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Solution approaches for combining first-mile pickup and last-mile delivery in an e-commerce logistic network: A systematic literature review

M. I. D. Ranathunga*
Department of Industrial Management
University of Kelaniya, Sri Lanka
isharadil26@gmail.com

A. N. Wijayanayake
Department of Industrial Management
University of Kelaniya, Sri Lanka
anni@kln.ac.lk

D. H. H. Niwunhella
Department of Industrial Management
University of Kelaniya, Sri Lanka
hirunin@kln.ac.lk

Abstract **- Logistics is one of the primary areas of operation within cutting-edge supply chain operations. In the e-commerce supply chain also logistics operations play a vital part. The logistics operations must be controlled effectively and efficiently since they deal with the high-cost besides environmental impacts. In e-commerce logistics operations, first-mile and last-mile delivery operations are considered as the operations with the highest costs incurred. So, e-commerce service providers are interested in optimizing their first-mile and last-mile delivery operations. Though it is known that the integration of first-mile pickup and last-mile deliveries will minimize the cost of transportation, there are more practical concerns to be taken into account when combining the first-mile pickup and last-mile delivery operations. Capacitated Vehicle Routing Problem (CVRP) is discussed in the literature as a solution approach for this kind of problems. The objective of this study is to provide a comprehensive overview of the current CVRP related literature, including models, algorithmic solution approaches, objectives, and industrial applications, with a focus of identifying interesting study paths for the future to improve distribution in e-commerce logistics networks by combining first-mile pickup and last-mile delivery operations. The findings of the study have demonstrated that constraints and features of Vehicle Routing Problem with Backhauls are very attractive with today's e-commerce operations, and the majority of the cited publications employed approximation methods rather than precise algorithms to solve these types of models.**

Keywords - capacitated vehicle routing problem, e-commerce, first-mile and last-mile delivery

I. INTRODUCTION

E-commerce or electronic commerce is the activity of purchasing and selling things over the Internet or through online services. Global e-commerce sales are expected to reach $6.5 trillion by the end of 2023 [1]. Due to the uninterrupted growth rate, e-commerce can be considered as one of the fastest-growing industries currently. The E-commerce supply chain incorporates supply chain operations including product warehousing, inventory management, delivery and order management. For e-commerce to be succeeded, it must be efficient at all levels of business. Therefore, optimizing each of these components is essential to ensure that everything is working smoothly and efficiently. Since e-commerce delivery operations incurred a substantial amount of the total cost of operations in an e-commerce supply chain, it is in their best interest to optimize these delivery operations costs which will ultimately benefit the e-commerce service providers and their customers.

In the logistics supply chain of an e-commerce enterprise, first-mile delivery is the initial stage of transportation. This is where the package leaves the merchant's door for the first time. Merchants could drop off their goods at the collection points or the drop-off stations, or request that the company's logistic service providers to fetch their products from where they are stored. The difference between pick-ups and drop-offs is that the pick-ups are carried out by the logistic service providers so that merchant can have their products picked up at their warehouses or storefronts. Merchants transporting their products to collection points or drop-off stations is known as drop-offs. Therefore, the process of collecting goods from merchants using logistic service providers is known as the first-mile pickup. The phrase "last-mile" was first used in the telecommunications sector to describe the final leg of a network [2]. The movement of packages from the transportation hub to the ultimate delivery destination is known as last-mile delivery in an e-commerce supply chain. This last-mile logistics in any of the supply chains is often considered as the most expensive, least efficient, and with the most pressing environmental concerns [3]. As a result of the rapid expansion of the e-commerce industry and the increase of online purchases, the volume of first-mile pickups and last-mile deliveries increased and puts barriers to the transportation networks with the increased volume of vehicles on roads.

The introduction of new business strategies has been a significant driver of total cost reduction in most recent business organizations. Whether driven by minimizing costs or by modern trade methodologies, reconsidering around distribution network optimization has presently gotten to be more pertinent than ever. One such way of optimizing distribution networks is shipment consolidation, which has been a popular research area over the past few years. Shipment Consolidation is a coordination methodology that combines two or more orders or shipments. It may empower significant economies of scale, incredibly decreasing the transportation cost and fewer environmental impacts. According to [4] combination of deliveries from a depot and pickups destined to the same depot on the same vehicle is considered a specific case of consolidation. This combined pickup and delivery can also lead to significant efficiency gains. According to the findings of [5] combining first-mile pickup and last-mile delivery operations can result in efficiency benefits of up to 30% for e-commerce delivery operations. In practice, combined deliveries and pickups on the same vehicle are appealing owing to the long-term environmental benefits of fewer vehicles on the road and lower emissions.

The Capacitated Vehicle Routing Problem (CVRP) is one of the most important combinatorial optimization problems which recently has been receiving much attention from researchers and scientists [6]. The objective of CVRP is to serve a set of delivery customers or a set of pickup customers through a set of vehicles stationed at a central depot without violating the capacity of vehicles. CVRP has several variants and extensions. Vehicle Routing Problem with Pickup and Deliveries (VRPPD) where the mixed loading of pickups and deliveries are considered, Vehicle Routing Problem with Simultaneous Pickup and Deliveries (VRPSPD) where vehicle's load in any given route is a mix of pickup and delivery loads, Vehicle Routing Problem Backhauls (VRPB) where customers with delivery demands should meet first before pickup demands are examples of such variations. Several solution approaches such as heuristic algorithms, metaheuristic algorithms, genetic algorithms, and exact methods have been developed to solve CVRP and its variants.

This study was carried out to examine the solution techniques utilized in the literature linked to CVRP. It aids future research in building a model to improve distribution in e-commerce logistics networks by combining first-mile pickup and last-mile deliveries together. The techniques utilized to achieve solutions in the literature, such as exact optimization, heuristic, metaheuristic, or genetic algorithms, have been explored in this study. This study's findings will aid future research in selecting an appropriate model and to improve distribution in an e-commerce logistic network by combining first-mile pickup and last-mile deliveries together.

The remaining sections of this are organized as follows; Section 2 describes the methodology employed in the study, which is followed by the findings of the literature review in section 3. Section 4 includes the overview with the analysis of the solution approaches and finally the conclusion is presented in section 5.

II. Methodology

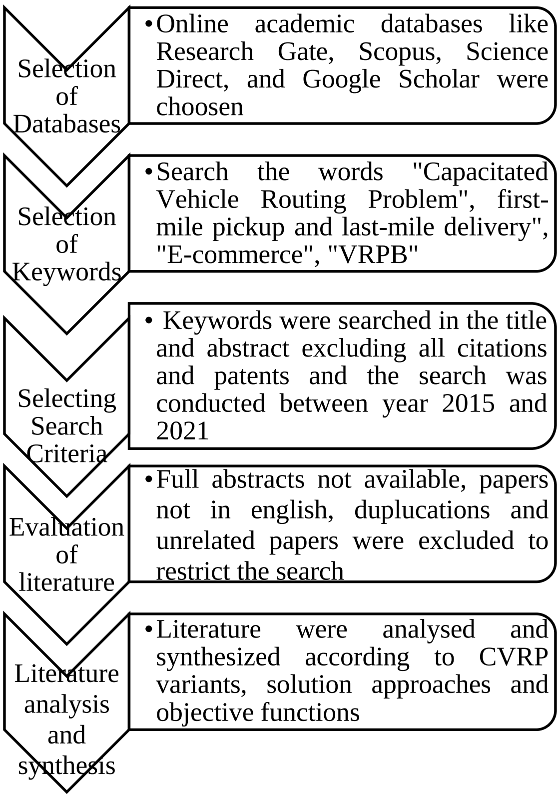

Fig. 1 Methodology of the literature review

The systematic review of the literature was based on the content analysis of the main domain areas including first-mile pickup and last-mile delivery operations, combined pickup and delivery operations, and CVRP. The publications were reviewed in the following steps for the literature search and analysis process: (a) choose the database source; (b) choose the search terms; and (c) choose the search criteria. (c) evaluate the appropriateness of the literature subset; e) review and synthesis of the literature. Thus, the literature was searched and gathered from using keywords from different academic databases like Research Gate, Scopus, Science Direct, and Google Scholar. 61 papers were selected through search keywords and they have been sorted by the published year. The articles published after 2015 were only considered. Then, using inclusion and exclusion criteria, 39 papers were examined and selected for analysis. The study design, keywords, and date serve as inclusion criteria while unrelated, duplicated, or unavailable full texts, as well as abstract-only articles and papers not written in English, considered as the exclusion criteria. Literature analysis was conducted based on the CVRP variants, solution approaches and objective functions used in the selected papers. The flow diagram of the methodology could be summarized as in the Fig. 1

III. Literature Review

A. E-commerce

The phrase electronic commerce, or e-commerce in its original form, was coined by IBM in 1997 which is a form of e-business activity centered on and around individual Internet transactions [7].

The number of digital purchasers grows every year as internet availability and usage grow at a rapid pace throughout the world. Consumers are increasingly purchasing items through the Internet is quite popular. They not just to buy little items on the internet, but also big items such as home appliances, construction materials, furniture, delicate goods, and so on [2]. Retail e-commerce sales globally reached 4.28 trillion dollars in 2020, with e-retail revenues expected to reach 5.4 trillion dollars in 2022 [8].

E-commerce has already had a significant growth trend that has resulted in a slew of issues, including excessive and costly business procedures, low efficiency, together with expensive e-commerce freight costs [9]. Therefore, this growth of online shopping in recent years has resulted in significant supply chain restructuring and a multiplicity of delivery strategies used by e-retailers and package shipping companies [10]. Also, academic research in the e-commerce area has gained pace as a result of the growing adoption of online shopping.

B. First-mile pickup and last-mile delivery

A study was conducted by [11] to identify the challenges and concerns with first-mile and last-mile deliveries. There the authors referred the terms "first and last mile delivery" to freight transportation logistics for the first and final miles to the consumer, respectively. Also, they have mentioned that the first and last miles of freight transportation are the most expensive and it is difficult to assemble and put goods together in the last step of transportation, resulting in disproportionately high expenses in that sector. According to the authors last-mile delivery issues are typically caused because deliveries are made up of individual orders and a considerable amount of destination dispersion, since each item must be delivered to a separate location and the first-mile freight transportation also has similar issues.

The study conducted by [12] with the objective of identifying the current difficulties in urban logistics that have arisen with the increased freight volumes as a result of the growth of e-commerce. It suggested that integrated methods to network and process optimization may increase service quality while improving network quality as well as profit to all stakeholders.

C. CVRP for Combined Pickup and Delivery

CVRPs are a significant class of pickup and delivery problems, and a multitude of CVRP variations have attracted special attention in recent decades. This study investigated CVRP with pickup and delivery problems in-depth and provided a categorization of varieties and solution approaches for these problems. In transportation industry, CVRP is an important concern as it is difficult to solve using some optimization methods. Unfortunately, finding a globally optimal solution is difficult. As a result, many researchers combine two or more optimization techniques to solve CVRP [13].

1) VRPPD – Vehicle Routing Problem with Pickup and Delivery

The VRPPD pertains to the scenario in which the pickup and delivery destinations are unpaired. To put it another way, a homogenous good is taken into account, which implies that items loaded at any pickup location may be used to meet demand at any delivery location [5].

The study was conducted by [5] to describe the VRPPD mathematical formulations and heuristic solution approaches, which serve as the foundation for a series of numerical experiments. The authors look at the route efficiency trade-offs that arise when first-mile pickup and last-mile delivery activities are combined in an urban distribution system. They suggest adjustment parameters that account for the impact of integrated pickup and delivery operations, based on existing research on continuum approximation of optimal route lengths. They use multiple linear regression to estimate a generalized correction factor based on the outcomes of their numerical tests to increase the quality of their closed-form prediction of the route efficiency effect from first-mile and last-mile integration. In solving this problem authors have considered a heterogeneous fleet of vehicles and homogeneous products. Together with the pickup requests and delivery requests they also considered the short-circuiting requests where deliveries fulfilled along a single route without shipping the respect pickup request to the depot. The authors used the local search heuristic augmented with a large neighborhood search method as the solution approach to solve the mathematical model. The heuristic algorithm was developed in python using the OR-Tools routing library. Finally, they applied the theory developed in the study to actual data from the first-mile pickup and last-mile delivery operations of a major e-commerce marketplace and logistics service provider in India, Flipkart, to demonstrate the real-world relevance of the findings for urban first- and last-mile logistics operational planning and strategic system design. According to the study's findings, combining first-mile pickup and last-mile delivery operations can result in efficiency benefits of up to 30% and they discovered that firm could decrease its urban traffic and pollution effect by up to 16% while improving asset utilization and minimizing its vehicle fleet's operating costs. The study further suggests that the impact of line-haul components, time window constraints, and other variants of CVRP can be incorporated to solve the model.

The study conducted by [14] offers a first-mile and last-mile model with an integrated supply chain. This study proposes a VRPPD mathematical model to formulate the problem of real-time smart scheduling of first- and last-mile operations. Constraints like time windows and availability were considered when optimizing the cost of integrating first-mile and last-mile operations. Here the authors considered the first-mile and last-mile operations of a general supply chain without focusing on any specific industry. In solving this model authors considered a homogeneous fleet of vehicles and a single product type. The model created in this study also considered scheduled pickup requests, scheduled delivery requests, short-circuiting requests together with the open tasks which were not scheduled. A newly discovered meta-heuristic algorithm was used to solve the smart scheduling problem in this study. Black Hole Optimization (BHO) and Big Bang Big Crunch (BBBC) algorithms are combined in this meta-heuristic. The sensitivity study was conducted and it revealed that combining both swarming heuristics was effective. This study model can be further extended in the future by considering other constraints like the availability of human resources or the stochasticity of the parameters, heterogeneous fleet of vehicles, and mixed products. Also, the authors suggest that other heuristic approaches may be more appropriate for solving this problem.

The study conducted by [15] presented an optimization algorithm for solving the VRPPD and as the solution approach, authors have used Variable Neighborhood Search and Tabu Search meta-heuristics. Time window constraints, capacity constraints, compatibility between orders and vehicles, the maximum number of orders per vehicle were considered as constraints for the study model. Also, they have considered a heterogeneous fleet of vehicles to transport a single product type and only the short-circuiting requests and delivery requests were taken into consideration in solving the problem. The objective of this study was to the cost and the distance traveled and by reducing vehicle utilization while providing an optimal service quality for the customers. The solution approach has been verified using a real-world dataset from a transport company in Spain and concludes that the algorithm is capable of effectively solving real-world cases with hundreds of orders, and also computes the answers in an acceptable amount of time. Finally, the authors suggest that this idea might be used in future research to tackle more generic types of vehicle routing issues with more real-world objectives and limitations. This algorithm's ability to discover effective solutions to challenging combinatorial optimization problems should make it beneficial for a variety of other freight and distribution concerns.

2) VRPSPD – Vehicle Routing Problem with Simultaneous Pickup and Delivery

The multiple-vehicle Hamiltonian one-to-many-to-one Pickup and Delivery Problem (PDP) with coupled demands is another name for this VRPSPD. In this problem, some customers have delivery demands, while others have pickup demands, and at least, customer has both pickup and delivery demands. Many variants of the VRPSPD have been studied in the past by adding various constraints to the problem. VRPSPD with time windows, heterogeneous VRPSPD, the multi-depot VRPSPD, the green VRPSPD, stochastic VRPSPD, and miscellaneous VRPSPDs were the variants of VRPSPD's studied in the past [16]. Instead of considering the first-mile pickup, this type of problem considers the reverse flow packages or else customer return packages as pickups. So, VRPSPD considers integrating last-mile delivery with the pickup of reverse flow packages. In VRPSPD any place of the route, the load of the vehicle is a combination of delivery and pickup packages.

The vehicle routing problem with simultaneous pick-up and delivery, as well as time windows, is examined by [17] in their study. A heuristic solution approach which is Particle Swarm Optimization (PSO) algorithm was used in this study to solve the VRPSPD by considering time windows as a constraint. The results of the study demonstrate that the PSO method can discover solutions that are competitive with those found by other algorithms previously published in the literature. In addition, the PSO method solves the issue in a reasonable amount of time. This study further can be improved by incorporating environmental objectives as well.

The study conducted by [18] proposed a hybrid meta-heuristic approach to solve the VRPSPD. The hybrid meta-heuristic solution approach they used to solve the problem was an ant colony system (ACS) based variable neighborhood search (VNS) algorithm. VNS is a strong optimization technique that allows for in-depth local search. But it does not have a memory structure. This flaw was mitigated by leveraging ACS's long-term memory structure, which improved the algorithm's overall speed. In this problem, the authors have considered a heterogeneous fleet of vehicles. For comparison, the ACS empowered VNS algorithm used in this study was evaluated on well-known benchmark test problems from the open literature of VRPSPD and found out that the developed method is both resilient and efficient. The authors also noted that with little changes, this work may be used to address a variety of additional VRP variations.

A study was conducted in 2016 to address the problem of multi-depot heterogenous fleet VRPSPD. A novel mathematical model is constructed, and two meta-heuristic approaches based on Imperialist Competitive Algorithm (ICA) and Genetic Algorithm (GA) were used to solve the problem in this study. The objective of this study was to reduce the overall cost, which was divided into three components. The first component was the cost of vehicle routing, the second part was the penalty cost of drivers who exceed travel distance restrictions, and the third element was the fixed expenses of hiring drivers. For 25 customer pickups and demands, random test issue instances were produced and experimental settings were employed to obtain the results for the proposed model. The results obtained show better results for the ICA algorithm. Finally, the authors have mentioned that in other types of vehicle routing problems, such as problems with periodic and time window constraints. It is worthwhile to consider significant features of drivers such as experience, age, working shifts, and income as well [19].

To tackle the problem of Green VRPSPD a study was carried out in 2020 and the authors mathematically defined it and devised a hyper-heuristic (HH-ILS) method based on iterative local search and variable neighborhood descent heuristics. The objective of the problem is to design vehicle routes that minimize the cost of fuel consumption due to vehicle load and travel distance. The influence of the GVRPSPD and the HH-ILS was studied using extensive computer studies with using [20] data set which consisted of 28 problems involving between 50-199 customers and [21] data set which included 40 instances each involving 50 customers. The authors also reported that they did a sensitivity study to explore the performance of neighborhood structures, hyper-heuristics, and local search, as well as a comparative analysis to investigate the performance of HH-ILS [22].

3) VRPB – Vehicle Routing Problem with Backhauls

The distinction of the VRPB which is a variant of CVRP is that it has two types of customers: those who receive products from the depot, known as linehaul, and those who send goods back to the depot, known as backhauls [23]. In VRPB both linehaul and backhaul clients must be visited on the same route, and each route must have at least one linehaul customer. All deliveries must be loaded at the depot, and all pickups must be brought there as well [7]. This variant is CVRP is a cost-effective method for lowering routing costs while simultaneously lowering transportation's environmental and social consequences through combining inbound and outbound routes simultaneously [24].

VRPB is significant among other variants of CVRP because of the precedence constraint which implies that linehaul customers are visited before backhaul customers. There are several VRPB variants as a result of additional constraints being added to the standard VRPB. Multi depot VRPB, VRPB with the heterogeneous fleet, VRPB with Time Windows, Green VRPB, and Mixed VRPB are some examples of those variants.

A deterministic iterated local search method was described by [23]. It was a meta-heuristic approach to solve the VRPB model and the authors mentioned that the technique was efficient on the traditional benchmark instances which were tested on two sets of benchmark instances from past literature. The study considered a homogeneous fleet of vehicles and a single product type where all the pickups were collected and deliveries were dispatched through a single depot. The objective of this study was to minimize the cost. The authors also mentioned that this approach is straightforward, deterministic, parameter-free, and quick. As a result, it may be a viable alternative to more complicated and advanced algorithms.

[25] suggested a meta-heuristic solution approach named as Pareto ant colony method for solving a multi-objective variation of the multi-depot VRPB to minimize distance, trip time, and energy consumption. Each arc was given a random fixed speed between 30 and 90 km/h, and the energy consumption was calculated using the function proposed by [26]. The model was tested on new 33 instances with 50-200 customers around 2-3 depots based on those [20]. This study considered a general model for a homogeneous fleet of vehicles to pick up and deliver the same type of product. The authors recommend that the suggested method be applied to various routing problems such as the Multi-Depot Vehicle Routing Problem, the Periodic Location Routing Problem, and the Multi-Depot Vehicle Routing Problem with Heterogeneous Fleet.

[27] proposed a multi-objective non-linear programming paradigm. In this study authors considered a heterogeneous fleet of vehicles to deliver and pickup single product type through multiple depots using an exact solution approach.

The model is linearized, verified, then solved using a suitable fuzzy method. Finally, the suggested model's dependability and viability are tested using an actual case study. The authors looked at a case of returned-remanufactured items in a VRPB environment with pickup and delivery while considering green requirements in this study. They examined both product delivery and pickup at the same time across shared channels in this bi-objective issue. The model can be expanded by including a third goal, which is to maximize the profit from used goods. To make the model more consistent with real distribution systems, it is also recommended to incorporate the quantities of return products as a stochastic parameter. Furthermore, the model may be enhanced by including time frames.

[28] investigated the VRPB for a case study in terms of time windows, order-dependent heterogeneous fleet, order loading and delivery limits, a maximum number of stores per route, warehouse loading capacity, and maximum tour duration. The issue arose at Kroger, one of Ohio's major grocery chains, in the Cincinnati-Columbus area. The number of shops varies between 120 and 150. To find solutions, the authors created a greedy randomized adaptive search method (GRASP) that was supplemented with tabu search. Experiments on Kroger cases revealed cost savings of $4887 per day on average, or 5.58 percent per day when compared to the existing method. The objective function of the study was to keep the cost of traversing the arcs between each pair of successive nodes in a route as low as possible which indirectly decreases the total time, drivers must wait at a node before service can begin by penalizing the idle time before order fulfillment.

[29] proposed the multi-trip VRPB, in which a vehicle may make several journeys in a certain amount of time while also collecting items on each trip. The issue was defined as a mixed-integer linear program, and the authors devised a two-level variable neighborhood search technique to solve it. A multi-layer local search method was used to increase and diversify the heuristic, which was incorporated within a sequential variable neighborhood search. Based on two previous investigations, a new benchmark set was created. When compared to CPLEX's solutions for small and medium-sized instances with up to 50 clients, the algorithm produced good results. On two classic VRPB examples data sets, the algorithm also produced competitive results. The heuristic model used in this study considered a homogeneous fleet of vehicles, a single product type, and a single depot as constraints to achieve the objective to minimize the total travel distance.

The VRPB is NP-hard in the strong sense and is described in the literature as an extension of the capacitated vehicle routing problem. Because the VRPB is NP-hard and has a precedence constraint, there are a lot of heuristic approaches that may be used to solve it. As a result, the majority of available literature on the VRPB is focused on high-quality heuristics and meta-heuristics approaches [30].

IV. LITERATURE OVERVIEW

This section provides an overview of the CVRP literature, including a broad descriptive analysis of the published articles between 2016 and 2021, as well as the VRPB categorization. The section concludes with a summary of the literature and a list of research gaps to be filled.

TABLE I. ANALYSIS OF CVRP VARIANTS

Reference	CVRP Variant	Solution Approach	Objective Function	Algorithm
[31]	VRPB	MH	Economical	HS
[23]		MH	Economical	ILS
[25]		MH	Eco. and Env.	ACO
[32]		MH	Economical	LNS
[33]		Exact	Economical	Exact
[34]		MH	Economical	ACO
[28]		MH	Economical	GRASP & TS
[4]		Exact	Environmental	Exact
[29]		H	Economical	VNS & LS
[35]		H	Economical	TS
[27]		Exact	Eco. and Env.	Exact
[36]		H	Economical	TS
[37]		H	Economical	LS
[30]		Exact	Economical	Exact
[38]		MH	Economical	FOA
[39]		H	Economical	RO
[40]		MH	Economical	BNGS
[41]	VRPSPD	H	Economical	GA & LS
[18]		MH	Economical	ACO & VNS
[42]		MH	Economical	ACO
[19]		MH	Economical	ICA & GA
[43]		H	Eco. and Env.	GA & VNS
[44]		H	Economical	APGA
[14]		MH	Economical	BHO
[17]		H	Economical	PSO
[46]		MH	Economical	SA
[47]		H	Eco. and Env.	AGHC
[22]		MH	Eco. and Env.	ILS
[48]		H	Economical	GA
[49]		H	Economical	GA
[50]		MH	Economical	MS, LS & ENS
[51]		MH	Economical	PSO
[5]	VRPPD	H	Eco. and Env.	CA
[52]		H	Economical	LNS
[53]		MH	Environmental	MA
[54]		H	Economical	IRA
[55]		H	Economical	LS & LNS
[56]		MH	Economical	TS, GA & SS
[57]		MH	Economical	ACO

Table I is a summary of the CVRP variants which were used in the past literature including the solution approaches, objective functions, and the type of algorithms used to solve the problems. Literature was analyzed within the latest 6-year period from 2016 to 2021 and the selected articles were summarized.

- Abbreviations for solution approaches: Meta Heuristic (MH), Heuristic (H).
- Abbreviations for objective function: Economical and Environmental (Eco. and Env.)
- Abbreviations for algorithms: Harmony Search (HS), Iterative Local Search (ILS), Ant Colony Optimization (ACO), Local Neighborhood Search (LNS), Greedy Randomized Adaptive Search Procedure (GRASP), Tabu Search (TS), Variable Neighborhood Search (VNS), Local Search (LS), Fix-and-Optimize Approach (FOA), Re-Optimization (RO), Block Nonlinear Gauss–Seidel Solution (BNGS), Genetic Algorithm (GA), Imperialist Competitive Algorithm (ICA), Adaptive Parallel Genetic Algorithm (APGA), Black Hole Optimization (BHO), Particle Swarm Optimization Algorithm (PSO), Simulated Annealing (SA), Adaptive Genetic Hill Climbing (AGHC), Memetic Search (MS), Extended Neighborhood Search (ENS), Continuum Approximation (CA), Incremental Rerouting Algorithm (IRA), Scatter Search (SS)

After analyzing the literature, 3 variants of CVRP were identified to solve pickup and delivery problems.

- VRPPD: This variant most of the time considered as a homogeneous product and a vehicle in a route mixed with pickup and delivery packages from customers. In most of the VRPPD literature authors considered about a pick-up and delivery products on a same route without taking picked up products in to the depots for sorting. This process is referred to as short circuiting as well.
- VRPSPD: This variant is considered the reverse flow of products or the return of products as picked up packages instead of considering collecting packages from merchants.
- VRPB: This variant considered the products collected from merchants as pickups and the packages to be delivered to customers as deliveries. Visiting both pickup and delivery clients on same routes, routes must have at least one delivery package, pickups must be done after deliveries and all the pickups must be brought back to the depot were some of the common constraints considered when solving VRPB.

When considering about the characteristics and the constraints considered for solving the 3 variants of CVRP, the constraints used in solving VRPB is much appealing to the current first-mile and last-mile operations of most of the e-commerce service providers. Also [4] in their research study has mentioned that VRPB may be appealing, not only because shorter routes save money, but also that the distance savings will result in lower environmental effect.

As in the Fig. 2., 3 types of solution approaches were used in the past literature to solve the variants of CVRP related to pickup and delivery problems. Those solution approaches were Exact, Heuristic and Meta Heuristic approaches. Because of the NP-hardness of CVRPs, most of the researches used heuristic and meta heuristic approaches to solve these types of problems. When the number of clients to be served is high or increasing, the solution space expands dramatically. In these instances, using approximation methods to solve the VRPB might be a viable alternative. Also, these approximation methods will simplify the complexity of search process through optimality conditions [25].

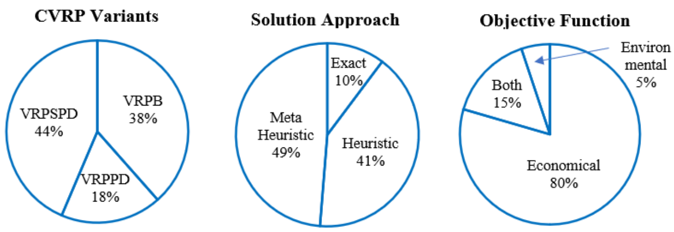

Fig. 2.CVRP Variants, solution approaches and objectives

Finally, the variants of CVRP were classified according to the type of objective function as per the dimensions it covers as economic, environmental and both. Out of all the literature reviewed, most of the literature were with pure economic objectives. 5% of the literature focused on environmental objectives and 15% were with both economic and environmental objectives. To tackle the problems related to managing the cost of first-mile and last-mile operations and to address the impact on the environment due to those operations, solving the problem with both economic and environmental objectives should be considered.

Table II, below is a summary about a detailed classification of VRPB work reviewed within the time 2016-2021. First column categorizes the past VRPB work according to whether they used mathematical models to solve the VRPB or not. If yes it is indicated with "√" and else with "×". Second column indicates the solution approach of the VRPB. The third column indicates the type of the vehicle fleet considered as a constraint, whether it is heterogenous or homogeneous and the fifth column categorizes according to no of depots considered while the sixth column categorizes according to the product type.

- Abbreviations for solution approaches: Meta Heuristic (MH), Heuristic (H).
- Abbreviations for vehicle fleet: Heterogeneous (He), Homogeneous (Ho)
- Abbreviations for depot: Single Depot (SD), Multi Depot (MD)
- Abbreviations for product: Single Product (SP), Multi Product (MP)

According to the above classification on VRPB, there is a lack of past literature which considered solving the VRPB with heterogenous fleet of vehicles, multiple product types, single depot and with both economic and environmental objectives using a heuristic approach. Also, most of the references in Table II were not considered any specific industry except [32] which is a case of construction equipment provider, [28] which was about retail industry, [4] and [40] which was about 3PL industry and [38] about forest industry related case study for solving VRPB.

TABLE II. ANALYSIS OF VRPB VARIANTS

References	Math. Model	Solution Approach	Objective Function	Vehicle Fleet	Depot	Product
[31]	√	MH	Economical	He	SD	SP
[23]	×	MH	Economical	Ho	SD	SP
[25]	×	MH	Eco. & Env.	Ho	MD	SP
[32]	√	MH	Economical	Ho	SD	MP
[33]	√	E	Economical	He	SD	SP
[34]	√	MH	Economical	He	SD	SP
[28]	√	MH	Economical	He	SD	SP
[4]	×	E	Eco. & Env.	Ho	SD	SP
[29]	√	H	Economical	Ho	SD	SP
[35]	×	H	Economical	Ho	MD	MP
[27]	√	E	Eco. & Env.	He	MD	SP
[36]	√	H	Economical	Ho	SD	SP
[37]	×	H	Economical	He	SD	SP
[30]	√	E	Economical	Ho	SD	SP
[38]	√	MH	Economical	He	SD	SP
[39]	√	H	Economical	Ho	SD	SP
[40]	√	MH	Economical	He	SD	SP

V. CONCLUSIONS

Combining first-mile pickup and last-mile delivery is an effective and efficient method for e-commerce service providers to minimize the cost of operations and as well to the impact on the environment due to increase of first-mile and last-mile delivery complexities with the rapid growth of e-commerce industry. In the past, pick-up and delivery issues have been explored in the literature, with different approaches taken into account. Three CVRP variants which employed to solve pickup and delivery problems were identified through the review of this literature. These 3 variants include VRPPD, VRPSPD and VRPB. In most situations, VRPPD is considered for homogenous products, and it considers delivering packages to consumers within the same region as merchants, so that picked-up packages were not transferred to depots. Because most e-commerce service providers offer various product kinds for their clients, large e-commerce service providers should consider multiple product types when optimizing their logistic operations. Also, the package sortation process is an important operation when dealing with multiple product types. So future research perspectives can be identified to consider multiple product types and package sortation process for solving VRPPD in e-commerce industry. VRPSPD is another variant of CVRP where it considered returned packages as pickup requests. Therefore, VRPSPD were formulated for solving problems related the reverse flow of packages and last-mile deliveries. Collection of packages from merchants is not taken as pickups in VRPSPD variant. In VRPB variant, it considered pickup of packages from merchants and bringing them to the depots on the way back after completing last-mile delivery operations. Also, there were few studies which incorporated multiple product types or heterogeneous fleet of vehicles as a constraint when solving VRPB. So, out of these 3 variants constraints and features of VRPB are much appealing for optimizing the current e-commerce related pickup and delivery operations. Furthermore, this research reveals that there is still opportunity for some gaps to be filled.

- No study has yet considered solving the VRPB focusing on e-commerce industry or with the combination of constraints including heterogenous fleet of vehicles and multiple product types with different capacities in one model.
- When it comes to tackling VRPB, no research considered including failed deliveries and returned items in their models. It would be more realistic to explore incorporating these factors into VRPB models that are already in use.
- Despite the fact that the VRPB is typically treated as a cost reduction problem, some research has already extended the problem to incorporate environmental objectives. It is also better if it can incorporate social objectives as well because the sustainability of logistic operations depends on all economic, environmental and social aspects.

The analysis also revealed that when solving models associated to pickup and delivery problems, the majority of the publications employed approximation methods such as meta-heuristics and heuristics. As a result, the paper concludes that there is a gap to address the issue of developing a model to optimize the distribution of an e-commerce service provider by combining first-mile pickup and last-mile delivery while considering a heterogeneous fleet of vehicles and multiple product types as constraints using an approximation algorithm to solve the VRPB.

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