A real-world logistic districting problem: an approach by TS

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1 Introduction

The planning and design of districts represent a fundamental logistic decision, having a strong effect on the performance of daily operations. From a formal point of view, districting is a clustering problem, a rich theme useful to a multiplicity of fields, usually defined as a process of organizing objects into groups whose members are similar in some way [1]. One strategy to solve the problem is hierarchical, which may be bottom-up, starting with each element being a cluster, or top-down, starting with just one cluster. Another strategy is partitioning, which starts with a given number of clusters, and elements interchanges generate new configurations, evaluated by an objective function. In Logistics these strategies have been frequently applied as in [2], [3], [4] and [5]. The problem complexity is in the highest class (NP-Hard), so, large practical problems are in fact solved using heuristics or metaheuristics, as showed in [6]. Reference [7] also presents a heuristic approach for a logistic districting problem for an operation of pickup and delivery of packages. In fact, several authors treat the problem, as in [8] and [9]. One particular metaheuristic, the well known tabu search (TS), can be used in different clustering problems, such as the classical graph partitioning problem [10] or the problem of generating manufacture cells, as well as, the vehicle routing problem [11].

This paper presents a TS experiment applied to a real-world large-scale logistics districting problem, with demand points spread out over three states of the Brazil southern region. The experiment was developed to compare different TS strategies, giving the opportunity of highlighting strong points of each strategy. A discussion of the experiment and of all these interesting results is presented in the paper.

2 TS Applied to a Districting Problem

The metaheuristic TS needs an initial feasible solution, which is one of the possible arrangements for the system configuration. The algorithm searches for new solutions applying small perturbations (very little modifications) to the current configuration, in order to generate new feasible solutions (neighbour solutions). The algorithm moves always to the neighbourhood best solution, even though it is not always better than the current solution. This is a form of introducing diversification in the process, and escaping from a local optimum. Another mechanism of diversification is the tabu list, that keeps the last solutions, and for a number of iterations the algorithm cannot return to those solutions. But, TS has also a strategy of intensification, which allows the return to a very good solution, defined by an aspiration criterion, even though the solution pertains to the tabu list. The algorithm repeats these steps for a given number of iterations. The optimal solution will be the best of all that were found.

In the proposed model the initial solution subdivides the set of demand points in a number of clusters (clustering partitioning strategy). The perturbation means the change of a single point from one cluster to another. These demand point movements were allowed just for adjacent clusters, and an additional condition was defined establishing a minimum number of points per cluster, in order to avoid the occurrence of clusters too small. The objective of the model was to maximize the homogeneity of workload among clusters, and for this, it was adopted a degree of homogeneity (DH), proposed in [5], which is defined based on the coefficient of variation (CV) of the workload, as showed in equation 1:

$$DH = 1 - CV,\ if\ CV \leq 1 \quad or \quad DH = 0,\ otherwise \quad (0 \leq DH \leq 1) \qquad (1)$$

The workload was defined as the "transport moment (TKM)", which is a well accepted measure of transport production, because it involves the two key transport factors: weight and distance. It is defined as the multiplication of the loaded weight in a vehicle (LW) by its travel distance (TD), as in equation 2:

$$TKM = LW \cdot TD \quad (2)$$

This model was applied to a real case, with more than two hundred demand points, spread all over the south region of Brazil, an area greater than many countries. The demand was about 45,000 cubic meters per month, served by a fleet of over one hundred vehicles, making more than 1,000 trips per month. The research focused on the planning and design of the TS experiment, facing specifically this districting problem. The goal was achieving the best possible performance for the model, in this type of problem. A variety of configurations for the model parameters have been tested, following the literature orientation, as well as, finding new patterns from the empirical results. The main parameters tested were: the neighbourhood structure, aspiration criterion, attributes to keep in tabu list and number of iterations. Moreover, two main strategies were applied: a fixed and a variable tabu list. With a fixed list, the solutions occurred in a quasi cyclical format, and the optimal solution was reached in most of these cycles. In the variable list size case, the solutions were more diversified. DH varied from 0.85 to 0.984, and cyclical behaviour did not occur. On the other hand, a deeper intensification has been observed, once the best solutions were visited more frequently. Regarding the initial solution, this has been generated based on a clustering heuristic, proposed in [5], what generated DH with a fairly high value (0.931). However, even then, the metaheuristic was able to improve this solution, leading to a maximum DH of 0.984, near to 1.0, an evolution of +5.7%, Besides, it is important to highlight the magnitude of costs in large logistics operations, so, a cost reduction proportional to the improvement in DH may represent a significant saving.

Finally, taking into account all these considerations, it seems reasonable to suppose that this TS research has provided useful learning in planning and design experiments for this fundamental logistic combinatorial problem, which were capable of generating solutions at levels of performance fairly satisfactory. This accomplishment may be attributed to the series of tests applied in the model parameters, creating a parameters configuration able of generating such results.

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