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Trends in Green Vehicle Routing in Reverse Logistics

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Abstract

With the rapid industrialization that swarmed across the globe in the past few decades, various environmental issues have emerged due to negligence of humans. Hence, in the recent history people across the globe have joined together in minimizing the environmental impacts from industrial activities. Special concern has been placed on the logistics arena of the supply chain leading to a shift in the traditional objectives of Vehicle Routing Problem (VRP) towards the minimization of environmental impacts from distribution. The new branch of VRP that emerged is known as Green Vehicle Routing Problem (VRP) and consists of three predominantly identified categories as Green-VRP, Pollution Routing Problem and VRP in Reverse Logistics. In nowadays, a high concern is placed on the management of reverse logistic flows in the supply chain for minimizing the adverse environmental impacts and thus requires a proper optimization in the distribution channels associated with this process. This literature review extensively analyses the available literature in VRP in Reverse Logistics to identify the current trends, limitations in the applicability to real world and the available research gaps. Hence it is hoped that the article will provide guidance for future researches.

Keywords
Green Vehicle Routing, Green Logistics, Reverse Logistics, Literature Review

1. Introduction

Over the years, with the industrialization that engulfed the world people drove towards economic success while exploiting the environment thus resulting in many environmental catastrophes that will haunt the world for generations. In order to minimize the projected environmental catastrophes and to prevent the environmental negligence in economic activities many environmental frontiers and governments around the glove has joint hands thus forcing the organizations to implement environmentally sustainable processes. This has led to the rise of processes like environmental conscious manufacturing, waste reduction, product recovery and green logistics.

Green logistics is concerned with the product distribution strategies through which minimum costs are attained while ensuring the high quality and minimum negative environmental impacts. Currently the existing distribution schemes are defined to be unsustainable in the long term and hence it is required to deduce new strategies to ensure environmental sustainability while coping with high customer demands and other external business environmental constraints. Also, with the increased pressure placed upon organizations for recycling the remnants of the products, supply chains are designed as Closed-Loop in order to ensure that waste materials do not flow out of the organizational system.

Logistic process accounts for a larger portion of the supply chain cost and hence organizations are continuously in search of strategies to minimize costs associated in the process. Vehicle routing optimization is one such strategy that has been incorporated by organizations to optimize their distribution networks to achieve minimum costs while achieving higher customer satisfaction thus ensuring the sustainability in the customer partnership. With time optimization of the distribution network has been tied with multiple objectives to suit the complex nature of the real world businesses. Within the past few decades with the increased concern in the environmental sustainability new branch of vehicle routing optimization emerged namely Green Vehicle Routing Problem (GVRP). Lin et al. (2014) in their survey on Green Vehicle Routing Problem has classified GVRPs into three major categories as Green-VRP, Pollution Routing Problem (PRP) and VRP in Reverse Logistics (VRPRL).

Today many organizations are facing the challenges in developing Closed-Loop Supply Chains (CLSC) in which they are in need to minimize the costs associated with managing both forward and reverse product flows while ensuring the environmental sustainability. These distribution networks can be properly optimized by incorporating VRPRL.

With this study authors have comprehensively analyzed available literature on vehicle routing in reverse logistics with the intention of ascertaining trends and available research gaps. It is hoped that the findings of this study will assist organizations in identifying the modifications and developments that can be incorporated into their distribution networks for achieving sustainability and cost benefits simultaneously.

Rest of the paper is structured as follows; Section 2 provides the methodology followed in the study, Section 3 provides an in detail literature review under the four categories of VRPRL and the paper concludes with Section 4 giving a conclusion and future trends derived with the review of literature.

2. Methodology

In developing a comprehensive literature review a standard procedure has been followed in the article selection process. In this study initial article search was carried out via a simple web search based on a set of selected keywords in the study area. Web searched allowed accessing many research articles in the said study area from different academic databases like IEEE Xplore, Science Direct, Research gate etc. The pool of articles received were initially filtered based on the year of publication in order to ensure the relevance to the current practices in the study area and hence only article in the year span 2000-2017 were selected. This resulted in total of fifty-five articles. Secondary screening was done based on the title and the abstract and this filtering resulted in the rejection of ten articles. As the final screening process, the selected articles were fully reviewed to identify the relevance in the context to the four categories of VRPRL under which the literature were reviewed. This resulted in the rejection of nine more articles leaving the authors with a total of thirty-six articles and all the reviewed articles are stated in the list of reference.

Selected pool of research papers were fully analyzed to identify current trends in VRPRL and to identify research gaps in the literature and predictable future trends.

3. Main Results Of The Reviewed Studies

Vehicle Routing Problem in Reverse Logistics (VRPRL) associates itself with the optimization of distribution channels in the reverse flows of a supply chain. Over the years various researches has been contributed to the VRPRL literature but the amount of research conducted in the area is comparatively to be low. (Lin, et al., 2014)

In order to provide a comprehensive review of analyzed literature in the field of VRPRL, categorization introduced by (Lin, et al., 2014) as given in the *Figure 1* is followed in this paper. This categorization is based on problem characteristics and the relevant applicable situations of these problems.

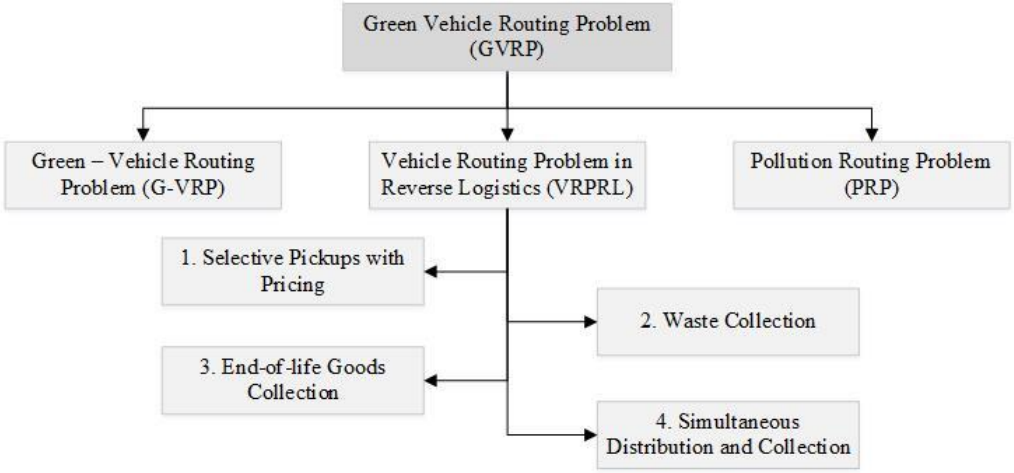

Figure 1: Classification of GVRP

3.1. Selective Pickups and Pricing

In reverse logistics, product reacquisition process plays a major role as the recovery process initiator. Thus it has to be ensured that only the products with a reliable quality standard are reabsorbed into the organization's supply chain and also it is required to encourage the product holders to return old, obsolete or unnecessary items. In order to ensure the efficiency and the effectiveness in the product reacquisition process organizations tend to implement incentive schemes to product holders (Aras, et al., 2010).Despite the incentives given to product holders, organizations have to ensure that altogether the entire reverse logistics process is of profit and hence Selective-pickup VRP with pricing came into practice. This VRP model focuses on increasing the profitability of the reverse logistics process and hence distribution channel is modeled to visit only the selected profitable pickup points (Lin, et al., 2014).

Prive´ et al. (2006) carried out a research considering the distribution network in a Quebec-based soft drink company. Organization's supply chain is modeled in order to facilitate both the processes of product delivery and recollection of the recyclable product remaining s back into the supply chain. Recollection of the recyclable materials at the collection points is considered as an optional step which is dependent on the availability of the vehicle space. Delivery network optimization in this situation was modeled as a VRP with pickups and delivery referred for simplicity as Soft-drink Distribution Problem (SDP). This model incorporates multiple products, a heterogeneous vehicle fleet and time window constraints with the objective set to be achieved as the minimization of the routing cost minus the revenue obtained from recollection of recyclable product remaining. Problem solving process incorporated three heuristics; a nearest neighbor procedure that is used as a construction heuristic and two petal algorithms used for the purpose of selecting the best vehicle routes from a set of prospective solutions.

Gribkovskaiaa, et al. (2008) have also carried out a research similar in nature to the afore mentioned research where all the delivery demands of the customers are satisfied while only some pickup demands are satisfied depending on the profitability of the pickup. Situation has been modeled as a Single Vehicle Routing Problem with Deliveries and Selective Pickups (SVRPDSP) with the objective set as to achieve minimum cost while performing all deliveries and some selected pickups. Problem has been solved by Mixed Integer Linear Programming (MILP) formulation and a construction heuristic, three improvement heuristics i.e. shifting pickups, optimization of the sequence of customers in the route, reducing the number of second visits and a Tabu-Search (TS) heuristic has been developed and tested for different test cases taken from VRPLIB.

In the durable goods industry, organizations encourage customers for replacement purchases via buy-back campaigns. These campaigns lead to accumulation of returned products at the dealer centers for which the dealers charge a reservation fee and the organization will purchase back from the dealers only if the reservation price is lesser than the acquisition price announced by the firm. Organizations will include dealer centers in its reverse logistics distribution network with consideration to the profitability offered by visiting the said dealer center. This scenario was modeled as a Selective Multi-Depot Vehicle Routing Problem with Pricing (SMDVRPP) and the researchers have developed two MILP formulations for solving the problem. SMDVRPP is NP-hard and hence it has been proposed the use of Rich Neighborhood Tabu-Search (TS-RN) heuristic which yields promising result than commercial solvers. (Aras, et al., 2011)

3.2. Waste Collection

Process of waste management practiced in a society has a direct impact on the maintenance of the environmental sustainability of an ecosystem. Implementing a proper municipal waste management process has been considered as a critical and yet a very complex task faced by governing authorities across the world. (Nuortio, et al., 2006) The concern placed over proper waste management has increased over the years with the increased health and environmental concerns and over the time different mechanisms has been placed in order to achieve the environmental and cost targets of the process. One such technology incorporated in the waste management process is the optimization of waste collection networks in order to minimize the costs, time and environmental negativities. One of the earliest use of VRP model for waste collection process is recorded as Beltrami and Bodin (1974).

The waste collection industry consists of three main categories as commercial waste collection process, residential waste collection process and roll-on-roll-off process and these three categories involves different types of VRP applications as of the relevant requirements to be achieved. (Kim , et al., 2006) Residential waste collection associates with waste collection from private homes which is done either as house wise collection in small bins or as

streetwise collection. Commercial waste collection involves the waste collection from malls, restaurants, office buildings etc. (Faccio, et al., 2011; Bing, et al., 2014) and roll-on-roll-of waste collection associates itself with construction waste collection. (Han & Ponce Cueto , 2015) Commercial waste collection and roll-on-roll-off waste collection differs from each other from the vehicle size used for the collection purpose. (Faccio, et al., 2011; Bing, et al., 2014)

Residential waste collection process:
The review of literature showed that the researches carried to analyze the VRP associated with residential waste collection are low in number. A research was carried out by Faccio et al. (2011) in which the researchers developed an advanced vehicle routing model for residential waste collection by integrating with cutting edge technology to get real time updates on the garbage levels in the bins. In developing the model researchers have employed technologies like volumetric sensors, Radio Frequency Identification (RFID), General Packet Radio Service (GPRS) and Global Positioning System (GPS). VRP model is developed as a multi-objective network model consisting of a variable fleet sized homogenous vehicle fleet, in which the taken vehicle type for this problem is compactors and the network originates from a single depot. Problem solving has been carried out as a simulation model in Matlab software.

Bing et al. (2014) also carried out a scenario based study considering the household plastic waste collection in real world situation in Netherland city. The model was developed with the objective of minimizing the total cost which includes both operational cost and the emission cost which is accumulated both during driving and idling. In order to cater to the real world application the distances between collection points are generated via the software Microsoft MapPoint. TS heuristic has been used in solving the problem and the scenarios developed in this study are generated based on the collection approaches in Netherlands. Experimental results proved the applicability of the developed model in increasing the eco-friendliness of the waste collection approach. .

Commercial waste collection process:
Tung and Pinnoi (2000) carried out a case study based research on a real world situation faced by URENCO, a public company operating in the field of waste collection in Hanoi, Vietnam in order to optimize their daily operations. The problem was modeled as a Vehicle Routing and Scheduling Problem (VRSP) which is considered as an extended version of VRP that consists of additional time constraints like time windows, inter-arrival time constraints, total time utilizations etc. Problem has been formulated as a mixed integer program and a combination of improvement and construction heuristics has been used for solving this NP-hard problem. Construction heuristic taken was a modification of the Solomon's I1 insertion heuristic and the improvement heuristic taken was a combination of two local search procedures known as Or-opt procedure or more commonly known as node exchange heuristic and 2-opt* procedure.

A case study based research has been carried out by Nuortio et al. (2006) to address the real world waste collection optimization in Eastern Finland. Researchers have provided a conceptual diagram of the problem that can easily be incorporated into problems of similar nature and capacity. The problem was formulated as a Stochastic Periodic Vehicle Routing Problem with Time Windows and a limited number of vehicles (SPVRPTW) and since the problem is NP-hard hence heuristics has been used for the problem solving process. Researchers have used the Guided Variable Neighborhood Thresh-holding (GVNT) meta-heuristic in the problem solving and the process also incorporates seven renowned improvement heuristics namely Heur2Opt, Heur3Opt, HeurOrOpt, HeurRelocate, HeurExchange, Heur2Opt* and HeurCROSS and also incorporates Dijkstra algorithm in the solving process for calculating the shortest routes. Calculated results have proved the cost savings of the optimization model developed in comparison to the traditional practices.

Through the revised literature it was found that many studies has been conducted to solve the waste collection problem with consideration to time windows and driver rest periods. The first one found was Kim et al. (2006) in which the researchers analyzed a real life commercial waste collection situation while taking into consideration the practical aspects associated with the process such as the requirement of making multiple trips for waste disposal, driver's lunch hours, workload balancing, computational time and route compactness and territory. The situation has been modeled as an advancement of Vehicle Routing Problem with Time Windows (VRPTW) by considering afore mentioned practical aspects thus leading to a model of capacitated clustering-based waste collection VRPTW. This is NP-hard and hence in order to achieve more optimality to the solution the problem has been solved using heuristics. The route construction algorithm incorporated for this study was an extension of the Solomon's insertion algorithm while route improvement was done by Simulated Annealing (SA) meta-heuristics using the CROSS

exchange local search method. Data set used for the solution purpose was a publically available data set consisting of 2092 customers and 19 waste disposal facilities.

Ombuki-Berman et al. (2007) has carried out a research of the same capacity where the solution was obtained by a multi-objective Genetic Algorithm (GA). This study is considered to be the first instance where a GA has been used for solving waste collection VRPs. Experiment was tested with the same data set used by Kim et al. (2006) and the study proved the potentiality of using GA in the solution approach. Future modifications of the GA were suggested for handling issues in solution compactness, load balancing and to minimize the computational time of the problem.

Another study of this same capacity was done by Benjamin and Beasley (2010) for a case where there are several disposal facilities, unlimited number of homogenous vehicles and the activities are originated from a single depot. The situation has been modeled as a VRPTW accounting the time windows associated with customers, disposal facility and depot and also driver rest period was taken into account same as in Kim et al. (2006). Problem has been solved heuristically using TS, Variable Neighborhood Search (VNS) and a combined algorithm named Variable Neighborhood Tabu-Search (VNTS) that has VNS as the base and TS for searching the neighborhood. The solution was obtained for the same data set used by Kim et al. (2006) and the results proved that VNS to be more effective than the other two heuristics in solving this problem. Improvements for this research has been conducted by Benjamin and Beasley (2013) in which the researchers introduced a new route evaluation procedures i.e. Disposal Facility Positioning (DFP). For route improvement the same heuristics applied in Benjamin and Beasley (2010) i.e. TS, VNS and VNTS have been used and as an improvement researchers have included three procedures for route evaluation i.e. newly introduced DFP, change tracking and reverse order. In this research also the same data set used in Kim et al. (2006) has been used and the experiment resulted in a huge reduction in the travelling distance but required more computational time for the problem solving process.

Buhrkal et al. (2012) also carried out a research to address waste collection VRPTW in city logistics context in which the study was tested against benchmarked instances in literature and real life case study considering a Danish garbage collecting company. Researchers have used Adaptive Large Neighborhood Search (ALNS) meta-heuristics for solving the problem and the solving approach has shown considerable improvements in means of reductions in the distance which in turn yields reduction in fuel consumption and CO_2 emissions.

A complex situation of a waste collection VRP was analyzed by Markova et al. (2016) by taking considerations on intermediate facilities, heterogonous fixed vehicle fleet, driver rest periods, flexibility in assigning destination depots etc. and this problem can be stated as an extension of VRP with Intermediate Facilities (VRP-IF). The situation was modeled as a MILP and solved both in exact approach and heuristics approach. Due to the complexity in the problem commercial solvers are only able to solve small scale and medium scale situations and hence heuristic approach should be incorporated for large scale real world situations. Researchers have developed multiple neighborhood search heuristic for solving this problem and the heuristic was tested with a real world situation in waste collection company in Switzerland.

Roll-on-roll-off process:
Baldacci et al. (2006) has conducted a study in which they modelled the Multiple inventory location Roll-on–Roll-off Vehicle Routing Problem (M-RRVRP) as a Time-constrained Vehicle Routing Problem on a Multi-Graph (TVPR-MG) and has developed an exact solution approach for the problem based on bounding procedure. Developed model has been tested with three sets of benchmarked instances taken from literature on M-RRVRP, Roll-on–Roll-off Vehicle Routing Problem (RRVRP) and CVRP and the computational results proved the efficiency of the proposed procedure in comparison to the results in earlier instances. This study is considered as one of the first instances where multi-graphs have been used in solving VRPs.

Wy et al. (2013) analyzes a problem of Roll-on–Roll-off Vehicle Routing Problem with Time Windows (RRVRPTW). The scenario is generated with consideration to seven different service types that is devised from a real world situation associated with a waste collection company in US. Researchers have proposed Large Neighborhood Search (LNS) based iterative heuristic for solving the problem. The solution approach has been tested with two sets of benchmarked instances derived from organizational data and developed by the researchers. Experimental results showed better solutions compared to the current practices in the organization and hence will contribute to the reduction in operational cost which is achieved via the reduction in number of vehicles required and the reduction in time needed for traversing the routes.

3.3. End-of-Life Goods Collection

With the increased environmental sustainability considerations that sprang across the globe many responsibilities and legislations has been implemented in order to guide the actions of industries. One such concept that guides the proper management of supply chains is the Extended Producer Responsibility (EPR) that requires the manufacturers to implement a proper take back mechanism for End-of-Life (EOL) goods and to ensure the environmental friendliness in the recycling process of EOL goods. (Kim, et al., 2009) Also this process is guided by various legislations implemented by the world organizations or by country's government that has the power in fining the organizations upon deviating from the said standards. (Schultmann , et al., 2006; Kim, et al., 2009; Pazhani , et al., 2013) Hence these had led to the requirement of modeling cost effective reverse flows for EOL goods that lead to many researches in the area of optimizing the vehicle routing plan in reverse flows.

A research was carried out based on a real life situation associated with End-of Life Vehicles (ELVs) in a CLSC in Germany. Researchers have developed a tailor made VRP with the objective of minimizing the total distance traversed in all tours to suit the specialties associated with the situation. Problem has been solved using TS heuristics and the model developed in this situation is adjustable to serve reverse logistic processes associated with other EOL goods by changing the constraints to match the relevant industries and situations. Researchers also stress on the requirement of integrating the approaches developed in this manner into software systems associated in the supply chain processes to ensure better coordination among different stakeholders. (Schultmann , et al., 2006)

Another study in the field of ELV has been carried out by Krikke et al. (2008) as a case study for the said industry in Nederland to optimize the collection process of the dismantled ELVs. In order to provide an optimal solution, researchers have schemed co-management of distribution and inventory handling in the situation along with the applications of information technology for monitoring of the inventory level. Hence the VRP was developed as an Inventory Routing Problem (IRP) to serve two types of orders: MUST and CAN in which the distribution network is triggered with online monitoring of the inventory levels.

Kim et al. (2009) have conducted a research based on a real world case study considering the reverse logistic flows of EOL consumer electronic goods in South Korea. The EOL goods collection network consists of four regional Recycling Centers (RCs) with fixed yet adequate number of identical trucks with defined mileage per day. The problem was formulated as a Symmetric Capacitated Vehicle Routing Problem (SCVRP) for a situation associated with a single depot, fixed vehicle fleet and predefined maximum routing distance for each of the four regional RC. The problem was solved heuristically using TABUROUTE algorithm which is a variant of TS consisting of three procedures namely generalized insertion (GENI), the unstringing and stringing (US) and a SEARCH procedure. Experimental results showed a huge reduction in the cost factor associated with the optimization of the VRP thus proving the inefficiencies in the current practices and also this solution has resulted in a considerable reduction in the distance hence resulting in a drop of CO_2 emissions. An advancement of this research has been carried out by Kim et al. (2011) by modelling the problem as a Multi-Depot Vehicle Routing Problem (MDVRP) and the solution process was carried out following the two step methodology of Giosa et al. (2002). First step handles the assigning of Collection Centers (CCs) dispersed around the country to a regional RC and the process was carried out by five assignment algorithms: Parallel Assignment (PA), Simplified Assignment (SA), Cyclic Assignment (CA), Coefficient Propagation (CP) and Three-Criteria Clustering (TC). The second step involves solving the VRP with the TABUROUTE algorithm for each of the results obtained from the five assignments of CCs to RC. The optimal solution obtained with this approach showcased a huge reduction in the total cost and the Green House Gas (GHG) emissions. Depending on the observations of the problem researchers have also suggested some policy requirements relevant to the problem area.

At present the world population has been more biased towards e-commerce solutions in order to satisfy their product requirements. A special trend seen in the industry is the increased percentage of returned products compared to traditional businesses and also in most of the situations these returned products lacks any quality defects thus enabling the retailers to reenter the products into the forward supply chain by following a simple repackaging process. This scenario describes a manufacturing plant, Merchandising Centers (MCs) for distribution of products and for storing and repacking of returned products and Demand Points (DPs) that acts as retailer centers for distributing the products to consumers. The problem was formulated as a Location-Inventory-Routing Problem

(LIRP) with the objective of minimizing the total cost of the system and the problem has been solved by using Hybrid Genetic Simulated Annealing Algorithm (HGSAA). Experiments have been carried out by analyzing the test cases found in literature though which the efficiency of usage of HGSAA has been proved over GA. Researchers have also put forward suggestions for future improvements in means of more efficient heuristics and assumptions considered in the model. (Li, et al., 2013)

Nowadays, Vendor Managed Inventory (VMI) systems are incorporated into many businesses and this requires the supplier to take on the responsibility of both forward and return product deliveries and managing of customer inventories. Hence the problem is modeled as a Closed-loop Inventory Routing Problem (CIRP) which is an extension of the IRP with the capability in tackling the collection of EOL products or Returnable Transport Items (RTI). Soysal (2016) has conducted a case study of this nature at a soft drink company in which the researcher has used a probabilistic MILP model for solving approach. The research has proved the applicability of CIRP for real life situations and the assistance that it can provide to decision makers in developing cost effective and environmental friendly closed-loop supply chains. As future developments, researcher has suggested the development of a MILP based rolling horizon heuristic for handling cases of larger capacity and as another extension of the research it is suggested to consider the uncertainty associated with supply chains.

Today, businesses are dealing with multiple objectives of conflicting nature and hence modeling supply chains to achieve optimality in these considerations is a challenge. Zhalechian et al. (2016) carried out a study to model a CLSC network with reverse flows of EOL goods by integrating the location selection, vehicle routing and inventory management features thus bridging an existed gap in the research field. Hence the proposed network model is generalization of Capacitated Facility Location Problem (CFLP), CVRP and MDVRP. The model was also developed with considerations to the environmental and social impacts. Problem has been solved using SGV algorithm which is a meta-heuristic algorithm based on Self-adaptive Genetic Algorithm (SGA) and VNS algorithm.

Soleimani et al. (2017) analyzed a situation of simultaneous delivery and pickup of remanufactured and returned goods through a common distribution channel. The situation was modeled as a multi-objective GVRP with pickup and delivery to achieve the objectives of minimizing the air pollution and the totals cost. The problem was first formulated as a non-linear model and then was converted into a linear model and solution was obtained via a commercial solver. The experimental results proved the efficiency of the model in reducing the costs and in minimizing the emissions. A case study was conducted based on a CLSC network of an Iranian paper to validate the proposed model.

3.4. Simultaneous Distribution and Collection

Over the years with the increased concerns in environmental sustainability, government legislations related to emission minimization and recycling of EOL goods and other damaged or waste materials in supply chains has tightened. Hence this has forced organizations to implement optimized CLSCs. One of the strategies followed in this model is the implementation of simultaneous distribution and collection networks in order to minimize the total costs in transportation and other environmental negativities. Vehicle touring optimization associated with this network is commonly named as Vehicle Routing Problem with Simultaneous Pickups and Deliveries (VRP-SPD) (Bianchessi & Righini, 2007; Çatay, 2010) or Vehicle Routing Problem with Simultaneous Distribution and Collection (VRPSDC) (Dell'Amico, et al., 2006) and the network consists of a single depot and a set of customers who are served by a homogenous fleet of vehicles for both collection and distribution of products. (Çatay, 2010) A comprehensive literature review was published by Berbeglia et al. (2007) on the afore mentioned VRP category with a classification of VRP problems associated in the area as given in *Figure 2*.

VRP-SPD is a NP-hard problem and hence many researchers have incorporated different heuristics over the years as a solution approach to generate more efficient and effective solutions. A brief literature review is presented below to generate an idea on the different heuristics that has been tried by researchers between the years 2006-2017.

A research was carried out by Dell'Amico et al. (2006) in order to develop an exact solution to VRP-SPD in means of a branch-and-price algorithm and this is recorded to be the first instance of using the said algorithm in this problem area. In this research the pricing problem has been addressed by two means i.e. exact dynamic programming and state space relaxation and new strategies are proposed to increase the efficiency of the dynamic programming algorithm used for pricing by means of bi-directional search and restricted number of steps. The proposed model was tested with five sets of benchmarked instances taken from the literature.

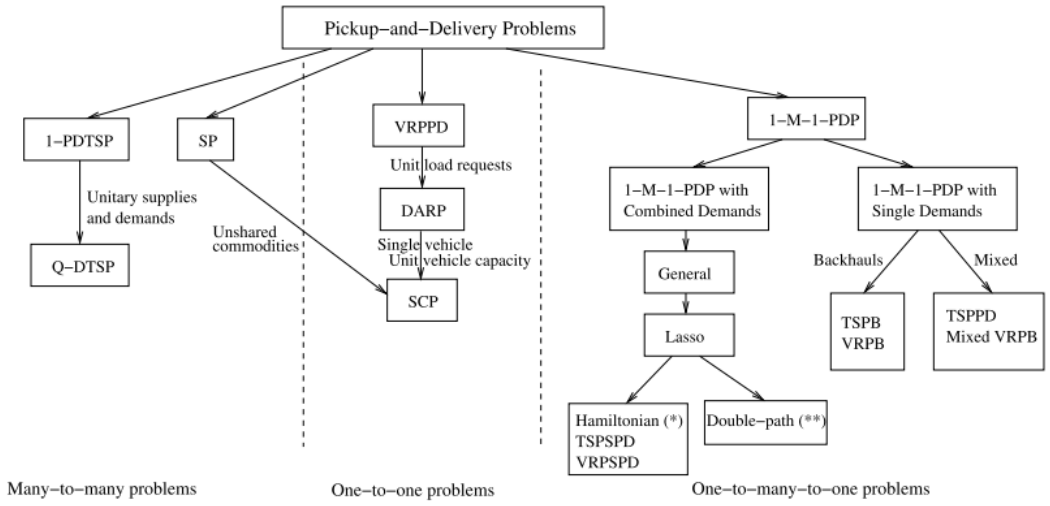

Figure 2: A classification scheme for Pickup-and-Delivery problems
Note. 1-PDTSP; One-Commodity Pickup and Delivery Traveling Salesman Problem, Q-DTSP; Q-Delivery Traveling Salesman Problem, SP; Swapping Problem, VRPPD; Vehicle Routing Problem with Pickups and Deliveries, DARP; Dial-a-Ride Problem, SCP; Stacker Crane Problem, 1-M1-PDP; one-to-Many-to-one Pickup and Delivery Problem, TSPSPD; Traveling Salesman Problem with Simultaneous Pickups and Deliveries, VRPSPD; Vehicle Routing Problem with Simultaneous Pickup and Delivery, TSPB; Traveling Salesman Problem with Backhauls, VRPB; Vehicle Routing Problem with Backhauls, TSPPD; Traveling Salesman Problem with Pickups and Deliveries

Bianchessi and Righini (2007) carried out a research to analyze the functioning of several heuristics for solving the VRP-SPD. In this study they considered the problem as to have invisible demands that are either simple or composite with mixed pickups and deliveries and the objective functions is considered to be the reduction of distance instead of minimizing the number of vehicles as in practical situations. Researchers have compared the applicability of constructive algorithms, local search algorithms and TS algorithms for solving the problem. Experimental results of the study show cased that the local search algorithms consisting of both complex and variable neighborhood are both efficient and effective in solving VRP-SPD. With this study researchers have stressed on the applicability of TS model for solving algorithms based on complex and variable neighborhoods. The heuristics applied in this study can also be applied to both symmetric and asymmetric instances of the VRP-SPD.

A research carried out by Zachariadis et al. (2009) proposed a hybrid meta-heuristic approach for solving the VRP-SPD in which the meta-heuristic incorporated for the model are TS and guided local search. Experiment of the model was done with three sets of benchmarked instances taken from the literature in which the applied hybrid meta-heuristic proved to be efficient in delivering high quality results. Subramanian and Ochi (2009) carried out a research to experiment the applicability of the ILS-VND meta-heuristic which incorporates Iterated Local Search (ILS) and Variable Neighborhood Descent (VND) into its procedure. In the experiment process an initial solution was generated by a Greedy algorithm which then was improved by ILS and the local search was carried out by means of VND. Proposed approach was tested with seventy-two benchmarked instances in the literature and the results obtained proved to be of good quality and were generated as a reasonable computation time.

Çatay (2010) carried out a research for solving VRP-SPD by employing an Ant Colony Optimization (ACO) and this is identified as the first instance of using ACO for this problem type. Researcher has modified the ACO by occupying a new saving based visibility function named SavAnt and a new pheromone updating procedure. The developed model was tested with three eminent test cases in literature i.e. (1) a real-world scenario given by Min (1989), (2) Dethloff (2001) and (3) Salhi and Nagy (1999). Experiment yields more effective results compared to the results available in the literature but the computational time required to complete the process was relatively high. In the same year, a parallel algorithm named P-ILS-RVND is presented by Subramanian et al. (2010) as a solution approach for VRP-SPD. This algorithm consist of a parallel algorithm embedded into a multi-start heuristics consisting of variable neighborhood descent procedure with a random neighborhood ordering (RVND) that is

integrated in an iterated local search (ILS) framework. Proposed algorithm was tested with benchmarked instances in literature and has proved itself to be efficient and effective comparative to results obtained in previous studies of similar capacity.

Tasan and Gen (2012) studied a solution approach for VRP-SPD by the implementation of a GA in which the experiment was carried out with twenty-four CVRP test case provided by Augerat et al. (1995) that are altered by the randomized addition of pickup demands to suit the situation of VRP-SPD. The situation was also computed with CPLEX 10.0 solver and the comparison of the experimental results proved the GA to device better solutions at a comparatively smaller time period than the CPLEX solver.

When modeling distribution networks consideration has to be taken on the available time periods of the customers in order to provide a better customer service. This situation has been modeled in VRP literature as vehicle routing problems associated with time windows i.e. VRPTW and the same considerations are taken in simultaneous pickup and delivery networks and hence the situation is modeled as Vehicle Routing Problem with Simultaneous Pickups and Deliveries and Time Windows (VRP-SPDTW). Mingyong and Erbao (2010) carried out a research in which the VRP-SPDTW was modeled as a general mixed integer programming model and the problem solving approach incorporated meta-heuristics i.e. Improved Differential Evolution (IDE) algorithm. Experimental evidence proved the efficiency of the proposed approach for solving VRP-SPDTW. Researchers have also stressed the research gap in literature for using Differential Evolution (DE) algorithms for solving VRPs. Another research was carried out by Wang and Chen (2012) for the same VRP in which the researchers modeled the situation as a mixed binary integer programming model and a co-evaluation GA was used for speeding up the computational process. Model was tested with revised test cases obtained taken from Solomon (1987) benchmarked instances of VRPTW. Developed model proved to be efficient and effective compared to the usage of CPLEX solver or a basic GA.

Organizations are highly focusing on the development of sustainable packaging materials that can be reused within the production processes in order to contribute to the minimization of the resource wastage and accumulation of product residues as waste materials. These reusable packaging materials are addressed as RTIs and require the optimization of distribution flows for the recovery of RTIs from customers at the least cost. Iassinovskaia et al. (2017) addressed a distribution flow of this nature with homogenous vehicles simultaneously handling pickup and delivery processes and the situation has been addressed as a Pickup and Delivery Inventory-Routing Problem within Time Windows (PDIRPTW) with objective of minimizing the cost. The problem was developed both as a MILP which is tested on CPLEX solver for small-scale test cases and also using a matheuristic: cluster first-route second.

4. Conclusion and Future Trends in VRPRL

Many researches have been carried out with the concern of ensuring environmental sustainability and it can be seen that many of the academic research has been conducted as case studies to solve real world commercial problems in organizations across the world. This shows a positive integration of engaging the academically derived solutions for commercial purposes.

Table 4.1: Revised article list

VRP Type		No. of Literature found (2000-2017)
Selective Pickups and Pricing		3
Waste Collection	Residential waste collection process	2
	Commercial waste collection process	8
	Roll-on-roll-off process	2
End-of-Life Goods Collection		8
Simultaneous Distribution and Collection		11

Articles revised under the four categories in reverse logistics are stated in *Table 4.1* above. Analysis showcased a deficiency in academic research considering vehicle routing optimization for distribution networks following selective pickups and pricing strategy. When considering the network optimizations in waste collection, it showcased a research gap in problems concerning residential waste collection and also in Roll-on-Roll-off waste collection. When analyzing the article in means of the solution approach followed only a very few researches have incorporated simulation based approach for generating the solution. Though a considerable amount of research has

been carried out in this study area, it still shows a redundancy in the studies that considers the real world practical constraints like time windows, periodic delivery, heterogeneous vehicle fleets and catering to stochastic demand requirements of customers.

In nowadays consumers are more driven towards e-businesses instead of brick-and-motor businesses in order to satisfy their products requirements and these businesses deal with a large amount of returned goods with zero quality defects in daily basis and hence the reverse flow optimization is crucial to these businesses to achieve cost benefits and to ensure the availability of products for customer requirements. To the best of the authors' knowledge reverse flow optimizations carried out related to this business area is very limited and hence needs future emphasis placed on this area.

Vehicle routing optimization can be linked with cutting edge technologies and strategies like GPS, Internet of Things (IOT) in order to get real-time location details, replenishment levels etc. thus allowing the modeling of distribution networks to be more optimized in means of both minimized costs and in eco-concerns. Another trend predicted in this study arena is the applicability of vehicle routing optimization in multi-echelon distribution systems. Up to now only few researches have been conducted to devise models for achieving the optimality in this field and with the significant role played by multi-echelon distribution networks in reverse logistic flows it can be predicted that the applicability of vehicle routing optimization to this field will result in increased environmental sustainability.

Over the years researchers around the globe have contributed to the VRPRL literature with models devised to suit complex constraints and to achieve multiple objectives of minimized costs and highlighted eco-concerns. However, research topic still consists of areas that require the bridging between academic models and real world complications. Hence, it is hoped that this review of literature will help in the identification of existing gaps in the study area for shaping the future researches.

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