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GRASP with path relinking for the selective pickup and delivery problem

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ABSTRACT

Bike sharing systems are very popular nowadays. One of the characteristics is that bikes are picked up from some surplus bike stations and transported to all deficit bike stations by a repositioning vehicle with limited capacity to satisfy the demand of deficit bike stations. Motivated by this real world bicycle repositioning problem, we study the selective pickup and delivery problem, where demand at every delivery node has to be satisfied by the supply collected from a subset of pickup nodes. The objective is to minimize the total travel cost incurred from visiting the nodes. We present a GRASP with path-relinking for solving the described problem. Experimental results show that this simple heuristic improves the existing results in the literature with an average improvement of 5.72% using small computing times. The proposed heuristic can contribute to the development of effective and efficient algorithms for real world bicycle reposition operations.

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1. Introduction

The pickup and delivery problem (PDP) contributes one of the most important classes of the problems because its models have various logistic applications such as reverse logistics, shipping cargoes, dial-a-ride systems, the distribution of beverages and the collection of empty cans and bottles, bike repositioning operations, etc. It aims to determine routes to distribute the commodities between nodes to minimize the total transportation cost. Different variants of the PDP are studied in the literature.

Berbeglia, Cordeau, Gribkovskaia, and Laporte (2007) classified the variants of the PDP according to their structures, the number of deployed vehicles, and the pickup and delivery activities in the nodes. The structure criterion categorizes the PDP into one-to-one (1–1), one-to-many-to-one (1-M-1), and many-to-many (M-M) schemes, based on the number of origins and destinations of the commodities. In the one-to-many-to-one scheme, the commodities from the depot are delivered to delivery nodes and commodities from the pickup nodes are transported to the depot; in the one-to-one scheme, each commodity has exactly one pickup node and one delivery node. In the many-to-many scheme, any node can serve as a origin or as a destination for any commodity. The criterion of the number of deployed vehicles divided the PDP into single and multiple vehicle cases. The activity criterion classifies the PDP according to the way that pickup and delivery operations are performed at nodes. Under this classification, many PDP studies can be categorized explicitly.

Table 1 compares different variants of the PDP according to the schemes laid out by Berbeglia et al. (2007), the node features, and the vehicle characteristics and Table 2 gives the abbreviations of the variants and solution methods. The node features include the selectivity, depot supply/demand, time windows, the pickup and delivery operations, and the perfect balance requirement. The selectivity of nodes is about whether all nodes are required to be visited. Depot supply/demand is concerned with whether the depot supplies or receives commodities. Time windows define the time period during which the vehicle visit the nodes. The pickup and delivery operations are concerned with whether either a pickup or delivery activity is performed at a node and whether both activities are performed at a node separately or simultaneously. The perfect balance requirement is related to whether the total supply equals the total demand. The vehicle characteristics include the number and capacity of vehicles.

Clearly, the classification does not fully list out all elements in the PDP, such as the number of types of commodities or side constraints etc., but it should be enough to distinguish five features of the selective pickup and delivery problem (SPDP) which is also a variant of the PDP under the M–M scheme. First, different from existing 1-M-1 and M–M PDP variants, the SPDP does not require the depot to provide commodities. Second, the SPDP does not have

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Table 1
Comparison of the SPDP with PDP variants.

PDP variants	References	Structure	Node					Vehicle		Solution methods
			Sel	Dep	TW	Act	PB	Cap	Num	
SVRPPD	Gribkovskaia, Halskau sr., Laporte, and Vlček (2007)	1-M-1		✓		P-D	Y	✓	1	Tabu search
FDPPTW	Wang and Chen (2013)	1-M-1		✓	✓	P-D	Y	✓	> 1	Coevolutionary algorithm
VRPSPD	Zachariadis, Tarantilis, and Kiranoudis (2009)	1-M-1		✓		PD	Y	✓	> 1	Tabu search + GLS
	Çatay (2010)									ACO
	Zachariadis and Kiranoudis (2011)									Local search metaheuristic
	Li, Pardalos, Sun, Pei, and Zhang (2015)									ILS
SVRPDSP	Gribkovskaia, Laporte, and Shyshou (2008)	1-M-1	✓	✓		P-D	N	✓	1	Tabu search
	Bruck, dos Santos, and Arroyo (2012)									EA+VNS
VRPDSPTW	Gutiérrez-Jarpa, Desaulniers, Laporte, and Marianov (2010)	1-M-1	✓	✓	✓	P-D	N	✓	> 1	Branch-and-price
TSPPDF	Cordeau, Dell'Amico, and Iori (2010a)	1–1				P/D	Y		1	Branch-and-cut
TSPPDL	Cordeau, Iori, Laporte, and Salazar González (2010b)	1–1				P/D	Y		1	Branch-and-cut
TSPPD	Dumitrescu, Ropke, Cordeau, and Laporte (2010)	1–1				P/D	Y		1	Branch-and-cut
TSPPDF	Erdoğan, Cordeau, and Laporte (2009)	1–1				P/D	Y		1	PTS/ILS
PDPTW	Nanry and Barnes (2000)	1–1			✓	P/D	Y	✓	> 1	Reactive tabu search
	Bent and Van Hentenryck (2006)									SA+LNS
m-PDTSP	Hernández-Pérez and Salazar-González (2009)	1–1				P-D	Y	✓	1	Benders decomposition
	Hernández-Pérez and Salazar-González (2014)	M–M								Branch-and-cut
1-PDTSP	Hernández-Pérez and Salazar-González (2004)	M–M		✓		P/D	Y	✓	1	Greedy algorithm; branch-and-cut
	Hernández-Pérez, Rodríguez-Martín, and Salazar-González (2009)									Hybrid GRASP+VND
	Zhao, Li, Sun, and Mei (2009)									Genetic algorithms
	Mladenović, Urošević, Hanafi, and Ilić (2012)									GVND
SP	Anily, Gendreau, and Laporte (1999)	M–M		✓		P-D	Y	✓	1	Exact $\mathcal{O}(n^2)$ algorithm
	Anily, Gendreau, and Laporte (2011)									1.5-approximation algorithm
MSP	Bordenave, Gendreau, and Laporte (2010)	M–M		✓		P-D	Y	✓	1	Local search heuristics
NCSP	Erdoğan, Cordeau, and Laporte (2010)	M–M		✓		P-D	Y	✓	1	Branch-and-cut
1-TSP-SELPD	Falcon, Li, Nayak, and Stojmenovic (2010)	M–M	✓	✓		P/D	N	✓	1	ACO
SPDP	Ting and Liao (2013)	M–M	✓			P/D	N	✓	1	Memetic algorithm
	This study									GRASP+PR

Sel: selectivity; Dep: depot supply/demand; TW: time window; Act: pickup and delivery activities; PB: perfect balance; Cap: capacity; Num: number; P-D: two activities may be performed together or separately at each delivery node; PD: each delivery node is visited exactly once for the combined pickup and delivery; P/D: either activity is performed at each delivery node but not both.

time-window constraints related to the pickup and delivery nodes. Third, based on the problem setting, either pickup or delivery is performed at a customer node. Fourth, the perfect balance requirement does not need to be satisfied. Fifth, some nodes are not visited.

Unlike other PDP studies that consider selectivity, the SPDP requires that only *some, but not necessary all, pickup* nodes are visited by the vehicle to gather sufficient commodities for all delivery nodes. Moreover, despite the vehicle capacity constraint for each pickup activity, there is another constraint for the delivery activity to ensure that the vehicle *must* have enough commodities to satisfy the demand of the delivery customers once the vehicle visits the corresponding nodes (i.e., split or incomplete deliveries are not allowed). These are the two distinguished features of this problem (Ting & Liao, 2013). The SPDP is related to applications that supply sufficient commodities to the customers using the cost minimizing principle while visiting all pickup nodes is not a requirement. An illustrative example is the single vehicle bicycle repositioning problem, where bikes are picked up from some surplus bike stations and transported to all deficit bike stations by a repositioning vehicle with limited capacity using the shortest route. Given that the total surplus is larger than the total deficit and all bikes are identical, it is not necessary to visit all the surplus bike stations to satisfy the demand of each deficit station. Hence, some surplus stations are not visited in order to lower the transportation cost.

Although there are realistic applications related to the SPDP, only Ting and Liao (2013) proposed and studied this problem as shown in Table 1. As recognized by them that the SPDP is a NP-hard problem, it is impractical to adopt exact methods to solve instances of realistic sizes. Hence, they adopted a metaheuristic approach and proposed a memetic algorithm for solving the SPDP. The performance was illustrated by comparing the results obtained from the memetic algorithm with the results from the genetic algorithm and tabu search. However, many existing heuristics could solve the variants of the PDP with great success as reflected by the last column of Table 1. These heuristics and their hybrids may give a much better performance.

Table 1 also shows that GRASP has been considered in very few PDP studies despite its success in solving combinatorial optimization problems and industrial applications (Festa & Resende, 2011). GRASP is a multi-start heuristic for producing diverse solutions to combinatorial optimization problems. There are two phases at each iteration of GRASP. In the first phase, a new solution is constructed based on some principles that rely on greediness and randomness. Then, the solution is improved by local search in the second phase. However, Resende and Ribeiro (2010) stated that the searching efficiency of GRASP can be improved via adopting fine tuning mechanisms, multiple neighborhoods, and path relinking.

Path relinking (PR), as an evolutionary method, generates solutions by combining elements from a pair of elite solutions

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