**Dissertation Defense**

Drone-Truck Arc Routing Problems: Models and Algorithms

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## Abstract

The development of drones can enhance the effectiveness of logistics by utilizing drones to provide services. This is because drones are not required to follow the ground road network system and can avoid congested areas. However, drones are also characterized with shortcomings such as short battery life which hinders their use alone for routing services. The use of a combined system of drone(s) and truck(s) can overcome these drone shortcomings.

The modeling and optimization of the combined operation of a drone(s) and truck(s) for ARP are considered in this dissertation, defined as Drone-Truck ARP (DT-ARP). First, a single-drone-single-truck case is considered. An IP model is developed based on the modeling concept called an operation. In addition, a heuristic solution approach is provided to the problem. The heuristic is characterized with the use of multiple initial truck routes and the adoption of local search and Simulated Annealing (SA) for the selection of the initial truck solution. Initial computational results show that the deviation between the heuristic and the IP model solution is less than 6 % for the test sets. Moreover, the average expected savings of the heuristic over the truck-only ARP solution is 24 % for the test sets.

Next, the multiple-drone-multiple-truck ARP case is considered, where each truck is working as a mobile hub to support the drone operations and each truck holds only a single drone. The problem is labeled mD-mT_s-ARP. This system is first studied in this dissertation. The studied system requires simultaneous optimization of the truck routes along the ground network and the drones' network of required edges/arcs. Thus, the studied problem integrates the traveling salesman problem (TSP) and the ARP. Due to the complex nature of the problem, a heuristic consisting of multiple phases is proposed. Starting with generating multiple giant drone routes each assuming infinite drone endurance. Then, partitioning the giant drone route into multiple drone routes by assuming a more practical drone endurance. Next, splitting each drone route into feasible subroutes by considering the actual drone endurance and the time relationships between each drone and its truck. Computational results are given on 45 problem instances. Sensitivity analysis of drone and truck parameters including drone inspection speed and drone endurances is provided.

Finally, the mD-mT_s-ARP is extended to allow each truck to hold more than a single drone. A proposed mathematical model is proposed building on the single-truck single-drone routes resulting from the mD-mT_s-ARP with a single drone/truck solution where each drone subroute is defined by its launch and recovery nodes, and the drone subroute length. A MILP model is proposed by modeling the problem as an instance of the pickup and delivery problem with back-hauls. In addition, a proposed two-phase methodology is proposed based on the multiple strip packing problem to pack the set of drone subroutes to trucks, then schedule them to a set of trucks that work as transporters for drones who work as a set of parallel machines. The average potential savings relative to the mD-mT_s-ARP with a single-drone/truck case are 29.62 % and 16.72 % for the MILP and the proposed solution methodology, respectively.