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Greedy heuristic algorithms for manpower shift planning

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Abstract

Consideration is given to a particular personnel planning problem faced by a food manufacturing company. This problem, referred to herein as *manpower shift planning* (MSP), seeks for the minimum workforce needed to work in each available workday shift over a given planning horizon in order to complete predetermined production objectives associated with individual production lines. We formulate MSP as an integer linear program, whose structure allows us to conjecture that it is an NP-Complete problem. We then propose two greedy heuristic algorithms for solving MSP. One for single and another for multiple workday shifts. Using results from a standard ILP optimiser together with a lower bound developed for the MSP solution, we test the performance of the multi-shift heuristic for a variety of operating environments. The results demonstrate very satisfactory performance in terms of both solution time and quality. The paper is concluded with a discussion on the results and proposals for further research.

Keywords: Production planning; Manpower planning; Heuristics

1. Introduction

In several companies, particularly those in the foods and pharmaceuticals industrial sectors, other than some initial processing phases, production largely consists of simple packaging operations. Packaging is accomplished on dedicated packing lines usually requiring one skilled operator and several (practically) unskilled workers. The latter are often hired under short term contracts to work on a particular workday shift (i.e. day, evening or night shift respectively). At the end of their contract, often of one month duration, workers are fired to be recalled later, if needed. Workers cannot be fired before their contract expires.

In manufacturing environments as the above, total work requirements for a particular month are usually determined by a master production schedule, which gives the total production load of each packing line for all the products it produces. However, the production capacity of each packing line directly depends on the number of unskilled workers available. Therefore, a common planning problem faced by management is to decide how many unskilled workers to employ in every daily work-shift of some particular month of the master schedule so as to complete the production load of each packing line, while maximising workforce utilisation. It should be noted that the objective of

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maximising workforce utilisation is in most cases equivalent with minimising the total workforce to be employed.

We will refer to this particular personnel and capacity planning problem as the *manpower shift planning* (MSP) problem. It is with the formulation and the solution of MSP, which to our knowledge has never been formally addressed in the past, that this paper is concerned. In fact, as described here, the MSP problem has been the subject of an industrial research project carried out for the Greek affiliate of a multinational company operating in the processed foods and beverages sector.

Since the first published work by Dantzig [1], there has been an abundance of research related with personnel planning problems. This traditional paradigm has been primarily concerned with the determination of the workforce to be assigned to each one of a given set of work-time patterns so as to minimise total labour costs, while satisfying given labour requirements associated with each period of a planning horizon. In its most general form where one practically considers any work-time patterns, this problem is known as the *tour scheduling* problem. However, other simpler variations of this problem have also been studied. Jarrah et al. [2] provides a recent brief review of these variations, while more comprehensive, but somewhat dated, reviews are given in [3–5].

All variations of tour scheduling have invariably been formulated as integer linear programs. Since these have been shown to be NP-Complete [6], most associated research concentrated in developing efficient heuristic solutions. Although it is not our intention to provide a comprehensive description of the related work, it is worth stating that these heuristics have been based on a wide range of different methodologies such as simulated annealing [7], LP-based approaches [8–10] and goal programming [11].

There are two major differences between MSP and the above traditional personnel planning paradigm. Firstly, traditional research is concerned with deriving directly applicable detailed labour schedules. In this context, related models attempt to encapsulate all possible work specifications and minute details (such as meal breaks, days-off and part-time work) in order to realistically represent the respective operating environments. In contrast, MSP effectively tackles an aggregate capacity planning problem under general production targets and constraints. Secondly, traditional research assumes that workforce requirements for all time periods of the planning horizon are known in advance. In contrast, it is the goal of MSP to determine these workforce requirements for each individual period of the planning horizon so as to ensure that specific production objectives (using equipment of given manning needs) are completely satisfied.

The remainder of the paper is organised as follows. Section 2 provides a formal definition of the MSP problem and formulates it as an integer optimisation program. It also discusses the problem computational complexity in comparison with other known problems and presents a lower bound for its solution. Section 3 presents two heuristic algorithms for solving MSP together with information concerning their order of convergence. Section 4 describes an example of using one of the algorithms for the solution of a particular application problem. Section 5 reports computational results for testing the performance of the heuristics for a variety of operating conditions. Finally, Section 6 discusses possible MSP extensions and concludes with directions for further research.

2. Problem formulation

In this section, we present a formal statement of the MSP problem and develop the corresponding optimisation model. We also present some initial observations, which help position the MSP problem in the context of previously identified problems and provide comments and conjectures on the problem of computational complexity. We also present a lower bound for the problem solution, which is later used for testing the quality of the proposed heuristics.

2.1. Formal problem definition

A machine shop consists of n independent machines and operates P shifts per day. Each machine i requires a_i unskilled workers for its operation and