New models for multi-activity shift scheduling

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1 Context and introduction

A warehouse is a industrial building for storing goods. Warehouse usually have loading docks to load and unload goods from trucks. They often have cranes and forklifts for moving goods, which are usually placed on ISO standard pallets and then loaded into pallet racks. Stored goods can include any raw materials, packing materials, spare parts, components, or finished goods associated with agriculture, manufacturing, and production.

We consider the case of warehouses with human operators. Periodically, warehouse managers have to estimate the required numbers of workers for the upcoming workload. The workload is distributed among different professions. Each operator can perform one or several professions, with different efficiencies. These professions can be for example: forklifting, picking, packing, etc.

We are interested in modelling and solving some resource planning problems that occur within a resource management system developed by Generix Group. For the manager, solving these problems by hand is time consuming, as they involve up to hundreds of workers, dozens of professions, and thousands of tasks. These problems are known in the literature under various names, such as the Multi-Activity Shift Scheduling Problem (MASSP).

The MASSP was already studied more than seventy years ago [1]. Different variants were then considered by researchers [3, 4, 5]. The MASSP remains of interest today [7]. It generally consists in minimizing costs related to resources, and costs of unmet demand. The demand is expressed per period and per profession, as a required number of workers.

We consider new variants, introduced with the development of the resource management system by Generix Group. Here are some of their specificities. First, workers have different efficiencies for the professions. Second, demand is expressed as workloads. Each workload has to be completed within a given time window. It requires a given number of work hours of a profession, measured with a standard productivity, that depends on its profession, and possibly on its scope. The primary objective is to maximize the adequacy of the planning. The adequacy is defined as the ratio of the provided work hours for the upcoming workloads over the total demanded hours, both measured with standard productivities. Five other objectives are optimized in the first variant of the problem.

2 A first model

Within a graphical user interface, the manager can create an initial planning for the operators, and estimate its adequacy rates for the different professions. He can then call an optimization module, to improve the planning. The optimization problem is as follows.

The initial time slots of a resource are a set of disjoint time intervals. An initial profession may be assigned to each interval. The time intervals define resources' availabilities. They can be split during optimization. With this variant, it is not possible to insert an interval for a time that was inactive in the initial solution. Six objectives are optimized in a lexicographic manner. In addition to the global adequacy, they include, in this order, the number of operators impacted by changes, the number of changed slots, the number of profession changes, the average efficiency and the earliness. Several constraints are considered, related to the profession assignment, as well as to the progression of workloads.

This first problem has been formulated as a time-indexed mixed integer linear program, whose objective is a weighted sum of the criteria [2]. It has been implemented and validated by the product team. We will also discuss a second problem in which the time slots have to be created.

We used the SCIP solver [6] to perform numerical experiments on generated instances. The objectives were to evaluate the performance of the solving approach, regarding running time and optimality gap. Results show that the current solving approach allows to obtain near optimal solutions in less than one hour for plannings at one day, using a period width of 15 minutes, considering up to 50 operators, 10 professions and 200 workloads. In the presentation, we will further discuss the problems and their models, the multi-objective approach, and the obtained numerical results.

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