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 a *Straight* or a *Split*. In the first type the tasks are accomplished with interruption for the meal. If the meal interval is larger than two hours, the workday is of the Split type. In this case, that interval is not paid. When defining workdays the following restriction should be taken into account: a) the crew's change can occur at preset points, only; b) the crew can operate vehicles from the same group of lines, only; c) the workdays duration is 7 hours and 10 minutes, and a maximum of 2-hour overtime can be added; d) a crew that does not follow the split system is entitled to a 30-minute rest during the workday. This 30-minute period can be divided into smaller intervals if one of them is larger or equal to 15 minutes. Restrictions of this type turn real problems untreatable by computational means and justify the application of metaheuristic to their resolution.

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, $N(s) \subset S$, 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 1: Computational Results

	# of Crews	Idleness (hh:mm)	Line Changes	Split	Overtime (hh:mm)	CPU time (hh:mm)
Current solution	218	188:22	2	21	116:00	-
Best solution	206	113:54	59	67	133:47	07:30

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 changes. Line changes allow a flexibility and, as a consequence, a reduction of operational costs. As these can only occur in Split situations, the number of this workday's type was increased. In this case, the idleness reduction does not generate enough time for the execution of all tasks, demanding, 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.

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