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Editorial

Flowshop scheduling research after five decades

Jatinder N.D. Gupta *, Edward F. Stafford Jr.

College of Administrative Science, The University of Alabama in Huntsville, Huntsville, AL 35899, USA

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Abstract

Since Johnson's seminal paper in 1954, flowshop scheduling problems have received considerable research attention over the last fifty years. As a result, several optimization and heuristic solution procedures are available to solve a variety of flowshop scheduling problems. This paper provides a brief glimpse into the evolution of flowshop scheduling problems and possible approaches for their solution over the last fifty years. It briefly introduces the current flowshop problems being solved and the approaches being taken to solve (optimally or approximately) them. The paper concludes with some fruitful directions for future research.

Keywords: Flowshop scheduling; Historical developments; Problem assumptions; Current research status; Future research directions

1. Introduction

A frequently occurring operational problem is one of processing a given number of jobs (commodities) on a specified number of machines (facilities)—referred to by various investigators as scheduling, dispatching, sequencing, or combinations thereof. The first of these terms will be used here since this encompasses dispatching and sequencing. The desire to process the jobs in a special order to achieve some objective function is what creates a problem that remains largely unsolved. The actual situations that give rise to scheduling problems are wide and varied. Thus, for example, we have single machine scheduling problem, multiple machine scheduling problem, manpower scheduling problem, to name a few. In this paper and in this feature issue, we will consider a specific class of multiple machine scheduling problems, called the *flowshop scheduling problems*.

The first paper on flowshop problem was published fifty years ago. In the 50 years since Johnson (1954) published his seminal paper on flowshop scheduling, more than 1200 papers on various aspects of this problem have been published in the operational research literature. We are, therefore, quite pleased to be serving as guest editors

* Corresponding author. Tel.: +1 256 824 6593; fax: +1 256 824 2929.
E-mail address: guptaj@uah.edu (J.N.D. Gupta).

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of this special issue of *European Journal of Operational Research* on *flowshop scheduling* celebrating a golden jubilee of Johnson's paper. This special issue also honors Johnson's contributions by providing a glimpse of the research that evolved since his original paper.

In his paper, Johnson credited Richard Bellman with giving him the problem for analysis and research. Our research revealed that shortly after Johnson's work, Bellman published at least two papers that deal with two-machine flowshop problem (Bellman and Gross, 1954; Bellman, 1956; Bellman et al., 1982). A study of Bellman's work indicates that the two-machine flowshop problem in Johnson's paper was inspired by a real-life situation. This settles the issue raised by Dudek et al. (1992) about the relevance of the flowshop problems. Johnson's *rule* or *algorithm*, as his method is known today, is a simple technique for optimally sequencing a set of n jobs to be processed in a two-machine manufacturing system. Johnson also offered an optimizing technique for the three-machine system wherein the processing times for the jobs on the three machines had certain restrictive relative relationships. It is noteworthy that Johnson did not use the term *flowshop* to identify the production system represented by his model.

As a part of our research for this paper, we attempted to identify the published paper wherein the term *flowshop*, *flow shop*, or *flow-shop* was first used. In our first pass, we found that Ignall and Schrage (1965) used the term in the title of their early paper on branch-and-bound for the regular flowshop. Subsequently, we have traced the term to an earlier paper by Heller (1960). In one of his previous working papers, Heller (1959) used the term *conservative assembly line* to describe a flowshop.[1]

This paper provides a glimpse of the developments in flowshop scheduling over the last fifty years.[2] The problem assumptions, problem formulation, and solution approaches used in solving the flowshop scheduling problem are described and current state of research is introduced. Subsequently, several plausible and fruitful directions for future research are outlined.

2. The flowshop scheduling problem

A flowshop is characterized by more or less continuous and uninterrupted flow of jobs through multiple machines in series. In such a shop, the flow of work is unidirectional since all jobs follow the same technological routing through the machines. Although this description of flowshop resembles an assembly-line operation, there are several differences. First: a flowshop is equipped to handle a variety of jobs as opposed to a standard product manufactured by an assembly-line. Second: the jobs in a flowshop do not have to be processed on all machines; that is, a job may skip some operations according to its technological requirements. However, in an assembly-line, all jobs have to move from one station to another without skipping any work-station. Third: in a flowshop, each machine is independent of other machines and can be loaded independently; whereas in assembly-line operations, each work station depends on the preceding one. And finally, each job has its own processing time at each machine in a flowshop; however, all units of a product have a standard time at each work station in an assembly-line (Ashour, 1972). Because of these differences, Heller (1959) characterized a flowshop as a *conservative assembly line*.

2.1. Flowshop problem definition

As stated earlier, the work-flow in a flowshop is unidirectional. This means that the order in which

[1] To settle this issue once and for all, we make the following offer to all in the flowshop research community. We will take to dinner the first person to correctly identify the earliest published paper in which the term flowshop, or one of its variant spellings, was used. Simply send us a copy of that paper along with the correct citation. Deadline is December 31, 2005, and the dinner will be at a future operational research meeting, or in Huntsville, Alabama, USA. In Huntsville, we will also take you for a tour of the Space and Rocket Center.

[2] Since the purpose of this paper is to provide a glimpse into flowshop scheduling research and to introduce this special issue, references cited are neither exhaustive nor complete. They are cited for convenience of the reader to locate some additional readings if desired.