Simulated Annealing Approach to Solve the Dialy Crew Scheduling Problem

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1 Introduction

The Crew Scheduling Problem (CSP) of a public transportation system consists of determining the minimum number of crews in order to achieve a successful vehicles’ programming. The solution of this problem also involves the sequencing of the crews’ activities and the generation of a set of work days with minimum operational cost. This problem becomes particularly complex due to its magnitude, operational restrictions, and labor laws. In addition, the conditions of the transport systems are in continuous transformation and they demand increasingly an efficient management of the available resources [5], [6]. The development of the metaheuristic Genetic Algorithms, Tabu Search, Simulated Annealing and others [3] have offered new possibilities for the resolution of NP-hard problems like CSP. Although such methods do not guarantee the obtaining of the optimum global they allow to easily include any restriction. Among the works that have applied metaheuristic to solve CSP problems the followings must be cited: Wren and Wren [7], Kwan et al. [2] and Shen and Kwan [4]. Although CSP has widely been studied, its main restrictions are related to the compliance of labor laws, and the effective operational norms of companies. Such factors do not allow that models, which were successful developed in other countries, be applied in Brazil. This work proposes a heuristic procedure to solve CSP based on the metaheuristic Simulated Annealing and taking into account the operational restrictions of the Brazilian reality. A study case of a public transportation company operating in the city of Belo Horizonte, southeastern Brazil, is presented.

2 Daily Crew Scheduling

The crew’s scheduling is usually done after the vehicles’ programming, which contains Relief Opportunities (RO). The RO’s are time intervals, which are necessary for the shift of two crews. Each RO is associated to the Relief Time (RT) and the Relief Point (RP), which represent the hour and the place, respectively, where the change can occur. A Task is a set of trips between two successive RO. The daily crew scheduling is formed by a set of tasks also called workday. The Brazilian workdays can be
3 Simulated Annealing Application to Daily Crew Scheduling

Simulated Annealing [3] is a method of local search that accepts worsening movements to avoid becoming trapped early in a local optimum. This method can be characterized as a search form in a neighborhood, where each $s \in S$ solution has an associated set of neighbors, $N(s) \subseteq S$, which is called $s$ neighborhood. Any $s' \in N(s)$ solution can be reached directly from $s$, starting from a movement, which is probabilistically accepted as a function of the temperature parameter. The developed algorithm works with the movement Insert Task, which attributes a task from an i crew to a j crew. In order to generate such a movement any two crews i and j are drawn obeying the condition that the i crew must have at least one task. Next, a task of the i crew is raffled, on which the movement is done. The objective function to be minimized, which evaluates the crew scheduling, is a penalty function that has the following goals: a) to eliminate unfeasibility situations such as task superposition, insufficient meal interval, etc., b) to reduce costs that are related to the number of crews, overtime, etc., and c) to maximize the use of labor by minimizing crew idleness.

4 Computational Results

The algorithm was successful tested using data from a Belo Horizonte public transportation company. Table 1 display the characteristics of the best solution. This solution was obtained from several tests, which used different seeds of random numbers. The algorithm was run in an Intel Celeron (400 MHz clock, 64 MB RAM memory) microcomputer.

<table>
<thead>
<tr>
<th># of Crews</th>
<th>Table 1: Computational Results</th>
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<tbody>
<tr>
<td></td>
<td>Idleness (hh:mm)</td>
</tr>
<tr>
<td>Current solution</td>
<td>218</td>
</tr>
<tr>
<td>Best solution</td>
<td>206</td>
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Table 1 shows a 5.5% reduction in relation to the current number of crews (in the Current solution). This is the most important factor affecting the objective function. The idleness reduction indicates a better labor use. This fact can be explained by the increase of crews that are responsible for line
as a consequence, an overtime increase. A cost analysis must be required because the increase of the number of crews must provoke an overtime reduction. The proposed algorithm does not deal with monthly scheduling. This will be the focus of future research.

5 Conclusions

This work presents an optimization heuristic model based on the metaheuristic Simulated Annealing for the CSP resolution of a public transportation company in Belo Horizonte, Minas Gerais, Brazil. Despite the inherent difficulties of the CSP approach, the obtained results showed significant operational labor cost reductions of the daily scheduling. Such a result emphasizes the metaheuristic Simulated Annealing potential and incentives the method application to generate monthly crew scheduling.

References


