PERGAMON

Engineering Applications of Artificial Intelligence 14 (2001) 387–399

Engineering Applications of
ARTIFICIAL INTELLIGENCE

www.elsevier.com/locate/engappai

Handling soft constraints in hoist scheduling problems: the fuzzy approach

Hélène Fargier[a,*], Jacques Lamothe[b]

[a] Institut de Recherche en Informatique de Toulouse, 118 route de Narbonne, 31062 Toulouse Cedex, France
[b] Ecole des Mines d'Albi-Carmaux, Campus Jarlard, Route de Teillet, 81000 Albi Cedex 09, France

Received 17 May 2000; received in revised form 5 December 2000; accepted 10 December 2000

Abstract

The Hoist Scheduling Problem (HSP) deals with the scheduling of hoists that move products between tanks in electroplating facilities that perform chemical surface treatments. In HSP, the gradual effect of soaking times (operation duration in tanks) on the quality of treatment can be represented by means of fuzzy sets: the satisfaction degree in a fuzzy interval models a quality evaluation of the chemical treatment. When temporal bounds are required, an implicit relaxation of these flexible constraints can thus be performed so as to meet the due-date. When the objective is rather a minimization of the makespan, a bi-criteria decision problem has to be dealt with that involves both the quality and the line throughput optimization. Rather than an aggregation of the two evaluations under the form of a single criterion, we propose a decision-support approach that quickly converges to a good trade-off between the two criteria.

Keywords: Fuzzy logic; Hoist scheduling; Fuzzy constraints

1. Introduction

When batch processing times on workstations are close to batches travelling times, controlling and scheduling the movements of the batches becomes necessary for process performance. This point is crucial in chemical treatment or electroplating lines, since the chemical process strongly limits the in-process inventories and consequently the line flexibility and productivity. However, electroplating and surface treatment are widely used in manufacturing processes and, as a result, are often the cause of a bottleneck.

This situation has resulted in much research work over the last 20 years on the scheduling problem of hoists that move products between tanks in automated electroplating lines, called Hoist Scheduling Problem (HSP). In this kind of scheduling problem, the duration of the operations can be chosen in an interval. The definition of the bounds of this interval results from a trade-off between two aims:

- ensuring the quality surface treatment by defining a short interval,
- generating flexibility by fixing a large interval so that line productivity can be increased.

Usually, this trade-off is defined a priori without identifying consequences on productivity. Thus, the HSP consists in controlling the hoist moves in order to maximize productivity while satisfying given bounds on workstation processing times.

In this paper we propose a fuzzy approach to the HSP that allows to handle the gradual effect of soaking times on the quality of treatment: in fuzzy HSP the duration of an operation is selected in a fuzzy interval, the satisfaction degree of which is a quality evaluation of the chemical treatment. The trade-off between quality and productivity then clearly results from a bi-criteria decision process.

Fuzzy approaches have already been adopted in PERT problems (Chanas and Kamburowski, 1981;

*Corresponding author.
E-mail addresses: fargier@irit.fr (H. Fargier), lamothe@enstimac.fr (J. Lamothe).

0952-1976/01/$ - see front matter
PII: S0952-1976(01)00008-2

Lootsma, 1989; Nasution, 1993) and more recently in project scheduling (Hapke et al., 1994; Hapke and Slowinski, 1996), in master production scheduling (Fargier and Thierry, 1999) and in job-shop or flow-shop scheduling (Dubois, 1989; Kerr and Walker, 1989; Ishii et al., 1992; Ishibushi et al., 1994a, b; Dubois et al., 1995; Ptuskin, 1995; Fargier, 1996; Fortemps, 1997). Fuzzy sets usually represent uncertain time parameters like due-dates and durations, or preference levels for parameters. However, these works either consider only one optimization criterion or make the assumption that the criteria may be aggregated a priori so as to define only one final and global decision criterion. The latter approach becomes tricky when two criteria such as the quality and the makespan optimization (as is the case in HSP) are considered. To avoid having to follow this strong hypothesis, we would rather let the users make their own trade-off between both criteria: we adopt an approach oriented toward decision support.

The fuzzy approach will be analyzed in the context of the dynamic HSP control organization of the line. However, it should be noted that the fuzzy analysis can be the same for other kinds of HSP control organization. Our conclusions may lead to a reappraisal and application to classical HSP models and resolution procedures that would follow the same logic as the ones presented in this paper.

The paper is organized as follows. Section 2 presents the various HSPs and more particularly the Local Problem of dynamic HSP. The fuzzy model of this particular HSP is described in Section 3. Then, Section 4 introduces resolution procedures for the fuzzy model. Finally, in Section 5, we propose a decision support approach that may help the user converge rapidly on a trade-off between both criteria.

2. Classical HSPs

2.1. Definition of the various HSPs

An electroplating is a chemical treatment that consists in laying a thin and homogeneous chemical deposit of materials on a product. Generally, a chemical treatment line performs different elementary treatments. Each one requires a series of chemical reactions made in tanks. As a result, depending on the desired treatment, a product will have some of the elementary treatments in a fixed sequence.

In fact, a chemical treatment line is composed of (see Fig. 1):

- Tanks, each of them containing a chemical agent. Tanks can contain active reagents such as acids in order to strip product surfaces or an electroplating process which deposits a metal layer on the product surfaces. They can also contain inactive reagents such as water for cleaning.
- Loading and unloading workstations and buffers. At the loading workstation, products that will have the same treatment are secured on a carrier. At the unloading workstation, products are removed from the carrier.
- Hoists which move carriers from tank to tank, one by one, depending on the carrier routing. Collisions between hoists must be avoided as they move on the same track. The hoist charge is then composed of:
  - loaded hoist movements to move carriers from tank to tank, the duration of which is specified in the carrier routing;
  - empty hoist movements to go to the next starting tank or to avoid a collision with another hoist. The duration of these empty movements depends on the hoist schedule.

Therefore, the electroplating process results from the soaking of a carrier in tanks depending on the carrier routing.

Due to the chemical process, the following specific constraints must also be considered:

1. Once a carrier finishes its processing in a tank, it must go to the next one as quickly as possible. This means that there are no in-process buffers.
2. The soaking time of a given carrier in a tank (i.e. the time a given carrier needs to complete a chemical reaction in a tank) is not given precisely. But in

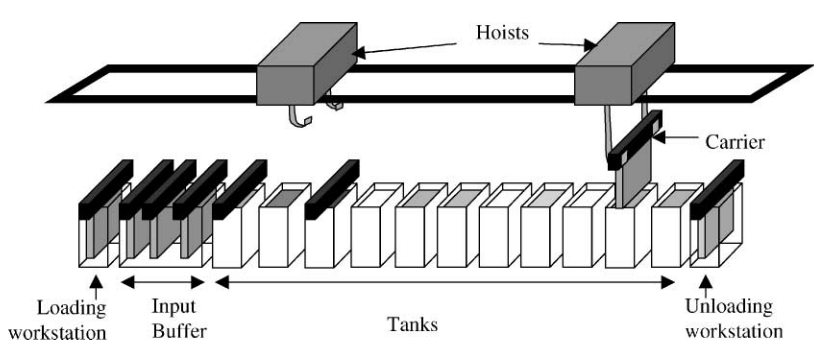

Fig. 1. A chemical treatment line.