The Pickup and Delivery Problem (PDP) is a problem that the objective is to construct the optimal routes that satisfied all transport requests and constraints. It is classified as a NP-hard problem; since the problem can be viewed as a Vehicle Routing Problem (VRP) with precedence constraints (e.g. node i have to be visited before node j) which is NP-hard, also VRP is the general case of the well-known Traveling Salesman Problem (TSP), which is also NP-hard. Therefore, many researchers have used heuristics and meta-heuristics to solve this kind of problems rather than exact methods. There are many variations of the problem that we will review below.

(note: all articles have the vehicle ‘capacity’ in their constraints)

First, the single vehicle PDP. Xin-Lan Liao, et al. used the Genetic Algorithm (GA) to solve the Minimum Latency PDP (MLPDP)[1] (Liao, 2014). The objective was to minimize the sum of transportation time between demanders and the corresponding suppliers. The vehicle is capacitated and has LIFO constraints. The study focuses on many-to-many PDP, where a delivery customer can have any source of supply. They create their own techniques called reverse weighting to evaluate fitness, and Edge Aggregation Crossover (EAC). The results show that their EAC give better solutions than the other kinds of crossovers. GA is also used for Dynamic PDP problems (DPDP) (requests are dynamic, optimal solutions can change by those requests). Yamming and his team used GA hybrid with Local Sensitive Hashing (LSH) based local search called the multi-objective memetic algorithm based on request prediction to solve DPDP[2] (Yamming Yan, 2017). They also used Google Maps API and test the efficacy of their algorithm on the real map at Shenzen. Ant Colony Optimization (ACO) are also used. In the paper An Ant System for the Selective Pickup and Delivery Problem[3] (Yu-Wei Chang, 2016) (SPDP, not all pickup nodes have to be visited), the researchers found that ACO outperformed GA in terms of the solution quality (the route length).

Next, we will review more about the multi-vehicle PDP with one central depot. Margaretha Gansterer et al. used two variations of general variable neighborhood search (GVNS) namely sequantial GVNS (GVNSseq) and self-adaptive GVNS (GVNSsa) and compare them to the algorithm based on Guided Local Search (GLS) to solve multi-vehicle profitable PDP. The objective of the problem was to maximize the profit (revenue - travel cost). The results show that both variations of GVNS outperform GLS regarding to solutions quality but used more computational time[4] (Margaretha Gansterer, 2016). Another interesting article is “Nature-inspired Heuristics for the Multiple-Vehicle Selective Pickup and Delivery Problem under Maximum Profit and Incentive Fairness Criteria” (Javier Del Ser e. a.)[5]. The objective of the problem was to maximize profits while giving a fair share of net benefit among the company staffs based on their driving distance. They compare 4 meta-heuristics which are GA, Harmony Search, Firefly Algorithm, and ACO. The results showed that ACO solutions outperform all other algorithms in both test instances and practical test instances (Spain).

For the PDP with time windows (PDPTW) and handling operations (one depot), branch and price and cut technique was also used[6] [Marjolein Veenstra, 2016], but computational time was rather expensive (96 requests in up to 2 hours).

Next, for the Multi-Depot and Multi-Vehicle PDP (m-MDPDPTW), E. Ben Alaia and Imen Harbaoui Dridi et al. use GA to solve this problem[7] (E. Ben Alaia, Optimization of the Multi-Depot & Multi-Vehicle Pickup and Delivery Problem with Time Windows using Genetic Algorithm, 2013). They later extend the problem to multi-objective (minimize travel distance, tardiness time, and vehicles number) PDPTW[8] (E. Ben Alaia, Genetic Algorithm with Pareto Front selection for Multi-Criteria Optimization of Multi-Depots and Multi-vehicle Pickup and Delivery Problems with Time Windows, 2014) and solve it with GA hybrid with Pareto Dominance Optimization. Later, the bi-objective (minimize travel distance and tardiness time) dynamic PDPTW[9] (Imen Harbaoui Dridi, 2015) solved with GA hybrid with aggregation method.

For the VRP problems, there is an article[10] that show the superiority of ACO over GA in terms of solution qualities.

Swarm Optimization are also used to solve PDP and VRP, there is a literature review for this topic.[11]

# **Bibliography**

E. Ben Alaia, I. H. (2013). Optimization of the Multi-Depot & Multi-Vehicle Pickup and Delivery Problem with Time Windows using Genetic Algorithm.

E. Ben Alaia, I. H. (2014). Genetic Algorithm with Pareto Front selection for Multi-Criteria Optimization of Multi-Depots and Multi-vehicle Pickup and Delivery Problems with Time Windows.

Javier Del Ser, A. I.-B. (2017). Nature-inspired Heuristics for the Multiple-Vehicle Selective Pickup and Delivery Problem under Maximum Profit and Incentive Fairness Criteria.

Javier Del Ser, e. a. (n.d.). Nature-inspired Heuristics for the Multiple-Vehicle Selective Pickup and Delivery Problem under Maximum Profit and Incentive Fairness Criteria.

Liao, X.-L. C.-H.-K. (2014). A Genetic Algorithm for the Minimum Latency Pickup and Delivery Problem. *IEEE Congress on Evolutionary Computation (CEC)*.

Margaretha Gansterer, M. K. (2016). The multi-vehicle profitable pickup and delivery problem.

Marjolein Veenstra, M. C. (2016). The pickup and delivery problem with time windows and handling operations.

Nature-inspired Heuristics for the Multiple-Vehicle Selective Pickup and Delivery Problem under Maximum Profit and Incentive Fairness Criteria. (n.d.).

Yamming Yan, Y. S. (2017). Multi-objective Memetic Algorithm based on request prediction for solve Dynamic Pickup and Delivery Problem.

Yu-Wei Chang, C.-C. L.-K. (2016). An Ant System for the Selective Pickup and Delivery Problem.

[10] R. J. Kuo and Ferani E. Zulvia (2017). Hybrid Genetic Ant Colony Optimization Algorithm for Capacitated Vehicle Routing Problem with Fuzzy Demand - A Case Study on Garbage Collection System.

[11]  Jyoti Gupta, Chander Diwaker (2015). Vehicle Routing Problem using Swarm Optimization Techniques.