Strategic decision support for the bi-objective Location-Arc Routing Problem

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Abstract—This article develops an intelligent decision support tool for a complex supply chain management problem. In order to solve the bi-objective Location-Arc Routing Problem (LARP) facilities have to be located and routes must be determined simultaneously. The first objective is the minimization of the total costs which are the fixed cost of opening the facility, the fixed cost for the vehicles as well as the travelled distances. Additionally, a second objective related to a service aspect is investigated: the total sum of the delivery times for servicing the required demands. This idea arises since e.g. in a snow plowing application lead times for satisfying the required demands play an important role for the safety of people using the road network. To the best of our knowledge, this paper presents the first study devoted to the bi-objective LARP. The trade-off between the proposed objectives is investigated on adapted benchmark instances.

I. INTRODUCTION

In the last decades, two basic planning tasks namely the (Un)Capacitated Facility Location Problem and the Capacitated Arc Routing Problem (CARP) have been studied independently. However, it is well-known that making decisions with respect to the determination of facilities and the CARP separately leads to suboptimal planning results, since strategic location decisions have a strong impact on routing decisions [7], [22], [32]. Based on these findings, our research is dedicated to the combination of the proposed planning areas.

Selecting the facilities and determining the routes are essential tasks for the decision maker (DM) in a supply chain network and has a strong impact on the success of a company. One of our aims is to apply an intelligent software tool to support complex decision analysis. Thereby, it is important that the decision support system is understandable and intuitive for the managers [3]. Our software tool contributes in this direction and can also be adapted to an interactive decision support system.

Moreover, the software tool deals with multi-objective decision-making which gives the DM a more realistic point of view of the decision problem. In order to cope with the LARP, this study focuses on the investigation of the trade-off between the total costs and the service aspect. We believe that the formulation of the minimization of the total delivery times (service aspect) becomes apparent in a LARP model. This proposition arises on the idea that e.g. in a snow plowing application lead times for satisfying the required demands play an important role for the safety of people using the road network. For example, usually the total costs, especially the travelled distances, can be reduced by combining two or more routes. However, the sum of the delivery lead times to fulfill the demands increases simply due to the fact that required edges are added to one route and therefore, are serviced later.

The main contributions of this research are:

1) Provide a Literature survey on the objectives in the Location-Routing Problem (LRP), LARP and the ARP (see section II).
2) The formulation of a bi-objective LARP (in section III) and the proposition of a solution method which is understandable for the DM (section IV).
3) Description of modified test instances proposed by [24] and the analysis on the trade-off between service- and cost aspects. Moreover, the suitability of the proposed alternative encoding is investigated (section V).

II. REVIEW OF THE LITERATURE

Location-Routing Problems simultaneously integrate the determination of facilities and establish the routes to the customers [20]. Recent literature overviews on the “standard” LRP are given by [29], [30]. For a summary on the variants and extensions of the LRP, we refer the reader to [7], [24]. A survey of the multi-objective Vehicle Routing Problem (VRP) is presented in the work of [17].

In contrast to LRPs/vertex-routing problems, which assume the demand on the vertices, LARPs examine the service on the links of the supply chain network [7]. A link can either be an edge or an arc. Typical applications of the LARP are garbage collection, road maintenance, snow plowing, sweeping and postal delivery [1], [12], [18]. In comparison to the number of LRP articles, only few studies have addressed the single-objective LARP [1], [7], [15]. To the best of our knowledge, no research discusses the multi-objective LARP. However, some work is dedicated to the multi-objective LRP [13], [26], [33] and e.g. to the multi-objective Arc Routing Problem [18], [28]. It seems, that there exists a lack of studies including both areas, namely the LARP and multiple objectives [23].

This section describes the different objectives considered in the literature with respect to the LRP, ARP and the LARP.
Thereby, the main focus lies in the multi-objective problem formulations. Due to the lack of multi-objective studies on the LARP, also single-objective approaches are included in Table I. Objectives are classified based on cost- and service aspects.

A. Objectives related to cost aspects

The state of the art in the investigated research areas is the minimization of costs. A typical objective in the single-objective Location-Routing Problem is the minimization of the linear combination of 1) routing cost, 2) vehicle fixed cost and 3) facility operating cost [20].

Six of the investigated multi-objective approaches minimize the total costs [10], [13], [15], [21], [26], [33]. The term ‘Total costs’ consists of the fixed cost for opening a facility and the routing cost. The work of [13] additionally includes inventory cost at the Distribution Centers/retailers and a penalty for time-window violations. Alternatively, the studies of [10], [24] include fixed cost for the vehicles in the total costs.

In the studies of [4], [16], [31], the routing cost and the fixed cost of the facility are investigated separately. The objective is to minimize the fixed cost of the facility which includes the start-up and the maintenance cost [4]. A similar idea is proposed by [31] who also includes the procurement and the operative cost of the fleet in the cost function. In the study of [16] the LRP is divided in two subproblems: the Uncapacitated Facility Location Problem and multi-objective Multi-Depot Vehicle Routing Problem (MDVRP). In a first step the facilities are determined with the objective of minimizing the facility cost. Then, the two other objectives are combined by a sum to solve the MDVRP. Note that this idea is not assumed to be truly multi-objective, since the objectives are separately used for subproblems.

B. Objectives related to service aspects

A variety of ideas exist in the literature to formulate a service aspect in the objective function. For example, the idea of [4] takes three objectives into account that involve a service aspect. Their work studies where to place incineration plants for the disposal of solid animal waste. The disposal of this waste has an associated risk which influences the affected population negatively. Social rejection takes into account the rejection of towns that trucks pass through and the size of the population. The second objective deals with an equitable distribution of damage caused by the waste transportation, is minimized. The last objective is called collective disutility and includes the social rejection near the incineration plant. Disutility is measured by the size of the population and the distance from the plant to the town. A town is “nearby” the plant if its distance is equal or less to a given parameter. Only “nearby” towns are included in the collective disutility computation.
Similar to the ideas of [4], an objective function that measures the environmental impact of the network is included in [13]. This objective includes several components, e.g. the environmental impact of opening a Distribution Center or the environmental effect of traversing an arc as well as the effect of handling/ producing each unit.

**Balance** objectives are defined to even out disparities between the tours. The motivating idea is to include an element of fairness [17]. [21] are minimizing the working time imbalance (maximal working time minus minimal working time) and the load imbalance (difference between the maximal and the minimal load). In [26], the minimization of the route balance is investigated. Route balance is defined as the difference between the longest and the shortest route. Alternatively, [25] define route balance in their work as the difference between the most costly and the least costly tour.

The study of [10] includes a service aspect by the minimization of the expected delivery times at the customers. Lacomme et al. [18] exclusively include objectives related to a service aspect, namely the minimization of the longest route and the total duration.

When objectives related to the node/ arc are considered, usually time windows are integrated [17]. In multi-objective LRP’s a service aspect is taken into account which is measured by the served demand [16], [31], [33]. This formulation is suitable, since it can happen that the total demand of the customers is not satisfied. More specifically, the study of [16] assumes a stochastic availability of facilities and arcs and therefore maximizes the probability of a delivery to customers.

### III. Problem Description

In the LARP, the determination of facilities and routes are taken into consideration simultaneously. The undirected version of the LARP can be described on a weighted graph with vertex set \( V \) and a set of edges \( E \). The vertex set contains a nonempty set of \( m \) potential facilities \( (F \subseteq V) \) where every facility \( v_i \in F \) has fixed/ operating cost \( o_i \) and unlimited capacity. Facilities can be of different types such as plants, depots, warehouses, hubs, cross-docks etc. [7]. Note that these terms can be used interchangeably. It should be emphasized that the decision must be made which facilities should be opened. This also implies where the fleet is positioned.

Every edge \( e = (v_i, v_j), i \neq j \) in the edge set \( E \) has an associated distance cost \( d_{ij} \) and a travel time duration \( t_{ij} \). \( E_R \subseteq E \) is the set of required edges which have a nonnegative demand \( q_{ij} \). This means that every edge in this set must be serviced exactly once. An unlimited number of identical vehicles with limited capacity \( Q \) and fixed cost \( C \) is based at the selected facilities. Herein other typical assumptions are used:

- Each tour starts and ends at the selected facility location.
- The fleet is homogeneous.
- Split deliveries are not permitted.
- Each required edge/ task must be serviced by one vehicle. However, all edges can be traversed any number of times.

The problem aims to determine the set of opened facilities in \( F \) and the routes to satisfy the demand of the required edges \( E_R \), such that the sum of the fixed facility cost, the fixed vehicle cost and the traversal cost is minimized as given in Expression 1. As described in section II, a cost aspect has been the primary objective function in single- and multi-objective LRP- and (L)ARPs to measure the effectiveness of an alternative.

\[
\min \sum_{i \in F} o_i y_i + C z + \sum_{e \in E} \sum_{k \in K} d_e x_{ek} \tag{1}
\]

Decision variables are: \( y_i \) equals to 1 if and only if facility \( i \) is to be opened. \( z \) is denoted as an integer number that demonstrates the number of vehicles used in the solution. \( x_{ek} \), equals to 1 if and only if edge \( e \in E \) is used in the route performed by vehicle \( k \in K \).

The second objective function should incorporate a service aspect, since this is another important criterion that greatly influences the route planning [25]. Based on the literature survey, minimizing the sum of delivery times to service all required demands [10] seems appropriate for the LARP. We denote this second objective function in Expression 2.

\[
\min \sum_{e \in E} \sum_{k \in K} t_e x_{ek} \quad \forall e \in E_R \tag{2}
\]

For example in road salt applications for de-icing operations [34] or snow plowing applications servicing roads is a key factor for road safety. The main goal is to plow the roads as early as possible, since this helps to avoid accidents.

### IV. Solution Approach

Since the (Un) Capacitated Facility Location Problem and the Capacitated Arc Routing Problem are \( \mathcal{NP} \)-hard, the combination of the problems is also \( \mathcal{NP} \)-hard [23]. Since the problem is computationally challenging and in order to study larger instances, a Variable Neighborhood Search (VNS) [14] is formulated for a multi-objective LARP and designed to meet the following criteria:

- It must be suitable for testing the performance of the proposed encoding of an alternative.
- Can be adapted to the capacitated LARP.
- It is capable of studying the trade-off between the proposed objective functions.

VNS has been studied extensively for single-objective optimization. However, applications of the VNS for multi-objective optimization are scarce [2]. Examples are the
studies of [8], [9]. We contribute in this research direction by the adoption of a VNS considering two conflicting objectives for the LARP.

A. Encoding of an alternative

A brief overview on alternative representations and the assignment procedure of facilities to the customers in the LARP is given, since we do not apply a commonly used alternative encoding. Hashemi Doulabi and Seifi [15] present an insertion arc routing heuristic where initial tours are generated and then connected to a potential depot. Additionally, an insertion procedure is defined to combine two routes by using different sequence types. The work of [21] develops a three-stage procedure which is either embedded in a Tabu-Search or a Simulated-Annealing metaheuristic. For the location assignment, a facility is selected systematically of a list where facilities are sorted by the distances to the customers in a non-decreasing order. A similar procedure is applied in [24], where the required demands are assigned to the closest facility. In the solution approach of [33] a lower bound for the number of locations (sum of the demand divided by the capacity of the facility) is computed. Then, all combinations of facilities are enumerated and the customers are allocated to the closest facility.

Different to the studies mentioned above, an alternative is represented by an n-dimensional vector \( \pi = (1, \ldots, n) \) of integer numbers. This vector is named a decision vector consisting of n decision variables. Every value in the vector represents the assignment of a location to a required demand. For example, the vector \( \pi = (2, 5, 9) \) shows that the first required edge is assigned to facility 2, the second edge is delivered by location 5 and the last demand is satisfied from depot 9. A detailed description of a first assignment is presented in section IV-B.

One of our next research goals is to address the capacitated LARP and overcome the following drawback by the newly defined alternative representation. This alternative representation is introduced in this study, since we believe that a route-first-cluster-second idea might be counterproductive in a capacitated LARP: first, routes are constructed and then they are decomposed when the clustering is done [19]. On this basis, it might happen that routes cannot be assigned to facilities due to the fact that the capacity of the facilities is not sufficient. Then, the algorithm must start from the beginning or several routes must be removed and reconstructed.

B. Generation of feasible solutions

In figure 1, the flowchart depicts the idea of the solution approach. The construction procedure is composed of two decision levels: 1) the assignment heuristic which determines the facilities \( v_i \in F \) for the required demands \( E_R \) and then 2) this assignment is used as an input for the routing heuristic.

Construction procedure: During the optimization procedure, an archive \( P_{*} \) of non-dominated solutions is retained which is an approximation of the true Pareto-set \( P \) [27]. As presented in figure 1, it is checked if the solution is accepted. Thereby, \( P_{*} \) is updated such that dominated solutions are discarded and newly computed non-dominated solutions are added, i.e. the archive only consists of non-dominated ones. In a minimization problem, an objective vector \( z^* \in Z \) is non-dominated if there does not exist another objective vector \( z \in Z \) such that \( z_l \leq z^*_l \) for all objectives \( l = 1, \ldots, g \) and \( z_m < z^*_m \) for at least one index \( m \) [27].

An initial assignment is generated by allocating every required demand to the same facility. This is possible, since we are investigating the uncapacitated LARP.

For example, instance gdb-20 has 3 potential facilities (see section V-A). Thus, 3 decision vectors are computed where the first assignment vector only consists of the first facility, the second vector exclusively contains the second depot and the third vector solely involves the third depot. Since the DM might want to investigate more solutions, the integer values inside the vector \( \pi \) are randomized between the first and the second depot as well as the second and the third depot. It is important to have this variety in the assignment vector where the improvement procedure can build up on.

Based on the assignment of the facilities, direct deliveries to the required edges are determined. Since not every required edge can be reached directly from the depot, shortest path computation are used based on the well-known Dijkstra algorithm [6]. Then, it is checked if two routes can be merged in a combined route. This procedure is similar to the Savings-Algorithm proposed by [5]. These versions are investigated separately, since we believe that direct deliveries give a good estimation for the service objective function. Having these two versions is particular interesting for the practical usage with the decision maker, since it is important for the DM to understand different solution methods and analyze the consequences. This is especially true for a strategic problem where a decision is remanent and cannot easily be revised. At a later stage, more ideas can be applied to improve the routing cost such as described in [15], however this goes in hand with time-consuming computations.

Throughout first experiments, we realized that a so-called “repair operator” must be included in the solution approach which changes the selected facility in the assignment vector if another depot is already installed that can reduce the deadheading of the routing plan.

Improvement procedure: For the improvement procedure, nine neighborhood operators are applied where each operator systematically modifies the integer values in the vector \( \pi \). The fist operator changes each position by \( \pm 1 \), the second by \( \pm 2 \) etc. and the last operator modifies the values by \( \pm 9 \).

The idea is to apply a basic VNS since this is the first time
where a bi-objective LARP is investigated. Problem specific in the VNS are e.g. the proposed neighborhood operators since the alternative encoding has not been proposed in previous studies (see also section IV-A for further explanations on the alternative encoding).

Again, taking the example above $\pi = (2, 5, 9)$ where 10 potential facilities exist. The idea of the neighborhood operators is exemplarily illustrated by applying the first operator. Starting with the adaption of the first position inside the vector $\pi$ by $\pm 1$ while retaining the other values, resulting in $\pi = (1, 5, 9)$ and $\pi = (3, 5, 9)$. Then the second position is adapted and all the other values do not change $\pi = (2, 4, 9)$ and $\pi = (2, 6, 9)$. Finally the third position is modified: $\pi = (2, 5, 8)$ and $\pi = (2, 5, 10)$. Obviously, values greater than the number of facilities are not accepted. Additionally, values smaller 1 are discarded, since the depot index starts with one. For each possible assignment vector, the routing is computed and then the archive $\hat{P}$ is updated by dominance comparisons. For each operator the maximal number of neighboring alternatives is $2|E_R|$.

The stopping criterium is reached when all neighboring solutions are investigated.

V. EXPERIMENTS AND RESULTS

A. Description of the test instances

Our algorithm is conducted and evaluated on test instances which are similar to the instances proposed in [24]. A more detailed description of the datasets is presented in [24] and a summary is shown in table II. The first column introduces the name of the test instance, the second one gives the number of vertices used in the instance, the third one the number of edges in the network and the fourth column presents the number of required edges, which must be satisfied. Then, the number of potential facilities, the average fixed cost ($\bar{o}$), the capacity as well as the fixed cost of the vehicles are given. Since a second objective function is introduced, the benchmark instances are adapted by assigning travel times for traversing the edges. Consequently, delivery lead times for the required demands can be computed. Thereby, the times for the edges with no demand are modified by multiplying the distance by at most 20%. The travel times associated with the required edges are estimated by taking into account the distances, the demand and a random factor, which should e.g. simulate traffic congestion or service times to satisfy the demand. This is similar to the idea of [11], who define travel and service times based on the average speed and a specific service time to unload a
container.

B. Comparative analysis

Results are obtained for the adapted test instances in order to study the proposed solution method. The main goal is to support the DM by analyzing the consequences of the different strategies, named all neighborhood operators and one neighborhood operator (see table III). Furthermore, the trade-off between the total costs and the total sum of the delivery lead times to fulfill the demands is investigated in more detail. The solution method with all neighborhood operators takes all operators at once and tries to converge to the Pareto-set \( P \). Differently, one neighborhood operator uses the first neighborhood operator and only modifies the values inside the assignment vector \( \pi \) by \( \pm 1 \). Note that all experiments are conducted with an Intel Xeon X5650 processor 2.66 GHz on a single CPU core.

For each strategy the results are given in table III. The first column illustrates the name of the instance, followed by the number of evaluations and the size of the approximation \( P \). Then the values of CPU times (in seconds) and the index of the opened facilities can be seen. The term “selected facilities” means that the mentioned depots are used at least in one of the solutions.

Regarding the all neighborhood operators, the CPU times are obviously higher than the CPU times for the one neighborhood operator. For the first eight instances the CPU times are smaller than 6 seconds with the exception of instance gdb-22 and gdb-23. This is due to the problem size, since the number of edges is e.g. doubled from gdb-20 to gdb-22. For the bccm instances the maximal CPU value is 386.70 and for the eglese instances 3,353.67. Overall, the differences for the first 27 instances might be negligible (maximum 6 minutes) as a strategic problem is analyzed. The last three instances 28 eglese-S1-B to 30 eglese-S4-A must be investigated in more detail, since the CPU time is much higher than for the other instances. In the work of [24], who are testing a single objective problem, the CPU times for the last three instances also differ significantly from the rest of the instances. Suggesting that this is due to special characteristics in the graph. We believe that the relation between the number of all edges and the number of required edges might influence the computational time. Further experiments should be conducted to verify this aspect. For example, the number of required edges can be varied for every test instance in order to study this effect. Looking at the results of the different strategies, it can be concluded that the method incorporating all neighborhood operators performs better than the one with only one operator with respect to the solution quality. This is true for all tested instances. Exemplarily, figure 2 clearly shows that the method with all neighborhood operators outperforms the idea with one operator. This is due to the idea of allowing a greater diversity in the assignment procedure easing the finding of better solutions. This diversity mechanism also yields to a higher computational time (3,353.67) and in a higher number of evaluations (157,834) which is around 6 times higher than the number of evaluations for the one neighborhood operator (25,546). It is e.g. not 9 times higher, since some neighborhood operators do not have a huge impact. For example, in instance 29 eglese-S1-C the neighborhood operator which modifies the values by \( \pm 9 \) cannot change any value inside the 13 assignment vectors, since the values would be outside the feasible facility indexes (see table II and table III). Moreover, this behaviour is also stressed for the smaller instances with less depots (1 gdb-20 until 22 bccm-10D). Thus, it can be concluded that this

![Figure 2](image2.png)  
Figure 2. Investigation of the trade-off between the total costs and the total sum of delivery times for fulfilling the required demands on dataset 29 eglese-S1-C. The ‘*’ represents the solutions computed by one neighborhood operator with 1,000 randomly changed positions in the construction procedure. Solutions obtained by all neighborhood operators (also with 1,000 randomly changed positions) are illustrated with ‘•’.

![Figure 3](image3.png)  
Figure 3. Investigation of the trade-off between the total costs and lead times on dataset 23 eglese-E1-A obtained by the direct deliveries (‘*’) and the merge procedure (‘•’).
operator has a minor importance for these datasets. However, this insight can change when e.g. different cost structures are assumed for the fixed facility cost where then different depots might be enabled. Additionally, we observed that some facilities are not attractive for a selection, since they only have one outgoing edge, e.g. facility \( v_1 \) of 29-eglese-S1-C.

Exemplarily, in figure 2 the trade-off investigation between the total costs and the total sum of lead times to satisfy the required edges is described for dataset 29-eglese-E1-A. Comparing both strategies, it can be seen that the covering of the solution space is better after allocating more computational time to the assignment vector (all neighborhood operators). Having a closer look on the trade-off, a minimization in the total costs results in an increase of the sum of the travel times. The decrease in the total costs is e.g. achieved by combining routes, which also means that the demand at a later position in the routing plan is serviced later. It can be shown that the objectives are in conflict to each other. Especially, at the extreme ends it is beneficial to the decision maker to increase the total costs by a small amount and improve the sum of the delivery times noticeably. It can be illustrated that the introduction of the second objective function comes with a clear advantage at the extreme ends.

In the light of computing a good estimation on the second objective function the minimization of the sum of the delivery times for fulfilling the demands, we implemented the direct deliveries concept. This idea is based on the direct deliveries in the Savings-Algorithm for the classical VRP.

<table>
<thead>
<tr>
<th>Testinstance</th>
<th>all neighborhood operators</th>
<th>one neighborhood operator</th>
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<tr>
<td></td>
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<td>( \hat{P} )</td>
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<tr>
<td>1 gdb-20</td>
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The investigation of the values in figure 3 shows that a good estimation cannot be computed via the direct deliveries idea. The merge procedure achieves better values with respect to the delivery times and the total costs, which is at first glance counterintuitive. That is due to the fact that some required edges can only be reached by traversing other edges. In this case, the shortest path to the required edge already includes links, which must be serviced. So this is also the main difference to the VRP where customers can be reached directly. This is an insightful finding, since a good estimation of a value for the total sum of the lead times cannot be found via this simple idea of direct deliveries.

Figure 4. Graphical representation of an optimal solution for dataset 5 gdb-1 obtained by [24] with a single costs objective function. The objective function value is 353.

C. Evaluation of the graphical representations

Figure 4 presents an optimal solution for the LARP with a single objective function (minimization of the total costs) computed by [24]. Alternatively, a graphical presentation of the proposed all neighborhood operators for the bi-objective LARP can be seen in figure 5. Note that the number in brackets are the given distances $d_{ij}$ and both figures are not in scale. Moreover, in figure 5 neither the way back nor the delivery times $t_{ij}$ are displayed due to clarity reasons.

Both plans are investigated in more detail in order to gain insights of the properties of a routing plan. Analyzing figure 5, it can be seen that 2 depots are installed and 10 routes are established. Differently, in figure 4 only 1 depot is opened and 5 routes are determined. Comparing both plans, the routes in figure 5 are usually much shorter with respect to the number of the required demands (e.g. “dark green” route in figure 5). Suggesting that this is due to the second service objective function. For example, the “light blue” and the “dark blue” routes are not combined, since one demand would be serviced later, resulting in a later delivery time. Moreover, two “repair moves” were applied for the “orange” and the “red” route since both required routes were initially assigned to depot 11.

VI. CONCLUSIONS

The article presented an intelligent decision support tool for the strategic multi-objective LARP. One of the major research goals was to define a second objective function to include a service aspect in the model. With the aim of formulating an additional objective function, a part of our work was dedicated to a Literature survey to report commonly used objectives in the LRP, ARP and the LARP.

In order to test the performance of the solution method and analyze the trade-off between the proposed objectives, the test instances were modified by introducing lead times for the edges. We investigated the trade-off between the total costs and the total sum of the lead times for fulfilling the demands and showed that the objectives are in conflict to each other. This is especially true for the extreme solutions of the approximation. A small increase in the total costs, results in a considerable improvement in the delivery times. This finding underlines the integration of these objectives in
Further studies and supports the decision maker in finding a most-preferred solution.

Concerning the representation of an alternative by an assignment vector \( \pi \), the results showed that this idea is suitable for the proposed problem and the DM can be supported with good solutions.

As a guideline for future research, we state the following: The results of the experiments showed that the adoption of the assignment is important, since the solution quality could be improved significantly. This might lead to the conclusion that the depot configuration is important, at least for the investigated instances. In this sense, more work should be dedicated in this direction. For example, the depots for the required demands could be selected e.g. by the sum of the shortest distance and lead time.

Finally, it is important to investigate further representations for an alternative encoding which might be better suited for the problem. Therefore, we want to consider an approach where first the routes are computed and then the best depot is selected. The insights of both approaches must also hold for the capacitated LARP. Since we believe that our approach might be especially applicable in this case.

**REFERENCES**


