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Importance of time limit constraint for multiple-vehicle bike sharing system routing problem

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Abstract— In this study, we investigated the importance of a time limit constraint for a bicycle sharing system (BSS) rebalancing problem. As a result, we found that the variance of the number of visited ports by each vehicle can be reduced by setting a working time on ports and imposing the time limit constraint.

1. Introduction

A BSS is attracting attention as one of the eco-friendly transportation systems. However, the BSS has a problem that users cannot rent/return bicycles at ports. Therefore, multiple vehicles are used to adjust the number of bicycles at each port. Recently, many researchers proposed various BSS rebalancing problems (BSSRPs) to find efficient routes [1, 2]. In the BSSRPs, multiple constraints such as capacity and time limit constraints of the vehicles are considered to determine the efficient routes. For example, Dell'amico et al. proposed a bike sharing rebalancing problem (BRP) and an extension of the one-commodity pickup and delivery vehicle routing problem with maximum duration (1-PDVRPD) to BRP [1]. Then, we proposed multiple-vehicle bike sharing system routing problem (mBSSRP) [2]. In the BRP, capacity constraint is imposed, but time limit constraint and working time on each port are not imposed. On the other hand, in the 1-PDVRPD and the mBSSRP, capacity, time limit and working time on each port are considered. It is desirable that operators who are rebalancing bicycles have same working time when we consider real situation for rebalancing bicycles. However, the importance of whether or not to set a time limit and working time on each port have not been discussed. In this study, we investigate the variance of the number of visited ports of vehicles when we set and change the time limit constraint and working time on each port using two heuristic algorithms.

2. BSS rebalancing problem and heuristic methods

In the BSSRP, a depot, ports and a set of cost C_{ij} from port i to port j are given. An objective of many BSSRPs is to minimize traveling costs for vehicles with a capacity constraint. The capacity constraint is that vehicles cannot pickup more bicycles than their capacity, and delivery less than zero. Then, the time limit constraint is that vehicles must return to the depot within the time limit, and the working time on each port is the time pickup/delivery one bicycles on a vehicle.

To solve the BSSRP, in this study, we use destroy and repair algorithm (DR) [1] and tabu search (TS) [2]. In the DR, an initial tour is constructed by using a greedy algorithm. Then, the initial tour is improved by seven local search methods. Finally, the tour is iteratively destroyed and repaired, and improved by the seven local search methods, until a stopping criterion is met.

In the TS, the search for solution is performed by iteratively transitioning to neighborhood solutions. In the method, the neighborhood solutions are constructed by the Or-opt, the CROSS-exchange and the 2-opt. First, an initial solution is constructed by a greedy method that is based on the farthest insertion method. Then, the initial tour is improved using two local search methods. Finally, the tour is iteratively improved using the Or-opt and the CROSS-exchange which are controlled by the TS. In the tabu list, combinations of staring ports for exchanged/inserted subtours are recorded.

3. Numerical experiment

To investigate the variance of the number of visited ports of vehicle in case with and without the time limit constraint, we used the instances used in Ref. [1]. The details of the instances are shown in Table 1. In Table 1, the first column shows the city name, the second column shows the number of ports and the third column shows the capacity of a vehicle. The values of parameters in the DR were set to the same values as described in Ref. [1]. In the TS, tabu tenure was set to 100 for San Antonio instance and 150 for Denver and Minneapolis instances. The stopping criterion for small size instance (San Antonio) was set to 10 seconds, 600 seconds for medium size instance (Denver) and 1,800 seconds for large size instance (Minneapolis) in case

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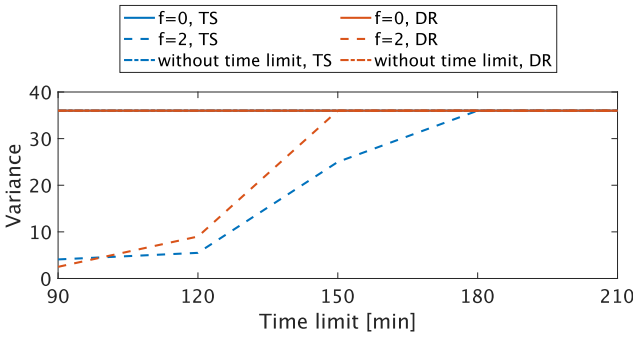
of using both methods.

We investigated the variance of the number of visited ports for vehicles in three scenarios: (1) without a time limit, (2) with a time limit but without a working time ($f = 0$) [min] at each port, and (3) with a time limit and a working time ($f = 2$) [min] at each port.

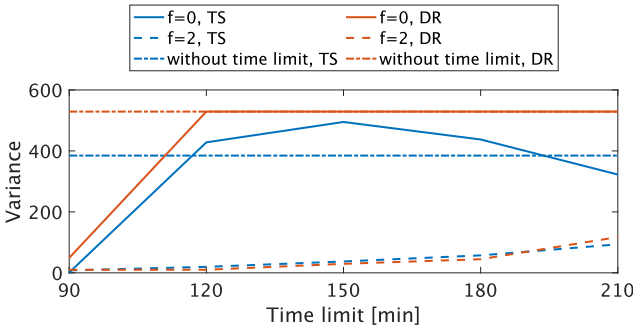
Table 1: BRP instances [1].

City	# of ports	capacity of a vehicle
San Antonio	23	30
Denver	51	30
Minneapolis	116	30

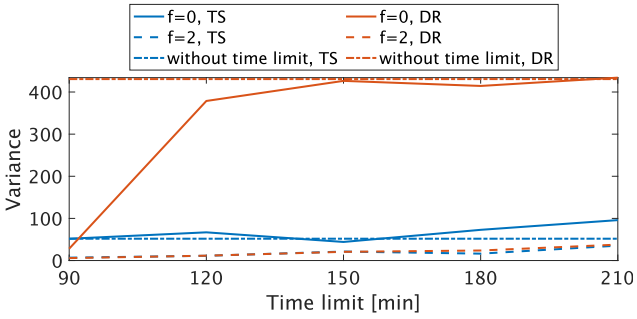
Figure 1 shows the variance of the number of visited ports of vehicles as the length of the time limit is changed. For the small size instance (Fig. 1 (a)), the variance of the number of visited ports of vehicles takes large values as the time limit increases when the working time on each port was set (dotted line). Then, similar result was obtained for the medium size instance in Fig. 1 (b). Therefore, working time on each port and the time limit constraint are important to equalize the workload of the operators who are rebalancing bicycles. For the large size instance (Fig. 1 (c)), the variance of the number of visited ports of vehicles also takes small value by the setting working time on each port and the time limit constraint. However, the difference between TS and DR values is large. Since TS uses two types of local search and DR uses seven types of local search, the number of iterations differs, which may have caused the difference in the value of variance. Therefore, TS can construct tour with small variance of the number of visited ports, when we treat large size instances.



(a) San Antonio



(b) Denver



(c) Minneapolis

Figure 1: Relationship between the length of the time limit and variance of the number of visited ports of vehicles.

4. Conclusion

In this paper, we investigate the importance of the time limit constraint for the BSSRP. As a result, we found that the variance of the number of visited ports of vehicles takes small value by the setting working time on each port and the time limit constraint. Therefore, to equalize the work time of operators, it is important to set the time limit constraint and working time on each port.

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