Review on Optimization of a Parking Garages In the Emerging Truck-Drone Delivery Network

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ABSTRACT

Drone-assisted collaborative routing for last-mile delivery (LMD) has been the subject of a lot of recent research. This article introduces a brand-new LMD optimization problem for cooperative routing involving a truck and a fleet of drones. A new method for coordinating a vehicle and a fleet of drones to serve a certain group of consumers is suggested by the challenge. The strategy is focused on figuring out where to park the truck and where to send the drones to service the consumers. The best way to find these parking lots is provided. A mixed linear integer programming formulation is offered for the transportation network, which comprises these points, with the goal of reducing the time it takes to serve every client. To examine the qualities of the model solutions and establish their computational bounds, computational experiments were performed on a collection of issue instances. Experiments revealed that the suggested methodology might greatly enhance outcomes over using just a vehicle for logistics. We also suggest a Greedy Randomized Adaptive Search Procedure (GRASP) met heuristic to solve larger-scale situations. Instances with various features were used to study how well it performed computationally. The study proposes future research ideas and analyses some findings from computational experimentation.

INDEX TERMS: drones routing, collaborative, truck-drone, and parking lots.

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I. INTRODUCTION

Supply Chain Management (SCM) is recognized to be influenced by the structure of e-commerce due to its rapid growth[3]. A significant portion of this effect is associated with the logistical effort involved in the routine delivery of packages to the various clients in the network. Several techniques and models have been created in the field of Logistics of Distribution to effectively control the high expenses involved with this process. The ever-increasing urban traffic and congestion, noise and air pollution, and energy consumption are all negative externalities that need to be factored into these plans and models.

Last-Mile Delivery Problem refers to the issue of parcel delivery, which is the final stage in Supply Chain Networks (SCN) (LMD). The conventional approach for this problem involves a set of distribution hubs from which a fleet of vehicles gathers the packages transports them to the end-users, etc. In [22], a commercial strategy for LMD is outlined. Several scenarios are constructed, each of which describes a probable relationship between economic, technical, and cultural dimensions and emerging transportation options. When it comes to the logistics of delivering items, it's crucial to take into account the terrain and the packages themselves when determining the best route to take. If the packages being shipped are particularly hefty or cumbersome, for instance, then only vans or trucks

would be suitable for the job. However, if the majority of items are tiny and light, bicycles or motorbikes mightalso be employed.

Unmanned Aerial Vehicles (UAV) are being used by major logistics distributors like Amazon [10], UPS [47], and DHL [17] to assist in package delivery, opening up a new area of study in the field of LMD.

UAVs have recently been included into the distribution strategies of a number of multinational corporations. An intriguing scholarly article explores the history of collaboration between logistics firms and academics[12]. LMD comes from the integration of Unmanned Aerial Vehicles (UAV) in aid with parcel delivery, including key corporations operating in Logistics Distribution like Amazon[10], UPS[47], and DHL[17]. The use of unmanned aerial vehicles in international distribution operations has recently gained traction among several companies. An intriguing piece from the academic sector explores the interaction between logistic businesses and academic scholars[12]. In example, he has described some of the early efforts of Matternet, one of the most prominent firms engaged in drone delivery operations at the present time [32].

Drone-assisted package delivery in Europe has the potential to be a lucrative business, and a new paper [2] includes research on the market and economic sustainability of the service. In order to predict the optimal position of drone-beehives (centres built to allow landing and take-off of drones in highly populated regions), they provide a modeling approach that uses EU-wide high-resolution population and land-use data. Their research reveals that up to 7% of EU inhabitants might obtain access to such services under a technologically plausible scenario and that number can climb to 30%, if certain technological advancements are adopted. Mathematical formulations for two distinct kinds of collaboration between vehicles and drones have been proposed for the first time in [35]. Two novel optimization challenges involving the use of drones and a delivery vehicle were presented. The Flying Sidekick Travelling Salesman Problem (FSTSP) model takes into account a group of clients that need to be delivered to exactly once using either a human delivery person or a drone in tandem with the truck. Both the truck and the drone can only leave and come back to a single distribution centre. Both vehicles can leave (or return) together, with the truck carrying the drone during the former option. In order to get both cars back to the depot as quickly as possible, the FSTSP prioritizes speedy customer service.

When most clients are located close to the depot, the Parallel Drone Scheduling TSP (PDSTSP) problem is explored. Every drone in a fleet of identical aircraft takes off and lands from the same truck. Customers along a TSP route are served by the truck, while those closer to the depot are served by drones. In the PDSTSP, drone and vehicle movements are not coordinated like they are in the FSTSP. Since each client should only be served once, the goal is to reduce the amount of time that passes between when a vehicle leaves the depot and when it returns.

The two challenges outlined in [35] have been the subject of a large number of studies suggesting various solutions, including models and algorithms; for a current overview, see [37]. This article's companion piece, [48], examines truck and drone collaboration in a broader situation, where a fleet of trucks is used for parcel delivery, and each vehicle maintains a fleet of drones. Trucks can drop off and pick up drones at the warehouse or at the convenience of the client. Also, it is acceptable practice for a vehicle and a drone to work in unison. To achieve this goal, we must find routes with the shortest possible overall travel time (i.e., the total completion time).

To the best of our knowledge, a number of articles have proposed varying degrees of cooperation between trucks and drones. The literature review that follows contains references to these studies. GRASP is a single-solution metaheuristic algorithm. Based on this, the research team has developed an algorithm that starts by constructing the entire truck route as a classical TSP. The route obtained from the TSP is then partitioned into truck nodes and drone nodes, to give an initial TSP-D solution. The researchers have experimented with a variety of initial routes, or tours, to find out if they could obtain a better solution. They applied several heuristic algorithms that used the local search method to modify the initial tour, and iteratively search for improvements. After considering several neighborhood functions, two local search alternatives were selected for use in this innovative self-adaptive neighborhood-selection scheme.

Truck and drone partnership techniques may be broken down into two broad categories.

Type 1: drones traveling mounted on a truck:

[35] proposed the FSTSP problem, and others are mentionedin the Literature review.

Type 2: truck delivering parcels into drone stations:

[25] Proposed locating a station for drone dispatching and collection, and customers are served only by drones. Other variants of Type 2 are analyzed in the Literature review.

Contribution. Given a network consisting of a depot, a set of consumers, a truck, and a fleet of drones (which travel affixed to the truck), our approach formulates an alternative strategy for FSTSP to address the LMD problem. To begin, the network is analyzed using a clustering algorithm-based technique to locate convenient parking spots from which the truck may dispatch drones to deliver packages and pick them up again. Put another way, the car acts as a makeshift storage locker while parked.

Using the updated network, a new optimization problem is formulated: the Traveling salesman problem with drone and parking, in which parking facilities work together to shorten the makespan.

Rather than stopping at a customer's home, like in the original, this version of the concept has the truck stopping at a node. It's possible that many drones may take off from this spot, cutting down on the need for pilots to return to base to refuel. Similar to the Steiner problem in graphs [30], [50], in which a set of demand nodes must be connected at lowest cost, other nodes besides the demand nodes (customers in our example) might be used. A better answer might be possible if we could just connect the demand nodes with "excellent" Steiner nodes.

Our concept is able to tackle traffic congestion by creatively combining the activities of a truck and drones, and it was inspired by a broad variety of consumer distribution problems in real-world networks.

We present a Mixed Integer Linear Programming MILP formula for TSPDP in which the makespan is decreased. The model takes into account the parking lot locations and the truck's route to identify a subset of parking lots used by the truck and then uses this information to plan how the fleet of drones and the vehicle will serve the consumers.

When it is impractical to derive optimal solutions using the optimization model, a greedy randomized adaptive search procedure (GRASP) meta heuristic has been created to solve bigger instances of the TSPDP. The optimization model was solved using commercial tools and then applied to many different scenarios. The experimental findings demonstrated a considerable improvement over the baseline results achieved using solely the truck delivery method, supporting the validity of the suggested approach. Variables such as client volume, drone fleet size, and flight speeds were all taken into account in the analysis of the results. To ensure that greedy randomized adaptive search procedure (GRASP) was working with the same data as the optimization model, it was applied to the same dataset.

Evaluating the new greedy randomized adaptive search procedure GRASP algorithm to test this new approach, the research team used the most challenging scenarios. These had no limits to the drone's range and both the drone and truck could visit all locations. They applied their approach to 200 examples with different properties, selected from the publicly available 'Instances of TSP with Drone' benchmark dataset.

The research team compared the outcomes from their proposed GRASP approach with the results of two studies using state-of-the-art algorithms. The performance of their novel approach compared favorably with that of the two rival algorithms. Non-parametric statistical analysis demonstrated that this new approach has comparable performance, in terms of tour duration, to the rival algorithms ($p = 0.074$).

Moreover, given certain combinations of parameters, such as the drone and truck having the same speed, it outperformed the rival algorithms.

Although the application of meta heuristic algorithms to the TSP-D problem is not new, perhaps the most rewarding outcome of this algorithm is the self-adaptive selection of the search neighborhood. Another advantage of the proposed algorithm, particularly in comparison to rival algorithms, is the lower computational requirements, which both employ the best-improvement search strategy. This exhaustively explores the search neighborhoods and returns the solution with the minimum cost. The proposed GRASP algorithm, on the other hand, employs the first- improvement strategy, accepting the first neighbour, with a cost that is lower than that of the current solution.

To understand how to approach these challenges, the national and international outlook of drone deliveries is scrutinized, as well as the new trends in the logistics and transportation industry, the future role of drones in delivery and the several approaches to delivery problems with drones. Interestingly, the literature highlights the relevance of the problem studied since the researched studies consider that drones will eventually be adopted in the future for the last-mile deliveries in rural areas. Regarding the approaches reviewed for drone delivery problems, the parallel drone scheduling travelling salesman problem (PDSTSP) since its formulation considers the drone integration concurrently with a road vehicle. Therefore, this work proposes the parallel drone scheduling vehicle routing problem (PDSVRP), which is based on the PDSTSP but allows for multiple road vehicle routes. Four variants of this problem were modeled and implemented with real data to support analyses and decisions. Finally, the results obtained suggest that it is possible to obtain savings in the cost and transportation time of the deliveries. Despite the issues with regulation, there are still logistics challenges to be tackled in the implementation of a drone-based distribution operation. Planning and managing the day-to- day logistics of an operation

TABLE 1. Main characteristiCs of the related literature about TSPDP.

References	Problem	# truck / # drone	Launch ≠ Return	Drone net ≠ Truck net	Solution Method
Murray and Chu, 2015	FSTSP PDTSP	1/1 1/m	✓ ✓	✓ ✓	MILP Heuristics
Agatz et al. 2016	**TSP-D**	1/1 1/1			MILP, DP Heuristics
Ha et al. 2015	TSP-D	1/1	✓	✓	MILP, GRASP, TSP-LS
Wang et al. 2017	VRDP	n/m			Worst case scenarios
Carlsson and Song 2017	FSTSP	1/1	✓	✓	Continuous appr. scenarios
Ferrandez et al.2017	TSP-D	1/m	✓	✓	Genetic alg., k-means scenarios
Daknama et al. 2017	VRD	n/m	✓	✓	Local search scenarios
Marinelli et al. 2017	FSTSP	1/1		✓	**MILP, GRASP**
Poikonen et al. 2017	VRDP	n/m			Worst case scenarios
Pugliese and Guerriero 2017	VRDPTW	n/m	✓	✓	IP formulation
bin Othman, 2018	NW-ALSDP NW-LSDP	1/1 1/1	✓ ✓		Min cost bipartite alg
Chang and Lee 2018	TSP-D	1/1	✓	✓	MILP, Iterative decomp.
Yurek and Ozmutlu 2018	TSP-D	1/1	✓	✓	MILP, Iterative decomp.
Dell´Amico et al. 2019	FSTSP	1/1	✓	✓	Branch and cut
Wang and Sheu, 2019	VRPD	1/m	*	✓	Branch-and-price
Karak and Abdelghany 2019	VRPD	1/m	*		MILP, Heuristics
Kim and Moon 2019	TSP-D	1/m	*	✓	MILP, Decomposition
Kitjacharoenchai et al. 2019	mTSP-D	n/m		✓	MILP, Genetic algorithm
Mbiadou Saleu et al. 2018	PDSTSP	1/m			Heuristic, Dynamic Progr.
Schermer et al. 2019	VRPD	n/m		✓	MILP, VNS, Tabu Search
Peng et al. 2019	VRPD	1/m		✓	Genetic algorithm
Remer and Malikopoulos,2019	VRPD	1/m		✓	Bi-objective, decomposition
Dukanci et al., 2019	VRPD	n/m			Non-linear model, Reformulation
De Freitas and Penna 2020	FSTSP TSP-D	1/1 1/1	✓	✓	General variable neighborhood search
This work, 2020	**TSPDP**	1/m		✓	**MILP, GRASP**

The number of trucks and drones in use is specified in the third column, whether or not the drone returns to the truck after a delivery is made is specified in the fourth column, whether or not the drones follow the same route as the trucks is specified in the fifth column, and the methods used to solve the models are specified in the sixth and final column.Our formal definition of TSPDP will be presented in the next section. This issue is formulated as a mixed-integer linear programming problem, and a metaheuristic called (greedy randomized adaptive search procedure) GRASP is introduced to help solve it. The purpose of this paper is to investigate the effectiveness of implementing unmanned aerial delivery vehicles in delivery networks. We investigate the notion of the reduced overall delivery time, energy, and costs for a truck-drone network by comparing the in-tandem system with a stand-alone delivery effort. The objectives are (1) to investigate the time, energy, and costs associated to a truck-drone delivery network compared to standalone truck or drone, (2) to propose an optimization algorithm that determines the optimal number of launch sites and locations given delivery requirements, and drones per truck, (3) to develop mathematical formulations for closed form estimations for the optimal number of launch locations, optimal total time, as well as the associated cost for the system.

II. INSIGHTS AND CONCLUSION

A number of concepts for parcel delivery including a partnership between trucks and drones have been proposed since 2015. The literature research indicates that there have been two main types of collaborative tactics. One scenario involves a strong partnership, with drones being transported on the back of trucks. This procedure entails making a delivery to a single or more customers (depending on the proposal). This initial wave was initiated by the synchronized model given in [35], and since then, various modifications of this model have been offered by outlining alternate tactics regarding the mechanisms intended for the coupled delivery truck- drone.

This research deals with ensembling of centers around the truck-mounted drone fleet. This paper introduces effective idea of parking lots for truck-drone system on flexibility of operation to optimize delivery of goods to consumers The suggested model's effects were examined for variety of networks by tweaking parameters including fleet size, route density stoppage along the route. This study can go in different directions with respect to advancement in ecommerce, transportation, technologies and logistics. Given the economic technological and environmental significance of the LMD challenge, the work will contribute to the ongoing investigation of novel methods of cooperation between unmanned aerial vehicles (UAV) and other types of transportation.

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