SINGLE MACHINE SCHEDULING WITH SEQUENCE-DEPENDENT SETUP TIMES BY USING AHP AND MULTI-CHOICE GOAL PROGRAMMING

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ABSTRACT

This study proposes a multi-choice goal programming for the single machine scheduling problem of minimizing the weighted number of tardy jobs, total weighted completion time and makespan with sequence-dependent setup times. In this problem, there are n candidate jobs for processing in a single machine, each job has a weight, a due date, a processing time, and also sequence-dependent setup times exist between two consecutive jobs. In the first stage of the proposed methodology, job weights of each job are determined by using Analytic Hierarchy Method (AHP) method. In the second stage, 0-1 mixed integer non-linear programming model is built by considering three objective functions and the ideal point is obtained by minimizing the objectives individually. Then, the multi-choice goal programming is used to allow the decision makers to set multi-choice aspiration levels for each goal.

Keywords: AHP; single machine scheduling problem; sequence-dependent setup times; Multi-choice goal programming; 0-1 mixed integer non-linear programming model

Introduction

In the field of scheduling problems, sequence-dependent setup time and job weights are very important elements and non-execution of proper scheduling and sequencing of jobs will cause a significant increase in both makespan and the number of tardy jobs. In the literature, there are numerous studies on single machine scheduling problem with sequence-dependent setup times (Panwalker and Iskander (1977), Lee and Asllani (2004)). Our problem is to minimize the weighted number of tardy jobs, total weighted completion time and makespan on a single machine under the existence of sequence-dependent setup times. To our best knowledge, in the literature, research on the problems of single machine scheduling with sequence-dependent setup times by using AHP and multi-choice goal programming for minimizing the weighted number of tardy jobs, total weighted completion time and makespan has not been studied. Although many researchers have focused on the tangible criteria; intangible criteria cannot neglected in real life problems. AHP provides to consider both tangible and intangible criteria. There are a few studies related with the scheduling problems by using AHP method. Wu et al. (2007) used AHP method to select the best solution for the multi-objective flexible job shop scheduling problem. Witkowski et al. (2009) presented an evaluation of job shop scheduling problem under multiple objectives by using AHP method for comparing schedules in accordance with multiple objectives. Goal programming is an analytical approach devised to address decision making problems where targets have been assigned to all the attributes and where the decision maker is interested in minimizing the non-achievement of the corresponding goals. An efficient multi-choice goal programming formulation based on the conic scalarizing function is proposed by Ustun (2012) with three contributions: (1) the alternative formulation allows the decision maker to set multi-choice aspiration levels for each goal to obtain an efficient solution in the global region, (2) the proposed formulation reduces auxiliary constraints and additional variables, and (3) the proposed model guarantees to obtain a properly efficient (in the sense of Benson) point.

Material and methodology

In this study, a single machine scheduling problem of minimizing the weighted number of tardy jobs, total weighted completion time and makespan with sequence-dependent setup times is considered. A 0-1 mixed integer non-linear programming model is proposed. There are 6 jobs with 3 customers. The problem is assumed to be without preemption and breakdown. All jobs are ready at time zero. Processing times, due dates and initial setup times in minutes are given in Table 1. Also, the sequence-dependent set-up times in minutes exist between the job pairs as given in Table 2.

Table 1
Parameters of the jobs

Jobs	1	2	3	4	5	6
Processing time (p_j)	12	8	3	10	4	18
Due date (d_j)	10	2	72	11	24	60
Initial Setup time	5	4	6	7	10	3

Table 2
Setup time of switching from *i* to job *j*

Jobs	1	2	3	4	5	6
1	---	7	8	6	14	15
2	5	---	18	20	5	8
3	3	11	---	19	9	10
4	7	12	1	---	6	11
5	8	4	8	3	---	16
6	9	2	7	1	2	---

A three-stage solution methodology is proposed to solve the multi-objective scheduling problem. The flow chart of the proposed methodology is given in Figure 1. In the first stage, the jobs are evaluated by AHP to obtain job weights. These weights are used as parameters for the objectives of the weighted number of tardy jobs and the total weighted completion time in the second stage. Also, the ideal point is determined to define the multi-choice goals. The multi-choice goal programming model is constructed and solved to obtain a satisfactory schedule in stage 3.

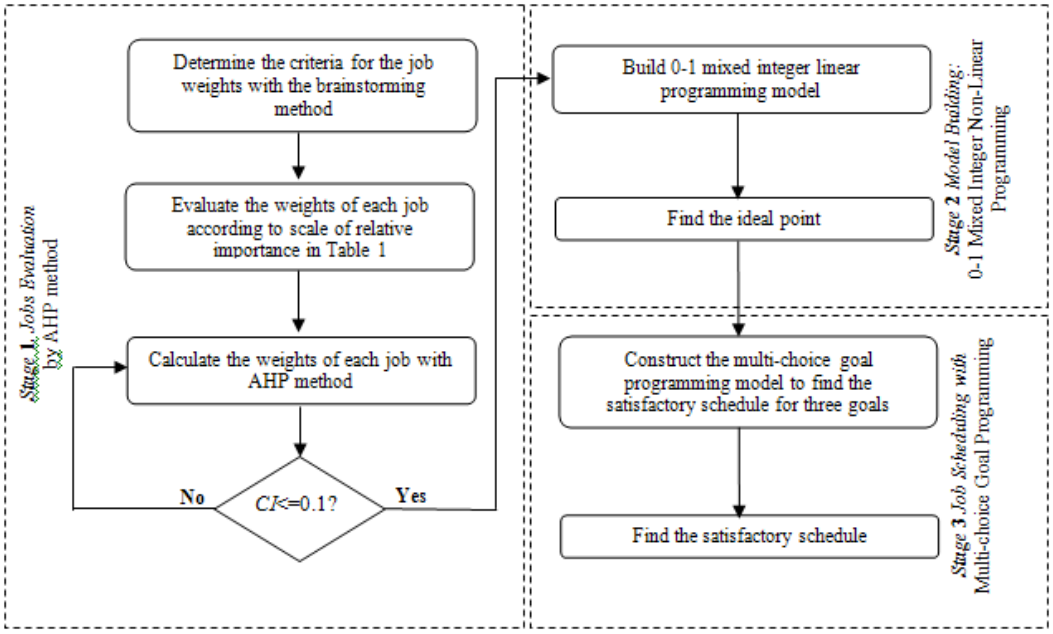

Figure 1 The flow chart of the proposed methodology

1.1 Stage 1: Job evaluation with AHP method

Jobs are evaluated by using AHP, developed by Saaty (1980). The AHP hierarchy for the job evaluation problem is given in Figure 2.

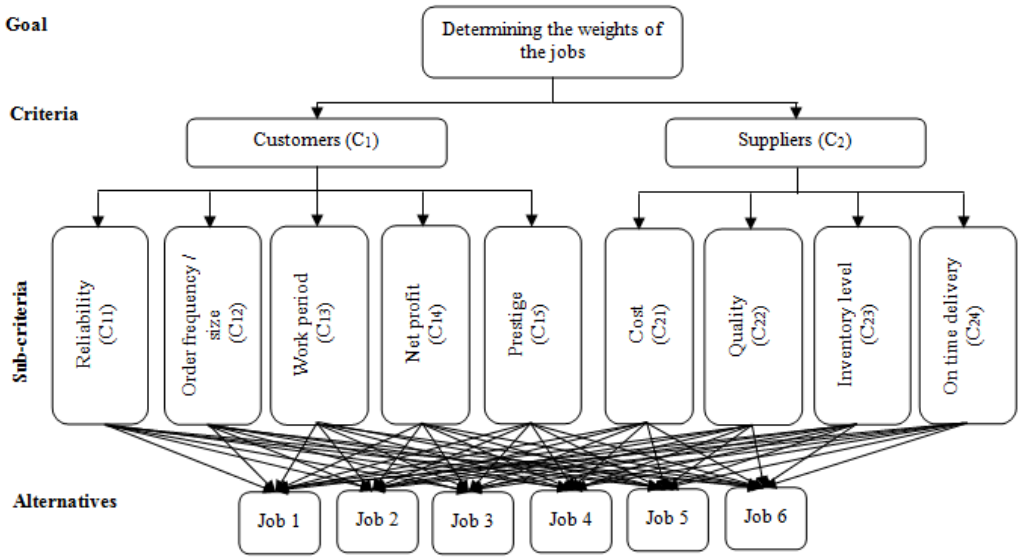

Figure 2 The hierarchy of the proposed problem

The final weights of the jobs are obtained by using AHP as 0.2182, 0.2163, 0.2200, 0.1450, 0.1022 and 0.0984, respectively.

1.2 Stage 2: Model Building: 0-1 Mixed Integer Non-Linear Programming

0-1 mixed integer non-linear programming model is built in this stage to obtain the ideal point.

1.3 Stage 3: Job Scheduling with Multi-choice Goal Programming

The weights of objectives of minimizing the weighted number of tardy jobs, the total weighted completion time and makespan were used as 0.4, 0.3 and 0.3, respectively. The multi-choice goal programming model was constructed and solved by Lingo 11.0 Solver on an Intel (R) Core ™ i7-2760QM CPU 2.40 GHz-based computer in a few seconds of computer time for the case study. The values of negative and positive deviations were calculated as $d_1^+ = d_2^- = d_3^- = 0;\quad d_1^- = 0.1896; d_2^+ = 0.1346$ and $d_3^+ = 0.0001$, respectively. The objective functions' values were determined as 0.5795, 47.4196 and 90, respectively.

Conclusion

In this paper, a methodology consists of AHP, 0-1 mixed integer non-linear programming and multi-choice goal programming is proposed to schedule the jobs for a single machine with sequence-dependent setup times. AHP allows a flexible multi-criteria decision making process by considering tangible and intangible criteria in production scheduling environment. The scheduling constraints and the multiple objective functions for a single machine scheduling problem with sequence-dependent setup times are considered by using 0-1 mixed integer non-linear programming. The multi-choice goal programming provides the decision maker to set multi-choice aspiration levels for each goal to obtain an efficient solution in the global region.

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