A heuristic algorithm for a single vehicle static bike sharing rebalancing problem

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Abstract

The static bike rebalancing problem (SBRP) concerns the task of repositioning bikes among stations in self-service bike-sharing systems. This problem can be seen as a variant of the one-commodity pickup and delivery vehicle routing problem, where multiple visits are allowed to be performed at each station, i.e., the demand of a station is allowed to be split. Moreover, a vehicle may temporarily drop its load at a station, leaving it in excess or, alternatively, collect more bikes from a station (even all of them), thus leaving it in default. Both cases require further visits in order to meet the actual demands of such station. This paper deals with a particular case of the SBRP, in which only a single vehicle is available and the objective is to find a least-cost route that meets the demand of all stations and does not violate the minimum (zero) and maximum (vehicle capacity) load limits along the tour. Therefore, the number of bikes to be collected or delivered at each station should be appropriately determined in order to respect such constraints. We propose an iterated local search (ILS) based heuristic to solve the problem. The ILS algorithm was tested on 980 benchmark instances from the literature and the results obtained are quite competitive when compared to other existing methods. Moreover, our heuristic was capable of finding most of the known optimal solutions and also of improving the results on a number of open instances.

Keywords: Bike-sharing; Vehicle Routing; Split pickup and delivery; Iterated local search.

1 Introduction

The task of repositioning a commodity from one location to another is a well-known problem arising in different contexts such as logistics, transportation, and various disciplines, notably industrial engineering and operations management. A practical application arises in self-service bike sharing systems (BSS), which are becoming increasingly popular in recent years. Users rent bikes and return them at stations distributed over a region. A vehicle with limited load capacity then periodically collects and delivers bikes across different stations so as to rebalance the system.

Alternatives to the street traffic are important not only because of its impact in urban congestion, but also in the environment, commuting, and so on. The emerging worldwide BSS are proving to be an effective solution to mitigate the effects of traffic issues in large urban centers. Up to 2009, there were about 120 bike sharing programs around the world and, according to DeMaio (2009), they have a favorable impact on: decreasing traffic congestion, improving public health, and helping reducing the level of CO_2 emissions. One of the most famous systems is the *Vélib'* system in Paris, with 1800 stations and more than 20,000 bikes.

In such systems, each station has an inventory with a load capacity, an initial number of bikes, and consequently a number of free slots where users can return bikes to the system. Throughout the day, some stations may have no bike to be rented or free slots to store returned bikes. Therefore, an attempt to avoid this scenario, which is unpleasant for users, is to determine an initial acceptable number of bikes (and free slots) at each station. This task can be done based on demand history and peaks at each station.

The activity of repositioning bikes among stations on a regular basis is called rebalancing, and this is done by one or more vehicles that move bikes from one station to another in order to restore its inventory to the initial desired configuration. As per DeMaio (2009), good rebalancing systems are present in successful bike sharing programs, and since the vehicles move back and forth across an urban area, a vehicle routing optimization can be utilized.

The rebalancing is either static, performed when nearly no bikes are being used, or dynamic, which is done while the system is still in use. The static bike rebalancing problem (SBRP) is motivated by the fact that very few bikes are being used at night. Indeed, according to Chemla *et al.* (2013a) and Dell'Amico *et al.* (2014), there are many systems that are even closed during the night.

In this work we consider the single vehicle SBRP, which is clearly $\mathcal{NP}$-hard, because it includes, among others, the classical traveling salesman problem (TSP) as a special case. The SBRP can be seen as a variant of the one-commodity pickup and delivery TSP (Hernández-Pérez and Salazar-González, 2004a,b), where multiple visits are allowed to be performed at each station, i.e., the demand of a station is allowed to be split. Moreover, a vehicle may arbitrarily drop its load at a station, leaving it in excess or, alternatively, collect more bikes from a station (even all of them), thus leaving it in default. Both cases require further visits in order to meet the actual demands of such station. This strategy of allowing a station to act as a buffer or a temporary depot is denoted as *preemption* or *temporary operation* (i.e., temporary pickup and temporary dropoff). Finally, visits to balanced stations are optional for the SBRP. Salazar-González and Santos-Hernández (2015) considered a similar yet different problem, in which an upper limit is imposed on the number of visits to the customers and to the depot, and the single vehicle that performs the rebalancing is not forced to leave the depot with an empty load.

An increasing number of works regarding bike sharing systems and related issues, such as the balancing of their stations, has been published over the last years. Exact approaches for multiple vehicle SBRPs were suggested by Dell'Amico *et al.* (2014); Di Gaspero *et al.* (2013a,b, 2015); Kloimüllner *et al.* (2015); Raviv *et al.* (2013). Moreover, Alvarez-Valdes *et al.* (2016); Dell'Amico *et al.* (2016); Forma *et al.* (2015); Papazek *et al.* (2014, 2013); Raidl *et al.* (2013); Rainer-Harbach *et al.* (2013, 2014) also addressed different types of multiple vehicle SBRPs, but with heuristics.

Several exact Benchimol *et al.* (2011); Chemla *et al.* (2013a); Erdoğan *et al.* (2015, 2014); Salazar-González and Santos-Hernández (2015) and heuristic (Ho and Szeto, 2014; Pal and Zhang, 2015) algorithms were proposed for single vehicle SBRPs. Furthermore, in contrast to static rebalancing, there are relatively few works related to dynamic rebalancing Caggiani and Ottomanelli (2013); Chemla *et al.* (2013b); Contardo *et al.* (2012); Kloimüllner *et al.* (2014); Schuijbroek *et al.* (2013).

The works of Chemla *et al.* (2013a) and Erdoğan *et al.* (2015) were the only ones to consider the same variant dealt in the present paper. Chemla *et al.* (2013a) proposed a mathematical formulation over an extended graph, where each station is replicated according to an upper bound on the number of visits. Due to its visible intractability, two relaxations were developed. The authors also presented among other contributions, a polynomial algorithm to compute optimal bike displacements for a given sequence of vertices, which is useful to determine if a route is feasible or not, as well as tabu search heuristics and a branch-and-cut algorithm that solves a relaxation of the problem. Erdoğan *et al.* (2015) proposed the first exact method for the problem, which consists of a branch-and-cut algorithm that makes use of no-good cuts, and they reported optimal solutions for instances with up to 60 stations.

Despite the advances on the development of efficient exact approaches for SBRPs, heuristic methods still appear to be more suitable for dealing with medium and large size instances of this challenging class of problems. In addition, high quality heuristic solutions may be crucial to improve the runtime performance of exact algorithms.

This work proposes a hybrid iterated local search (ILS) based heuristic for the single vehicle SBRP considered in Chemla *et al.* (2013a) and Erdoğan *et al.* (2015). Hybridized ILS algorithms, especially when combined with randomized variable neighborhood descent (RVND), revealed to be very effective when solving a large variety of vehicle routing problems Dell'Amico *et al.* (2016); Penna *et al.* (2013); Silva *et al.* (2015); Subramanian (2012); Subramanian *et al.* (2010); Vidal *et al.* (2015), including those involving only a single vehicle (Blum and Roli, 2003; Subramanian and Battarra, 2013).

The algorithm that was developed combines successful ingredients from previous works with some problem-specific procedures suggested in Chemla *et al.* (2013a) to improve the solution quality, as well as to check if a solution is infeasible. We also implemented several perturbation mechanisms and the impact of each possible combination on the solution quality and CPU time are measured by extensive computational experiments on a subset of challenging test-problems. The results obtained on 980 benchmark instances from the literature show that our algorithm is quite competitive when compared to other methods, and a number of new best known solutions is reported. We also conduct an analysis on how the performance of the algorithms in terms of solution quality and CPU time varies according to the number of stations and the vehicle capacity.

The remainder of the paper is organized as follows. Section 2 presents a formal problem definition. Section 3 describes the proposed heuristic algorithm. Section 4 reports and discusses the computational results, and Section 5 contains the concluding remarks.

2 Problem description

Let n be the number of stations, $V = \{1, ..., n\}$ be the set of vertices representing their locations (station 0 represents the depot), and A be the set of arcs in a complete and directed graph $G = (V \cup \{0\}, A)$. For each arc $a_{(i,j)} \in A$, there is a cost c_a, satisfying the triangular inequality $(c_{(i,j)} + c_{(j,k)} \geq c_{(i,k)}, \forall i, j, k \in V)$.

For each $i \in V$, let $p_i \in \mathbb{Z}$ be the amount of bikes initially stored, $p'_i \in \mathbb{Z}$ be the number of bikes requested by i after the service is performed, and $d_i = p'_i - p_i$ be the total demand. When $d_i > 0$ and $d_i < 0$, we assume that $i \in V$ is a delivery and a pickup station, respectively. A station $i \in V$ may have no demand ($p_i = p'_i$) and in this case the visit becomes optional. Each station $i \in V$ has a capacity $q_i \in \mathbb{Z}$ and the depot is assumed to have no bikes, i.e., $q_0 = p_0 = p'_0 = 0$. Finally, let $Q \in \mathbb{Z}$ be the vehicle capacity.

The objective is to find a least-cost route that starts and ends at the depot, visits each station with non-zero demand at least once, meets the demands of all stations (i.e., the initial load p_i is changed to the target demand $p'_i, \forall i \in V$), and does not violate the minimum (zero) and maximum (Q) load limits. Therefore, the number of bikes to be collected or delivered at each visit to a station should be appropriately determined in order to respect such constraints.

Finally, stations may serve to perform temporary operations (preemption), either as a temporary depot or a temporary buffer, i.e., supply more bikes than their initial demand or hold more bikes (without exceeding its inventory load capacity), and in both cases have their demand satisfied in later visits.

Figure 1 shows a graphical representation of an optimal solution for the benchmark instance n20q10D ($n = 20$ and $Q = 10$). The nodes are distributed according to the spatial coordinates of the stations. The positive and negative values next to the nodes are the number of bikes collected and delivered, respectively. The arcs and their associated values represent the vehicle traveling to the next station in the sequence and the vehicle load, respectively. For example, the vehicle delivers 2 bikes in the first visit to station 12, collects 10 at station 10, returns to 12 to deliver 6 more (meeting the demand of 8) and then travels to station 14 with a load of 4 bikes.

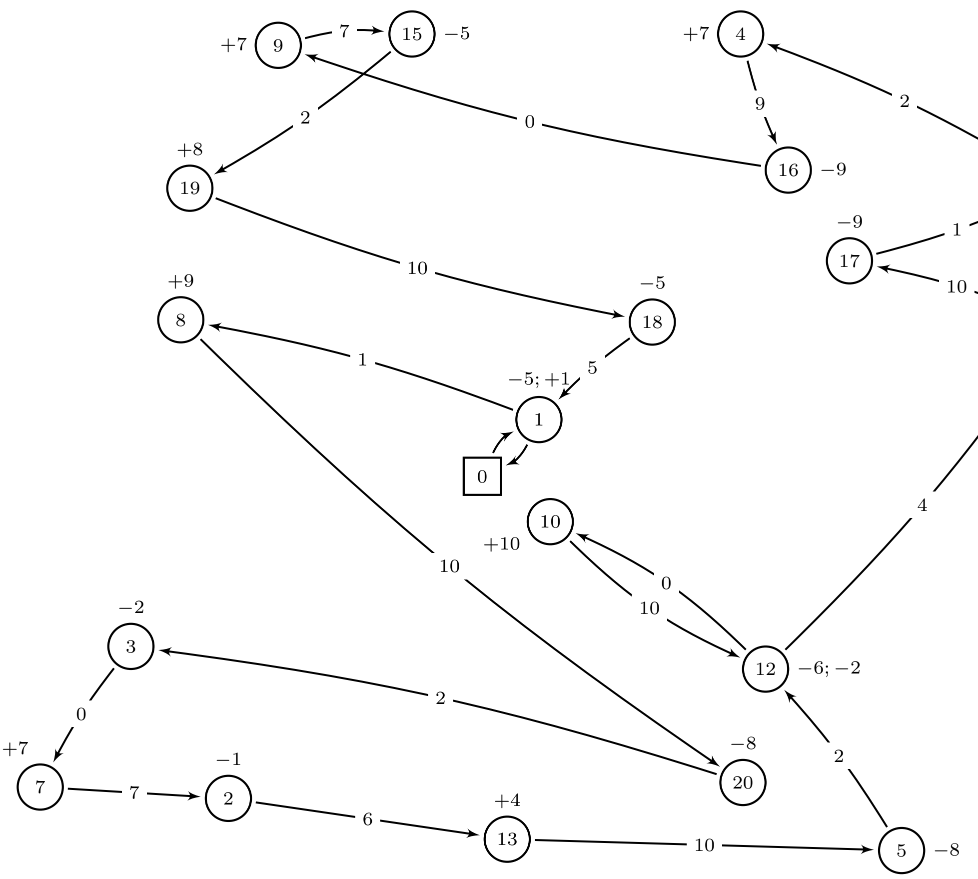


Figure 1: Representation of optimal solution with value 5989 for instance n20q10D

3 Proposed heuristic

ILS iteratively alternates between local search (intensification) and perturbation (diversification) mechanisms with a view of finding high quality solutions. In our case, we embed a variable neighborhood descent (VND) (Mladenović and Hansen, 1997) based procedure in the local search phase of the metaheuristic. As in previous works (e.g., Penna *et al.*, 2013, and Silva *et al.*, 2015), the neighborhoods of our algorithm are examined in a random ordering during the search (RVND).

As opposed to most of the former ILS implementations cited in Section 1, infeasible solutions are temporary accepted after the application of perturbation moves, not only for the sake of diversification, but also as an attempt to escape from local optimal solutions. This modification was crucial for the favorable performance of the heuristic when dealing with the single vehicle SBRP considered here, which appears to be more challenging to solve than other VRPs where ILS was successfully applied to obtain high quality solutions by only considering the feasible search space.

The proposed hybrid heuristic, called ILS_{SBRP}, combines multiple restarts, local search, perturbations mechanisms, and a repair phase. Figure 2 illustrates the flowchart of ILS_{SBRP}. For each of the I_R restarts, a feasible initial solution is generated using a simple greedy randomized constructive algorithm (see Section 3.3). Next, local search, perturbation and repair procedures are successively applied until the

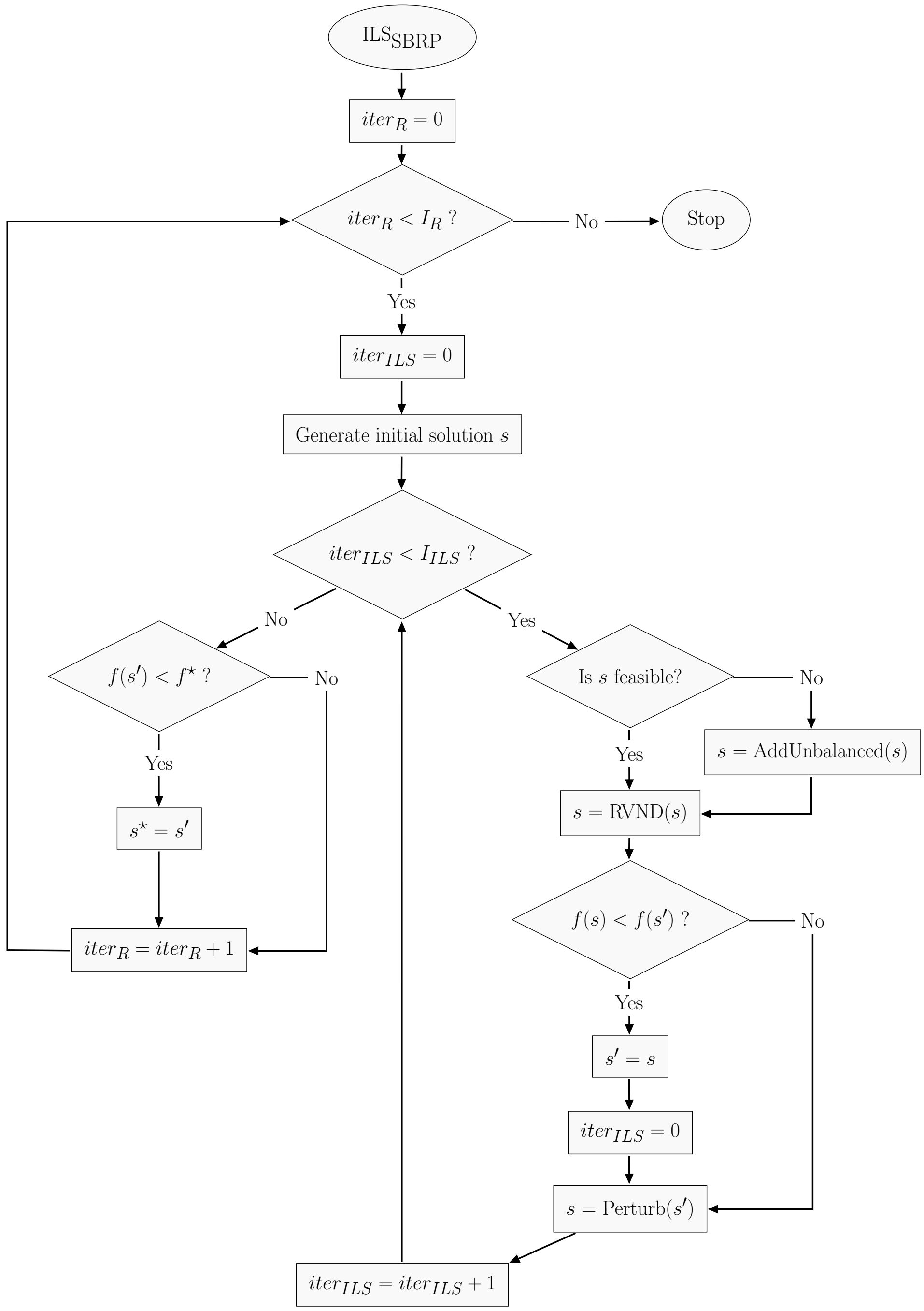


Figure 2: ILS$_{\text{SBRP}}$ flowchart

stopping criterion is met, that is, when the number of consecutive attempts to escape from a local optimal solution reaches I_{ILS} trials. Because perturbation moves are allowed to produce infeasible solutions, we implemented a procedure called AddUnbalanced (Chemla *et al.*, 2013a) (see Section 3.2) with the aim of repairing such solutions. Nevertheless, there is no guarantee that a solution will be feasible after applying this procedure. When an infeasible solution is not totally repaired and the local search does not find a move that leads to a feasible solution, then the infeasible solution is disregarded. Note that perturbation is always applied over the best solution of the current multi-start iteration. Finally, ILS$_{\text{SBRP}}$ returns the best solution found among all restarts.

3.1 Solution representation

A solution for the single vehicle SBRP considered in the present work can be represented as a sequence of visits to stations, starting and ending at the depot, along with the amount of bikes collected or delivered at each visit.

Three vectors are used as data structures to store: (i) the route, where the first and last element are fixed at 0, i.e., the depot; (ii) the operation performed by the vehicle during a visit, where negative and positive values indicate the amount of bikes delivered and collected, respectively; and (iii) the vehicle load during the route.

As in Chemla *et al.* (2013a), a flow network is used to check in polynomial time whether or not a solution is feasible, with respect to bike displacements and vehicle capacity, given a sequence of vertices representing visits to stations. A detailed explanation can be found in Appendix A.

We also use another data structure which consists of a key-value map composed by $n + 1$ elements that store the number of visits performed at each station. This is useful, for example, to check whether a solution includes all stations with non-zero demand. Note that information hold in (ii) is extracted from the computed bike displacements when solving the max-flow problem (see Appendix A). From such, it is possible to derive, in linear time, the vehicle loads in (iii) by the adding or subtracting the bike displacements at each visit.

3.2 Repairing infeasible solutions

As already mentioned, infeasible solutions are allowed after perturbations. We therefore implemented a procedure called AddUnbalanced (Chemla *et al.*, 2013a), which tries to repair a solution by adding stations to the route. More precisely, both the most unbalanced station in excess and in default, i and j, respectively, are selected and three moves are possible: (i) adding arcs (j, i) and (i, j) after the existing visit to j; (ii) adding arcs (i, j) and (j, i) after the existing visit to i; (iii) if both i and j are not in the sequence, adding (i, j) at the end of the sequence, before returning to the depot.

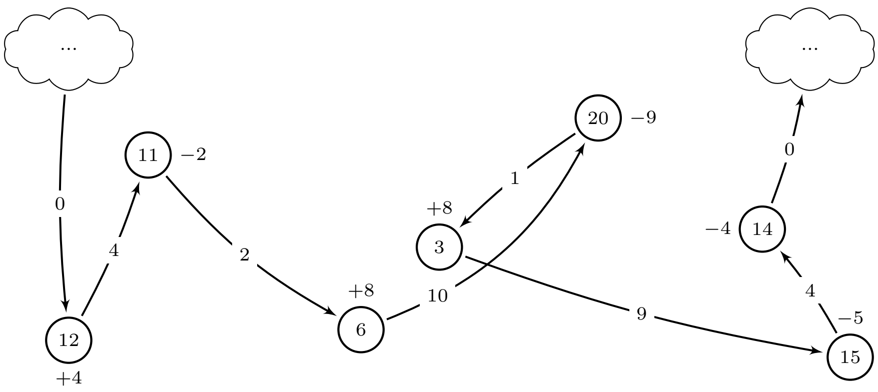
For example, let us consider a scenario where stations $i = 12$ and $j = 14$ are the most unbalanced. More precisely i has initially 20 bikes and a demand of -10, i.e., a pickup station, while j is initially holding 3 out of 10 (target) bikes, i.e., a delivery station with demand 7. An infeasible solution is presented in Figure 3a, where the referred stations are not balanced, that is, their demands are not met, since only 4 bikes were collected in station 12 and 4 bikes were delivered at station 14. Figure 3b shows a modified solution, where after the addition of arcs $(14, 12)$ and $(12, 14)$, a new and feasible configuration of bike displacements were determined by means of the maximum flow check (see Appendix A). We can observe that the second visit complements the first one, meeting the demand of both stations: the vehicle deliveries 1 bike at station 14, collects the remaining 7 at station 12, now balanced, and finally meets the demand of station 14 by delivering 6 more bikes.

It is worth emphasizing that the AddUnbalanced procedure does not necessary lead to a feasible solution. However, in general, experimental results showed that such procedure has a high level of success in fully repairing infeasible solutions.

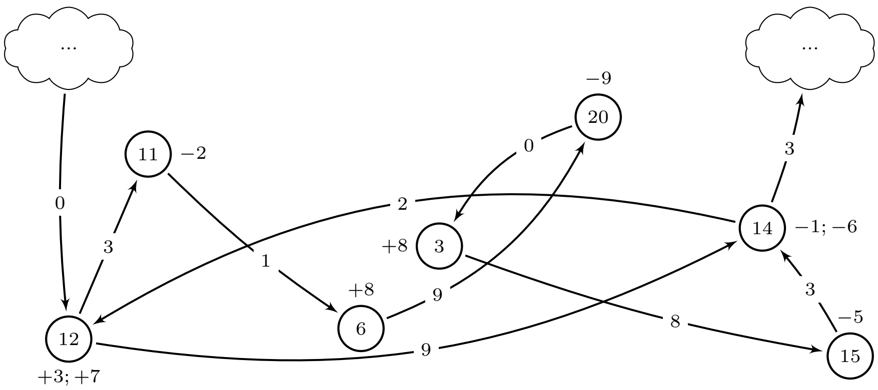
3.3 Constructive Procedure

The pseudocode of the greedy randomized constructive procedure is presented in Alg. 1. The algorithm stores and maintains a list of open vertices (OV) corresponding to stations whose demands are still not fully met. Stations without demand are also included in this list. In order to ensure a level of diversity during the process of generating an initial solution, OV is sorted in random order (line 4).

The algorithm follows a greedy procedure by selecting the first vertex to be inserted at the end of



(a) Infeasible solution



(b) Feasible solution after additional visits to unbalanced stations 12 and 14

Figure 3: Handling an infeasible solution by considering additional visits to unbalanced stations

the route (before the depot) whose demand is completely met by a single visit without violating the load limits ($[0, Q]$). Next, the vehicle load is updated and the station that was inserted into the partial solution is removed from OV (lines 8-12).

However, it may come to a point where no station can be fully served in a single visit, either because the vehicle has not enough bikes to deliver, or the residual capacity is not sufficient to collect the required bikes at once. Hence, a split becomes necessary. The second part of the constructive procedure (lines 13-17) iterates over OV searching for a station whose demand maximizes the number of bikes that can be delivered or collected. Ties are broken according to the nearest insertion criterion. The station demand and vehicle load are updated after the insertion. Next, the algorithm restarts from line 5 and the entire insertion procedure is repeated until OV becomes empty. Note that the generated initial solution is always feasible.

3.4 Local search

Initial and perturbed solutions are possibly improved by means of an RVND based procedure during the local search. RVND consists of systematically examining different types of neighborhoods in a random ordering. In particular, if the best neighbor consists of an improving move, then the search may continue from any of the existing neighborhoods (including the last one to be explored) at random. Otherwise, a different neighborhood other than those that did not succeed in finding an improved move is randomly selected. The procedure ends when all neighborhoods fail to refine the current solution. Only feasible moves are accepted.

The following six neighborhood structures were implemented.

Algorithm 1 Initial Solution Constructive Procedure

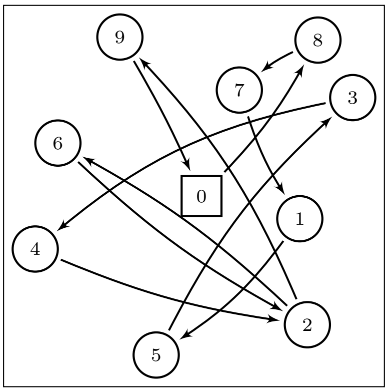
```
Procedure GenerateInitialSolution
Q′ ← Q
Solution ← ∅
OV ← List sorted in random order with all stations where d_i ≠ 0 + random ones with d_i = 0
repeat
    inserted ← false
    for all i ∈ OV do
        if d_i ≤ Q′ or Q − Q′ ≥ d_i then
            Solution ← Solution ∪ i
            Update vehicle capacity and remove i from OV
            inserted ← true
            break
    if not inserted then
        for all j ∈ OV do
            compute exchange_j
        i ← max{exchange_j | j ∈ exchange}
        Solution ← Solution ∪ i
    update OV
    update Q′
until OV ≠ ∅
return Solution
end GenerateInitialSolution.
```

- Reinsertion — $N^{(1)}$: A station is removed and then reinserted in another position of the sequence.
- Or-opt2 — $N^{(2)}$: Two consecutive stations are removed and then inserted in another position.
- Or-opt3 — $N^{(3)}$: Three consecutive stations are removed and then inserted in another position.
- 2-opt — $N^{(4)}$: Two non-adjacent arcs are removed from the sequence and then two new ones are inserted. In other words, a subsequence of the tour is reversed.
- Swap — $N^{(5)}$: Permutation of two stations.
- Suppression — $N^{(6)}$: Given a sequence $L = i_0, i_1, ..., i_k$, a suppression list is composed of visits to stations $i_j, \forall j \in \{1, \ldots, k-1\}$, such that $p'_{i_j} = p_{i_j}$ (zero demand) or $p'_{i_j} \neq p_{i_j}$ and i_j is visited more than once in the tour. The best move, if any, consists in selecting one station to be removed from L so that the solution cost is minimized and the resulting new sequence L' is feasible. For example, Figure 4b shows the removal of an additional visit to station 2, thus modifying the subsequence $2, 6, 2, 9, 0$ to $2, 6, 9, 0$. This neighborhood was originally proposed by Chemla *et al.* (2013a), but the authors considered all stations.

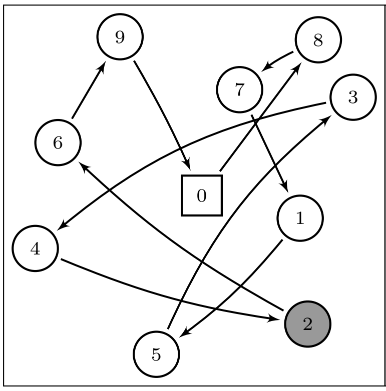
The first five are well-known TSP neighborhood structures, while the last is a problem-specific neighborhood. Figure 4a depicts an initial solution and Figures 4b to 4g illustrate modified solutions that were obtained after changing the previous one by means of one of the neighborhoods described above. For example, Figure 4d shows a solution in which a 2-opt move was applied over the solution shown in Figure 4c. For ease of presentation, values of pickup/delivery operations as well as the vehicle load are omitted.

3.5 Perturbation mechanisms

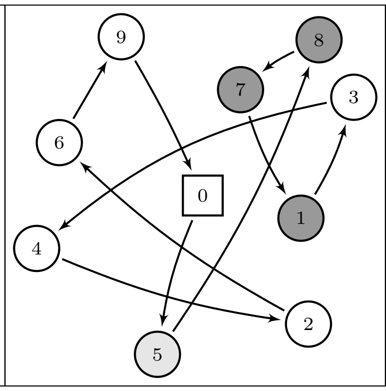
One of the four mechanisms described below is selected at random whenever the algorithm enters the perturbation phase.



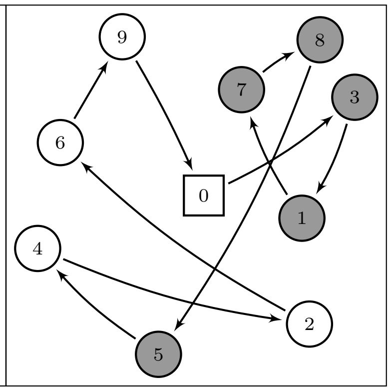
(a) Initial solution



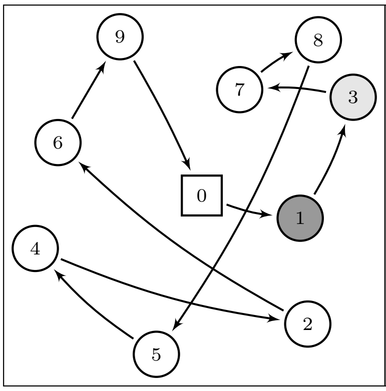
(b) Suppression of second visit to station 2 after visiting 6



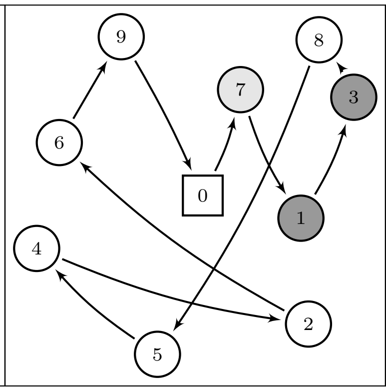
(c) Or-Opt3 of three consecutive stations 8 ,7 and 1



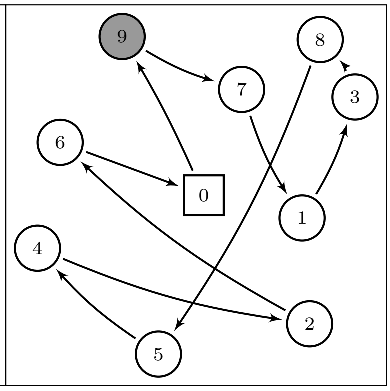
(d) 2-opt on subsequence $5, 8, 7, 1, 3$



(e) Swap between station 1 and station 3



(f) Or-Opt2 of two consecutive stations 1 and 3



(g) Reinsertion of station 9 before station 7

Figure 4: Example regarding the application of neighborhood structures

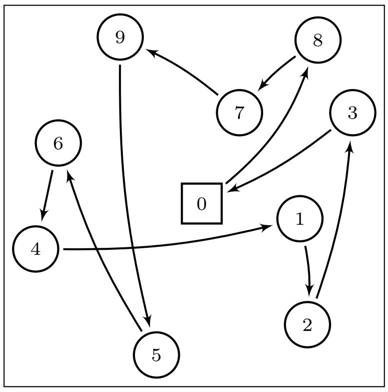
- AddBuffer — $P^{(1)}$: An additional visit to a station is included, expecting to act as buffer, using the cheapest insertion criterion. Unrouted stations are inserted twice using the same criterion (Chemla *et al.*, 2013a).

- AddStations — $P^{(2)}$: This perturbation mechanism generalizes the previous one in the sense of allowing multiple visits to be added in the solution, but with a different insertion criterion. More precisely, an additional visit (or two, in the case of unrouted stations) to up to three random stations are included towards the end of the route. Here we only consider stations that are visited at most once. Adjacent visits to the same station are forbidden.

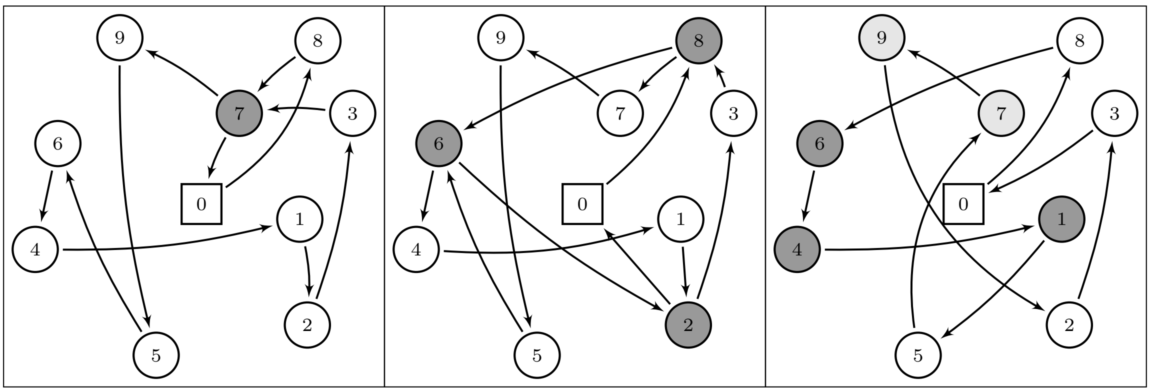
- Double-Bridge — $P^{(3)}$: Introduced by Martin *et al.* (1991) for the TSP, this perturbation consists of a permutation of two subsequences. As a result, four arcs are removed and four new ones are added so as to generate a new sequence.

- Suppression — $P^{(4)}$: A suppression move (see Section 3.4) is applied at random, but in this case the resulting modified sequence is allowed to be infeasible.

Figure 5 shows an example of perturbations applied over a (supposedly) local optimal solution. In Figure 5d, a Double-Bridge move is applied by interchanging subsequence $6, 4, 1$ with subsequence $7, 9$. Figure 5b shows the AddBuffer perturbation, when an additional visit to station 7 is performed expecting it to act as a buffer. In Figure 5c, the perturbation AddStations is applied by adding two random visits: one to station 8 and another one to station 6.



(a) Solution before perturbation



(b) AddBuffer (c) AddStations (d) Double-Bridge

Figure 5: Example regarding the application of perturbation mechanisms

4 Computational experiments

The ILS_{SBRP} algorithm was coded in C++ (g++ 4.6.4) and the computational tests were carried on an Intel®Core$^{\text{TM}}$ i7-3770 with 3.40 GHz and 16 GB of RAM running Ubuntu 14.04. Only a a single thread was used during the experiments.

4.1 Instances

The benchmark instances used to test the proposed algorithm are those suggested by Hernández-Pérez and Salazar-González (2004a), which were originally created for the one-commodity pickup and delivery traveling salesman problem. The benchmark contains instances ranging from 20 to 500 customers (stations), and vehicle capacities ranging from 10 to 1000. For each pair of problem size and vehicle capacity, there are 10 instances named from A to J and, for each vertex i, there is a demand $d_i \in [-10, 10]$. Chemla *et al.* (2013a) and Erdoğan *et al.* (2015) only reported results for a subset of instances of the referred benchmark. Therefore, in order to compare our results with theirs, we tested ILS_{SBRP} for all instances considered in at least one of the two works (see Section 4.4). Furthermore, to compute the initial and final targets as well as the load capacity for each station, the same procedures adopted by such authors were employed: for each vertex i, $p_i = \alpha \times 10$, $p'_i = \alpha \times (10 + d_i)$, $q_i = \alpha \times 20$, where α is an input parameter, and experiments were conducted with $\alpha = 1$ and $\alpha = 3$. In order to properly compare our results with those in Chemla *et al.* (2013a) and Erdoğan *et al.* (2015), we adopted their same convention of rounding down the values of the cost matrix to the nearest integer (floor), although we noticed that this can cause slight violations of the triangle inequality.

4.2 Impact of the perturbation mechanisms

In this section we are interested in evaluating the impact of the perturbation mechanisms described in Section 3.5, that is, AddBuffer ($P^{(1)}$), AddStations ($P^{(2)}$), Double-Bridge ($P^{(3)}$), and Suppression ($P^{(4)}$). In view of this, we selected a subset of 30 challenging instances for performing the experiments. These instances were chosen according to the largest gap values with respect to the lower bounds reported in Erdoğan *et al.* (2015). We ran ILS_{SBRP} 10 times for each of the 30 instances considering all possible combinations of perturbations. For this testing we arbitrarily adopted $I_R = 10$ and $I_{ILS} = n$.

Table 1 shows the impact of each combination over the average gaps (computed as $(UB - LB)/LB$) and CPU times required by ILS_{SBRP} to run to completion. From the results obtained we believe that $P^{(2)} + P^{(3)} + P^{(4)}$ seems to offer a good compromise between solution quality (average gap $< 1\%$) and CPU time. Hence, we herein decided to adopt this configuration for the perturbation mechanisms.

Table 1: Impact of different combinations of the perturbation mechanisms

Perturbations used	Avg. gap (%)	Time (s)
$P^{(1)}$	2.43	244.40
$P^{(2)}$	1.08	773.49
$P^{(3)}$	1.04	498.24
$P^{(4)}$	1.56	249.88
$P^{(1)} + P^{(2)}$	1.27	506.45
$P^{(1)} + P^{(2)} + P^{(3)}$	1.05	514.41
$P^{(1)} + P^{(2)} + P^{(3)} + P^{(4)}$	1.11	431.43
$P^{(1)} + P^{(2)} + P^{(4)}$	1.25	417.30
$P^{(1)} + P^{(3)}$	1.21	371.44
$P^{(1)} + P^{(3)} + P^{(4)}$	1.30	331.70
$P^{(1)} + P^{(4)}$	1.78	248.69
$P^{(2)} + P^{(3)}$	0.91	630.29
$P^{(2)} + P^{(3)} + P^{(4)}$	0.99	505.70
$P^{(2)} + P^{(4)}$	1.08	503.75
$P^{(3)} + P^{(4)}$	1.29	341.32

4.3 Parameter tuning

The main ILS_{SBRP} parameters to be calibrated are the number of restarts (I_R) and the maximum number of consecutive ILS iterations without improvement over the current local optimal solution (I_{ILS}). Here we set $I_R = 10$, as in Silva *et al.* (2015), where the authors put forward a multi-start ILS that was capable of obtaining state-of-the-art results for the split-delivery VRP.

In previous works, such as those mentioned in Section 1, the value of I_{ILS} was tuned based on the instance size. In VRPs (e.g., Penna *et al.* (2013); Silva *et al.* (2015); Subramanian (2012), and Vidal *et al.* (2015)), this parameter is usually set as a function of the number of customers and vehicles. In TSP-like (or single machine scheduling) problems (e.g., Silva *et al.*, 2012; Subramanian and Battarra, 2013; and Subramanian *et al.*, 2014), I_{ILS} was set only as a function of the number of customers (or jobs). We decided to use the same rationale as in Silva *et al.* (2012), by setting $I_{ILS} = \max\{I_{min}, \beta \times n\}$, where I_{min} and β are input parameters. For the latter we set $\beta = 4$, as in Subramanian *et al.* (2014). Note that I_{min} is more important for small size instances and its role is to prevent low values for I_{ILS}, which in this case may lead to an insufficient number of ILS iterations required for obtaining high quality (or even optimal) solutions. We then tested several values for I_{min}, more specifically, 100, 120, 140, 160, and 180. For each of them, we ran ILS_{SBRP} 10 times for all instances containing 20 and 30 stations. The average results obtained suggest that $I_{min} = 160$ seems to provide a good compromise between solution quality and CPU time, since the algorithm managed to find almost all best known solutions in a relatively short amount of time when using this value. Therefore, we set $I_{ILS} = \max\{160, 4 \times n\}$.

4.4 Comparison with the literature

ILS_{SBRP} was executed 10 times for each instance with a time limit of 1 hour. The results found by our algorithm are compared with the upper bounds determined by two versions of the tabu search heuristic of Chemla *et al.* (2013a). The first one (TS1) starts from an initial solution generated by a greedy procedure, while the second version (TS2) receives the solution produced by their branch-and-cut algorithm (over a relaxation of the problem) as initial solution. Detailed results of TS1 and TS2 are available at `http://cermics.enpc.fr/~meuniefr/SVOCPDP.html`. According to the authors, it should be noted that UB1 is the best solution found by TS1 and UB2 is the best solution found considering both TS1 and TS2. A comparison is also performed with the lower and upper bounds obtained by the exact Branch-and-cut algorithm of Erdoğan *et al.* (2015). Regarding the benchmark instances, Chemla *et al.* (2013a) considered $n \in \{20, 40, 60, 100\}$ and $Q \in \{10, 30, 45, 1000\}$, whereas Erdoğan *et al.* (2015) considered $n \in \{20, 30, 40, 50, 60\}$ and $Q \in \{10, 15, 20, 25, 30, 35, 40, 45, 1000\}$.

Chemla *et al.* (2013a) ran their experiments on an AMD Athlon 5600+ 2.8 GHz with 16 GB of RAM, while Erdoğan *et al.* (2015) performed their testing on an Intel i7 3.60 GHz and 8 GB of RAM. On the one hand, because the hardware performance of the first appears to be quite inferior to the second, as well as to our intel i7 3.40 GHz, we decided to estimate an approximation factor based on the single thread rating values reported in `https://www.cpubenchmark.net/compare.php?cmp[]=86&cmp[]=896`, so as to better compare the runtime performance of the methods. According to the referred website, the AMD Athlon 5600+ 2.8 GHz is roughly 2.43 times slower than our processor. We thus report the original CPU time values of Chemla *et al.* (2013a) divided by a factor of 2.43. On the other hand, since the machine used in Erdoğan *et al.* (2015) is rather equivalent to ours, perhaps even slightly faster, we decided to consider the original runtime values reported by the authors.

4.4.1 Results for instances with up to 60 stations

The aggregate average results for instances containing 20, 30, 40, 50, and 60 stations are reported in Tables 2 and 3, where **Instance group** denotes the set of 10 instances of a particular group (for example, group n20q10 contains 10 instances with $n = 20$ and $Q = 10$); **UB1 Gap (%)**, **UB2 Gap (%)**, and **Gap (%)** correspond to the gap between UB1, UB2, and the upper bound found by Erdoğan *et al.* (2015), respectively, and the lower bound reported in Erdoğan *et al.* (2015); **Time (s)**, **UB1 Time (s)**, and **UB2 Time (s)** indicate, respectively, the CPU time in seconds spent by Erdoğan *et al.* (2015), TS1, and TS2, where the last two are scaled to our processor as mentioned above; **Avg. Gap (%)** and **Best Gap**

(%) are the gaps of the average solution and the best solution, respectively, found by ILS_{SBRP} over the 10 runs with respect to the lower bounds in Erdoğan *et al.* (2015); **Avg. Time (s)** is the average CPU time in seconds spent by ILS_{SBRP} to completion over the 10 runs; **Avg.** $\mathbf{TT_{UB2}}$ **(s)** denotes the average time over the 10 runs to find or improve the best heuristic solution found in Chemla *et al.* (2013a) (UB2); and **Avg. NV** is the average number of visits of the final solutions found by ILS_{SBRP}. Detailed results are reported in Appendix B, including the best solution found when considering all experiments (**Best of all exp.**).

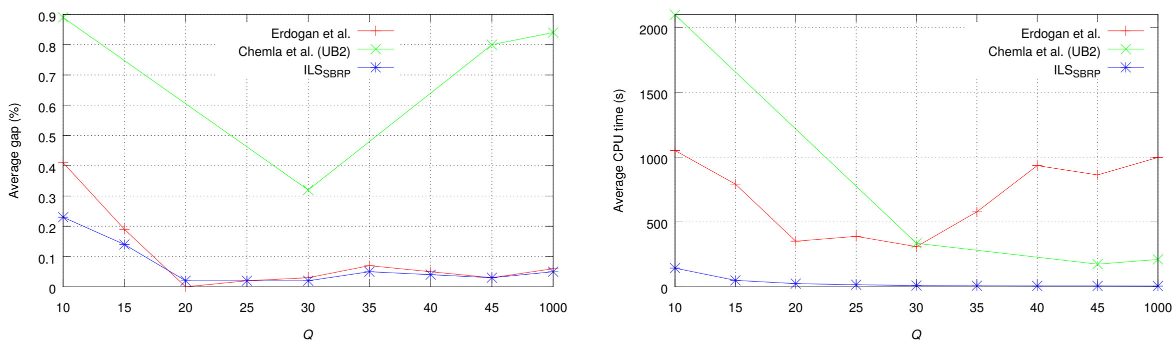
Table 2: Aggregate average results per instance group for $n \in \{20, 30, 40, 50, 60\}$ and $\alpha = 1$

Instance group	Erdoğan et al. 2015		Chemla et al. 2013b				ILS_{SBRP}				
	Gap (%)	Time (s)	UB1 Gap (%)	UB1 Time (s)	UB2 Gap (%)	UB2 Time (s)	Avg. Gap (%)	Best Gap (%)	Avg. Time (s)	Avg. TT_{UB2} (s)	Avg. NV
n20q10	0.00	0.35	2.57	2.75	0.00	3.53	0.06	0.00	5.84	0.38	20.10
n20q15	0.00	0.30	-	-	-	-	0.00	0.00	2.13	-	19.19
n20q20	0.00	0.13	-	-	-	-	0.00	0.00	0.94	-	18.65
n20q25	0.00	0.15	-	-	-	-	0.00	0.00	0.63	-	18.62
n20q30	0.00	1.96	2.47	2.22	0.39	2.38	0.00	0.00	0.62	0.01	18.66
n20q35	0.00	1.12	-	-	-	-	0.00	0.00	0.46	-	18.70
n20q40	0.00	1.22	-	-	-	-	0.00	0.00	0.46	-	18.65
n20q45	0.00	1.13	1.52	2.71	0.01	2.83	0.00	0.00	0.45	0.01	18.62
n20q1000	0.00	0.83	2.43	2.92	0.00	3.04	0.00	0.00	0.45	0.01	18.62
Avg.	0.00	0.80	2.25	2.65	0.10	2.95	0.01	0.00	1.33	0.10	18.87
n30q10	0.00	6.22	-	-	-	-	0.02	0.00	28.08	-	30.14
n30q15	0.00	3.87	-	-	-	-	0.12	0.00	10.29	-	28.49
n30q20	0.00	163.59	-	-	-	-	0.02	0.02	5.06	-	27.84
n30q25	0.00	5.61	-	-	-	-	0.00	0.00	2.36	-	27.53
n30q30	0.00	82.20	-	-	-	-	0.00	0.00	1.85	-	27.53
n30q35	0.00	293.27	-	-	-	-	0.02	0.00	1.89	-	27.70
n30q40	0.00	584.62	-	-	-	-	0.00	0.00	1.61	-	27.62
n30q45	0.00	221.69	-	-	-	-	0.01	0.00	1.47	-	27.62
n30q1000	0.00	190.20	-	-	-	-	0.00	0.00	1.42	-	27.64
Avg.	0.00	172.36	-	-	-	-	0.02	0.00	6.00	-	28.01
n40q10	0.00	124.80	3.56	151.92	0.09	1752.75	0.09	0.04	56.89	14.02	39.76
n40q15	0.00	25.55	-	-	-	-	0.01	0.00	21.78	-	37.53
n40q20	0.00	14.72	-	-	-	-	0.01	0.00	9.33	-	37.01
n40q25	0.03	723.88	-	-	-	-	0.04	0.03	5.79	-	36.83
n40q30	0.00	36.56	4.05	92.72	0.00	93.87	0.00	0.00	4.43	0.06	36.79
n40q35	0.00	38.66	-	-	-	-	0.00	0.00	3.36	-	36.77
n40q40	0.00	70.65	-	-	-	-	0.00	0.00	3.13	-	36.79
n40q45	0.00	74.28	4.69	93.63	0.61	94.82	0.00	0.00	2.99	0.04	36.83
n40q1000	0.00	70.17	5.07	112.48	0.77	114.54	0.00	0.00	2.95	0.03	36.82
Avg.	0.00	131.03	4.34	112.69	0.37	514.00	0.02	0.01	12.29	3.54	37.24
n50q10	0.79	1198.48	-	-	-	-	0.30	0.23	210.98	-	49.64
n50q15	0.43	1970.12	-	-	-	-	0.29	0.23	75.07	-	46.71
n50q20	0.00	295.45	-	-	-	-	0.05	0.00	35.85	-	46.11
n50q25	0.00	272.82	-	-	-	-	0.00	0.00	25.52	-	45.71
n50q30	0.00	177.40	-	-	-	-	0.00	0.00	13.18	-	45.47
n50q35	0.24	1461.09	-	-	-	-	0.16	0.16	10.61	-	45.63
n50q40	0.01	1408.94	-	-	-	-	0.01	0.01	8.83	-	45.48
n50q45	0.00	1221.33	-	-	-	-	0.00	0.00	8.35	-	45.41
n50q1000	0.11	1909.76	-	-	-	-	0.09	0.09	6.70	-	45.44
Avg.	0.18	1101.71	-	-	-	-	0.10	0.08	43.90	-	46.18
n60q10	1.24	3924.62	13.62	412.18	2.57	4533.96	0.67	0.57	419.95	35.15	60.21
n60q15	0.51	1957.50	-	-	-	-	0.30	0.27	140.29	-	56.48
n60q20	0.00	1285.03	-	-	-	-	0.00	0.00	72.99	-	55.65
n60q25	0.07	943.42	-	-	-	-	0.07	0.07	44.32	-	55.13
n60q30	0.13	1252.65	7.17	416.50	0.57	911.58	0.08	0.07	29.63	2.46	55.22
n60q35	0.13	1096.98	-	-	-	-	0.06	0.05	22.52	-	55.01
n60q40	0.22	2607.91	-	-	-	-	0.19	0.19	21.10	-	55.33
n60q45	0.15	2795.20	7.11	410.29	1.78	427.01	0.16	0.15	19.85	0.43	55.42
n60q1000	0.18	2816.42	7.14	413.87	1.76	515.42	0.18	0.18	16.28	0.49	55.31
Avg.	0.29	2075.52	8.76	413.21	1.67	1596.99	0.19	0.17	87.44	9.63	55.97

From Table 2, it can be observed that the quality of the solutions found by ILS_{SBRP}, as well as those obtained by the algorithm of Erdoğan *et al.* (2015), are visibly superior than the ones determined by the tabu searches of Chemla *et al.* (2013a), especially TS1. Such superiority becomes even more prominent for $\alpha = 3$, as presented in Table 3. Also, the average CPU times spent by ILS_{SBRP} to find or improve the best solutions reported by Chemla *et al.* (2013a) (UB2) are rather small in most cases, sometimes only a matter of relatively few seconds, except for the instance group n40q10 when $\alpha = 3$, where the proposed algorithm required more CPU time.

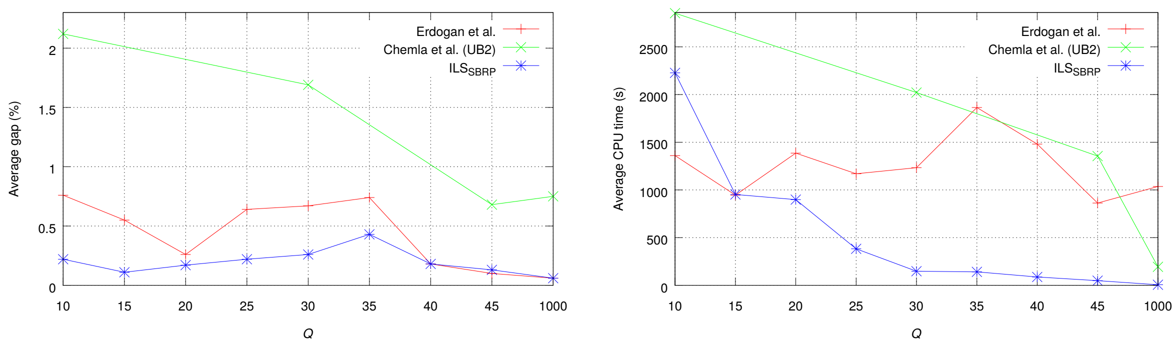
In addition, assuming the same values for the demands, the smaller the vehicle capacity, the larger the relative number of visits. This increases the size of the tour, thus affecting the number of operations performed during the local search, and possibly the number of ILS iterations, as more moves are required to be evaluated.

Figures 6 and 7 show how the average gaps and CPU times of each method vary according to the value of Q. We omit the results of TS1 because the associated gaps are quite inferior when compared to those obtained by the other algorithms. While the average gaps of ILS_{SBRP} tend to be larger for very small values of Q, the average CPU time decreases as the value of Q increases, both for $\alpha = 1$ and $\alpha = 3$. A similar behavior regarding the CPU time performance can be observed for the heuristic of Chemla *et al.* (2013a), as opposed to the algorithm of Erdoğan *et al.* (2015), which does not seem to have a consistent pattern when considering this aspect.



(a) Average gap (%) (b) Average CPU time (s)

Figure 6: Average gap (%) and average CPU time (s) per Q and $\alpha = 1$



(a) Average gap (%) (b) Average CPU time (s)

Figure 7: Average gap (%) and average CPU time (s) per Q and $\alpha = 3$

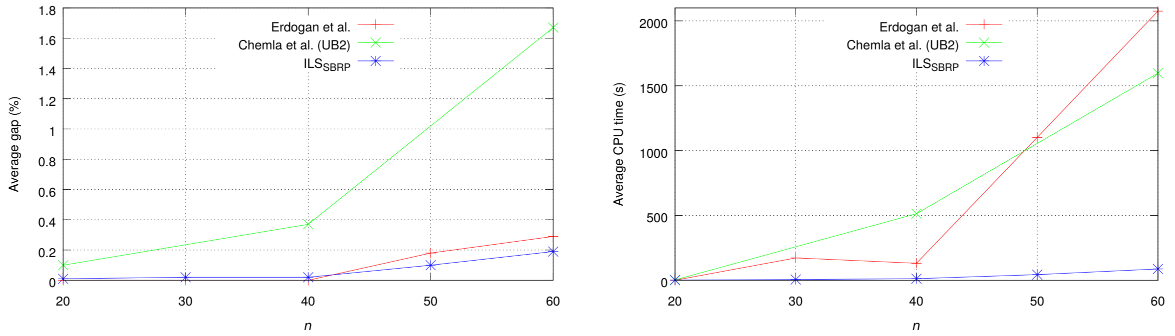
Figures 8 and 9 illustrate the behavior of the average gaps and CPU times of the algorithms as the number of stations increases. Overall, the quality of the solutions found by ILS_{SBRP} and by the algorithm of Erdoğan *et al.* (2015) are equivalent except for $n = 60$ and $\alpha = 3$, where the former clearly outperforms the latter. Moreover, there is a considerable increase on the CPU time for both methods from the literature for $n > 40$, in contrast to ILS_{SBRP}, whose increase appears to be more moderate.

Table 3: Aggregate average results per instance group for $n \in \{20, 30, 40, 50, 60\}$ and $\alpha = 3$

Instance group	**Erdoğan et al. 2015**		**Chemla et al. 2013b**				**ILS$_{\text{SBRP}}$**				
	Gap (%)	**Time (s)**	**UB1 Gap (%)**	**UB1 Time (s)**	**UB2 Gap (%)**	**UB2 Time (s)**	**Avg. Gap (%)**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. TT$_{\text{UB2}}$ (s)**	**Avg. NV**
n20q10	0.00	0.48	0.73	40.71	0.00	51.72	0.02	0.00	219.94	18.77	39.38
n20q15	0.00	0.32	-	-	-	-	0.01	0.00	46.86	-	29.27
n20q20	0.00	0.37	-	-	-	-	0.01	0.00	32.96	-	27.16
n20q25	0.00	0.39	-	-	-	-	**0.00**	0.00	12.10	-	22.29
n20q30	0.00	0.35	3.93	3.29	0.00	4.44	0.07	0.00	5.69	0.28	20.03
n20q35	0.00	0.33	-	-	-	-	0.16	0.05	4.46	-	19.71
n20q40	0.00	0.28	-	-	-	-	**0.00**	0.00	2.72	-	19.34
n20q45	0.00	0.31	3.39	2.67	0.00	3.62	**0.00**	0.00	2.12	0.05	19.17
n20q1000	0.00	0.93	3.47	2.63	0.00	2.63	**0.00**	0.00	0.45	0.01	18.60
Avg.	0.00	0.42	2.88	12.33	0.00	15.60	0.03	0.01	36.37	4.78	23.88
n30q10	0.00	153.85	-	-	-	-	0.04	0.00	1115.36	-	57.39
n30q15	0.00	65.36	-	-	-	-	0.03	0.00	206.32	-	42.47
n30q20	0.00	8.16	-	-	-	-	0.03	0.00	133.46	-	39.38
n30q25	0.00	10.27	-	-	-	-	0.10	0.03	65.47	-	33.97
n30q30	0.00	9.91	-	-	-	-	0.02	0.00	28.78	-	30.12
n30q35	0.00	9.37	-	-	-	-	0.22	0.00	24.29	-	29.83
n30q40	0.00	5.92	-	-	-	-	0.08	0.05	11.85	-	28.32
n30q45	0.00	2.96	-	-	-	-	0.14	0.00	9.96	-	28.49
n30q1000	0.00	221.30	-	-	-	-	0.02	0.00	1.39	-	27.59
Avg.	0.00	54.12	-	-	-	-	0.08	0.01	177.43	-	35.28
n40q10	0.00	235.42	4.76	408.07	0.39	3983.91	0.07	0.00	2619.68	457.03	73.67
n40q15	0.00	28.83	-	-	-	-	0.05	0.01	390.64	-	53.45
n40q20	0.00	62.22	-	-	-	-	0.01	0.00	331.38	-	50.29
n40q25	0.00	177.39	-	-	-	-	0.06	0.01	136.27	-	43.57
n40q30	0.00	108.31	4.64	101.43	0.00	1524.21	0.10	0.04	57.86	19.28	39.63
n40q35	0.00	304.70	-	-	-	-	0.13	0.03	55.48	-	39.35
n40q40	0.00	21.68	-	-	-	-	0.01	0.00	34.54	-	38.30
n40q45	0.00	25.74	5.14	113.43	0.00	219.71	0.01	0.00	21.41	3.29	37.49
n40q1000	0.00	80.91	4.58	91.08	0.30	95.60	**0.00**	0.00	2.97	0.03	36.81
Avg.	0.00	116.13	4.78	178.50	0.17	1455.86	0.05	0.01	405.58	119.91	45.84
n50q10	0.99	2693.41	-	-	-	-	**0.33**	0.19	3579.49	-	95.30
n50q15	0.00	1702.17	-	-	-	-	0.06	0.03	1503.56	-	69.44
n50q20	0.89	3085.39	-	-	-	-	**0.53**	0.42	1374.12	-	64.04
n50q25	0.59	2024.55	-	-	-	-	**0.34**	0.24	544.63	-	54.96
n50q30	0.46	1345.21	-	-	-	-	**0.38**	0.29	215.59	-	49.75
n50q35	1.27	4212.45	-	-	-	-	**0.79**	0.59	201.46	-	49.60
n50q40	0.45	3545.41	-	-	-	-	**0.45**	0.39	143.50	-	48.49
n50q45	0.23	2057.76	-	-	-	-	**0.23**	0.18	74.94	-	46.75
n50q1000	0.10	1938.98	-	-	-	-	**0.09**	0.09	6.66	-	45.41
Avg.	0.55	2511.70	-	-	-	-	**0.36**	0.27	849.33	-	58.19
n60q10	2.83	3718.02	46.25	401.91	5.97	4524.10	**0.63**	0.30	3602.77	39.70	115.50
n60q15	2.73	2932.58	-	-	-	-	**0.41**	0.36	2613.02	-	85.09
n60q20	0.39	3772.60	-	-	-	-	**0.26**	0.19	2619.83	-	78.76
n60q25	2.63	3636.12	-	-	-	-	**0.59**	0.46	1153.57	-	67.26
n60q30	2.88	4702.35	13.48	412.35	5.06	4533.51	**0.74**	0.57	430.87	5.75	60.34
n60q35	2.42	4795.69	-	-	-	-	**0.87**	0.66	418.48	-	60.05
n60q40	0.46	3829.99	-	-	-	-	**0.37**	0.31	244.74	-	57.60
n60q45	0.26	2223.52	15.14	413.41	2.04	3840.61	**0.26**	0.23	136.54	7.77	56.44
n60q1000	0.18	2940.39	7.47	414.81	1.94	483.46	**0.18**	0.17	15.97	0.11	55.26
Avg.	1.64	3616.81	20.59	410.62	3.75	3345.42	**0.48**	0.36	1248.42	13.33	70.70

However, this was somewhat expected since the CPU effort of the algorithms of Erdoğan *et al.* (2015) and of Chemla *et al.* (2013a) tend to increase exponentially with increasing values of n.

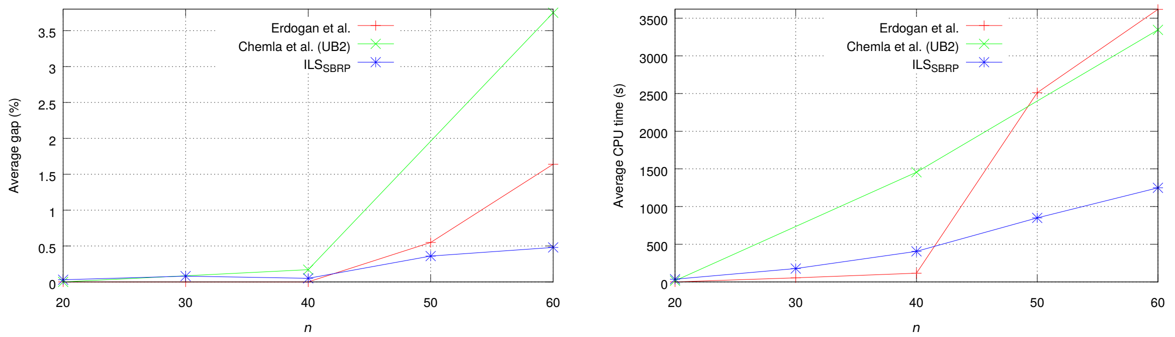
Finally, Table 4 shows a summary of the best solutions found by the proposed algorithm, where **#Opt**



(a) Average gap (%)

(b) Average CPU time (s)

Figure 8: Average gap (%) and average CPU time (s) per n and $\alpha = 1$



(a) Average gap (%)

(b) Average CPU time (s)

Figure 9: Average gap (%) and average CPU time (s) per n and $\alpha = 3$

denotes the number of optimal solutions, **#Impr.** corresponds to the number of improved solutions, **#Equal** indicates the number of equal solutions, and **#Worse** is the number of worse solutions. The results of Chemla *et al.* (2013a) were not included in these tables because they are dominated by those obtained by our heuristic for all instances. For $\alpha = 1$, ILS_{SBRP} found 419 of the 424 known optimal solutions and improved the result of 17 of the 26 instances that remain open. As for $\alpha = 3$, ILS_{SBRP} achieved 377 out of 399 proven optimal solutions and improved the best known solution of 44 out of 51 open instances.

Table 4: Summary of the performance of the best solutions aggregated by n

	n	**Erdoğan et al. 2015**	**ILS$_{\text{SBRP}}$**			
		#Opt	**#Opt**	**#Impr.**	**#Equal**	**#Worse**
$\alpha = 1$	20	90	90	0	90	0
	30	90	89	0	89	1
	40	89	87	0	88	2
	50	83	83	5	85	0
	60	72	70	12	76	2
	Total	424	419	17	428	5
$\alpha = 3$	20	90	89	0	89	1
	30	90	87	0	87	3
	40	90	83	0	83	7
	50	69	63	17	67	6
	60	60	55	27	58	5
	Total	399	377	44	384	22

4.4.2 Results for instances with 100 stations

Tables 5 and 6 illustrate the detailed results found by our algorithm and the tabu searches of Chemla *et al.* (2013a) for every instance containing 100 stations. In this case, the gaps are computed with respect to the lower bound reported in Chemla *et al.* (2013a). The results obtained show that ILS_{SBRP} clearly outperforms the methods from the literature, both in terms of solution quality and CPU time. In general, the proposed heuristic was capable of significantly improving the best known solution of all instances.

In addition, when considering $\alpha = 1$, ILS_{SBRP} required, on average, at most 8 seconds to find or improve the best results of Chemla *et al.* (2013a). In some cases, such as those involving $Q \geq 30$, our algorithm spent, on average, only a fraction of a second to achieve a superior solution than the best one from the literature. For $\alpha = 3$, more time was required, on average, to accomplish the same purpose, but mostly for $Q = 10$.

5 Concluding Remarks

In this work we proposed a hybrid ILS algorithm that was especially designed to solve a challenging single-vehicle SBRP variant. Extensive computational experiments were conducted on 980 instances from the literature ranging from 20 to 100 stations. The results were compared with those reported in Chemla *et al.* (2013a) and Erdoğan *et al.* (2015). For the 900 instances containing up to 60 stations, the proposed heuristic, called ILS_{SBRP}, was capable of finding 796 out of 823 known optimal solutions (97%) and improving the result of 61 out of 77 open instances (79%). Our algorithm only failed to be at least equal to the best known solution in 27 instances (3%). In addition, the average gap of the average solutions found by ILS_{SBRP} and the lower bound reported in Erdoğan *et al.* (2015), for each instance group, was always smaller than 0.7%, thus ratifying the robustness of our heuristic. As for the 80 instances involving 100 stations, ILS_{SBRP} outperformed the best heuristics available for the problem by considerably improving the best known solution for all instances.

Future work may include the development of an enhanced procedure to verify whether or not the solution is feasible. Currently, this is the most time consuming part of the algorithm, where we use a relatively costly max-flow based procedure (Chemla *et al.*, 2013a) for performing this task. Hence, any improvement on this procedure could possibly lead to an improvement on the CPU time. Also, other type of hybridizations could be experimented by combining, for example, efficient exact algorithms with the heuristic suggested in this work.

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Table 5: Detailed results for $n = 100$ and $\alpha = 1$

Instance	**Chemla et al. 2013b**						**ILS_{SBRP}**						
	UB1	**UB1 Gap (%)**	**UB1 Time (s)**	**UB2**	**UB2 Gap (%)**	**UB2 Time (s)**	**Avg. Sol.**	**Avg. Gap (%)**	**Best Sol.**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. TT_{UB2} (s)**	**Avg. NV**
n100q10A	14921	45.58	681.15	13273	29.50	4805.44	11283.20	10.09	11258	9.84	3558.39	3.23	97.30
n100q10B	17658	59.29	470.81	14981	35.14	4588.93	12669.20	14.29	12609	13.75	3600.31	5.28	102.20
n100q10C	17138	44.75	617.06	15636	32.07	4758.60	13251.00	11.92	13224	11.69	3600.47	4.72	100.70
n100q10D	19278	57.05	489.29	16586	35.12	4620.98	13832.80	12.69	13783	12.29	3600.54	3.23	98.40
n100q10E	16867	69.73	368.51	12513	25.91	4485.81	10974.90	10.44	10954	10.23	3385.98	6.10	105.70
n100q10F	14759	46.88	486.42	12621	25.60	4603.72	11226.20	11.72	11191	11.37	3600.31	5.26	101.30
n100q10G	16772	63.48	380.01	13820	34.71	4498.96	11186.60	9.04	11160	8.78	3347.66	2.40	100.10
n100q10H	15941	45.21	393.16	14863	35.39	4511.70	12339.70	12.41	12308	12.12	3600.40	4.02	106.70
n100q10I	17799	50.46	485.19	16602	40.34	4603.72	13540.70	14.46	13469	13.86	3600.81	4.15	104.60
n100q10J	20044	75.98	459.71	14988	31.59	4578.66	12491.30	9.67	12462	9.41	3600.54	3.72	96.90
Avg.	-	55.84	483.13	-	32.54	4605.65	-	11.67	-	11.33	3549.54	4.21	101.39
n100q30A	12175	62.41	518.46	8033	7.16	4634.94	7820.00	4.31	7820	4.31	225.57	1.47	91.00
n100q30B	11066	48.70	537.77	10223	37.37	4657.54	8094.50	8.77	8094	8.76	570.56	0.26	93.50
n100q30C	12106	50.14	430.96	9149	13.47	4549.08	8505.70	5.49	8503	5.46	480.66	0.70	91.80
n100q30D	11317	45.52	589.95	9690	24.60	4706.43	8339.90	7.24	8336	7.19	602.54	0.52	91.10
n100q30E	10446	35.42	451.91	8479	9.92	4569.21	7992.90	3.62	7986	3.53	403.74	1.03	95.90
n100q30F	11960	61.14	373.85	8281	11.57	4497.73	8028.60	8.17	8020	8.05	316.18	1.24	93.40
n100q30G	11290	46.31	490.94	8872	14.97	4609.88	8075.00	4.64	8075	4.64	246.69	0.24	90.00
n100q30H	11144	42.19	387.82	8944	14.12	4503.89	8257.00	5.35	8257	5.35	630.06	0.52	97.00
n100q30I	12112	45.32	450.68	9189	10.25	4568.80	8674.60	4.08	8652	3.81	547.99	1.61	96.50
n100q30J	10636	44.70	560.37	9014	22.63	4678.90	7923.00	7.79	7923	7.79	475.18	0.36	90.40
Avg.	-	48.19	479.27	-	16.61	4597.64	-	5.95	-	5.89	449.92	0.80	93.06
n100q45A	8494	18.12	757.56	8103	12.69	4876.10	7632.00	6.14	7632	6.14	179.88	0.12	91.00
n100q45B	8838	27.33	391.93	8020	15.54	4508.82	7660.00	10.36	7660	10.36	260.68	0.36	92.50
n100q45C	10056	30.21	435.07	8270	7.09	4551.96	7993.00	3.50	7993	3.50	189.28	0.97	90.40
n100q45D	9442	27.15	614.19	8535	14.94	4729.85	7914.70	6.58	7900	6.38	318.62	0.27	88.20
n100q45E	10258	39.47	613.77	7864	6.92	4729.85	7835.00	6.53	7835	6.53	171.33	7.82	94.10
n100q45F	10348	37.36	485.60	7817	3.76	4602.90	7731.00	2.62	7731	2.62	175.23	1.07	93.30
n100q45G	9856	31.59	668.00	8286	10.63	4791.88	7864.00	4.99	7864	4.99	139.25	0.10	90.00
n100q45H	9506	25.94	481.49	7796	3.28	4597.56	7740.00	2.54	7740	2.54	266.65	5.06	94.00
n100q45I	10334	32.23	426.85	8667	10.90	4543.33	8042.20	2.90	8037	2.84	288.97	0.21	96.10
n100q45J	9021	27.53	536.95	7860	11.12	4656.31	7588.50	7.28	7566	6.96	260.60	0.41	89.70
Avg.	-	29.69	541.14	-	9.69	4658.86	-	5.34	-	5.29	225.05	1.64	91.93
n100q1000A	8447	18.81	682.38	8199	15.32	4803.38	7453.00	4.83	7453	4.83	132.76	0.10	92.00
n100q1000B	8669	22.76	543.52	8183	15.88	4664.11	7491.00	6.08	7491	6.08	172.13	0.09	93.30
n100q1000C	8692	15.81	647.05	8673	15.56	4766.82	7898.50	5.24	7895	5.19	118.31	0.09	90.10
n100q1000D	10116	41.08	489.71	8363	16.63	4605.78	7572.80	5.61	7565	5.50	163.68	0.11	88.80
n100q1000E	8922	17.62	355.78	8071	6.40	4472.26	7771.00	2.44	7771	2.44	125.79	0.09	94.30
n100q1000F	10348	42.47	483.54	8053	10.87	4602.49	7648.00	5.30	7648	5.30	129.92	0.17	93.10
n100q1000G	10954	45.12	432.19	8516	12.82	4549.49	7817.50	3.57	7813	3.51	96.81	0.06	90.10
n100q1000H	9275	22.86	397.68	7786	3.14	3374.94	7593.00	0.58	7593	0.58	185.62	0.36	94.00
n100q1000I	10145	31.58	399.32	8461	9.74	4517.45	7975.00	3.44	7975	3.44	118.25	0.13	96.00
n100q1000J	9178	30.27	446.57	8655	22.84	4565.93	7315.00	3.82	7315	3.82	117.66	0.06	89.40
Avg.	-	28.84	487.77	-	12.92	4492.27	-	4.09	-	4.07	136.09	0.13	92.11

Table 6: Detailed results for $n = 100$ and $\alpha = 3$

Instance	**Chemla et al. 2013b**						**ILS$_{SBRP}$**						
	UB1	**UB1 Gap (%)**	**UB1 Time (s)**	**UB2**	**UB2 Gap (%)**	**UB2 Time (s)**	**Avg. Sol.**	**Avg. Gap (%)**	**Best Sol.**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. TT$_{UB2}$ (s)**	**Avg. NV**
n100q10A	36057	60.84	5133.28	28277	26.14	9301.11	24121.60	7.60	24014	7.12	3610.42	22.11	97.30
n100q10B	47107	71.99	7200.56	35199	28.51	11434.53	29709.60	8.47	29438	7.48	3631.88	49.10	102.20
n100q10C	50606	72.67	486.01	35779	22.08	4682.60	31802.50	8.51	31540	7.62	3623.25	67.37	100.70
n100q10D	47489	51.18	7768.73	37972	20.88	12010.51	33846.70	7.75	33654	7.14	3641.22	92.56	98.40
n100q10E	41002	75.89	776.05	30222	29.65	4938.55	25092.60	7.64	24917	6.89	3613.53	23.73	105.70
n100q10F	43544	86.70	459.30	28488	22.14	4660.42	25307.10	8.51	25176	7.94	3619.96	50.33	101.30
n100q10G	38539	69.26	454.37	28822	26.58	4629.19	24877.20	9.26	24642	8.23	3616.24	34.89	100.10
n100q10H	44411	67.69	587.89	33853	27.83	4816.94	29039.70	9.65	28794	8.72	3615.54	63.92	106.70
n100q10I	48727	65.76	5187.92	37199	26.54	9423.95	32380.00	10.15	32023	8.94	3643.19	62.52	104.60
n100q10J	45590	66.76	355.78	34086	24.68	4543.33	29373.50	7.44	29147	6.61	3630.50	71.32	96.90
Avg.	-	68.87	2840.99	-	25.50	7044.11	-	8.50	-	7.67	3624.57	53.79	101.39
n100q30A	16110	55.73	441.64	13366	29.20	4560.58	11278.00	9.02	11258	8.83	3550.25	2.40	91.00
n100q30B	18739	68.61	346.74	15537	39.80	4464.04	12650.70	13.83	12605	13.41	3600.72	4.28	93.50
n100q30C	18871	61.46	437.53	16116	37.89	4577.84	13231.50	13.21	13224	13.14	3600.42	3.55	91.80
n100q30D	18262	49.67	722.23	16419	34.56	4865.01	13786.00	12.98	13783	12.96	3600.72	3.61	91.10
n100q30E	16867	69.83	368.10	13118	32.08	4486.23	10984.10	10.59	10954	10.29	3194.65	3.51	95.90
n100q30F	14838	46.49	453.55	13674	35.00	4569.62	11245.80	11.02	11191	10.48	3600.31	2.21	93.40
n100q30G	16772	69.37	381.66	13262	33.92	4505.12	11183.30	12.93	11160	12.70	3404.20	3.92	90.00
n100q30H	15609	40.53	543.52	14495	30.50	4660.00	12332.80	11.03	12296	10.70	3600.52	4.03	97.00
n100q30I	19159	57.85	266.63	16620	36.93	4410.22	13519.20	11.38	13469	10.97	3600.51	3.48	96.50
n100q30J	20044	78.22	459.71	15423	37.13	4578.66	12513.00	11.26	12462	10.81	3600.43	3.17	90.40
Avg.	-	59.78	442.13	-	34.70	4567.73	-	11.73	-	11.43	3535.27	3.42	93.06
n100q45A	11372	36.43	717.71	10694	28.30	4833.78	9229.40	10.73	9192	10.28	1597.41	1.78	91.00
n100q45B	16114	74.68	409.59	14520	57.40	4526.08	10233.70	10.93	10209	10.67	2955.64	0.99	92.50
n100q45C	14817	50.09	516.00	13243	34.15	4633.30	10871.50	10.12	10815	9.55	3093.03	1.55	90.40
n100q45D	15845	62.58	424.79	15845	62.58	4540.87	11143.90	14.34	11103	13.92	3562.47	1.03	88.20
n100q45E	11628	32.52	602.68	11400	29.92	4718.34	9521.70	8.51	9498	8.24	1687.03	1.60	94.10
n100q45F	12821	50.90	446.16	12243	44.10	4742.17	9437.70	11.08	9398	10.62	1663.30	1.09	93.30
n100q45G	14829	71.60	436.30	10827	25.29	4553.60	9445.00	9.30	9445	9.30	1215.65	2.09	90.00
n100q45H	13072	42.35	652.80	12319	34.15	4768.87	10226.60	11.37	10206	11.14	2391.88	2.09	94.00
n100q45I	14366	46.89	387.00	14366	46.89	4503.07	10864.10	11.08	10841	10.85	3066.06	1.68	96.10
n100q45J	13989	53.75	494.64	11850	30.24	4611.12	10138.10	11.43	10131	11.35	2469.49	2.09	89.70
Avg.	-	52.18	508.77	-	39.30	4643.12	-	10.89	-	10.59	2370.20	1.60	91.93
n100q1000A	9402	29.43	469.57	8017	10.36	4590.16	7457.20	2.66	7453	2.60	117.51	0.08	92.00
n100q1000B	8793	25.68	506.96	7595	8.55	4627.14	7491.00	7.07	7491	7.07	182.14	0.82	93.30
n100q1000C	9312	21.43	422.74	8554	11.55	4541.69	7904.30	3.08	7895	2.96	118.19	0.07	90.10
n100q1000D	9832	33.73	531.61	7595	3.31	4649.73	7574.00	3.02	7565	2.90	154.08	26.25	88.80
n100q1000E	8922	15.87	355.78	8071	4.82	707.85	7771.00	0.92	7771	0.92	119.50	0.30	94.30
n100q1000F	9371	28.57	721.41	8783	20.50	4838.30	7648.00	4.93	7648	4.93	124.09	0.06	93.10
n100q1000G	10954	46.16	431.78	8219	9.67	4549.08	7816.50	4.30	7813	4.25	103.84	0.18	90.10
n100q1000H	8829	20.19	549.28	8488	15.55	4666.17	7593.00	3.37	7593	3.37	174.74	0.08	94.00
n100q1000I	10664	40.10	306.07	8149	7.06	4421.73	7975.00	4.78	7975	4.78	124.87	0.38	96.00
n100q1000J	8311	20.04	534.49	7976	15.20	4650.56	7315.00	5.65	7315	5.65	111.68	0.12	89.40
Avg.	-	28.12	482.97	-	10.66	4224.24	-	3.98	-	3.94	133.06	2.83	92.11

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Appendix A Checking feasibility

Let $L = i_1, i_2, ..., i_k$ be a sequence of vertices, where $i_1 = i_k = 0$. A directed graph can be built using p_i, p'_i, and q_i for each i in the sequence, as follows:

- Let s be the source of the flow network, and for each vertex i representing the first occurrence of each station in the sequence let us define a set of arcs u_i with capacity p_i;
- Let t be the sink of the flow network, and for each i' representing the last occurrence of each station in the sequence let us define a set of arcs $w_{i'}$ with capacity p'_i;
- For each $j = 2, ..., k-1$ let us define an arc $b_{j,j+1}$ with capacity Q; and
- If a station i is visited more than once, let us define an arc $d_{e,e+1}$ with capacity q_i, between the eth and $(e+1)th$ visits to i.

By computing an s–t maximum flow, one can find optimal bike displacements along the sequence L. For each station i, let us define $\hat{p}_i$ and $\hat{p}'_i$, respectively, as the resulting s–t flow on arcs u_i and w_i. Flow on arcs $b_{j,j+1}$ indicates the number of bikes from i_j to i_{j+1} and flow on arcs $d_{e,e+1}$ denotes the quantity of bikes remaining in a station i after the eth visit and before the $(e+1)th$ visit. Figure 10 depicts a flow network for a sequence $L = 0, 1, 4, 2, 3, 5, 2, 4, 1, 0$, where s and t correspond to the depot.

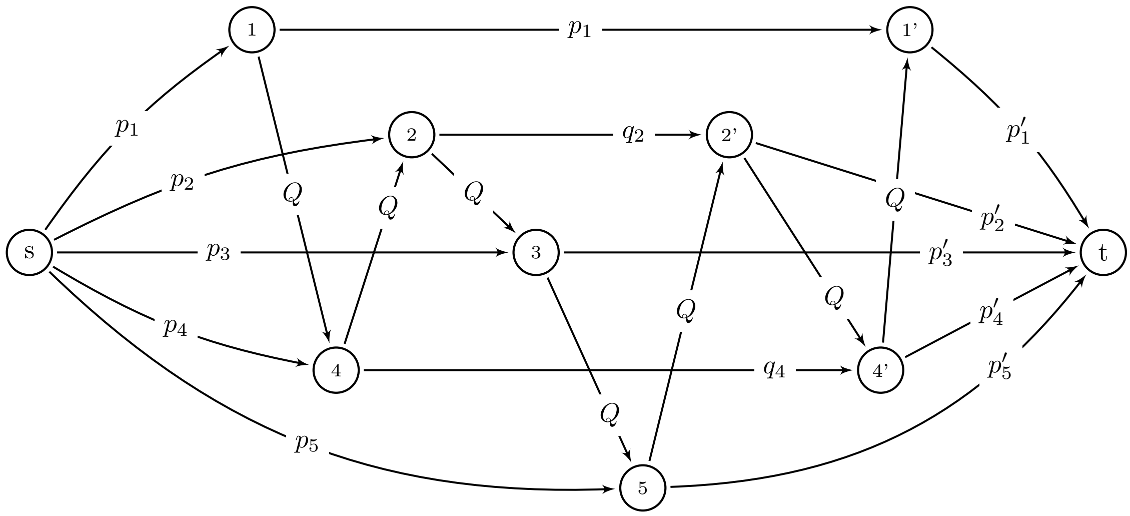

Figure 10: Flow network for feasibility checking

Chemla *et al.* (2013a) states that sequence L induces a feasible solution when $\hat{p}_i = p_i$, for each station i in the sequence. Also, if a vertex i' is not in L, then $\hat{p}_{i'} = \hat{p}'_{i'} = 0$.

Appendix B Detailed results

This appendix presents the detailed results found by ILS_{SBRB}, as well as those obtained by the exact algorithm of Erdoğan *et al.* (2015), for the instances with up to 60 stations.

Table 7: Detailed results for $n \in \{20, 30, 40, 50, 60\}$ and $\alpha = 1$

Instance	Erdoğan et al. 2015				ILS_{SBRP}						
	LB	UB	UB Gap (%)	UB Time (s)	Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n20q10A	4702	4702	0.00	0.26	4702.00	0.00	4702	0.00	2.93	18.00	4702
n20q10B	4769	4769	0.00	0.11	4769.00	0.00	4769	0.00	4.04	19.00	4769
n20q10C	6012	6012	0.00	0.68	6012.00	0.00	6012	0.00	18.64	24.00	6012
n20q10D	5989	5989	0.00	0.20	5989.00	0.00	5989	0.00	7.77	20.00	5989
n20q10E	6245	6245	0.00	1.31	6245.00	0.00	6245	0.00	8.81	20.00	6245
n20q10F	4717	4717	0.00	0.25	4717.00	0.00	4717	0.00	3.49	22.00	4717
n20q10G	5070	5070	0.00	0.07	5070.00	0.00	5070	0.00	2.74	19.10	5070
n20q10H	5542	5542	0.00	0.30	5575.20	0.60	5542	0.00	2.77	19.90	5542
n20q10I	4576	4576	0.00	0.14	4576.00	0.00	4576	0.00	5.07	21.00	4576
n20q10J	4078	4078	0.00	0.16	4078.00	0.00	4078	0.00	2.12	18.00	4078
n20q15A	3948	3948	0.00	0.21	3948.00	0.00	3948	0.00	0.97	17.00	3948
n20q15B	4174	4174	0.00	0.05	4174.00	0.00	4174	0.00	1.31	19.00	4174
n20q15C	5137	5137	0.00	1.20	5137.00	0.00	5137	0.00	4.12	21.00	5137
n20q15D	5446	5446	0.00	0.44	5446.00	0.00	5446	0.00	5.31	20.00	5446
n20q15E	5560	5560	0.00	0.60	5560.80	0.01	5560	0.00	3.73	18.90	5560
n20q15F	4290	4290	0.00	0.04	4290.00	0.00	4290	0.00	1.60	21.00	4290
n20q15G	4489	4489	0.00	0.08	4489.00	0.00	4489	0.00	1.03	19.00	4489
n20q15H	4559	4559	0.00	0.11	4559.00	0.00	4559	0.00	1.27	19.00	4559
n20q15I	4051	4051	0.00	0.08	4051.00	0.00	4051	0.00	0.88	19.00	4051
n20q15J	3905	3905	0.00	0.22	3905.00	0.00	3905	0.00	1.13	18.00	3905
n20q20A	3585	3585	0.00	0.06	3585.00	0.00	3585	0.00	0.53	17.00	3585
n20q20B	4073	4073	0.00	0.03	4073.00	0.00	4073	0.00	1.10	18.00	4073
n20q20C	4486	4486	0.00	0.15	4486.00	0.00	4486	0.00	2.20	20.00	4486
n20q20D	4674	4674	0.00	0.35	4674.00	0.00	4674	0.00	1.73	19.00	4674
n20q20E	4599	4599	0.00	0.29	4599.00	0.00	4599	0.00	1.04	18.00	4599
n20q20F	4108	4108	0.00	0.09	4108.00	0.00	4108	0.00	0.44	20.00	4108
n20q20G	4351	4351	0.00	0.10	4351.00	0.00	4351	0.00	0.49	19.00	4351
n20q20H	4143	4143	0.00	0.06	4143.00	0.00	4143	0.00	0.60	19.00	4143
n20q20I	4051	4051	0.00	0.11	4051.00	0.00	4051	0.00	0.69	19.00	4051
n20q20J	3674	3674	0.00	0.08	3674.00	0.00	3674	0.00	0.57	17.50	3674
n20q25A	3583	3583	0.00	0.06	3583.00	0.00	3583	0.00	0.40	17.00	3583
n20q25B	3792	3792	0.00	0.04	3792.00	0.00	3792	0.00	0.41	18.00	3792
n20q25C	4189	4189	0.00	0.07	4189.00	0.00	4189	0.00	1.43	20.00	4189
n20q25D	4226	4226	0.00	0.41	4226.00	0.00	4226	0.00	0.85	19.00	4226
n20q25E	4556	4556	0.00	0.32	4556.00	0.00	4556	0.00	0.83	18.00	4556
n20q25F	4108	4108	0.00	0.11	4108.00	0.00	4108	0.00	0.40	20.00	4108
n20q25G	4216	4216	0.00	0.24	4216.00	0.00	4216	0.00	0.45	19.00	4216
n20q25H	3992	3992	0.00	0.07	3992.00	0.00	3992	0.00	0.48	19.00	3992
n20q25I	3960	3960	0.00	0.08	3960.00	0.00	3960	0.00	0.60	19.00	3960
n20q25J	3650	3650	0.00	0.10	3650.00	0.00	3650	0.00	0.45	17.20	3650
n20q30A	3583	3583	0.00	0.03	3583.00	0.00	3583	0.00	0.36	17.00	3583
n20q30B	3792	3792	0.00	0.03	3792.00	0.00	3792	0.00	0.37	18.00	3792
n20q30C	4184	4184	0.00	16.48	4184.00	0.00	4184	0.00	1.19	20.00	4184
n20q30D	4089	4089	0.00	0.14	4089.00	0.00	4089	0.00	1.20	19.00	4089
n20q30E	4388	4388	0.00	2.28	4388.00	0.00	4388	0.00	0.90	18.00	4388
n20q30F	4108	4108	0.00	0.18	4108.00	0.00	4108	0.00	0.37	20.00	4108
n20q30G	4216	4216	0.00	0.12	4216.00	0.00	4216	0.00	0.39	19.00	4216
n20q30H	3992	3992	0.00	0.13	3992.00	0.00	3992	0.00	0.42	19.00	3992
n20q30I	3960	3960	0.00	0.07	3960.00	0.00	3960	0.00	0.55	19.00	3960
n20q30J	3650	3650	0.00	0.12	3650.00	0.00	3650	0.00	0.42	17.60	3650
n20q35A	3583	3583	0.00	0.03	3583.00	0.00	3583	0.00	0.37	17.30	3583
n20q35B	3792	3792	0.00	0.04	3792.00	0.00	3792	0.00	0.35	18.00	3792
n20q35C	4045	4045	0.00	7.82	4045.00	0.00	4045	0.00	0.71	20.00	4045
n20q35D	3806	3806	0.00	1.83	3806.00	0.00	3806	0.00	0.48	19.00	3806
n20q35E	4277	4277	0.00	0.87	4277.00	0.00	4277	0.00	0.56	18.00	4277
n20q35F	4108	4108	0.00	0.18	4108.00	0.00	4108	0.00	0.37	20.00	4108
n20q35G	4216	4216	0.00	0.14	4216.00	0.00	4216	0.00	0.37	19.00	4216
n20q35H	3992	3992	0.00	0.14	3992.00	0.00	3992	0.00	0.42	19.00	3992
n20q35I	3960	3960	0.00	0.07	3960.00	0.00	3960	0.00	0.52	19.00	3960
n20q35J	3650	3650	0.00	0.10	3650.00	0.00	3650	0.00	0.40	17.70	3650
n20q40A	3583	3583	0.00	0.03	3583.00	0.00	3583	0.00	0.36	17.00	3583
n20q40B	3792	3792	0.00	0.03	3792.00	0.00	3792	0.00	0.36	18.00	3792
n20q40C	4042	4042	0.00	8.82	4042.00	0.00	4042	0.00	0.74	20.20	4042
n20q40D	3806	3806	0.00	1.91	3806.00	0.00	3806	0.00	0.45	19.00	3806
n20q40E	4277	4277	0.00	0.85	4277.00	0.00	4277	0.00	0.54	18.00	4277
n20q40F	4108	4108	0.00	0.11	4108.00	0.00	4108	0.00	0.38	20.00	4108

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Instance	Erdoğan et al. 2015				ILS_{SBRP}						
	LB	**UB**	**UB Gap (%)**	**UB Time (s)**	**Avg. Sol.**	**Avg. Gap. (%)**	**Best**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. NV**	**Best of all exp.**
n20q40G	4216	4216	0.00	0.13	4216.00	0.00	4216	0.00	0.37	19.00	4216
n20q40H	3992	3992	0.00	0.13	3992.00	0.00	3992	0.00	0.41	19.00	3992
n20q40I	3960	3960	0.00	0.07	3960.00	0.00	3960	0.00	0.53	19.00	3960
n20q40J	3650	3650	0.00	0.12	3650.00	0.00	3650	0.00	0.41	17.30	3650
n20q45A	3583	3583	0.00	0.02	3583.00	0.00	3583	0.00	0.37	17.00	3583
n20q45B	3792	3792	0.00	0.03	3792.00	0.00	3792	0.00	0.36	18.00	3792
n20q45C	4042	4042	0.00	7.88	4042.00	0.00	4042	0.00	0.69	20.00	4042
n20q45D	3806	3806	0.00	1.93	3806.00	0.00	3806	0.00	0.44	19.00	3806
n20q45E	4277	4277	0.00	0.86	4277.00	0.00	4277	0.00	0.54	18.10	4277
n20q45F	4108	4108	0.00	0.11	4108.00	0.00	4108	0.00	0.37	20.00	4108
n20q45G	4216	4216	0.00	0.14	4216.00	0.00	4216	0.00	0.38	19.00	4216
n20q45H	3992	3992	0.00	0.13	3992.00	0.00	3992	0.00	0.40	19.00	3992
n20q45I	3960	3960	0.00	0.07	3960.00	0.00	3960	0.00	0.55	19.00	3960
n20q45J	3650	3650	0.00	0.13	3650.00	0.00	3650	0.00	0.39	17.10	3650
n20q1000A	3583	3583	0.00	0.03	3583.00	0.00	3583	0.00	0.37	17.00	3583
n20q1000B	3792	3792	0.00	0.04	3792.00	0.00	3792	0.00	0.36	18.00	3792
n20q1000C	4042	4042	0.00	4.97	4042.00	0.00	4042	0.00	0.66	20.00	4042
n20q1000D	3806	3806	0.00	1.99	3806.00	0.00	3806	0.00	0.44	19.00	3806
n20q1000E	4277	4277	0.00	0.69	4277.00	0.00	4277	0.00	0.53	18.00	4277
n20q1000F	4108	4108	0.00	0.11	4108.00	0.00	4108	0.00	0.38	20.00	4108
n20q1000G	4216	4216	0.00	0.13	4216.00	0.00	4216	0.00	0.37	19.00	4216
n20q1000H	3992	3992	0.00	0.13	3992.00	0.00	3992	0.00	0.42	19.00	3992
n20q1000I	3960	3960	0.00	0.08	3960.00	0.00	3960	0.00	0.54	19.00	3960
n20q1000J	3650	3650	0.00	0.13	3650.00	0.00	3650	0.00	0.40	17.20	3650
n30q10A	6236	6236	0.00	7.03	6236.00	0.00	6236	0.00	19.85	30.00	6236
n30q10B	6308	6308	0.00	2.56	6308.00	0.00	6308	0.00	12.98	26.00	6308
n30q10C	6335	6335	0.00	12.45	6339.20	0.07	6335	0.00	29.86	30.90	6335
n30q10D	6076	6076	0.00	1.98	6079.20	0.05	6076	0.00	43.72	33.80	6076
n30q10E	5877	5877	0.00	0.96	5881.20	0.07	5877	0.00	15.78	29.60	5877
n30q10F	5695	5695	0.00	1.78	5695.00	0.00	5695	0.00	15.51	30.00	5695
n30q10G	8891	8891	0.00	26.34	8891.00	0.00	8891	0.00	79.94	31.00	8891
n30q10H	5884	5884	0.00	2.29	5884.00	0.00	5884	0.00	21.81	29.10	5884
n30q10I	5430	5430	0.00	4.71	5430.00	0.00	5430	0.00	21.09	31.00	5430
n30q10J	5764	5764	0.00	2.10	5764.00	0.00	5764	0.00	20.21	30.00	5764
n30q15A	5442	5442	0.00	3.03	5442.00	0.00	5442	0.00	10.01	30.00	5442
n30q15B	5364	5364	0.00	2.18	5364.00	0.00	5364	0.00	6.86	26.20	5364
n30q15C	5170	5170	0.00	2.06	5170.00	0.00	5170	0.00	6.21	28.20	5170
n30q15D	5142	5142	0.00	2.27	5142.00	0.00	5142	0.00	10.61	30.00	5142
n30q15E	5121	5121	0.00	1.68	5121.00	0.00	5121	0.00	6.86	27.00	5121
n30q15F	4895	4895	0.00	1.19	4895.00	0.00	4895	0.00	5.36	29.00	4895
n30q15G	7146	7146	0.00	15.15	7206.00	0.84	7146	0.00	31.21	29.60	7146
n30q15H	5103	5103	0.00	2.32	5120.90	0.35	5103	0.00	9.09	29.00	5103
n30q15I	4622	4622	0.00	2.98	4622.00	0.00	4622	0.00	4.28	27.00	4622
n30q15J	5242	5242	0.00	5.88	5243.90	0.04	5242	0.00	12.43	28.90	5242
n30q20A	4894	4894	0.00	1.41	4894.00	0.00	4894	0.00	3.73	29.00	4894
n30q20B	4831	4831	0.00	2.74	4831.00	0.00	4831	0.00	3.71	26.10	4831
n30q20C	4821	4821	0.00	0.98	4831.00	0.21	4831	0.21	4.37	28.00	4831
n30q20D	4871	4871	0.00	2.02	4871.00	0.00	4871	0.00	6.41	29.00	4871
n30q20E	4547	4547	0.00	0.21	4547.00	0.00	4547	0.00	2.08	27.00	4547
n30q20F	4439	4439	0.00	1.52	4439.00	0.00	4439	0.00	1.99	29.10	4439
n30q20G	6399	6399	0.00	1625.81	6399.00	0.00	6399	0.00	19.71	29.00	6399
n30q20H	4275	4275	0.00	0.41	4275.00	0.00	4275	0.00	3.46	27.00	4275
n30q20I	4325	4325	0.00	0.47	4325.00	0.00	4325	0.00	1.79	27.10	4325
n30q20J	4536	4536	0.00	0.33	4536.00	0.00	4536	0.00	3.35	27.10	4536
n30q25A	4825	4825	0.00	26.49	4825.00	0.00	4825	0.00	2.40	29.10	4825
n30q25B	4530	4530	0.00	0.66	4530.00	0.00	4530	0.00	2.12	26.10	4530
n30q25C	4586	4586	0.00	15.79	4586.00	0.00	4586	0.00	2.11	28.00	4586
n30q25D	4723	4723	0.00	2.71	4723.00	0.00	4723	0.00	2.86	28.00	4723
n30q25E	4466	4466	0.00	0.25	4466.00	0.00	4466	0.00	1.05	27.00	4466
n30q25F	4439	4439	0.00	1.51	4439.00	0.00	4439	0.00	1.49	29.10	4439
n30q25G	5731	5731	0.00	6.42	5731.00	0.00	5731	0.00	5.63	27.00	5731
n30q25H	4142	4142	0.00	1.15	4142.00	0.00	4142	0.00	2.43	27.00	4142
n30q25I	4272	4272	0.00	0.24	4272.00	0.00	4272	0.00	1.20	27.00	4272
n30q25J	4465	4465	0.00	0.83	4465.00	0.00	4465	0.00	2.35	27.00	4465
n30q30A	4603	4603	0.00	0.12	4603.00	0.00	4603	0.00	1.69	29.00	4603
n30q30B	4496	4496	0.00	753.94	4496.00	0.00	4496	0.00	2.07	26.20	4496
n30q30C	4565	4565	0.00	50.05	4565.00	0.00	4565	0.00	2.22	28.00	4565
n30q30D	4701	4701	0.00	2.99	4701.00	0.00	4701	0.00	2.26	28.00	4701

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Instance	Erdoğan et al. 2015 LB	UB	UB Gap (%)	UB Time (s)	ILS$_{SBRP}$ Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n30q30E	4466	4466	0.00	0.16	4466.00	0.00	4466	0.00	0.90	27.00	4466
n30q30F	4384	4384	0.00	1.95	4384.00	0.00	4384	0.00	1.54	29.00	4384
n30q30G	5402	5402	0.00	10.20	5402.00	0.00	5402	0.00	3.78	27.00	5402
n30q30H	4030	4030	0.00	0.46	4030.00	0.00	4030	0.00	1.38	27.00	4030
n30q30I	4272	4272	0.00	1.82	4272.00	0.00	4272	0.00	1.09	27.00	4272
n30q30J	4300	4300	0.00	0.34	4300.00	0.00	4300	0.00	1.60	27.10	4300
n30q35A	4603	4603	0.00	0.31	4603.00	0.00	4603	0.00	1.50	29.00	4603
n30q35B	4434	4434	0.00	2706.58	4434.00	0.00	4434	0.00	2.52	27.20	4434
n30q35C	4525	4525	0.00	211.96	4525.00	0.00	4525	0.00	2.19	28.10	4525
n30q35D	4666	4666	0.00	6.18	4675.00	0.19	4666	0.00	2.07	28.70	4666
n30q35E	4466	4466	0.00	0.18	4466.00	0.00	4466	0.00	0.87	27.00	4466
n30q35F	4384	4384	0.00	2.03	4384.00	0.00	4384	0.00	1.30	29.00	4384
n30q35G	5211	5211	0.00	2.42	5211.00	0.00	5211	0.00	4.64	27.00	5211
n30q35H	4030	4030	0.00	0.60	4030.00	0.00	4030	0.00	1.23	27.00	4030
n30q35I	4272	4272	0.00	1.92	4272.00	0.00	4272	0.00	1.04	27.00	4272
n30q35J	4300	4300	0.00	0.56	4300.00	0.00	4300	0.00	1.53	27.00	4300
n30q40A	4603	4603	0.00	0.74	4603.00	0.00	4603	0.00	1.45	29.00	4603
n30q40B	4340	4340	0.00	395.41	4340.00	0.00	4340	0.00	1.28	26.00	4340
n30q40C	4475	4475	0.00	1164.15	4475.00	0.00	4475	0.00	2.23	28.00	4475
n30q40D	4666	4666	0.00	309.23	4666.00	0.00	4666	0.00	2.19	29.00	4666
n30q40E	4466	4466	0.00	0.16	4466.00	0.00	4466	0.00	0.87	27.00	4466
n30q40F	4384	4384	0.00	2.02	4384.00	0.00	4384	0.00	1.26	29.10	4384
n30q40G	5031	5031	0.00	3970.65	5031.00	0.00	5031	0.00	3.28	27.00	5031
n30q40H	4030	4030	0.00	0.38	4030.00	0.00	4030	0.00	1.20	27.00	4030
n30q40I	4272	4272	0.00	0.99	4272.00	0.00	4272	0.00	1.02	27.00	4272
n30q40J	4300	4300	0.00	2.47	4300.00	0.00	4300	0.00	1.33	27.10	4300
n30q45A	4603	4603	0.00	1.32	4603.00	0.00	4603	0.00	1.42	29.10	4603
n30q45B	4340	4340	0.00	409.72	4340.00	0.00	4340	0.00	1.28	26.00	4340
n30q45C	4475	4475	0.00	1479.63	4475.00	0.00	4475	0.00	2.11	28.00	4475
n30q45D	4666	4666	0.00	316.56	4672.00	0.13	4666	0.00	2.04	28.80	4666
n30q45E	4466	4466	0.00	0.17	4466.00	0.00	4466	0.00	0.88	27.00	4466
n30q45F	4384	4384	0.00	2.08	4384.00	0.00	4384	0.00	1.27	29.20	4384
n30q45G	4827	4827	0.00	2.25	4827.00	0.00	4827	0.00	2.17	27.00	4827
n30q45H	4030	4030	0.00	0.25	4030.00	0.00	4030	0.00	1.18	27.00	4030
n30q45I	4272	4272	0.00	2.54	4272.00	0.00	4272	0.00	1.01	27.10	4272
n30q45J	4300	4300	0.00	2.41	4300.00	0.00	4300	0.00	1.35	27.00	4300
n30q1000A	4603	4603	0.00	1.32	4603.00	0.00	4603	0.00	1.42	29.00	4603
n30q1000B	4340	4340	0.00	453.47	4340.00	0.00	4340	0.00	1.24	26.00	4340
n30q1000C	4475	4475	0.00	1064.21	4475.00	0.00	4475	0.00	2.02	28.10	4475
n30q1000D	4666	4666	0.00	324.79	4666.00	0.00	4666	0.00	2.24	29.00	4666
n30q1000E	4466	4466	0.00	0.17	4466.00	0.00	4466	0.00	0.87	27.00	4466
n30q1000F	4384	4384	0.00	2.13	4384.00	0.00	4384	0.00	1.25	29.10	4384
n30q1000G	4781	4781	0.00	51.13	4781.00	0.00	4781	0.00	1.57	27.00	4781
n30q1000H	4030	4030	0.00	0.66	4030.00	0.00	4030	0.00	1.17	27.00	4030
n30q1000I	4272	4272	0.00	2.29	4272.00	0.00	4272	0.00	1.03	27.10	4272
n30q1000J	4300	4300	0.00	1.79	4300.00	0.00	4300	0.00	1.37	27.10	4300
n40q10A	6949	6949	0.00	41.96	6965.40	0.24	6949	0.00	60.78	40.90	6949
n40q10B	5949	5949	0.00	8.16	5949.00	0.00	5949	0.00	27.50	39.00	5949
n40q10C	7237	7237	0.00	15.90	7237.00	0.00	7237	0.00	59.39	36.50	7237
n40q10D	7692	7692	0.00	13.23	7692.00	0.00	7692	0.00	115.57	39.40	7692
n40q10E	6424	6424	0.00	27.52	6441.00	0.26	6441	0.26	24.83	34.10	6441
n40q10F	7074	7074	0.00	886.39	7094.60	0.29	7085	0.16	70.32	40.80	7074
n40q10G	7375	7375	0.00	162.15	7375.50	0.01	7375	0.00	60.76	43.20	7375
n40q10H	6556	6556	0.00	13.37	6560.00	0.06	6556	0.00	56.63	42.40	6556
n40q10I	6901	6901	0.00	12.44	6902.00	0.01	6901	0.00	54.59	41.10	6901
n40q10J	6267	6267	0.00	66.84	6270.60	0.06	6267	0.00	38.55	40.20	6267
n40q15A	6059	6059	0.00	49.21	6059.00	0.00	6059	0.00	22.28	38.00	6059
n40q15B	5319	5319	0.00	3.12	5319.00	0.00	5319	0.00	10.35	37.00	5319
n40q15C	5912	5912	0.00	14.59	5912.40	0.01	5912	0.00	22.93	35.70	5912
n40q15D	6388	6388	0.00	8.86	6388.00	0.00	6388	0.00	37.94	37.70	6388
n40q15E	5671	5671	0.00	23.90	5671.00	0.00	5671	0.00	11.81	34.00	5671
n40q15F	5847	5847	0.00	57.85	5847.00	0.00	5847	0.00	20.52	38.20	5847
n40q15G	6409	6409	0.00	28.97	6414.10	0.08	6409	0.00	31.49	40.40	6409
n40q15H	5575	5575	0.00	6.62	5575.00	0.00	5575	0.00	20.46	39.20	5575
n40q15I	5732	5732	0.00	8.71	5732.00	0.00	5732	0.00	16.75	37.30	5732
n40q15J	5630	5630	0.00	53.71	5630.20	0.00	5630	0.00	23.26	37.80	5630
n40q20A	5435	5435	0.00	17.81	5435.00	0.00	5435	0.00	9.89	38.00	5435
n40q20B	5150	5150	0.00	3.91	5150.00	0.00	5150	0.00	4.40	37.00	5150

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Instance	Erdoğan et al. 2015 LB	UB	UB Gap (%)	UB Time (s)	ILS$_{SBRP}$ Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n40q20C	5331	5331	0.00	9.31	5336.20	0.10	5331	0.00	19.02	36.60	5331
n40q20D	5850	5850	0.00	79.70	5850.00	0.00	5850	0.00	11.71	37.00	5850
n40q20E	5271	5271	0.00	5.53	5271.00	0.00	5271	0.00	4.97	33.00	5271
n40q20F	5289	5289	0.00	9.96	5289.00	0.00	5289	0.00	7.52	37.00	5289
n40q20G	5476	5476	0.00	4.97	5476.00	0.00	5476	0.00	10.95	39.20	5476
n40q20H	5117	5117	0.00	3.49	5117.00	0.00	5117	0.00	7.82	38.30	5117
n40q20I	4984	4984	0.00	0.46	4984.00	0.00	4984	0.00	6.61	37.00	4984
n40q20J	4996	4996	0.00	12.05	4996.00	0.00	4996	0.00	10.38	37.00	4996
n40q25A	4949	4949	0.00	0.92	4949.00	0.00	4949	0.00	4.28	38.00	4949
n40q25B	5110	5110	0.00	5.40	5110.00	0.00	5110	0.00	3.09	37.00	5110
n40q25C	5069.67	5087	0.34	7182.69	5092.20	0.44	5087	0.34	14.05	36.70	5087
n40q25D	5748	5748	0.00	31.39	5748.00	0.00	5748	0.00	7.06	36.00	5748
n40q25E	5237	5237	0.00	6.37	5237.00	0.00	5237	0.00	2.62	33.00	5237
n40q25F	5048	5048	0.00	3.32	5048.00	0.00	5048	0.00	5.75	37.20	5048
n40q25G	5361	5361	0.00	2.31	5361.00	0.00	5361	0.00	5.74	39.30	5361
n40q25H	4886	4886	0.00	1.00	4886.00	0.00	4886	0.00	4.98	38.00	4886
n40q25I	4801	4801	0.00	0.41	4801.00	0.00	4801	0.00	5.00	37.00	4801
n40q25J	4811	4811	0.00	4.98	4811.00	0.00	4811	0.00	5.36	36.10	4811
n40q30A	4949	4949	0.00	1.23	4949.00	0.00	4949	0.00	3.06	38.00	4949
n40q30B	5110	5110	0.00	2.10	5110.00	0.00	5110	0.00	2.70	37.00	5110
n40q30C	4692	4692	0.00	333.72	4692.00	0.00	4692	0.00	9.48	36.60	4692
n40q30D	5378	5378	0.00	5.77	5378.00	0.00	5378	0.00	8.67	36.00	5378
n40q30E	5154	5154	0.00	8.90	5154.00	0.00	5154	0.00	3.15	33.20	5154
n40q30F	4921	4921	0.00	0.66	4921.00	0.00	4921	0.00	2.99	37.00	4921
n40q30G	5312	5312	0.00	9.86	5312.00	0.00	5312	0.00	3.96	39.10	5312
n40q30H	4840	4840	0.00	1.40	4840.00	0.00	4840	0.00	4.03	38.00	4840
n40q30I	4713	4713	0.00	0.50	4713.00	0.00	4713	0.00	3.08	37.00	4713
n40q30J	4753	4753	0.00	1.41	4753.00	0.00	4753	0.00	3.22	36.00	4753
n40q35A	4949	4949	0.00	1.79	4949.00	0.00	4949	0.00	2.74	38.00	4949
n40q35B	5110	5110	0.00	2.66	5110.00	0.00	5110	0.00	2.52	37.00	5110
n40q35C	4570	4570	0.00	326.78	4570.00	0.00	4570	0.00	6.50	36.60	4570
n40q35D	5238	5238	0.00	1.85	5238.00	0.00	5238	0.00	4.59	36.00	5238
n40q35E	5069	5069	0.00	1.24	5069.00	0.00	5069	0.00	1.85	33.10	5069
n40q35F	4921	4921	0.00	2.04	4921.00	0.00	4921	0.00	2.70	37.00	4921
n40q35G	5253	5253	0.00	3.04	5253.00	0.00	5253	0.00	3.85	39.00	5253
n40q35H	4840	4840	0.00	42.44	4840.00	0.00	4840	0.00	3.44	38.00	4840
n40q35I	4713	4713	0.00	0.44	4713.00	0.00	4713	0.00	2.83	37.00	4713
n40q35J	4753	4753	0.00	4.32	4753.00	0.00	4753	0.00	2.52	36.00	4753
n40q40A	4949	4949	0.00	2.08	4949.00	0.00	4949	0.00	2.67	38.00	4949
n40q40B	5110	5110	0.00	6.54	5110.00	0.00	5110	0.00	2.59	37.00	5110
n40q40C	4570	4570	0.00	650.51	4570.00	0.00	4570	0.00	5.91	36.70	4570
n40q40D	5202	5202	0.00	2.71	5202.00	0.00	5202	0.00	4.14	36.00	5202
n40q40E	5069	5069	0.00	1.22	5069.00	0.00	5069	0.00	1.79	33.20	5069
n40q40F	4816	4816	0.00	2.50	4816.00	0.00	4816	0.00	2.32	37.00	4816
n40q40G	5253	5253	0.00	5.64	5253.00	0.00	5253	0.00	3.58	39.00	5253
n40q40H	4804	4804	0.00	30.59	4804.00	0.00	4804	0.00	3.12	38.00	4804
n40q40I	4713	4713	0.00	0.44	4713.00	0.00	4713	0.00	2.70	37.00	4713
n40q40J	4753	4753	0.00	4.31	4753.00	0.00	4753	0.00	2.46	36.00	4753
n40q45A	4949	4949	0.00	2.11	4949.00	0.00	4949	0.00	2.61	38.00	4949
n40q45B	5110	5110	0.00	6.40	5110.00	0.00	5110	0.00	2.51	37.00	5110
n40q45C	4570	4570	0.00	683.60	4570.00	0.00	4570	0.00	5.69	36.80	4570
n40q45D	5202	5202	0.00	6.38	5202.00	0.00	5202	0.00	3.67	36.00	5202
n40q45E	5069	5069	0.00	3.35	5069.00	0.00	5069	0.00	1.78	33.30	5069
n40q45F	4816	4816	0.00	2.50	4816.00	0.00	4816	0.00	2.27	37.00	4816
n40q45G	5253	5253	0.00	5.66	5253.00	0.00	5253	0.00	3.49	39.10	5253
n40q45H	4804	4804	0.00	28.01	4804.00	0.00	4804	0.00	2.87	38.10	4804
n40q45I	4713	4713	0.00	0.45	4713.00	0.00	4713	0.00	2.60	37.00	4713
n40q45J	4753	4753	0.00	4.34	4753.00	0.00	4753	0.00	2.41	36.00	4753
n40q1000A	4949	4949	0.00	1.71	4949.00	0.00	4949	0.00	2.62	38.00	4949
n40q1000B	5110	5110	0.00	6.53	5110.00	0.00	5110	0.00	2.56	37.00	5110
n40q1000C	4570	4570	0.00	657.74	4570.00	0.00	4570	0.00	5.32	36.70	4570
n40q1000D	5202	5202	0.00	5.67	5202.00	0.00	5202	0.00	3.53	36.00	5202
n40q1000E	5069	5069	0.00	3.37	5069.00	0.00	5069	0.00	1.77	33.20	5069
n40q1000F	4816	4816	0.00	3.58	4816.00	0.00	4816	0.00	2.24	37.00	4816
n40q1000G	5253	5253	0.00	8.26	5253.00	0.00	5253	0.00	3.47	39.20	5253
n40q1000H	4804	4804	0.00	12.79	4804.00	0.00	4804	0.00	2.89	38.10	4804
n40q1000I	4713	4713	0.00	0.49	4713.00	0.00	4713	0.00	2.66	37.00	4713
n40q1000J	4753	4753	0.00	1.52	4753.00	0.00	4753	0.00	2.41	36.00	4753

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Instance	Erdoğan et al. 2015				ILS$_{\textbf{SBRP}}$						
	LB	**UB**	**UB Gap (%)**	**UB Time (s)**	**Avg. Sol.**	**Avg. Gap. (%)**	**Best**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. NV**	**Best of all exp.**
n50q10A	6520	6520	0.00	20.99	6527.50	0.12	6520	0.00	50.31	43.50	6520
n50q10B	9025	9025	0.00	255.40	9026.60	0.02	9025	0.00	246.97	50.20	9025
n50q10C	8151	8151	0.00	849.26	8151.00	0.00	8151	0.00	272.58	48.50	8151
n50q10D	9804	9804	0.00	682.26	9806.70	0.03	9804	0.00	433.55	50.90	9804
n50q10E	9086	9086	0.00	1636.88	9093.20	0.08	9086	0.00	253.79	50.20	9086
n50q10F	7661	7661	0.00	192.68	7664.70	0.05	7661	0.00	200.99	50.90	7661
n50q10G	6986	6986	0.00	64.50	6987.60	0.02	6986	0.00	65.76	49.40	6986
n50q10H	8369.53	9031	7.90	7183.24	8563.20	2.31	8563	2.31	190.83	49.00	8563
n50q10I	7964	7964	0.00	761.12	7996.40	0.41	7964	0.00	233.32	53.00	7964
n50q10J	8054	8054	0.00	338.46	8054.00	0.00	8054	0.00	161.71	50.80	8054
n50q15A	5975	5975	0.00	19.25	5975.00	0.00	5975	0.00	12.77	41.20	5975
n50q15B	7697	7697	0.00	3045.00	7737.50	0.53	7697	0.00	131.53	47.20	7697
n50q15C	6693	6693	0.00	183.62	6693.00	0.00	6693	0.00	133.03	48.00	6693
n50q15D	8042.29	8256	2.66	7183.15	8145.30	1.28	8136	1.17	113.09	49.20	8136
n50q15E	7649	7773	1.62	7183.20	7732.00	1.09	7732	1.09	120.23	47.10	7732
n50q15F	6464	6464	0.00	75.24	6464.00	0.00	6464	0.00	55.51	46.50	6464
n50q15G	6273	6273	0.00	23.75	6273.00	0.00	6273	0.00	34.09	48.10	6273
n50q15H	7005	7005	0.00	1679.01	7005.00	0.00	7005	0.00	53.44	47.00	7005
n50q15I	6423	6423	0.00	46.73	6423.00	0.00	6423	0.00	44.80	47.00	6423
n50q15J	6601	6601	0.00	262.20	6601.00	0.00	6601	0.00	52.19	45.80	6601
n50q20A	5728	5728	0.00	5.75	5728.00	0.00	5728	0.00	9.59	41.00	5728
n50q20B	6888	6888	0.00	190.34	6888.00	0.00	6888	0.00	70.69	47.00	6888
n50q20C	6165	6165	0.00	410.62	6189.40	0.40	6165	0.00	67.35	47.60	6165
n50q20D	7157	7157	0.00	447.11	7157.00	0.00	7157	0.00	38.44	46.00	7157
n50q20E	6905	6905	0.00	1217.13	6905.70	0.01	6905	0.00	40.58	46.00	6905
n50q20F	5921	5921	0.00	129.53	5921.00	0.00	5921	0.00	36.65	48.00	5921
n50q20G	5905	5905	0.00	157.99	5905.00	0.00	5905	0.00	20.02	48.00	5905
n50q20H	6326	6326	0.00	275.42	6326.00	0.00	6326	0.00	29.09	45.00	6326
n50q20I	6023	6023	0.00	76.53	6025.70	0.04	6023	0.00	22.11	47.30	6023
n50q20J	6050	6050	0.00	44.10	6050.00	0.00	6050	0.00	23.98	45.20	6050
n50q25A	5728	5728	0.00	23.51	5728.00	0.00	5728	0.00	7.35	41.00	5728
n50q25B	6687	6687	0.00	871.46	6689.10	0.03	6687	0.00	42.85	47.00	6687
n50q25C	5772	5772	0.00	61.48	5772.00	0.00	5772	0.00	54.78	47.00	5772
n50q25D	6817	6817	0.00	289.86	6817.00	0.00	6817	0.00	35.07	46.00	6817
n50q25E	6381	6381	0.00	81.05	6381.00	0.00	6381	0.00	27.60	46.00	6381
n50q25F	5673	5673	0.00	29.76	5673.00	0.00	5673	0.00	26.47	46.00	5673
n50q25G	5885	5885	0.00	1085.72	5885.00	0.00	5885	0.00	15.97	48.00	5885
n50q25H	5942	5942	0.00	71.60	5942.00	0.00	5942	0.00	17.38	45.10	5942
n50q25I	5615	5615	0.00	13.42	5615.00	0.00	5615	0.00	15.76	47.00	5615
n50q25J	5833	5833	0.00	200.35	5833.00	0.00	5833	0.00	11.96	44.00	5833
n50q30A	5634	5634	0.00	18.47	5634.00	0.00	5634	0.00	4.94	41.00	5634
n50q30B	6285	6285	0.00	59.61	6285.00	0.00	6285	0.00	19.40	46.20	6285
n50q30C	5610	5610	0.00	13.50	5610.00	0.00	5610	0.00	24.69	46.00	5610
n50q30D	6420	6420	0.00	36.88	6421.80	0.03	6420	0.00	16.91	46.30	6420
n50q30E	6219	6219	0.00	26.78	6219.00	0.00	6219	0.00	11.61	45.00	6219
n50q30F	5424	5424	0.00	2.97	5424.00	0.00	5424	0.00	17.15	46.00	5424
n50q30G	5864	5864	0.00	1275.54	5864.00	0.00	5864	0.00	10.45	48.00	5864
n50q30H	5804	5804	0.00	233.77	5804.00	0.00	5804	0.00	10.04	45.00	5804
n50q30I	5491	5491	0.00	18.81	5491.00	0.00	5491	0.00	8.46	47.00	5491
n50q30J	5747	5747	0.00	87.70	5747.00	0.00	5747	0.00	8.17	44.20	5747
n50q35A	5634	5634	0.00	25.65	5634.00	0.00	5634	0.00	4.14	41.20	5634
n50q35B	6192	6192	0.00	93.65	6195.90	0.06	6192	0.00	17.77	46.50	6192
n50q35C	5503	5503	0.00	12.05	5503.00	0.00	5503	0.00	15.45	46.00	5503
n50q35D	6277	6277	0.00	26.94	6277.00	0.00	6277	0.00	12.24	46.20	6277
n50q35E	6168	6168	0.00	13.05	6168.00	0.00	6168	0.00	9.37	45.00	6168
n50q35F	5276.38	5351	1.41	7182.69	5351.00	1.41	5351	1.41	13.88	47.00	5351
n50q35G	5854.57	5913	1.00	7183.30	5864.00	0.16	5864	0.16	9.67	48.00	5864
n50q35H	5684	5684	0.00	17.72	5684.00	0.00	5684	0.00	8.73	45.00	5684
n50q35I	5462	5462	0.00	11.59	5462.00	0.00	5462	0.00	7.70	47.00	5462
n50q35J	5675	5675	0.00	44.21	5675.00	0.00	5675	0.00	7.18	44.40	5675
n50q40A	5634	5634	0.00	30.73	5634.00	0.00	5634	0.00	3.96	41.20	5634
n50q40B	6105	6105	0.00	79.60	6105.00	0.00	6105	0.00	18.86	46.20	6105
n50q40C	5398	5398	0.00	16.84	5398.00	0.00	5398	0.00	10.31	46.00	5398
n50q40D	6220	6220	0.00	15.81	6220.00	0.00	6220	0.00	9.70	46.20	6220
n50q40E	6089	6089	0.00	21.65	6089.00	0.00	6089	0.00	7.55	45.00	6089
n50q40F	5256.67	5262	0.10	7183.30	5262.00	0.10	5262	0.10	10.02	46.00	5262
n50q40G	5864	5864	0.00	6626.36	5864.00	0.00	5864	0.00	8.42	48.00	5864
n50q40H	5559	5559	0.00	14.95	5559.00	0.00	5559	0.00	6.41	45.00	5559

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Instance	Erdoğan et al. 2015 LB	UB	UB Gap (%)	UB Time (s)	ILS_SBRP Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n50q40I	5462	5462	0.00	7.40	5462.00	0.00	5462	0.00	6.70	47.00	5462
n50q40J	5675	5675	0.00	92.78	5675.00	0.00	5675	0.00	6.36	44.20	5675
n50q45A	5634	5634	0.00	26.44	5634.00	0.00	5634	0.00	3.98	41.00	5634
n50q45B	6042	6042	0.00	280.74	6042.00	0.00	6042	0.00	12.57	46.10	6042
n50q45C	5289	5289	0.00	10.43	5289.00	0.00	5289	0.00	12.80	46.00	5289
n50q45D	6184	6184	0.00	19.76	6184.00	0.00	6184	0.00	11.00	46.00	6184
n50q45E	6080	6080	0.00	42.46	6080.00	0.00	6080	0.00	7.89	45.00	6080
n50q45F	5262	5262	0.00	5273.94	5262.00	0.00	5262	0.00	8.67	46.00	5262
n50q45G	5864	5864	0.00	6438.22	5864.00	0.00	5864	0.00	7.71	48.00	5864
n50q45H	5559	5559	0.00	9.65	5559.00	0.00	5559	0.00	6.03	45.00	5559
n50q45I	5462	5462	0.00	11.38	5462.00	0.00	5462	0.00	6.51	47.00	5462
n50q45J	5675	5675	0.00	100.28	5675.00	0.00	5675	0.00	6.32	44.00	5675
n50q1000A	5634	5634	0.00	30.10	5634.00	0.00	5634	0.00	4.11	41.30	5634
n50q1000B	5901	5967	1.12	7182.50	5955.00	0.92	5955	0.92	8.28	46.00	5955
n50q1000C	5139	5139	0.00	32.40	5139.00	0.00	5139	0.00	7.44	46.00	5139
n50q1000D	5836	5836	0.00	0.95	5836.00	0.00	5836	0.00	6.92	46.00	5836
n50q1000E	6023	6023	0.00	2125.32	6023.00	0.00	6023	0.00	6.85	45.00	6023
n50q1000F	5262	5262	0.00	6000.96	5262.00	0.00	5262	0.00	7.31	46.00	5262
n50q1000G	5864	5864	0.00	2626.17	5864.00	0.00	5864	0.00	7.83	48.00	5864
n50q1000H	5559	5559	0.00	996.30	5559.00	0.00	5559	0.00	5.93	45.00	5559
n50q1000I	5462	5462	0.00	12.57	5462.00	0.00	5462	0.00	5.91	47.00	5462
n50q1000J	5675	5675	0.00	90.28	5675.00	0.00	5675	0.00	6.41	44.10	5675
n60q10A	7810	7810	0.00	5160.79	7844.60	0.44	7843	0.42	314.30	59.00	7843
n60q10B	8156	8156	0.00	2730.44	8184.80	0.35	8156	0.00	254.98	60.70	8156
n60q10C	8931.40	9214	3.16	7182.58	9090.00	1.78	9090	1.78	586.59	61.40	9090
n60q10D	10159	10159	0.00	498.59	10159.00	0.00	10159	0.00	656.44	55.30	10159
n60q10E	8855.06	9339	5.47	7182.63	8974.00	1.34	8949	1.06	423.48	59.80	8949
n60q10F	8163	8163	0.00	552.76	8179.20	0.20	8163	0.00	423.50	64.80	8163
n60q10G	8585.88	8691	1.22	7182.94	8666.60	0.94	8665	0.92	392.32	63.20	8665
n60q10H	8114	8114	0.00	1256.22	8120.30	0.08	8114	0.00	226.46	56.70	8114
n60q10I	9078.09	9313	2.59	7183.23	9188.50	1.22	9188	1.21	670.18	62.20	9188
n60q10J	8050	8050	0.00	316.00	8078.00	0.35	8078	0.35	251.28	59.00	8050
n60q15A	6730	6730	0.00	1167.23	6730.00	0.00	6730	0.00	120.85	54.00	6730
n60q15B	6990	6990	0.00	388.69	6990.00	0.00	6990	0.00	89.68	55.00	6990
n60q15C	7517.48	7720	2.69	7183.05	7630.00	1.50	7630	1.50	221.01	60.60	7630
n60q15D	8280	8477	2.38	7182.33	8405.00	1.51	8380	1.21	231.82	55.20	8380
n60q15E	7446	7446	0.00	240.49	7446.00	0.00	7446	0.00	122.35	56.00	7446
n60q15F	7075	7075	0.00	688.04	7076.50	0.02	7075	0.00	137.39	58.00	7075
n60q15G	7344	7344	0.00	1835.21	7344.00	0.00	7344	0.00	157.18	58.30	7344
n60q15H	6743	6743	0.00	78.02	6743.00	0.00	6743	0.00	75.41	54.30	6743
n60q15I	7577	7577	0.00	546.46	7577.00	0.00	7577	0.00	176.32	59.20	7577
n60q15J	7043	7043	0.00	265.50	7043.00	0.00	7043	0.00	70.88	54.20	7043
n60q20A	6298	6298	0.00	309.20	6298.00	0.00	6298	0.00	68.95	54.40	6298
n60q20B	6363	6363	0.00	379.83	6363.00	0.00	6363	0.00	38.16	55.10	6363
n60q20C	6962	6962	0.00	1965.36	6962.00	0.00	6962	0.00	92.42	58.50	6962
n60q20D	7570	7570	0.00	7153.15	7571.20	0.02	7570	0.00	113.11	51.90	7570
n60q20E	6980	6980	0.00	700.54	6980.00	0.00	6980	0.00	48.78	54.00	6980
n60q20F	6285	6285	0.00	60.98	6285.00	0.00	6285	0.00	61.26	57.00	6285
n60q20G	6802	6802	0.00	920.04	6802.50	0.01	6802	0.00	94.92	58.00	6802
n60q20H	6248	6248	0.00	36.04	6248.00	0.00	6248	0.00	50.55	55.00	6248
n60q20I	6880	6880	0.00	1084.16	6880.70	0.01	6880	0.00	125.76	59.00	6880
n60q20J	6727	6727	0.00	240.95	6727.00	0.00	6727	0.00	35.98	53.60	6727
n60q25A	6069	6069	0.00	186.60	6069.00	0.00	6069	0.00	40.73	54.00	6069
n60q25B	6195	6195	0.00	103.88	6195.00	0.00	6195	0.00	22.98	55.00	6195
n60q25C	6620	6620	0.00	374.77	6620.00	0.00	6620	0.00	50.53	58.40	6620
n60q25D	7051	7051	0.00	144.17	7051.00	0.00	7051	0.00	63.10	51.00	7051
n60q25E	6633	6633	0.00	59.81	6633.00	0.00	6633	0.00	36.79	54.00	6633
n60q25F	6019.77	6060	0.67	7182.47	6060.00	0.67	6060	0.67	53.22	56.20	6060
n60q25G	6447	6447	0.00	144.27	6447.00	0.00	6447	0.00	49.23	57.10	6447
n60q25H	6030	6030	0.00	180.69	6030.00	0.00	6030	0.00	37.14	54.20	6030
n60q25I	6563	6563	0.00	987.03	6563.00	0.00	6563	0.00	60.55	58.00	6563
n60q25J	6496	6496	0.00	70.55	6496.00	0.00	6496	0.00	28.96	53.40	6496
n60q30A	5924	5924	0.00	98.35	5924.00	0.00	5924	0.00	27.16	54.30	5924
n60q30B	6195	6195	0.00	134.21	6195.00	0.00	6195	0.00	18.56	55.00	6195
n60q30C	6383	6383	0.00	57.45	6385.80	0.04	6383	0.00	37.13	58.10	6383
n60q30D	6596	6596	0.00	126.98	6596.00	0.00	6596	0.00	32.22	51.00	6596
n60q30E	6494	6494	0.00	71.77	6494.00	0.00	6494	0.00	30.39	54.00	6494
n60q30F	5948.67	6028	1.33	7182.20	5988.00	0.66	5988	0.66	29.22	56.00	5988

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Instance	Erdoğan et al. 2015				ILS$_{SBRP}$						
	LB	UB	UB Gap (%)	UB Time (s)	Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n60q30G	6360	6360	0.00	87.60	6360.00	0.00	6360	0.00	25.80	57.00	6360
n60q30H	5994	5994	0.00	300.20	5994.00	0.00	5994	0.00	27.56	55.50	5994
n60q30I	6419	6419	0.00	4439.43	6427.00	0.12	6419	0.00	51.29	58.00	6419
n60q30J	6389	6389	0.00	28.28	6389.00	0.00	6389	0.00	16.93	53.30	6389
n60q35A	5773	5773	0.00	7.00	5773.00	0.00	5773	0.00	19.61	54.20	5773
n60q35B	6132	6132	0.00	95.62	6132.00	0.00	6132	0.00	17.84	55.00	6132
n60q35C	6170	6170	0.00	37.07	6170.00	0.00	6170	0.00	21.81	57.30	6170
n60q35D	6491	6491	0.00	115.82	6491.00	0.00	6491	0.00	19.52	51.00	6491
n60q35E	6346	6346	0.00	62.29	6346.00	0.00	6346	0.00	22.76	54.00	6346
n60q35F	5928.33	6004	1.28	7183.22	5960.00	0.53	5960	0.53	28.36	56.00	5960
n60q35G	6308	6308	0.00	144.47	6308.00	0.00	6308	0.00	23.78	57.00	6308
n60q35H	5936	5936	0.00	1794.78	5937.90	0.03	5936	0.00	18.86	54.40	5936
n60q35I	6242	6242	0.00	1488.01	6242.00	0.00	6242	0.00	40.30	58.10	6242
n60q35J	6374	6374	0.00	41.49	6374.00	0.00	6374	0.00	12.34	53.10	6374
n60q40A	5773	5773	0.00	48.25	5773.00	0.00	5773	0.00	16.95	54.00	5773
n60q40B	6114	6137	0.38	7182.24	6132.00	0.29	6132	0.29	15.04	55.00	6132
n60q40C	6135	6135	0.00	19.67	6135.00	0.00	6135	0.00	23.38	58.40	6135
n60q40D	6369	6369	0.00	31.33	6369.00	0.00	6369	0.00	22.67	51.00	6369
n60q40E	6159	6159	0.00	214.01	6159.00	0.00	6159	0.00	17.49	54.00	6159
n60q40F	5871.17	5925	0.92	7181.92	5915.20	0.75	5912	0.70	33.15	58.00	5912
n60q40G	6273	6273	0.00	1862.08	6273.00	0.00	6273	0.00	23.61	57.00	6273
n60q40H	5884.67	5936	0.87	7182.14	5937.90	0.90	5936	0.87	16.76	54.90	5936
n60q40I	6072	6072	0.00	2335.79	6072.00	0.00	6072	0.00	31.13	58.00	6072
n60q40J	6374	6374	0.00	21.63	6374.00	0.00	6374	0.00	10.78	53.00	6374
n60q45A	5773	5773	0.00	73.34	5773.00	0.00	5773	0.00	15.92	54.70	5773
n60q45B	6125	6132	0.11	7182.23	6133.40	0.14	6132	0.11	14.65	55.00	6132
n60q45C	6135	6135	0.00	34.72	6135.00	0.00	6135	0.00	23.22	58.00	6135
n60q45D	6269	6269	0.00	101.05	6269.00	0.00	6269	0.00	22.94	52.00	6269
n60q45E	6131	6131	0.00	21.50	6131.00	0.00	6131	0.00	14.75	54.00	6131
n60q45F	5816.44	5888	1.23	7183.29	5886.00	1.20	5886	1.20	33.51	58.00	5886
n60q45G	6248	6248	0.00	96.76	6248.00	0.00	6248	0.00	18.51	57.00	6248
n60q45H	5878	5878	0.00	6052.07	5878.00	0.00	5878	0.00	22.28	54.40	5878
n60q45I	5982	5993	0.18	7183.38	5995.40	0.22	5993	0.18	22.40	58.00	5993
n60q45J	6374	6374	0.00	23.67	6374.00	0.00	6374	0.00	10.35	53.10	6374
n60q1000A	5773	5773	0.00	106.51	5773.00	0.00	5773	0.00	15.44	54.50	5773
n60q1000B	6124.50	6132	0.12	7183.33	6132.00	0.12	6132	0.12	14.64	55.00	6132
n60q1000C	6135	6135	0.00	699.03	6135.00	0.00	6135	0.00	21.08	58.00	6135
n60q1000D	6223	6223	0.00	9.94	6223.00	0.00	6223	0.00	11.71	51.00	6223
n60q1000E	6131	6131	0.00	132.15	6131.00	0.00	6131	0.00	13.56	54.00	6131
n60q1000F	5807.14	5879	1.24	7183.32	5878.00	1.22	5878	1.22	25.41	58.00	5878
n60q1000G	6169	6169	0.00	57.57	6169.00	0.00	6169	0.00	15.26	57.00	6169
n60q1000H	5878	5878	0.00	5576.65	5878.00	0.00	5878	0.00	16.31	54.20	5878
n60q1000I	5941	5970	0.49	7183.02	5970.00	0.49	5970	0.49	19.30	58.00	5970
n60q1000J	6374	6374	0.00	32.63	6374.00	0.00	6374	0.00	10.09	53.40	6374

Table 8: Detailed results for $n \in \{20, 30, 40, 50, 60\}$ and $\alpha = 3$

Instance	Erdoğan et al. 2015				ILS$_{SBRP}$						
	LB	UB	UB Gap (%)	UB Time (s)	Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n20q10A	9084	9084	0.00	0.13	9084.00	0.00	9084	0.00	116.11	35.00	9084
n20q10B	9883	9883	0.00	0.14	9883.00	0.00	9883	0.00	129.78	34.30	9883
n20q10C	14039	14039	0.00	1.62	14039.00	0.00	14039	0.00	384.84	42.40	14039
n20q10D	14925	14925	0.00	0.15	14925.00	0.00	14925	0.00	501.00	46.00	14925
n20q10E	14379	14379	0.00	0.82	14379.00	0.00	14379	0.00	319.86	43.00	14379
n20q10F	9752	9752	0.00	0.62	9752.00	0.00	9752	0.00	125.42	36.00	9752
n20q10G	10600	10600	0.00	0.19	10600.00	0.00	10600	0.00	116.54	37.00	10600
n20q10H	11895	11895	0.00	0.11	11895.00	0.00	11895	0.00	228.47	42.00	11895
n20q10I	9229	9229	0.00	0.86	9243.50	0.16	9229	0.00	163.51	40.70	9229
n20q10J	9230	9230	0.00	0.15	9230.00	0.00	9230	0.00	113.86	37.40	9230
n20q15A	6613	6613	0.00	0.11	6613.00	0.00	6613	0.00	20.01	24.00	6613
n20q15B	7404	7404	0.00	0.17	7404.00	0.00	7404	0.00	29.77	26.00	7404
n20q15C	9478	9478	0.00	0.13	9478.00	0.00	9478	0.00	74.69	31.10	9478

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Instance	Erdoğan et al. 2015				ILS$_{\mathbf{SBRP}}$						
	LB	**UB**	**UB Gap (%)**	**UB Time (s)**	**Avg. Sol.**	**Avg. Gap. (%)**	**Best**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. NV**	**Best of all exp.**
n20q15D	10376	10376	0.00	0.26	10376.00	0.00	10376	0.00	83.49	33.00	10376
n20q15E	10102	10102	0.00	0.26	10102.00	0.00	10102	0.00	98.31	33.00	10102
n20q15F	7169	7169	0.00	0.09	7169.00	0.00	7169	0.00	28.15	29.00	7169
n20q15G	7796	7796	0.00	0.62	7796.00	0.00	7796	0.00	29.18	27.00	7796
n20q15H*	8475	8475	0.00	0.40	8479.90	0.06	8474	-0.01	41.19	31.60	8474
n20q15I	6652	6652	0.00	0.94	6652.00	0.00	6652	0.00	23.20	29.00	6652
n20q15J	6730	6730	0.00	0.17	6730.00	0.00	6730	0.00	40.63	29.00	6730
n20q20A	5748	5748	0.00	0.41	5748.00	0.00	5748	0.00	13.73	23.00	5748
n20q20B	6296	6296	0.00	0.11	6296.00	0.00	6296	0.00	17.90	24.00	6296
n20q20C	8433	8433	0.00	1.18	8433.00	0.00	8433	0.00	77.78	30.00	8433
n20q20D	8647	8647	0.00	0.30	8652.20	0.06	8647	0.00	73.40	32.90	8647
n20q20E	8623	8623	0.00	0.28	8623.00	0.00	8623	0.00	46.54	30.00	8623
n20q20F	6159	6159	0.00	0.06	6159.00	0.00	6159	0.00	11.38	25.00	6159
n20q20G	6694	6694	0.00	0.10	6694.00	0.00	6694	0.00	17.27	25.20	6694
n20q20H	7208	7208	0.00	0.17	7208.00	0.00	7208	0.00	28.04	28.00	7208
n20q20I	5939	5939	0.00	0.68	5939.00	0.00	5939	0.00	20.14	27.00	5939
n20q20J	6056	6056	0.00	0.37	6056.00	0.00	6056	0.00	23.41	26.50	6056
n20q25A	5083	5083	0.00	0.20	5083.00	0.00	5083	0.00	3.65	19.00	5083
n20q25B	5387	5387	0.00	0.18	5387.00	0.00	5387	0.00	5.00	19.00	5387
n20q25C	7229	7229	0.00	1.15	7229.70	0.01	7229	0.00	25.86	24.90	7229
n20q25D	7182	7182	0.00	0.54	7182.00	0.00	7182	0.00	34.12	26.00	7182
n20q25E	7148	7148	0.00	0.88	7148.00	0.00	7148	0.00	16.10	23.00	7148
n20q25F	5121	5121	0.00	0.10	5121.00	0.00	5121	0.00	6.44	23.00	5121
n20q25G	5501	5501	0.00	0.21	5501.00	0.00	5501	0.00	6.38	22.00	5501
n20q25H	6027	6027	0.00	0.10	6027.00	0.00	6027	0.00	6.45	21.00	6027
n20q25I	5082	5082	0.00	0.08	5082.00	0.00	5082	0.00	9.43	24.00	5082
n20q25J	5150	5150	0.00	0.45	5150.00	0.00	5150	0.00	7.61	21.00	5150
n20q30A	4702	4702	0.00	0.25	4702.00	0.00	4702	0.00	2.83	18.00	4702
n20q30B	4769	4769	0.00	0.11	4769.00	0.00	4769	0.00	3.96	19.00	4769
n20q30C	6012	6012	0.00	0.75	6012.00	0.00	6012	0.00	18.00	24.00	6012
n20q30D	5989	5989	0.00	0.20	5989.00	0.00	5989	0.00	7.83	20.00	5989
n20q30E	6245	6245	0.00	1.34	6245.00	0.00	6245	0.00	8.28	20.00	6245
n20q30F	4717	4717	0.00	0.25	4717.00	0.00	4717	0.00	3.45	22.00	4717
n20q30G	5070	5070	0.00	0.07	5070.00	0.00	5070	0.00	2.75	19.00	5070
n20q30H	5542	5542	0.00	0.26	5579.80	0.68	5542	0.00	2.74	19.30	5542
n20q30I	4576	4576	0.00	0.12	4576.00	0.00	4576	0.00	4.88	21.00	4576
n20q30J	4078	4078	0.00	0.16	4078.00	0.00	4078	0.00	2.15	18.00	4078
n20q35A	4387	4387	0.00	0.14	4387.00	0.00	4387	0.00	1.65	18.00	4387
n20q35B	4688	4688	0.00	0.16	4688.00	0.00	4688	0.00	1.86	18.20	4688
n20q35C	5813	5813	0.00	0.81	5867.40	0.94	5813	0.00	10.87	21.70	5813
n20q35D	5983	5983	0.00	0.29	5983.00	0.00	5983	0.00	8.10	20.00	5983
n20q35E	5808	5808	0.00	0.42	5836.00	0.48	5836	0.48	7.53	20.20	5836
n20q35F	4691	4691	0.00	0.32	4691.00	0.00	4691	0.00	2.16	21.00	4691
n20q35G	5051	5051	0.00	0.38	5051.00	0.00	5051	0.00	2.88	19.10	5051
n20q35H	5320	5320	0.00	0.38	5330.90	0.20	5320	0.00	4.13	20.90	5320
n20q35I	4382	4382	0.00	0.17	4382.00	0.00	4382	0.00	3.41	20.00	4382
n20q35J	4078	4078	0.00	0.18	4078.00	0.00	4078	0.00	1.97	18.00	4078
n20q40A	4129	4129	0.00	0.09	4129.00	0.00	4129	0.00	1.80	19.00	4129
n20q40B	4295	4295	0.00	0.08	4295.00	0.00	4295	0.00	1.45	19.30	4295
n20q40C	5302	5302	0.00	0.38	5302.00	0.00	5302	0.00	5.30	21.00	5302
n20q40D	5648	5648	0.00	0.79	5648.00	0.00	5648	0.00	6.47	20.10	5648
n20q40E	5568	5568	0.00	0.20	5568.00	0.00	5568	0.00	3.31	18.00	5568
n20q40F	4614	4614	0.00	0.19	4614.00	0.00	4614	0.00	1.44	21.00	4614
n20q40G	4733	4733	0.00	0.29	4733.00	0.00	4733	0.00	1.89	19.00	4733
n20q40H	4954	4954	0.00	0.39	4954.00	0.00	4954	0.00	2.61	19.00	4954
n20q40I	4108	4108	0.00	0.12	4108.00	0.00	4108	0.00	1.10	19.00	4108
n20q40J	4049	4049	0.00	0.22	4049.00	0.00	4049	0.00	1.85	18.00	4049
n20q45A	3948	3948	0.00	0.12	3948.00	0.00	3948	0.00	0.97	17.00	3948
n20q45B	4174	4174	0.00	0.06	4174.00	0.00	4174	0.00	1.35	19.00	4174
n20q45C	5137	5137	0.00	1.48	5137.00	0.00	5137	0.00	4.02	21.00	5137
n20q45D	5446	5446	0.00	0.42	5446.00	0.00	5446	0.00	5.26	20.00	5446
n20q45E	5560	5560	0.00	0.46	5560.00	0.00	5560	0.00	3.74	19.00	5560
n20q45F	4290	4290	0.00	0.04	4290.00	0.00	4290	0.00	1.61	21.00	4290
n20q45G	4489	4489	0.00	0.07	4489.00	0.00	4489	0.00	1.02	19.00	4489
n20q45H	4559	4559	0.00	0.12	4559.00	0.00	4559	0.00	1.25	19.00	4559
n20q45I	4051	4051	0.00	0.07	4051.00	0.00	4051	0.00	0.88	19.00	4051
n20q45J	3905	3905	0.00	0.21	3905.30	0.01	3905	0.00	1.08	17.70	3905
n20q1000A	3583	3583	0.00	0.02	3583.00	0.00	3583	0.00	0.37	17.00	3583

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	LB	UB	UB Gap (%)	UB Time (s)	Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n20q1000B	3792	3792	0.00	0.03	3792.00	0.00	3792	0.00	0.35	18.00	3792
n20q1000C	4042	4042	0.00	5.81	4042.00	0.00	4042	0.00	0.67	20.00	4042
n20q1000D	3806	3806	0.00	2.06	3806.00	0.00	3806	0.00	0.43	19.00	3806
n20q1000E	4277	4277	0.00	0.74	4277.00	0.00	4277	0.00	0.54	18.00	4277
n20q1000F	4108	4108	0.00	0.11	4108.00	0.00	4108	0.00	0.38	20.00	4108
n20q1000G	4216	4216	0.00	0.24	4216.00	0.00	4216	0.00	0.37	19.00	4216
n20q1000H	3992	3992	0.00	0.13	3992.00	0.00	3992	0.00	0.41	19.00	3992
n20q1000I	3960	3960	0.00	0.07	3960.00	0.00	3960	0.00	0.56	19.00	3960
n20q1000J	3650	3650	0.00	0.13	3650.00	0.00	3650	0.00	0.41	17.00	3650
n30q10A	14470	14470	0.00	141.07	14476.40	0.04	14470	0.00	1462.34	59.20	14470
n30q10B	15092	15092	0.00	1359.16	15099.70	0.05	15092	0.00	1260.52	53.30	15092
n30q10C	12746	12746	0.00	16.00	12784.10	0.30	12746	0.00	1083.72	60.40	12746
n30q10D	11818	11818	0.00	2.25	11818.00	0.00	11818	0.00	777.70	57.40	11818
n30q10E	11704	11704	0.00	1.26	11704.00	0.00	11704	0.00	451.25	54.10	11704
n30q10F	12628	12628	0.00	0.90	12633.00	0.04	12628	0.00	458.21	55.90	12628
n30q10G	21203	21203	0.00	6.42	21203.00	0.00	21203	0.00	3255.23	64.10	21203
n30q10H	12656	12656	0.00	4.12	12656.00	0.00	12656	0.00	657.12	53.80	12656
n30q10I	10902	10902	0.00	4.54	10902.00	0.00	10902	0.00	791.06	58.10	10902
n30q10J	12639	12639	0.00	2.73	12639.00	0.00	12639	0.00	956.48	57.60	12639
n30q15A	10099	10099	0.00	617.89	10110.60	0.11	10099	0.00	185.79	41.00	10099
n30q15B	10234	10234	0.00	4.67	10234.00	0.00	10234	0.00	170.59	38.40	10234
n30q15C	9316	9316	0.00	2.86	9316.00	0.00	9316	0.00	205.99	44.20	9316
n30q15D	8662	8662	0.00	10.81	8665.50	0.04	8662	0.00	119.44	43.20	8662
n30q15E	9026	9026	0.00	5.26	9027.10	0.01	9026	0.00	150.12	41.90	9026
n30q15F	9028	9028	0.00	2.71	9029.20	0.01	9028	0.00	99.54	41.70	9028
n30q15G	14752	14752	0.00	6.04	14763.70	0.08	14752	0.00	713.98	48.00	14752
n30q15H	8993	8993	0.00	1.13	8993.00	0.00	8993	0.00	216.54	44.30	8993
n30q15I	7792	7792	0.00	1.38	7792.00	0.00	7792	0.00	97.20	42.00	7792
n30q15J	8706	8706	0.00	0.86	8706.00	0.00	8706	0.00	103.99	40.00	8706
n30q20A	8794	8794	0.00	27.67	8808.40	0.16	8794	0.00	219.20	42.90	8794
n30q20B	8820	8820	0.00	35.22	8820.00	0.00	8820	0.00	139.48	37.40	8820
n30q20C	8022	8022	0.00	1.37	8022.00	0.00	8022	0.00	120.62	41.40	8022
n30q20D	7544	7544	0.00	5.40	7544.00	0.00	7544	0.00	88.83	38.00	7544
n30q20E	7360	7360	0.00	0.39	7360.00	0.00	7360	0.00	50.86	36.00	7360
n30q20F	8061	8061	0.00	2.12	8068.40	0.09	8061	0.00	88.29	38.80	8061
n30q20G	11978	11978	0.00	4.08	11978.00	0.00	11978	0.00	332.29	44.00	11978
n30q20H	7723	7723	0.00	0.80	7723.00	0.00	7723	0.00	111.12	39.10	7723
n30q20I	6803	6803	0.00	1.53	6803.00	0.00	6803	0.00	76.82	39.00	6803
n30q20J	7788	7788	0.00	3.06	7788.00	0.00	7788	0.00	107.04	37.20	7788
n30q25A	7571	7571	0.00	55.65	7574.20	0.04	7571	0.00	72.23	33.80	7571
n30q25B	7055	7055	0.00	0.87	7055.00	0.00	7055	0.00	97.17	33.40	7055
n30q25C	6821	6821	0.00	3.30	6821.00	0.00	6821	0.00	53.55	34.60	6821
n30q25D	6464	6464	0.00	0.93	6464.00	0.00	6464	0.00	53.31	35.70	6464
n30q25E	6474	6474	0.00	6.17	6474.00	0.00	6474	0.00	52.99	35.00	6474
n30q25F	6721	6721	0.00	1.31	6721.00	0.00	6721	0.00	54.87	37.00	6721
n30q25G	10120	10120	0.00	16.73	10219.40	0.98	10149	0.29	131.83	32.70	10142
n30q25H	7087	7087	0.00	1.78	7087.00	0.00	7087	0.00	47.97	34.10	7087
n30q25I	6207	6207	0.00	2.64	6207.00	0.00	6207	0.00	24.43	31.00	6207
n30q25J	6937	6937	0.00	13.29	6937.00	0.00	6937	0.00	66.31	32.40	6937
n30q30A	6236	6236	0.00	6.92	6236.00	0.00	6236	0.00	20.08	30.00	6236
n30q30B	6308	6308	0.00	2.86	6308.00	0.00	6308	0.00	12.79	26.00	6308
n30q30C	6335	6335	0.00	33.91	6335.00	0.00	6335	0.00	32.19	31.10	6335
n30q30D	6076	6076	0.00	5.05	6079.20	0.05	6076	0.00	42.47	33.80	6076
n30q30E	5877	5877	0.00	1.06	5882.40	0.09	5877	0.00	16.04	29.20	5877
n30q30F	5695	5695	0.00	2.03	5695.00	0.00	5695	0.00	15.52	30.00	5695
n30q30G	8891	8891	0.00	38.10	8891.00	0.00	8891	0.00	86.26	31.00	8891
n30q30H	5884	5884	0.00	1.89	5884.00	0.00	5884	0.00	22.94	29.10	5884
n30q30I	5430	5430	0.00	5.23	5434.00	0.07	5430	0.00	20.16	31.00	5430
n30q30J	5764	5764	0.00	2.00	5764.00	0.00	5764	0.00	19.31	30.00	5764
n30q35A	6024	6024	0.00	12.09	6025.00	0.02	6025	0.02	15.37	29.00	6024
n30q35B	6108	6108	0.00	9.96	6110.50	0.04	6108	0.00	24.41	29.10	6108
n30q35C	5962	5962	0.00	15.10	5962.00	0.00	5962	0.00	21.67	29.40	5962
n30q35D	5826	5826	0.00	3.68	5872.80	0.80	5826	0.00	26.17	30.50	5826
n30q35E	5788	5788	0.00	1.51	5788.30	0.01	5788	0.00	16.36	29.70	5788
n30q35F	5230	5230	0.00	0.54	5230.00	0.00	5230	0.00	9.63	30.00	5230
n30q35G	8275	8275	0.00	35.96	8353.20	0.95	8275	0.00	72.00	31.40	8275
n30q35H	5678	5678	0.00	2.86	5678.00	0.00	5678	0.00	23.14	29.00	5678
n30q35I	5186	5186	0.00	2.69	5204.90	0.36	5186	0.00	13.04	30.20	5186

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	LB	**UB**	**UB Gap (%)**	**UB Time (s)**	**Avg. Sol.**	**Avg. Gap. (%)**	**Best**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. NV**	**Best of all exp.**
n30q35J	5622	5622	0.00	9.27	5622.00	0.00	5622	0.00	21.09	30.00	5622
n30q40A	5745	5745	0.00	16.71	5745.00	0.00	5745	0.00	10.84	31.00	5745
n30q40B	5570	5570	0.00	5.85	5570.00	0.00	5570	0.00	10.39	26.30	5570
n30q40C	5209	5209	0.00	0.41	5209.00	0.00	5209	0.00	7.75	28.10	5209
n30q40D	5614	5614	0.00	17.02	5614.00	0.00	5614	0.00	14.24	28.00	5614
n30q40E	5127	5127	0.00	1.06	5127.00	0.00	5127	0.00	6.91	27.00	5127
n30q40F	5221	5221	0.00	0.79	5221.00	0.00	5221	0.00	10.01	30.00	5221
n30q40G	7468	7468	0.00	7.47	7526.80	0.79	7507	0.52	26.47	28.30	7468
n30q40H	5300	5300	0.00	0.78	5300.00	0.00	5300	0.00	11.91	28.00	5300
n30q40I	4775	4775	0.00	4.49	4775.00	0.00	4775	0.00	6.78	28.30	4775
n30q40J	5469	5469	0.00	4.57	5469.00	0.00	5469	0.00	13.18	28.20	5469
n30q45A	5442	5442	0.00	3.47	5442.00	0.00	5442	0.00	9.50	30.00	5442
n30q45B	5364	5364	0.00	1.94	5364.00	0.00	5364	0.00	6.78	26.10	5364
n30q45C	5170	5170	0.00	1.49	5170.00	0.00	5170	0.00	6.18	28.10	5170
n30q45D	5142	5142	0.00	1.56	5157.60	0.30	5142	0.00	9.50	29.90	5142
n30q45E	5121	5121	0.00	1.90	5121.00	0.00	5121	0.00	7.03	27.00	5121
n30q45F	4895	4895	0.00	1.21	4895.00	0.00	4895	0.00	5.37	29.00	4895
n30q45G	7146	7146	0.00	8.92	7206.00	0.84	7146	0.00	30.23	29.60	7146
n30q45H	5103	5103	0.00	2.06	5112.80	0.19	5103	0.00	9.01	29.20	5103
n30q45I	4622	4622	0.00	2.04	4622.00	0.00	4622	0.00	4.16	27.00	4622
n30q45J	5242	5242	0.00	4.98	5242.90	0.02	5242	0.00	11.87	29.00	5242
n30q1000A	4603	4603	0.00	1.18	4603.00	0.00	4603	0.00	1.43	29.10	4603
n30q1000B	4340	4340	0.00	414.14	4340.00	0.00	4340	0.00	1.29	26.00	4340
n30q1000C	4475	4475	0.00	1414.99	4475.00	0.00	4475	0.00	2.00	28.00	4475
n30q1000D	4666	4666	0.00	324.67	4675.00	0.19	4666	0.00	1.94	28.80	4666
n30q1000E	4466	4466	0.00	0.17	4466.00	0.00	4466	0.00	0.87	27.00	4466
n30q1000F	4384	4384	0.00	2.46	4384.00	0.00	4384	0.00	1.27	29.00	4384
n30q1000G	4781	4781	0.00	52.42	4781.00	0.00	4781	0.00	1.57	27.00	4781
n30q1000H	4030	4030	0.00	0.39	4030.00	0.00	4030	0.00	1.20	27.00	4030
n30q1000I	4272	4272	0.00	1.06	4272.00	0.00	4272	0.00	1.01	27.00	4272
n30q1000J	4300	4300	0.00	1.55	4300.00	0.00	4300	0.00	1.35	27.00	4300
n40q10A	15039	15039	0.00	207.68	15063.80	0.16	15039	0.00	3310.23	78.60	15039
n40q10B	11832	11832	0.00	14.95	11835.70	0.03	11832	0.00	1395.33	71.30	11832
n40q10C	16963	16963	0.00	71.38	17025.80	0.37	16964	0.01	3600.77	76.90	16964
n40q10D	17104	17104	0.00	23.02	17104.00	0.00	17104	0.00	3586.80	71.10	17104
n40q10E	13159	13159	0.00	14.55	13159.00	0.00	13159	0.00	1183.01	69.80	13159
n40q10F	15019	15019	0.00	1858.16	15022.90	0.03	15019	0.00	2606.58	74.50	15019
n40q10G*	16600	16600	0.00	42.55	16605.40	0.03	16599	-0.01	3387.35	75.40	16559
n40q10H	13578	13578	0.00	22.19	13578.00	0.00	13578	0.00	2976.06	74.20	13578
n40q10I	14849	14849	0.00	86.55	14853.30	0.03	14849	0.00	2772.27	74.90	14849
n40q10J	12646	12646	0.00	13.15	12646.00	0.00	12646	0.00	1378.42	70.00	12646
n40q15A	10487	10487	0.00	39.21	10487.00	0.00	10487	0.00	467.21	54.00	10487
n40q15B	8491	8491	0.00	4.27	8491.00	0.00	8491	0.00	145.84	50.00	8491
n40q15C	11406	11406	0.00	6.06	11406.00	0.00	11406	0.00	476.37	53.40	11406
n40q15D	12166	12166	0.00	8.14	12166.00	0.00	12166	0.00	727.55	51.20	12166
n40q15E	9651	9651	0.00	33.92	9651.00	0.00	9651	0.00	213.92	50.80	9651
n40q15F	10590	10590	0.00	109.28	10636.90	0.44	10603	0.12	440.37	57.00	10590
n40q15G	11932	11932	0.00	49.94	11936.30	0.04	11932	0.00	544.03	55.90	11932
n40q15H	9670	9670	0.00	8.14	9670.10	0.00	9670	0.00	377.56	55.50	9670
n40q15I	10654	10654	0.00	6.46	10654.00	0.00	10654	0.00	307.28	54.30	10654
n40q15J	9241	9241	0.00	22.90	9241.00	0.00	9241	0.00	206.26	52.40	9241
n40q20A	9051	9051	0.00	89.13	9052.50	0.02	9051	0.00	306.29	50.00	9051
n40q20B	7523	7523	0.00	27.11	7523.00	0.00	7523	0.00	175.70	49.40	7523
n40q20C	9895	9895	0.00	5.11	9895.00	0.00	9895	0.00	522.16	50.90	9895
n40q20D	10390	10390	0.00	75.67	10390.00	0.00	10390	0.00	541.25	48.50	10390
n40q20E	8387	8387	0.00	122.40	8387.00	0.00	8387	0.00	170.19	46.20	8387
n40q20F	9310	9310	0.00	67.89	9310.00	0.00	9310	0.00	375.20	51.10	9310
n40q20G	10085	10085	0.00	23.98	10085.00	0.00	10085	0.00	377.55	52.70	10085
n40q20H	8685	8685	0.00	200.22	8690.20	0.06	8685	0.00	357.73	53.20	8685
n40q20I	8805	8805	0.00	2.18	8805.00	0.00	8805	0.00	208.50	49.40	8805
n40q20J	7760	7760	0.00	8.51	7760.00	0.00	7760	0.00	279.23	51.50	7760
n40q25A	7880	7880	0.00	90.05	7880.00	0.00	7880	0.00	134.48	44.00	7880
n40q25B	6607	6607	0.00	18.57	6607.00	0.00	6607	0.00	47.66	41.00	6607
n40q25C	8084	8084	0.00	8.22	8084.00	0.00	8084	0.00	154.79	41.80	8084
n40q25D	9049	9049	0.00	14.28	9053.00	0.04	9049	0.00	219.24	44.60	9049
n40q25E	7119	7119	0.00	12.06	7119.00	0.00	7119	0.00	50.57	39.20	7119
n40q25F	7620	7620	0.00	44.60	7638.00	0.24	7620	0.00	127.40	44.80	7620
n40q25G	9041	9041	0.00	1508.70	9070.90	0.33	9047	0.07	213.53	45.50	9041

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	LB	UB	UB Gap (%)	UB Time (s)	Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n40q25H	7488	7488	0.00	3.26	7488.00	0.00	7488	0.00	126.16	46.00	7488
n40q25I	7913	7913	0.00	42.90	7913.00	0.00	7913	0.00	121.00	43.30	7913
n40q25J	7226	7226	0.00	31.25	7226.00	0.00	7226	0.00	167.90	45.50	7226
n40q30A	6949	6949	0.00	35.89	6961.40	0.18	6949	0.00	62.93	40.90	6949
n40q30B	5949	5949	0.00	7.56	5949.00	0.00	5949	0.00	27.64	39.00	5949
n40q30C	7237	7237	0.00	15.41	7237.00	0.00	7237	0.00	60.97	36.50	7237
n40q30D	7692	7692	0.00	10.21	7692.00	0.00	7692	0.00	117.88	39.10	7692
n40q30E	6424	6424	0.00	16.43	6441.00	0.26	6441	0.26	25.52	34.00	6441
n40q30F	7074	7074	0.00	615.97	7095.90	0.31	7085	0.16	67.10	40.90	7074
n40q30G	7375	7375	0.00	154.15	7376.50	0.02	7375	0.00	63.49	42.70	7375
n40q30H	6556	6556	0.00	16.83	6570.60	0.22	6556	0.00	55.40	41.90	6556
n40q30I	6901	6901	0.00	19.37	6901.00	0.00	6901	0.00	57.97	41.10	6901
n40q30J	6267	6267	0.00	191.32	6269.10	0.03	6267	0.00	39.71	40.20	6267
n40q35A	6780	6780	0.00	133.02	6781.00	0.01	6780	0.00	61.87	40.00	6780
n40q35B	5829	5829	0.00	36.96	5839.00	0.17	5829	0.00	26.70	39.60	5829
n40q35C	6978	6978	0.00	246.70	6978.00	0.00	6978	0.00	72.78	39.10	6978
n40q35D	7341	7341	0.00	57.82	7378.40	0.51	7344	0.04	93.66	39.20	7341
n40q35E	6364	6364	0.00	227.64	6381.00	0.27	6381	0.27	28.57	34.00	6381
n40q35F	6825	6825	0.00	1835.26	6828.70	0.05	6825	0.00	66.96	40.00	6825
n40q35G	7146	7146	0.00	68.81	7146.00	0.00	7146	0.00	64.32	42.30	7146
n40q35H	6335	6335	0.00	60.80	6354.10	0.30	6335	0.00	41.62	39.90	6335
n40q35I	6377	6377	0.00	8.84	6377.00	0.00	6377	0.00	52.64	39.10	6377
n40q35J	6118	6118	0.00	371.13	6118.20	0.00	6118	0.00	45.71	40.30	6118
n40q40A	6119	6119	0.00	12.46	6119.00	0.00	6119	0.00	22.33	38.20	6119
n40q40B	5615	5615	0.00	12.52	5615.00	0.00	5615	0.00	19.81	38.00	5615
n40q40C	6398	6398	0.00	11.59	6398.00	0.00	6398	0.00	64.05	38.80	6398
n40q40D	6898	6898	0.00	43.03	6900.00	0.03	6898	0.00	60.06	39.00	6898
n40q40E	5969	5969	0.00	11.84	5971.10	0.04	5969	0.00	17.00	34.70	5969
n40q40F	6145	6145	0.00	13.00	6145.00	0.00	6145	0.00	24.38	37.30	6145
n40q40G	6532	6532	0.00	18.66	6532.00	0.00	6532	0.00	41.51	40.00	6532
n40q40H	6050	6050	0.00	30.00	6050.00	0.00	6050	0.00	29.62	39.10	6050
n40q40I	6089	6089	0.00	22.98	6091.60	0.04	6089	0.00	29.65	39.60	6089
n40q40J	5801	5801	0.00	40.67	5801.00	0.00	5801	0.00	36.95	38.30	5801
n40q45A	6059	6059	0.00	46.28	6059.00	0.00	6059	0.00	20.77	38.00	6059
n40q45B	5319	5319	0.00	3.24	5319.00	0.00	5319	0.00	10.41	37.00	5319
n40q45C	5912	5912	0.00	14.25	5912.00	0.00	5912	0.00	22.98	35.70	5912
n40q45D	6388	6388	0.00	9.29	6388.00	0.00	6388	0.00	35.07	37.40	6388
n40q45E	5671	5671	0.00	28.87	5671.00	0.00	5671	0.00	11.94	34.00	5671
n40q45F	5847	5847	0.00	55.83	5847.00	0.00	5847	0.00	21.73	38.30	5847
n40q45G	6409	6409	0.00	34.26	6412.40	0.05	6409	0.00	29.74	40.40	6409
n40q45H	5575	5575	0.00	4.65	5575.00	0.00	5575	0.00	21.09	39.20	5575
n40q45I	5732	5732	0.00	9.02	5732.00	0.00	5732	0.00	16.74	37.20	5732
n40q45J	5630	5630	0.00	51.74	5630.30	0.01	5630	0.00	23.64	37.70	5630
n40q1000A	4949	4949	0.00	1.05	4949.00	0.00	4949	0.00	2.66	38.00	4949
n40q1000B	5110	5110	0.00	2.81	5110.00	0.00	5110	0.00	2.58	37.00	5110
n40q1000C	4570	4570	0.00	759.52	4570.00	0.00	4570	0.00	5.34	36.80	4570
n40q1000D	5202	5202	0.00	3.28	5202.00	0.00	5202	0.00	3.62	36.00	5202
n40q1000E	5069	5069	0.00	4.49	5069.00	0.00	5069	0.00	1.75	33.30	5069
n40q1000F	4816	4816	0.00	3.99	4816.00	0.00	4816	0.00	2.26	37.00	4816
n40q1000G	5253	5253	0.00	4.80	5253.00	0.00	5253	0.00	3.46	39.00	5253
n40q1000H	4804	4804	0.00	27.07	4804.00	0.00	4804	0.00	2.85	38.00	4804
n40q1000I	4713	4713	0.00	0.48	4713.00	0.00	4713	0.00	2.71	37.00	4713
n40q1000J	4753	4753	0.00	1.61	4753.00	0.00	4753	0.00	2.45	36.00	4753
n50q10A	13136	13136	0.00	245.92	13139.00	0.02	13139	0.02	3386.10	83.30	13139
n50q10B	21374.43	21474	0.47	7182.99	21429.80	0.26	21396	0.10	3602.70	98.10	21396
n50q10C	18076.06	19623	8.56	7183.18	18375.60	1.66	18356	1.55	3602.22	96.10	18356
n50q10D	22824	22824	0.00	3131.87	22832.30	0.04	22824	0.00	3603.00	98.10	22824
n50q10E*	21223	21223	0.00	333.13	21222.80	0.00	21222	0.00	3601.88	98.60	21222
n50q10F	16566	16566	0.00	1238.28	16719.70	0.93	16576	0.06	3601.93	98.50	16576
n50q10G	14018	14018	0.00	46.28	14018.00	0.00	14018	0.00	3592.48	95.30	14018
n50q10H	18648.15	18815	0.89	7182.62	18686.00	0.20	18672	0.13	3601.81	89.50	18672
n50q10I	16436	16436	0.00	157.35	16464.60	0.17	16440	0.02	3601.22	94.70	16440
n50q10J	18123	18123	0.00	232.43	18123.00	0.00	18123	0.00	3601.54	100.80	18123
n50q15A	9254	9254	0.00	20.67	9254.00	0.00	9254	0.00	256.58	56.00	9254
n50q15B	14697	14697	0.00	178.59	14730.70	0.23	14697	0.00	1978.48	71.00	14697
n50q15C	12630	12630	0.00	1512.51	12630.00	0.00	12630	0.00	1932.07	65.30	12630
n50q15D	16449	16449	0.00	6444.76	16504.90	0.34	16503	0.33	2827.67	73.20	16503
n50q15E	14812	14812	0.00	1827.90	14812.90	0.01	14812	0.00	2357.85	75.30	14812

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	LB	**UB**	**UB Gap (%)**	**UB Time (s)**	**Avg. Sol.**	**Avg. Gap. (%)**	**Best**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. NV**	**Best of all exp.**
n50q15F*	11859	11859	0.00	954.82	11858.00	-0.01	11858	-0.01	1355.71	73.40	11858
n50q15G	10226	10226	0.00	8.27	10226.00	0.00	10226	0.00	435.05	70.30	10226
n50q15H	13137	13137	0.00	2168.21	13137.00	0.00	13137	0.00	1148.34	64.20	13137
n50q15I	11907	11907	0.00	39.15	11907.00	0.00	11907	0.00	1245.20	73.30	11907
n50q15J	13049	13049	0.00	3866.79	13049.00	0.00	13049	0.00	1498.72	72.40	13049
n50q20A	8431	8431	0.00	72.25	8431.70	0.01	8431	0.00	285.18	53.90	8431
n50q20B	12415.31	12662	1.99	7182.50	12562.00	1.18	12562	1.18	2065.70	65.00	12562
n50q20C	10811.35	11220	3.78	7182.39	11038.60	2.10	11031	2.03	2149.52	63.40	11031
n50q20D	13139	13139	0.00	1073.40	13195.60	0.43	13139	0.00	2056.14	65.70	13139
n50q20E	12532	12532	0.00	3099.14	12548.90	0.13	12541	0.07	2551.10	66.90	12533
n50q20F	10075	10075	0.00	2799.06	10080.60	0.06	10075	0.00	1028.47	67.90	10075
n50q20G	8870	8870	0.00	27.19	8870.00	0.00	8870	0.00	561.02	65.50	8870
n50q20H	11195	11551	3.18	7183.28	11341.90	1.31	11297	0.91	943.61	60.30	11297
n50q20I	10042	10042	0.00	379.57	10045.00	0.03	10042	0.00	856.78	63.70	10042
n50q20J	11132	11132	0.00	1855.16	11132.00	0.00	11132	0.00	1243.75	68.10	11132
n50q25A	7279	7279	0.00	54.07	7279.00	0.00	7279	0.00	107.40	45.00	7279
n50q25B	10656	10656	0.00	2116.39	10656.00	0.00	10656	0.00	943.50	57.50	10656
n50q25C	9129.21	9490	3.95	7183.25	9230.20	1.11	9217	0.96	685.99	54.10	9217
n50q25D	11364	11364	0.00	536.81	11369.60	0.05	11364	0.00	1010.26	59.80	11364
n50q25E	10241	10241	0.00	877.12	10241.00	0.00	10241	0.00	946.17	56.90	10241
n50q25F	8685	8685	0.00	1198.90	8707.20	0.26	8685	0.00	529.43	57.50	8685
n50q25G	7536	7536	0.00	15.23	7559.40	0.31	7536	0.00	109.37	53.70	7536
n50q25H	9476.81	9659	1.92	7183.17	9636.80	1.69	9612	1.43	365.71	53.40	9612
n50q25I	8614	8614	0.00	987.56	8614.00	0.00	8614	0.00	367.78	54.10	8614
n50q25J	9218	9218	0.00	92.99	9218.00	0.00	9218	0.00	380.69	57.60	9218
n50q30A	6520	6520	0.00	23.78	6526.00	0.09	6520	0.00	46.69	43.60	6520
n50q30B	9025	9025	0.00	132.50	9025.00	0.00	9025	0.00	252.04	50.10	9025
n50q30C	8151	8151	0.00	1767.40	8151.00	0.00	8151	0.00	286.87	48.40	8151
n50q30D	9804	9804	0.00	429.98	9813.90	0.10	9804	0.00	441.52	51.00	9804
n50q30E	9086	9086	0.00	1208.29	9086.00	0.00	9086	0.00	262.72	50.60	9086
n50q30F	7661	7661	0.00	247.61	7666.20	0.07	7661	0.00	207.83	51.40	7661
n50q30G	6986	6986	0.00	45.72	6991.20	0.07	6986	0.00	63.68	49.60	6986
n50q30H	8319.01	8699	4.57	7183.29	8564.10	2.95	8563	2.93	188.97	49.30	8563
n50q30I	7964	7964	0.00	2106.01	8002.70	0.49	7964	0.00	242.74	53.00	7964
n50q30J	8054	8054	0.00	307.55	8054.00	0.00	8054	0.00	162.88	50.50	8054
n50q35A	6410	6410	0.00	54.53	6416.00	0.09	6410	0.00	41.22	42.30	6410
n50q35B	8720.50	8963	2.78	7183.24	8785.50	0.75	8763	0.49	360.47	51.20	8763
n50q35C	7730.63	7781	0.65	7183.26	7817.60	1.13	7781	0.65	310.68	51.80	7781
n50q35D	9199.19	9404	2.23	7183.31	9425.80	2.46	9343	1.56	342.79	52.50	9343
n50q35E	8708	8708	0.00	3828.26	8714.10	0.07	8708	0.00	274.12	51.00	8708
n50q35F	7390	7390	0.00	2151.51	7399.70	0.13	7397	0.09	148.34	49.90	7390
n50q35G	6681	6681	0.00	84.18	6681.00	0.00	6681	0.00	56.55	49.00	6681
n50q35H	7927.23	8331	5.09	7183.30	8033.00	1.33	8033	1.33	157.93	48.40	8033
n50q35I	7328	7328	0.00	91.01	7332.10	0.06	7328	0.00	133.07	50.50	7328
n50q35J	7828.19	7981	1.95	7181.87	7976.30	1.89	7970	1.81	189.43	49.40	7970
n50q40A	6249	6249	0.00	35.61	6249.00	0.00	6249	0.00	28.73	41.00	6249
n50q40B	8187.74	8288	1.22	7183.27	8288.00	1.22	8288	1.22	250.35	49.50	8288
n50q40C	7158	7158	0.00	217.36	7158.00	0.00	7158	0.00	277.46	50.60	7158
n50q40D	8520.19	8709	2.22	7182.69	8672.60	1.79	8657	1.61	237.07	50.70	8657
n50q40E	8075	8075	0.00	5944.43	8087.10	0.15	8075	0.00	177.73	49.40	8075
n50q40F	7009.67	7042	0.46	7183.19	7048.00	0.55	7042	0.46	120.14	49.10	7042
n50q40G	6447	6447	0.00	21.15	6447.00	0.00	6447	0.00	39.25	48.00	6447
n50q40H	7561.06	7606	0.59	7183.22	7609.60	0.64	7606	0.59	95.45	46.90	7606
n50q40I	6926	6926	0.00	230.83	6929.20	0.05	6926	0.00	115.65	51.20	6926
n50q40J	7249	7249	0.00	272.31	7254.80	0.08	7249	0.00	93.21	48.50	7249
n50q45A	5975	5975	0.00	28.99	5975.00	0.00	5975	0.00	13.24	41.10	5975
n50q45B	7697	7697	0.00	3701.19	7728.50	0.41	7697	0.00	137.78	47.60	7697
n50q45C	6693	6693	0.00	145.38	6693.00	0.00	6693	0.00	125.46	48.00	6693
n50q45D	8054	8173	1.48	7182.94	8140.10	1.07	8136	1.02	123.78	49.40	8136
n50q45E	7671.50	7737	0.85	7182.80	7732.00	0.79	7732	0.79	120.00	46.70	7732
n50q45F	6464	6464	0.00	82.59	6464.00	0.00	6464	0.00	54.90	46.20	6464
n50q45G	6273	6273	0.00	24.53	6273.00	0.00	6273	0.00	31.05	48.10	6273
n50q45H	7005	7005	0.00	2047.46	7007.90	0.04	7005	0.00	51.98	46.90	7005
n50q45I	6423	6423	0.00	45.12	6423.00	0.00	6423	0.00	46.01	47.30	6423
n50q45J	6601	6601	0.00	136.61	6601.00	0.00	6601	0.00	45.16	46.20	6601
n50q1000A	5634	5634	0.00	22.23	5634.00	0.00	5634	0.00	3.99	41.10	5634
n50q1000B	5903.86	5961	0.97	7183.26	5955.00	0.87	5955	0.87	7.91	46.00	5955
n50q1000C	5139	5139	0.00	26.89	5139.00	0.00	5139	0.00	7.42	46.00	5139

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Instance	Erdoğan et al. 2015				ILS_{SBRP}						
	LB	UB	UB Gap (%)	UB Time (s)	Avg. Sol.	Avg. Gap. (%)	Best	Best Gap (%)	Avg. Time (s)	Avg. NV	Best of all exp.
n50q1000D	5836	5836	0.00	0.97	5836.00	0.00	5836	0.00	7.01	46.00	5836
n50q1000E	6023	6023	0.00	2299.40	6023.00	0.00	6023	0.00	6.68	45.00	6023
n50q1000F	5262	5262	0.00	6231.66	5262.00	0.00	5262	0.00	7.33	46.00	5262
n50q1000G	5864	5864	0.00	2546.87	5864.00	0.00	5864	0.00	7.87	48.00	5864
n50q1000H	5559	5559	0.00	957.35	5559.00	0.00	5559	0.00	5.89	45.00	5559
n50q1000I	5462	5462	0.00	11.45	5462.00	0.00	5462	0.00	6.24	47.00	5462
n50q1000J	5675	5675	0.00	109.74	5675.00	0.00	5675	0.00	6.27	44.00	5675
n60q10A	16622	16622	0.00	4811.18	16706.80	0.51	16626	0.02	3602.77	107.50	16624
n60q10B	17874.14	20003	11.91	7183.08	18124.20	1.40	18092	1.22	3601.72	119.50	18092
n60q10C	18765.30	21050	12.18	7182.20	19010.70	1.31	18962	1.05	3602.27	114.60	18962
n60q10D	24095	24095	0.00	481.56	24138.40	0.18	24123	0.12	3604.27	112.40	24123
n60q10E	18777.06	19356	3.08	7183.21	18935.40	0.84	18805	0.15	3602.51	110.80	18805
n60q10F	17303	17303	0.00	168.02	17337.90	0.20	17303	0.00	3602.31	125.20	17303
n60q10G	18713	18713	0.00	748.90	18752.00	0.21	18715	0.01	3602.49	120.00	18715
n60q10H	16888	16888	0.00	211.03	16994.90	0.63	16920	0.19	3602.15	111.00	16888
n60q10I	20469	20698	1.12	7183.21	20665.80	0.96	20526	0.28	3605.08	120.20	20526
n60q10J	16717	16717	0.00	2027.81	16725.10	0.05	16717	0.00	3602.13	113.80	16717
n60q15A	11944.32	12628	5.72	7183.13	12168.00	1.87	12156	1.77	2630.77	81.00	12156
n60q15B	12591	12591	0.00	946.24	12591.00	0.00	12591	0.00	1968.51	83.60	12591
n60q15C	13634.60	16390	20.21	7182.97	13765.70	0.96	13760	0.92	3542.02	87.00	13760
n60q15D	17109	17109	0.00	3765.23	17109.80	0.00	17109	0.00	3600.66	84.60	17109
n60q15E	13720.71	13910	1.38	7182.13	13852.80	0.96	13851	0.95	2910.99	82.50	13851
n60q15F	12392	12392	0.00	356.86	12399.20	0.06	12392	0.00	2028.12	88.30	12392
n60q15G	13092	13092	0.00	235.72	13102.60	0.08	13092	0.00	2440.64	84.50	13092
n60q15H	12417	12417	0.00	116.77	12437.60	0.17	12417	0.00	2171.47	86.80	12417
n60q15I	14695	14695	0.00	1030.42	14695.00	0.00	14695	0.00	3600.77	90.50	14695
n60q15J	12111	12111	0.00	1326.29	12112.80	0.01	12111	0.00	1236.31	82.10	12111
n60q20A	10309.88	10454	1.40	7183.39	10407.00	0.94	10407	0.94	2492.51	77.40	10407
n60q20B	11057	11057	0.00	7163.06	11088.00	0.28	11057	0.00	2767.91	82.70	11057
n60q20C	11253.61	11336	0.73	7183.05	11298.70	0.40	11298	0.39	2698.80	79.10	11298
n60q20D	13842	13842	0.00	1776.27	13858.00	0.12	13842	0.00	3600.77	75.40	13842
n60q20E	11478	11478	0.00	2267.20	11478.00	0.00	11478	0.00	2149.89	76.90	11478
n60q20F	10774	10774	0.00	2947.69	10799.80	0.24	10774	0.00	2709.86	83.30	10774
n60q20G	11523	11523	0.00	1910.91	11523.00	0.00	11523	0.00	3352.74	80.40	11523
n60q20H	10290	10290	0.00	63.28	10293.60	0.03	10290	0.00	1788.85	75.00	10290
n60q20I	12285.72	12506	1.79	7182.26	12363.10	0.63	12354	0.56	3600.55	82.90	12354
n60q20J	10342	10342	0.00	48.91	10342.00	0.00	10342	0.00	1036.41	74.50	10342
n60q25A	8701.14	9318	7.09	7182.44	8900.20	2.29	8870	1.94	761.27	62.90	8870
n60q25B	9378	9378	0.00	1253.64	9399.50	0.23	9378	0.00	1444.62	71.60	9378
n60q25C	9896.91	11090	12.06	7181.93	10089.30	1.94	10045	1.50	984.65	66.50	10045
n60q25D	11897.13	12490	4.98	7182.88	11972.60	0.63	11943	0.39	2335.87	65.50	11937
n60q25E	9701	9701	0.00	454.67	9703.60	0.03	9701	0.00	965.64	64.80	9701
n60q25F	9284	9284	0.00	602.48	9284.00	0.00	9284	0.00	1070.66	70.00	9284
n60q25G	9843.44	10054	2.14	7183.01	9918.00	0.76	9918	0.76	1393.30	69.40	9918
n60q25H	9366	9366	0.00	1213.42	9366.10	0.00	9366	0.00	732.42	64.60	9366
n60q25I	10530	10530	0.00	3794.76	10533.40	0.03	10530	0.00	1208.47	70.30	10530
n60q25J	9224	9224	0.00	312.01	9226.50	0.03	9224	0.00	638.82	67.00	9224
n60q30A	7810	7810	0.00	6719.77	7847.80	0.48	7843	0.42	314.94	58.90	7843
n60q30B	8156	8156	0.00	6096.33	8170.90	0.18	8156	0.00	262.33	61.70	8156
n60q30C	8892.41	10797	21.42	7183.27	9090.00	2.22	9090	2.22	581.86	61.40	9090
n60q30D	10159	10159	0.00	562.02	10159.00	0.00	10159	0.00	658.27	55.40	10159
n60q30E	8864.17	9060	2.21	7183.08	9018.30	1.74	8949	0.96	417.74	58.40	8949
n60q30F	8163	8163	0.00	2719.69	8185.90	0.28	8163	0.00	440.28	64.90	8163
n60q30G	8571.06	8926	4.14	7181.77	8667.80	1.13	8665	1.10	418.34	63.00	8665
n60q30H	8114	8114	0.00	1108.51	8117.60	0.04	8114	0.00	222.52	57.90	8114
n60q30I	9092.66	9189	1.06	7182.42	9188.50	1.05	9188	1.05	720.71	62.30	9188
n60q30J	8050	8050	0.00	1086.67	8074.50	0.30	8050	0.00	271.69	59.50	8050
n60q35A	7417.47	7744	4.40	7183.24	7615.40	2.67	7602	2.49	365.33	57.40	7602
n60q35B	7779	7779	0.00	5742.01	7789.40	0.13	7779	0.00	351.48	59.20	7779
n60q35C	8247.64	8916	8.10	7182.12	8372.30	1.51	8359	1.35	496.85	63.00	8359
n60q35D	9684.05	10091	4.20	7182.53	9785.70	1.05	9784	1.03	730.88	56.60	9784
n60q35E	8283	8283	0.00	4143.32	8321.00	0.46	8283	0.00	368.61	58.80	8283
n60q35F	7848	7848	0.00	4910.48	7859.80	0.15	7848	0.00	382.87	63.90	7848
n60q35G	8104	8104	0.00	1125.29	8104.00	0.00	8104	0.00	474.39	64.50	8104
n60q35H	7576	7576	0.00	189.34	7576.00	0.00	7576	0.00	224.77	56.40	7576
n60q35I	8530.25	9166	7.45	7182.00	8718.60	2.21	8675	1.70	530.73	62.60	8675
n60q35J	7876	7876	0.00	3116.61	7917.70	0.53	7876	0.00	258.85	58.10	7876
n60q40A	7112	7112	0.00	6438.93	7113.60	0.02	7112	0.00	190.53	55.50	7112

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Instance	Erdoğan et al. 2015				ILS_{SBRP}						
	LB	**UB**	**UB Gap (%)**	**UB Time (s)**	**Avg. Sol.**	**Avg. Gap. (%)**	**Best**	**Best Gap (%)**	**Avg. Time (s)**	**Avg. NV**	**Best of all exp.**
n60q40B	7259	7259	0.00	408.34	7259.00	0.00	7259	0.00	120.99	55.00	7259
n60q40C	7911.58	8070	2.00	7182.39	8021.40	1.39	8010	1.24	329.08	62.70	8010
n60q40D	8861.50	8959	1.10	7181.43	8943.40	0.92	8942	0.91	475.94	56.80	8942
n60q40E	7810	7810	0.00	1698.27	7810.00	0.00	7810	0.00	153.55	54.20	7810
n60q40F	7314	7314	0.00	401.02	7323.30	0.13	7314	0.00	215.14	61.30	7314
n60q40G	7744.25	7860	1.49	7180.92	7835.10	1.17	7819	0.97	314.84	60.90	7818
n60q40H	7059	7059	0.00	670.18	7059.00	0.00	7059	0.00	150.14	55.40	7059
n60q40I	8126	8126	0.00	4798.57	8131.10	0.06	8126	0.00	394.96	60.90	8126
n60q40J	7407	7407	0.00	2339.85	7407.00	0.00	7407	0.00	102.24	53.30	7407
n60q45A	6730	6730	0.00	1714.17	6730.00	0.00	6730	0.00	122.42	54.00	6730
n60q45B	6990	6990	0.00	280.31	6990.00	0.00	6990	0.00	89.42	55.00	6990
n60q45C	7555.57	7630	0.99	7183.29	7630.00	0.99	7630	0.99	220.51	60.40	7630
n60q45D	8285.54	8421	1.63	7181.34	8418.70	1.61	8395	1.32	213.70	54.10	8380
n60q45E	7446	7446	0.00	467.37	7446.00	0.00	7446	0.00	118.61	56.00	7446
n60q45F	7075	7075	0.00	1217.78	7075.30	0.00	7075	0.00	133.43	58.80	7075
n60q45G	7344	7344	0.00	3280.52	7344.00	0.00	7344	0.00	151.50	58.50	7344
n60q45H	6743	6743	0.00	72.59	6743.00	0.00	6743	0.00	78.77	54.30	6743
n60q45I	7577	7577	0.00	488.83	7577.00	0.00	7577	0.00	168.04	59.10	7577
n60q45J	7043	7043	0.00	349.01	7043.00	0.00	7043	0.00	68.99	54.20	7043
n60q1000A	5773	5773	0.00	131.08	5773.00	0.00	5773	0.00	14.55	54.20	5773
n60q1000B	6124.67	6132	0.12	7183.34	6133.40	0.14	6132	0.12	13.64	55.00	6132
n60q1000C	6135	6135	0.00	564.41	6135.00	0.00	6135	0.00	20.94	58.10	6135
n60q1000D	6223	6223	0.00	9.58	6223.00	0.00	6223	0.00	11.29	51.00	6223
n60q1000E	6131	6131	0.00	119.10	6131.00	0.00	6131	0.00	12.82	54.00	6131
n60q1000F	5810.62	5879	1.18	7183.40	5878.00	1.16	5878	1.16	24.96	58.00	5878
n60q1000G	6169	6169	0.00	43.36	6169.00	0.00	6169	0.00	15.78	57.00	6169
n60q1000H	5878	5878	0.00	6958.60	5878.00	0.00	5878	0.00	16.12	54.20	5878
n60q1000I	5942.83	5970	0.46	7183.21	5970.00	0.46	5970	0.46	19.07	58.00	5970
n60q1000J	6374	6374	0.00	27.81	6374.00	0.00	6374	0.00	10.57	53.10	6374

*Instance in which the cost of our best feasible solution is 1 unit smaller than the cost of the optimal solution reported in Erdoğan *et al.* (2015) (possibly due to rounding issues).