streams where there is some value to be recovered and the outcome enters a (new) supply chain [2] [3]. To recover value from used products, companies need to design an optimal logistics structure and so the question arises, how to design this logistic structure. where to locate the various processes of the reverse supply chain, how to collect recoverable products from the former user; where to segregate the collected products to identify the recoverable resources from the scrap in order to separate recoverable resources from scrap; where to refurbish the collected products to make them fit for reuse; and how to distribute recovered products to future customers [4], [5]. So it requires a deep understanding of the whole context so that the solutions we get should be optimal.

1.1. Motivation

The environmental profile of most of the industries is not very positive. Energy consumption is relatively higher than the international standard, due to interruptions in production, poor quality of fuel and equipment, and relatively low rate of used products in production [6]. Pollution emissions in to air and waste water and solid waste are also higher than the international average. Rapid urbanization and economic growth increase waste and at the same time reduce the available landfill space [7]. Large volume of different types of wastes is produced daily by the industries as well as the localities. If the things discarded by the user are not managed appropriately then it leads to a number of societal problems such as increased risks of epidemics, air pollution caused by illegal burning and pollution of ground water. The need arises to design our reverse logistics networks for the appropriate management of these products [8].

In this paper we have proposed a conceptual framework of various techniques like [(Linear programming (LP), Mixed integer linear programming (MILP), goal programming (GP), Genetic algorithm (GA), Simulated Annealing (SA)] that can be applied to the reverse logistics problems [9] [6] [10]. We have prepared a critical review in this regards to provide user friendly information in the context of applications of the above said approaches. Finally we end up with the conclusion and future scope. Rest of the paper is arranged as follows. Section 2 deals with the literature review in LP, MILP, GP GA and SA. Section 3 proposed a framework. Finally section 4 concludes the paper with future research**.**

Literature

In this paper we start by taking a look at related literature on the application part of the different modeling approaches in reverse logistics. In the literature many of the models have been developed by extensions and modifications of traditionally existing models. We briefly comment on the general things learned. Tables 1 to 4 summarize some of the recent examples and uses.

2.1. Linear programming Applications in RL

Table1. Review on LP applications

Author	Journal Name	Review on LP
Nengye Mu et al. (2023)	Environmental Science and Pollution Research	Developed a six-level sustainable dynamic reverse logistics network model from the perspectives of economy, environment, and society. Solve the multi-objective combinatorial optimization model to explore the layout of the sustainable reverse logistics network for retired new energy vehicle power batteries recycling. A case study is implemented to verify the effectiveness of the proposed model. [3]
A. Nagurney, and F. Toyasaki (2005)	Sustainability	Developed a mathematical model and two stage heuristic algorithms for systematically managing and integrating forward and reverse logistics network design for the recovery of end-of-lease computer products. Also developed a mathematical model for the locations of facilities jointly used by forward and reverse logistics operations.
F. Alarcón et.al. (2021)	Sustainability	Formulated a linear multi-objective optimization model to improve cost and the risk to optimize the operations of both the nuclear power generation and the corresponding induced waste reverse logistics.
D.H. Lee, and M. Dong (2008)	Resources, Conservation and Recycling	Formulated a linear multi-objective analytical model that minimizes both the total reverse logistics operating costs and corresponding risks. In this model environmental impacts caused by regional industrial hazardous wastes and a trade-off relationship between the goals of cost minimization and risk minimization are considered.
Listes and Dekker (2005)	European Journal of Operational Research	Presented a deterministic location model for product recovery network design by extending it to be explicitly accounted for the uncertainties. And this gives more insight into decision-making under uncertainty for reverse logistics networks.[25]

Nagurney and Toyasaki (2005)	Transportation Research Part E	Developed a multitiered e-cycling network model for reverse supply chain management of electronic waste, which includes recycling and solved the numerical examples. Formulated the consisting of sources of electronic Waste, recyclers, processors,and consumers associated with the demand markets for the distinct products.[4]
Jayaraman et al. (2003)	European Journal of Operational Research	Discussed reverse distribution, and proposed a mathematical programming model and introduced a heuristic solution methodology.[31]
Hu et al. (2002)	Transportation Research Part E	Formulated a discrete-time linear analytical model that minimizes total reverse logistics operating costs of hazardous waste reverse logistics system subject to constraints such as business operating strategies and governmental regulations.[28]
Fleishmann et al.(2001)	Report series research in management (ERIM)	An excellent overview on a no of case studies was given and used mathematical models to derive the characterization of networks.[18]
Thierry (1995)	California management review	LP model was formulated to address the problems of network good flow under given capacity constraint. Proposed a conceptual three echelon model to evaluate combined production/distribution and collection/recovery networks for photocopiers.[21]

2.2. Mixed Integer Linear programming applications in RL

Table2. Review on MILP applications

Author	Journal Name	Review on MILP
Mutha and Pokharel (2009)	Computers & Industrial Engineering	Proposed a model for designing reverse logistics networks allowing only a portion of capacity in warehouses.[3]
Du .and Evans (2008)	Computers & Operations Research	Developed a bi-objective MIP optimization model for the reverse logistic network problem. A reverse logistics problem was proposed, in which a third-party logistics company provides logistics service for the post-sales service network.[8]
Sayed et al.(2008)	Computers & Industrial Engineering	Developed a multi-period multi-echelon forward–reverse logistics network design under risk model. Formulated the problem in a stochastic mixed integer linear programming (SMILP) decision making form as a multistage stochastic program. By this model it was shown that the total ex-pected profit is directly affected by demand mean and return ratio for a given capacity of the network.[20]
Salema et al. (2007)	European Journal of Operational Research	Developed a mixed integer formulation for the design of a generic reverse logistics network by considering capacity limits, multi-product management and uncertainty on product demands and returns. Further solved it using standard B&B techniques and applied to an illustrative case.[19]

Lieckens and Vandaele (2007)	Computers & Operations Research	Formulated basic models such as MILP and determined which facilities to open that minimize the investment, processing, transportation, disposal and penalty costs while supply, demand and capacity constraints are satisfied.[16]
Hong et al (2006)	IEEE transactions on electronics packaging manufacturing	Used a scenario-based robust optimization MILP model for supporting strategic e-scrap reverse production infrastructure design decisions under uncertainty. Model is used to maximize the system net profit for specified deterministic parameter values in each scenario, and then a min-max robust optimization methodology to find a robust solution for all of the scenarios.[11]
Min et al.(2006)	Omega-The international journal of management science	Proposed a nonlinear MIP model and a Genetic algorithm that can solve the reverse logistics problem involving product returns from online sales.[10]
Klose and Drexl (2005)	European Journal of Operational Research	Reviewed and summarized the applications of some contributions in Mixed-integer programming models, Continuous location models and network location models.[2]
Grossman and Biegler (2004)	Computers and Chemical Engineering	Discussed recent developments in deterministic global optimization algorithms applied to both nonlinear programs and mixed-integer programs. Also discussed logic-based optimization and its influence in both modeling and solving mixed-integer optimization problems. Discussed issues and approaches related to large-scale optimization algorithms and applications.[12]
Jayaraman et al. (1999)	Journal of the Operational Research Society	Used MILP to analyze the logistics network of an electronic equipment remanufacturing company in the USA. Here the limited core supply acts as a capacity restriction to the overall level of operation.[30]
Barros et al. (1998)	European Journal of Operational Research	Developed a single-period, cost minimization MILP model for the configuration of an optimal sand recycling network, in which the sand originates from the demolition and reconstruction of old buildings.[1]
Spengler et al. (1997)	European Journal of Operational Research	Proposed a modified MILP warehouse location model to minimize overall costs to analyze which recycling processes or process chains to install at which locations at which capacity level by examining recycling networks for industrial by-products in the German steel industry.[29]

2.3. Goal Programming Applications in RL

Table3. Review on GP applications

Author	Journal Name	Review on GP
F. Dehghanian, and S. Mansour (2009)	International Journal of Environmental Research and Public Healt	Formulated a mixed integer goal programming (MIGP) model to assist in proper management of the paper recycling logistics system. The model studied the inter-relationship between multiple objectives (with changing priorities) of a recycled paper distribution network. The

		use of the model was illustrated through a problem of paper recycling in India.[24]
G. Kannan et al (2009)	Sustainability	Formulated a fuzzy MIGP vendor selection problem that includes three primary goals: Minimizing the net cost, minimizing the net rejections and minimizing the net deliveries.[17]
Pati et al. (2008)	Omega- The international journal of management science	Presented a disassembly-to-order system Where the products are taken back from the last user and/or collectors, disassembled for the retrieval of reusable components and resold in order to meet a certain level of demand. Model it as a multi-criteria decision making problem under uncertainty using the fuzzy GP technique. To illustrate the methodology a case example was presented.[6]
Kumar et al.(2004)	Computers & Industrial Engineering	Applied the compromise programming and GP techniques to ease the potential conflict among land filling, Incineration and recycling in a growing metropolitan region.[23]
Chang and Wang (1997)	European Journal of Operational Research	Applied a fuzzy GP approach for the optimal planning of solid waste management systems in a metropolitan region.[22]
Hoshino et al.(1995)	International journal of Production Research	Used a GP model to analyze the profitability and recycling rates for manufacturing systems.[27]

2.4. Genetic Algorithm Applications in RL

Table 4. Review on GA Applications

Author	Journal Name	Review on GA
H. Min, H. J. Koa, and C. S. Kob (2006)	Decision Science Letters	Applied Multi-objective genetic algorithm (MOGA) to find the Pareto-optimal Solutions. Presented a Multi-objective programming model for multi-objective optimization of sustainable recovery network of scrap tires.
Kannan et al.(2009)	Computers & Industrial Engineering	Applied the proposed heuristics based genetic algorithm (GA) as a solution methodology to solve mixed integer linear programming model to minimize the cost. Finally the computational results obtained through GA were compared with the solutions obtained by GAMS optimization software.
Lee et al. (2009)	Computers & Industrial Engineering	Formulated a mathematical model of remanufacturing system as three-stage logistics network model for minimizing the total of costs to reverse logistics shipping cost and fixed opening cost of the disassembly centers and processing centers and considered a multi-stage, multi-product and some attach condition for disassembly centers and processing centers, respectively solved this problem by genetic algorithm (GA) with priority-based encoding method.

Farahani and Elahipanah (2008)	Int. J. Production Economics	Applied GA to solve real-size problems of mixed-integer linear programming model. Designed GA to find the Pareto fronts for the large-size problem. Minimized the total costs for a distribution network by developing a new model for a three-echelon supply chain which follows JIT distribution purposes in order to better represent the real-world situations.
Dehghanian and Mansour (2009)	Omega- The international journal of management science	By GA, Solved and provided a min. cost solution for a reverse logistics network design problem involving product returns in the case when return of the products is focused on a centralized location.

2.3. Simulated Annealing Applications in RL

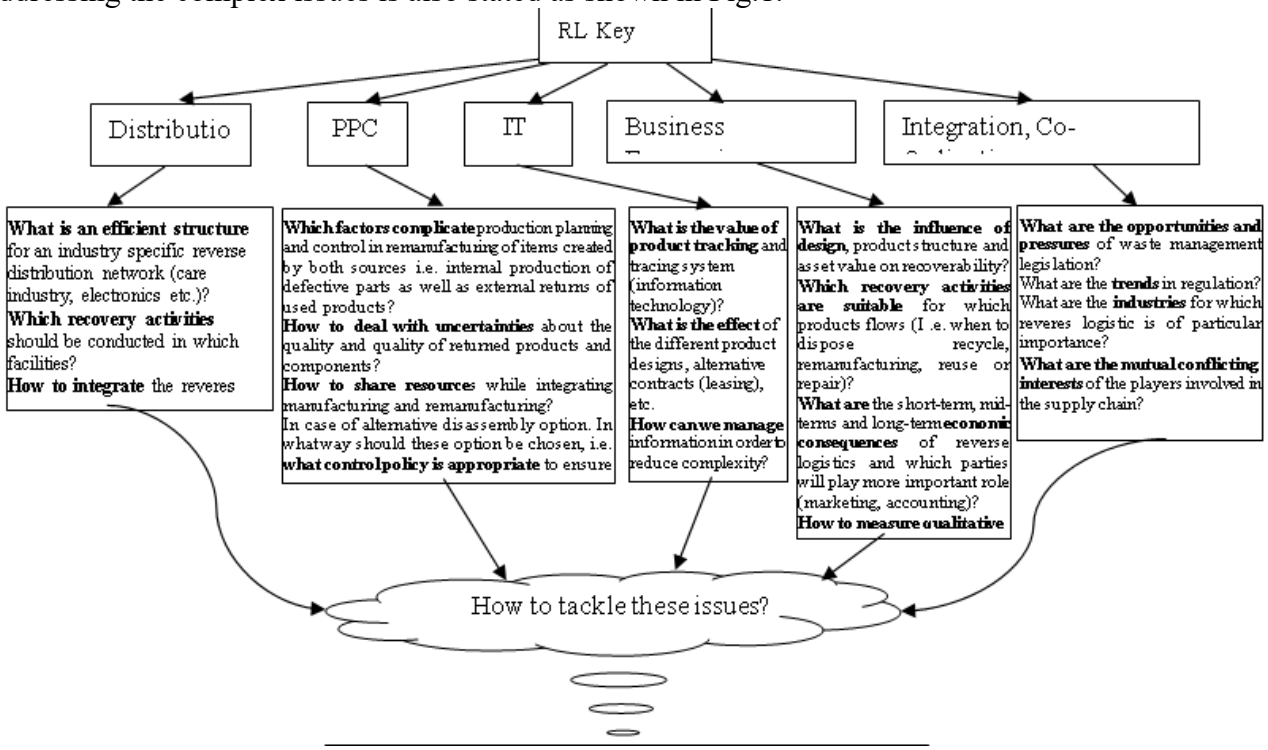
Table 3. Review on SA applications

Author	Journal Name	Review on SA
Mir Saman Pishvaee et al. (2009)	Int J Adv Manuf Technol	Network design problems belong to the class of NP-hard problems, therefore applied a simulated annealing (SA) algorithm with special neighborhood search mechanisms to find the near optimal solution. Also compared the associated numerical results through exact solutions in a set of problems to present the high-quality performance of the applied SA algorithm. [16]
Ali Diabat et al. (2015)	Journal of Manufacturing Systems	proposed a SA algorithm to address the complex network configuration of an RL system, which decides on the Optimal selection of sites, the capacities of inspection centers and remanufacturing facilities. Furthermore, introduced important transportation considerations, by providing the option of using in-house fleet as well as outsourcing option and this constitutes one of the main contributions of our work. [17]
H. Min, H. J. Koa, and C. S. Kob (2006)	Decision Science Letters	This paper addresses an inventory control model for a reverse logistics system that deals with two separated types of demand, for new products and remanufactured products, with different selling prices. The model consists of a single shared machine between production and remanufacturing operations, while the machine is subject to random failures and repairs. Three stock points respectively for returns, new products and remanufactured products are investigated. Meanwhile, in this paper, a modelling of the problem with Discrete-Event simulation using Arena® was conducted.
A. Mutha et. Al (2009)	Environmental Science and Pollution Research	This study developed a six-level sustainable dynamic reverse logistics network model from the perspectives of economy, environment, and society. We solve the multi-objective combinatorial optimization model to explore the layout of the sustainable reverse logistics network for retired new energy vehicle power batteries recycling by a simulated annealing (SA) algorithm with special

		neighbourhood search mechanisms to find the near optimal solution..
J.B. Sheu et. Al (2020)	European Journal of Operational Research	This paper proposed a profit maximization modelling framework for reverse logistics network design problems and presents a mixed-integer linear programming formulation that is flexible to incorporate most of the reverse network structures plausible in practice. In order to consider the possibility of making future adjustments in the network configuration to allow gradual changes in the network structure and in the capacities of the facilities, we consider a multi-period setting.

Proposed framework

After screening plethora of papers in RL, A framework lightening the application of modelling approaches from RL perspective is developed in Fig.1. Initially we identify key areas like distribution, production planning and control (PPC), Information technology (IT), Business economics, Integration and Co-ordination. Then some of the key issues (as shown in Fig.1) linked with the above said key areas are discussed for a qualitative analysis. To tackle these issues we use quantitative modelling and programming approaches. Here, we have taken Linear programming, MILP, Goal programming and Genetic algorithm for the modelling of the problems. The application of each of these techniques addressing the complex issues is also stated as shown in Fig.1.



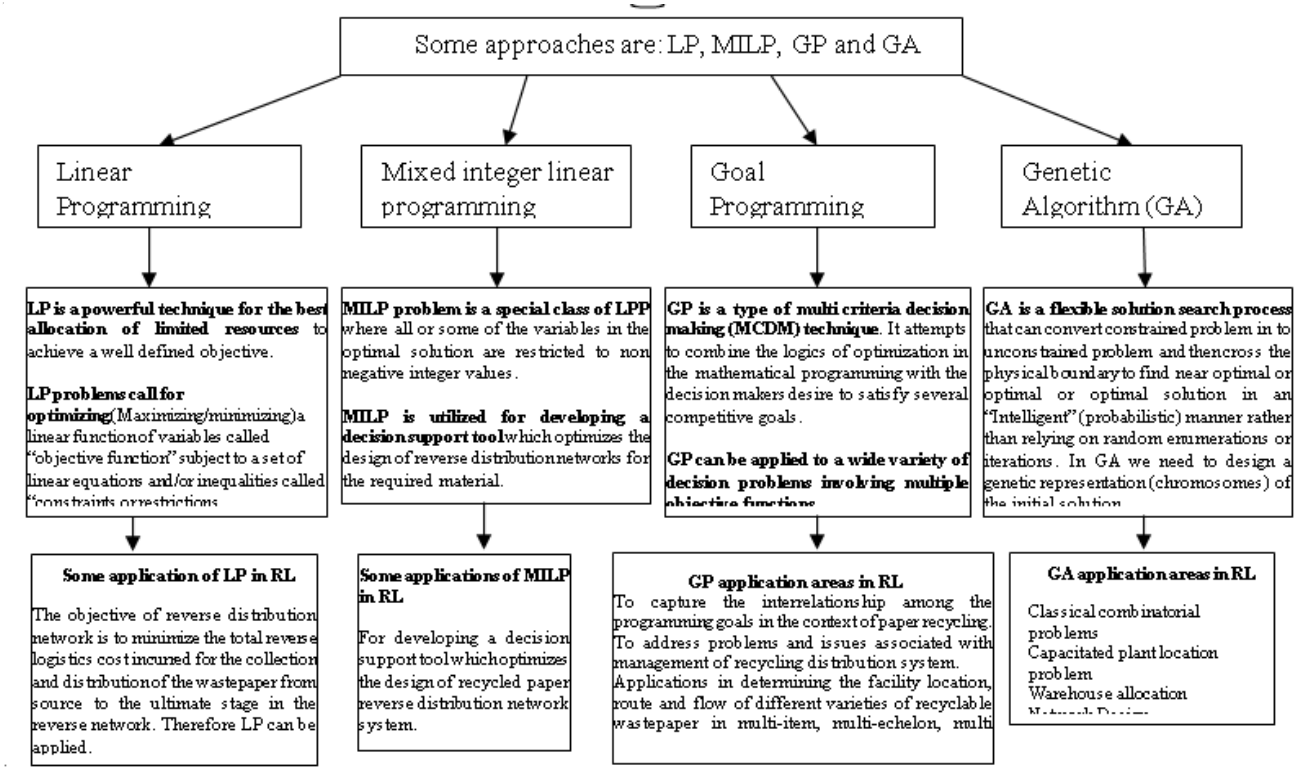


Fig.1 A framework lightening the application of modelling approaches from RL perspective

Conclusion and future work

An exhaustive literature review, highlighting the application of various modelling approaches has been done from reverse logistics perspectives. The considered modelling approaches are Linear programming, Mixed integer linear programming, Goal programming and Genetic algorithm. We categorized the RL issues in to 5 categories namely distribution, Production planning and control, Information technology, business economics and integration/co-ordination. Reverse logistics networks are having very distinctive characteristics and one of them is the high level of uncertainty. So opportunities can be exploited for the further research in the sustainability of the reverse logistics networks.

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