

# Last mile deliveries with lockers: formulations and algorithms

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## Research Article

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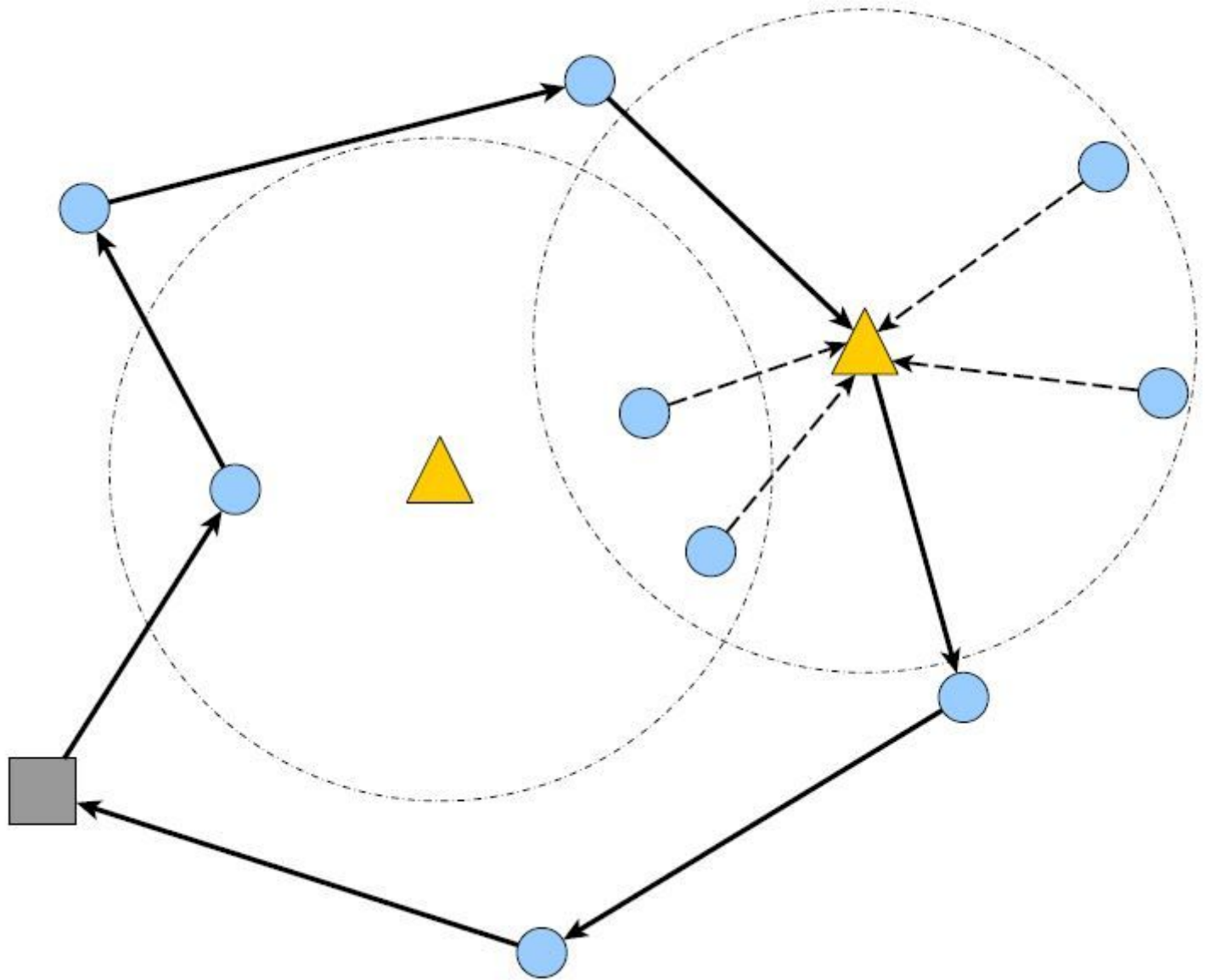
## Abstract

In this paper we consider the use of lockers in parcel delivery, a recent method used in the last mile logistics. Lockers are pick up points made of several cells that are located in several points of a city where customers can collect their parcels as an alternative to home delivery. We study routing problems in which one or multiple vehicles are used to deliver parcels directly to customers or to lockers. We also study the influence of the introduction of lockers when these problems include time windows. We propose a set of novel formulations for these problems, some valid inequalities, and a branch-and-cut algorithm. Moreover, we investigate the difference between the routing problems with lockers and the classical routing problems.

## Full Text

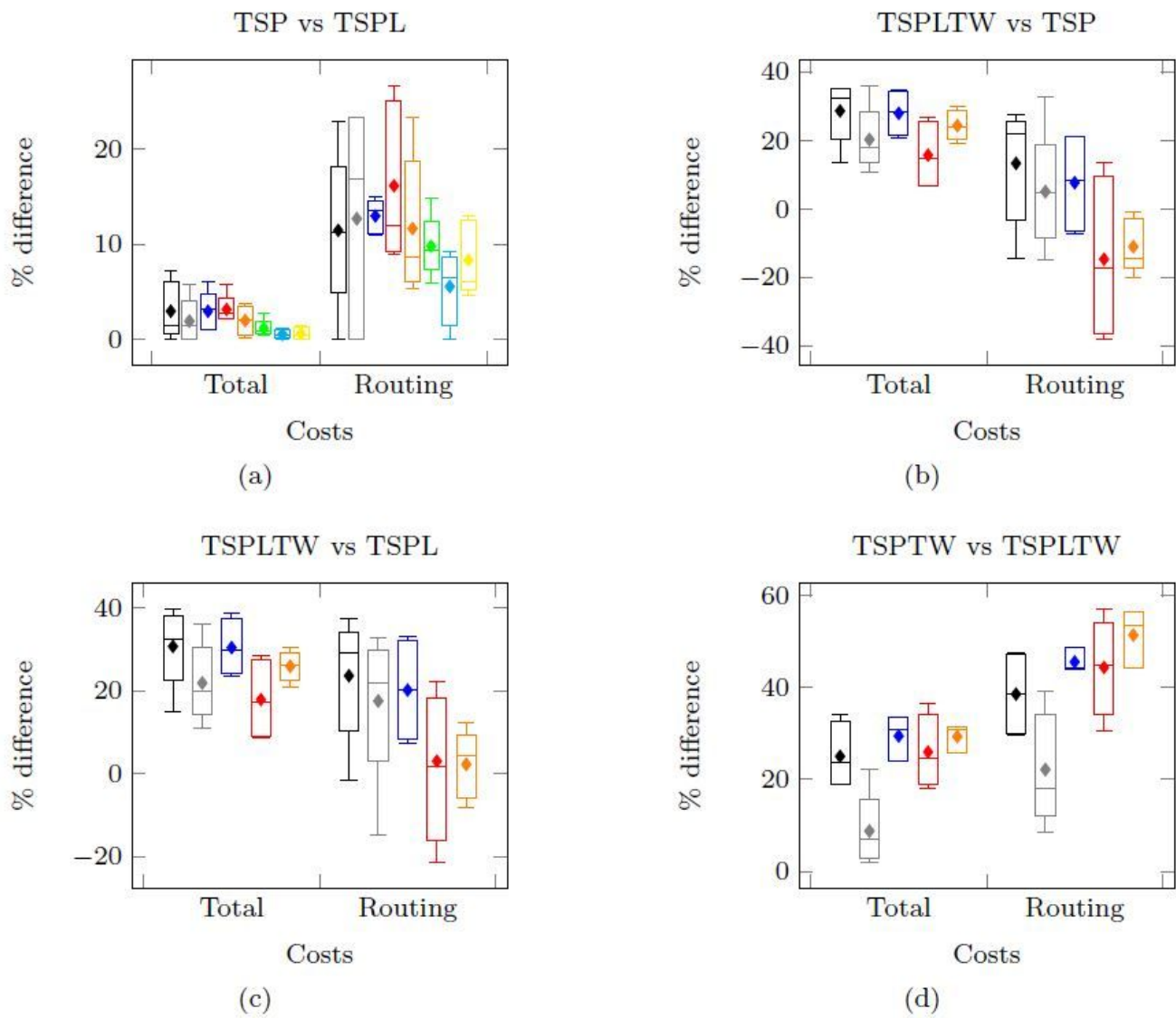
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## Figures



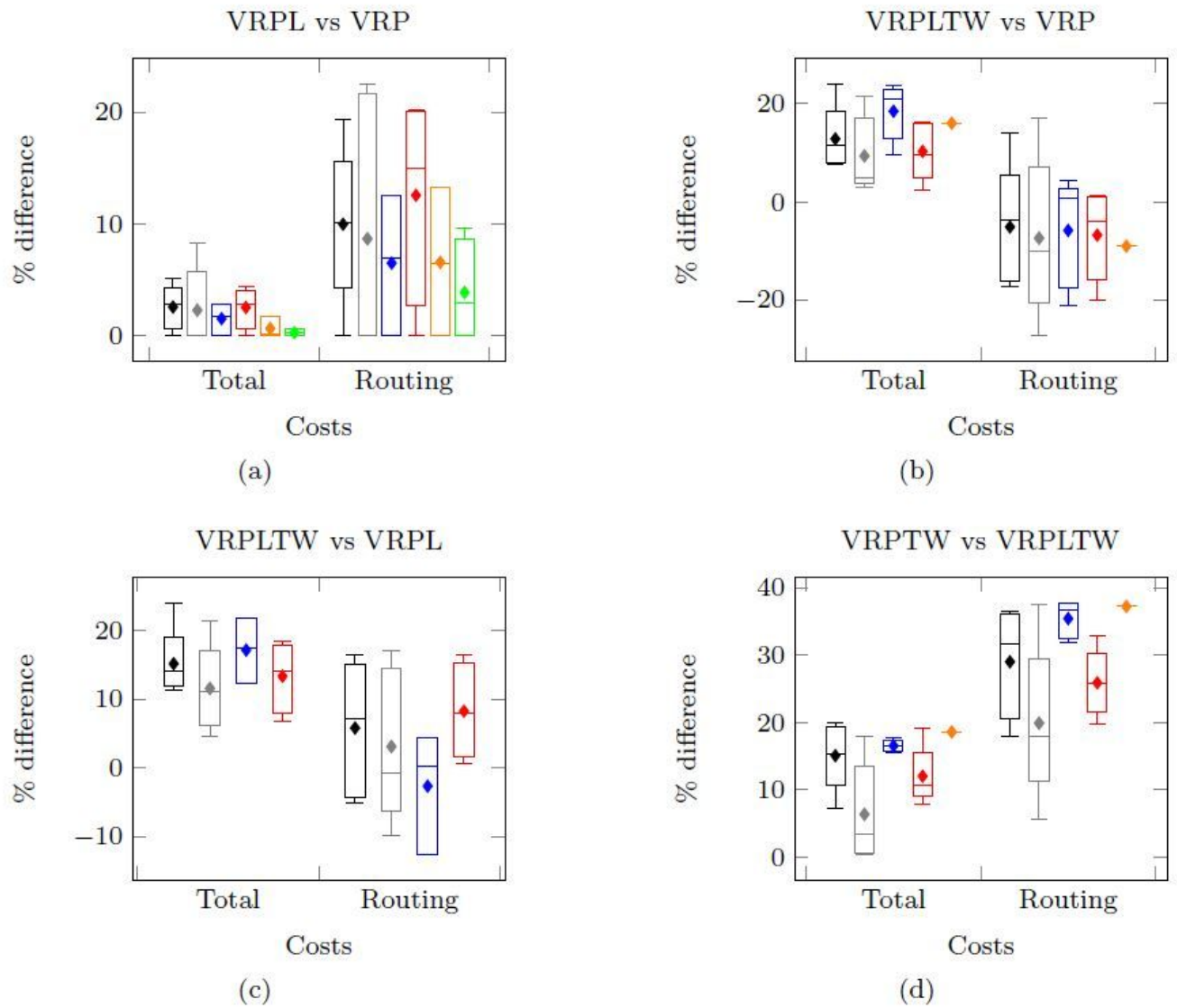
**Figure 1**

A feasible solution for the TSP.



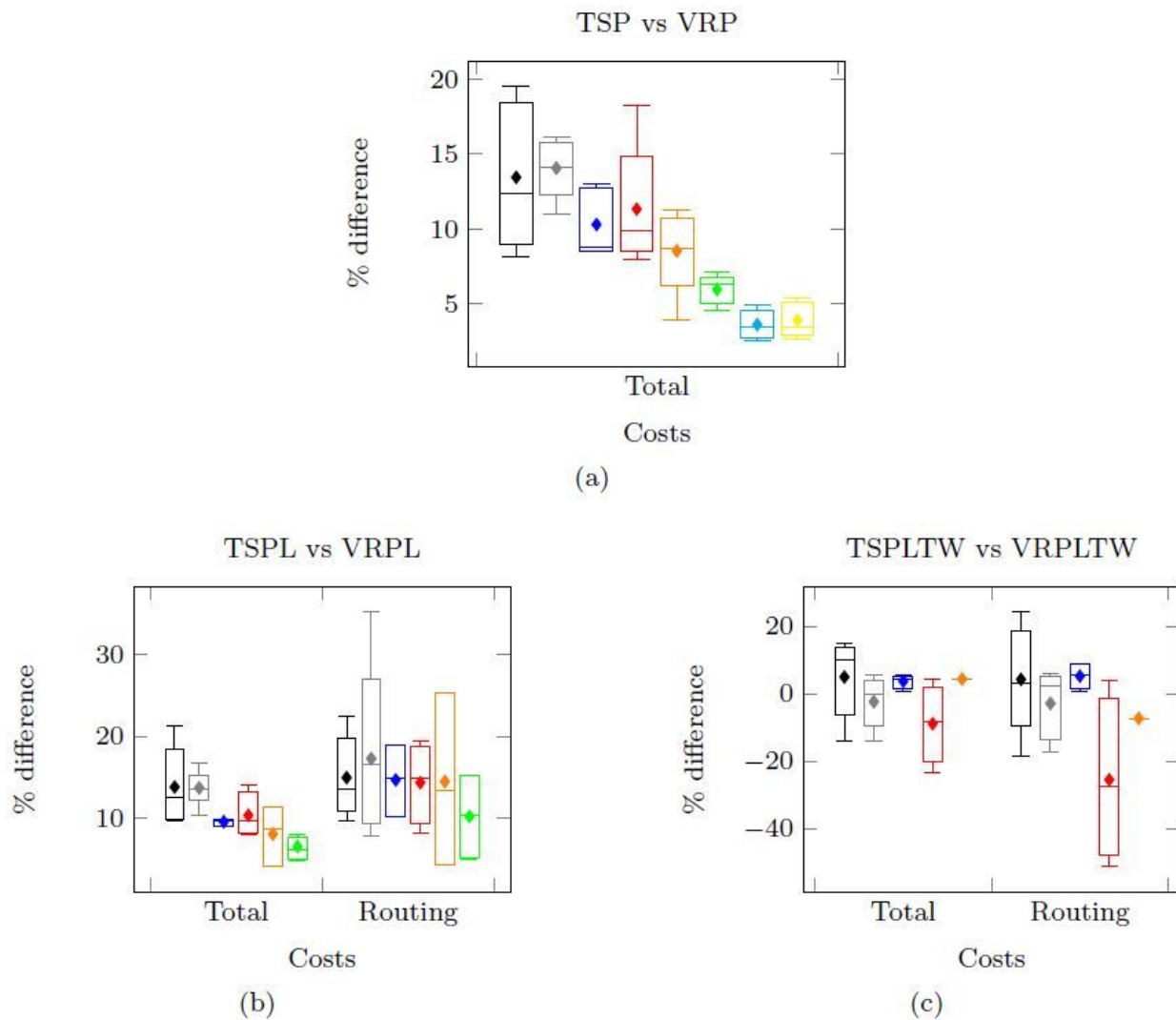
**Figure 2**

Increase or decrease of the total costs and routing costs with respect to the several versions of the TSP based problems solved. In black the instances with  $n = 20$  and with the time windows of 20, in gray the instances with  $n=20, tw=100$ , in blue  $n=40, tw=20$ , in red  $n=40, tw=100$ , in orange  $n=60, tw=20$ , in green  $n=60, tw=100$ , in light blue  $n=100, tw=20$ , and in yellow  $n=100, tw=100$ .



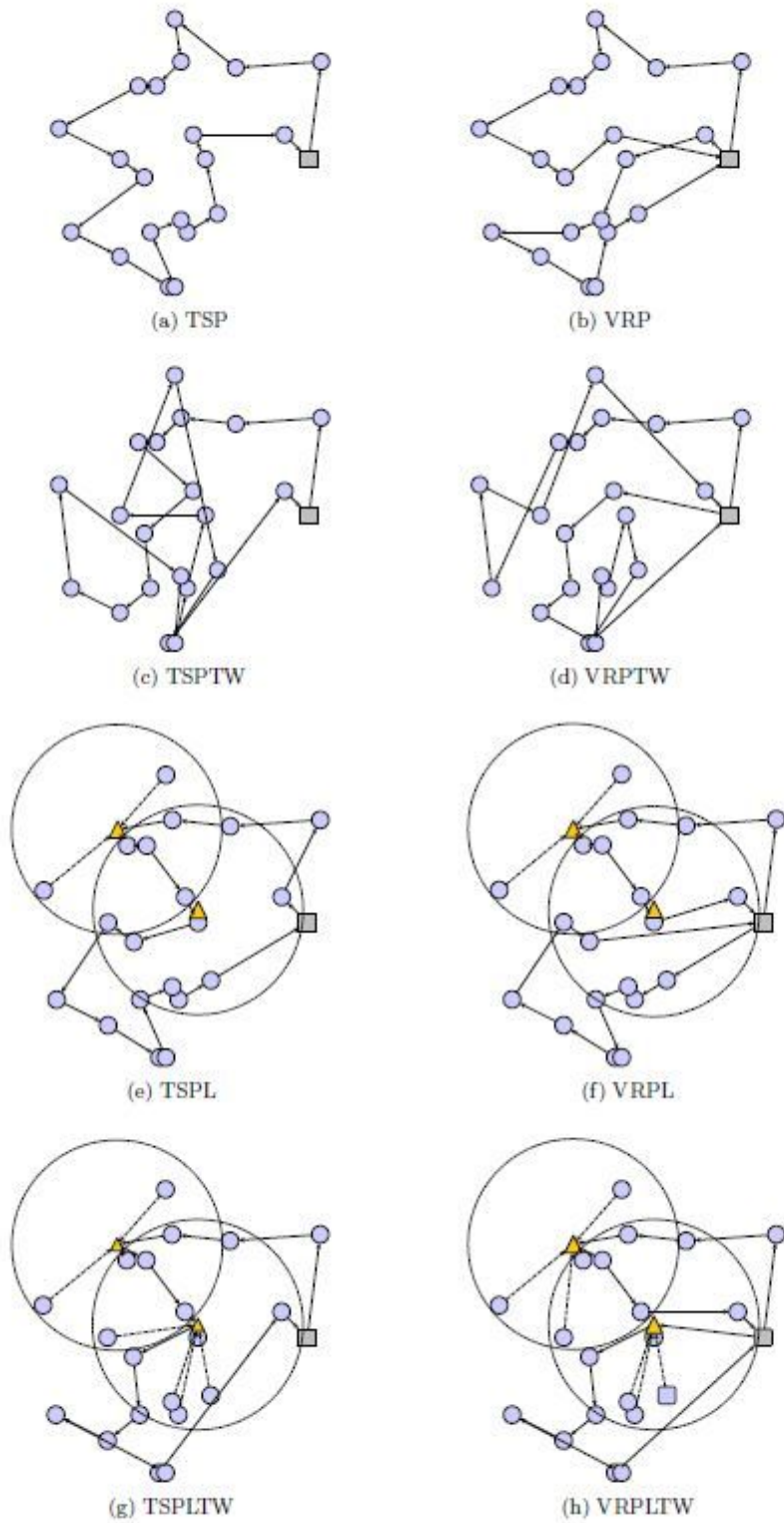
**Figure 3**

Increase or decrease of the total costs and routing costs with respect to the several VRP based versions of the problems solved. In black the instances with  $n = 20$  and with the time windows of 20, in gray the instances with  $n20tw100$ , in blue  $n40tw20$ , in red  $n40tw100$ , in orange  $n60tw20$ , and in green  $n60tw100$ .



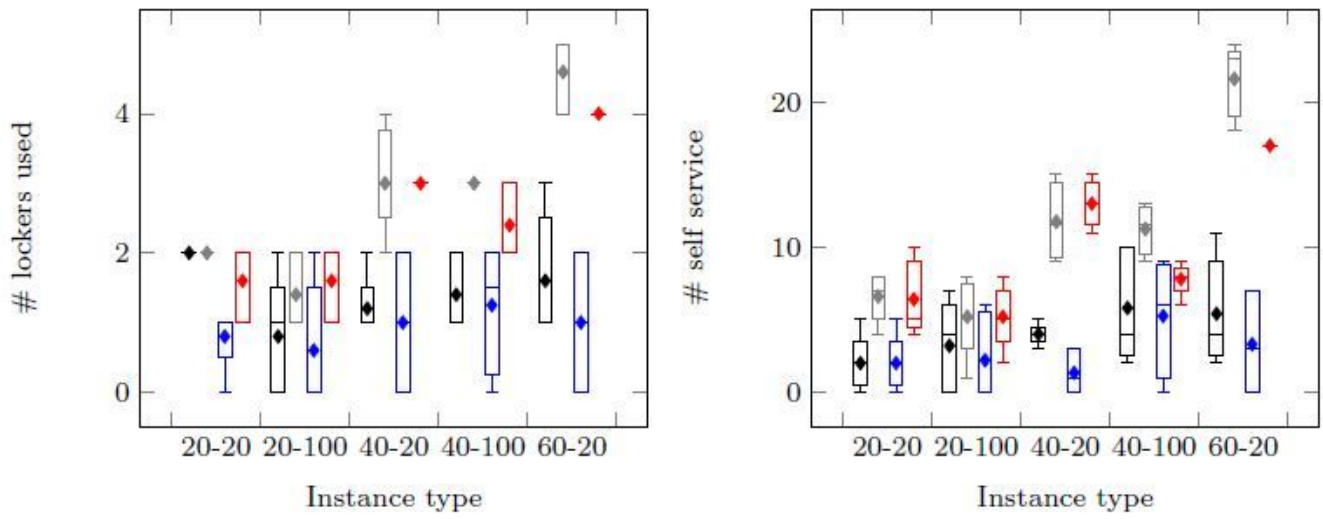
**Figure 4**

Increase or decrease of the total costs and routing costs with respect to the several versions of the problems solved. In black the instances with  $n = 20$  and with the time windows of 20, in gray the instances with  $n20tw100$ , in blue  $n40tw20$ , in red  $n40tw100$ , in orange  $n60tw20$ , and in green  $n60tw100$ , in light blue  $n100tw100$ , and in yellow  $n100tw100$ .



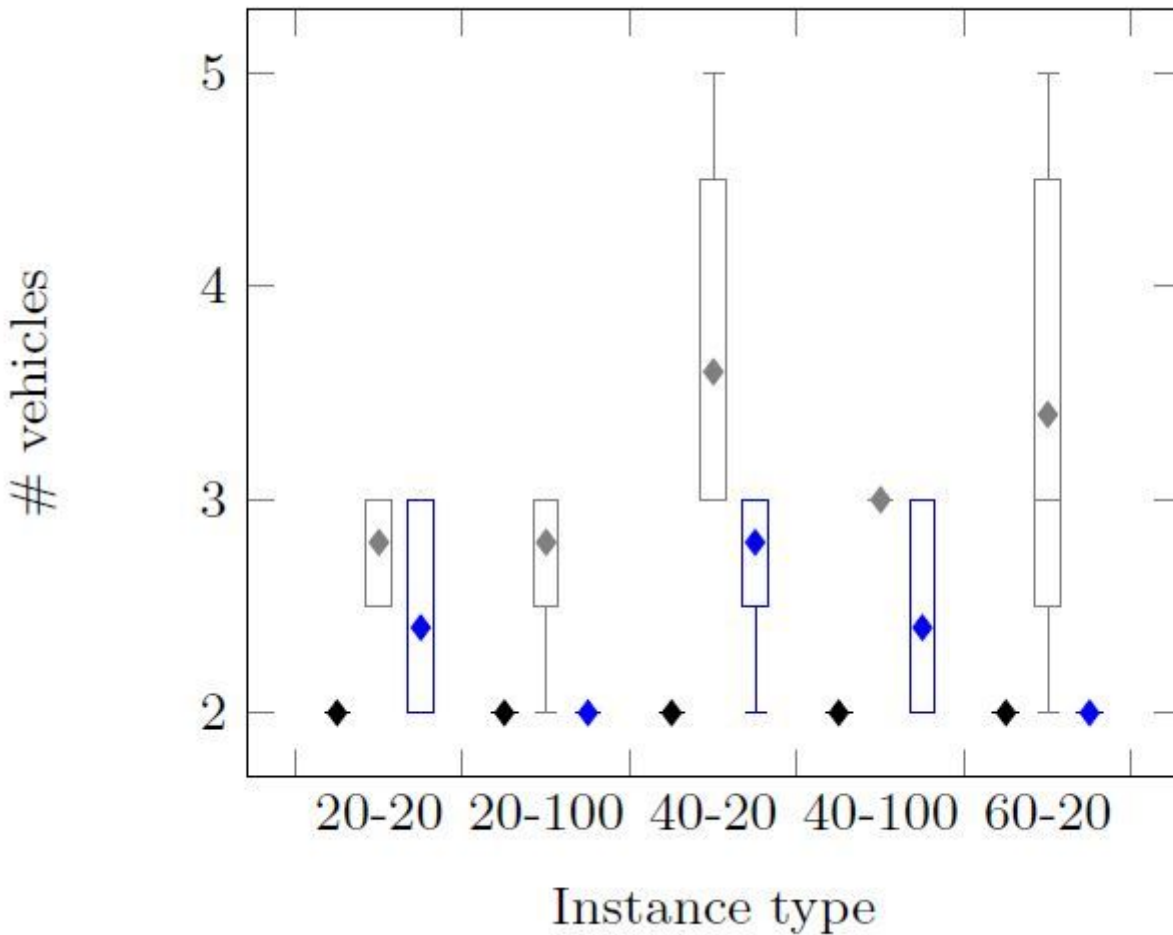
**Figure 5**

Graphical representation of the solutions of the studied problems on instance n2012w20 002.



**Figure 6**

Number of lockers opened and customers served via locker in the optimal solution of the considered problems. In black the case of TSPL, in gray that of TSPLTW, in blue that of the VRPL, and in red that of the VRPLTW.





## Figure 7

Number of vehicles used in the optimal solution of the considered problems. In black the number of vehicles used in the case of VRPL, in gray that of VRPTW, in blue that of the VRPLTW.