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Small and Medium-Size Manufacturing Staff Attendance Scheduling in a Productivity and Employee Surge Period

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Abstract:
Precisely assigning employee attendance is a key strategic issue for boosting employee morale and increasing productivity. Staff attendance shift scheduling programs are being implemented in many production and service sectors. Manually solving problems provides advantages of speed and can promote a stronger emotional connection between employees and management in the daily operation of small and medium enterprises (SMEs). However, this management style is not feasible in a situation of expanding production capacity and manpower. In this paper, a multi-objective optimization model that fully consider lawfulness, workload, and furlough fairness is employed to solve the problem of attendance shift scheduling faced by an SME under a surge of orders and employees. The numerical results are empirically demonstrated and related issues worth discussing are detailed.

Keywords: *Staff scheduling; multi-objective optimization; problem-solving; small and medium enterprises (SMEs).*

I. Introduction

Small and medium-size enterprises (SMEs) play a vital role in the economic, industrial, and social development of a country (Dar et al. 2017). According to Rohra and Panhwar (2009), the majority of developed countries recognize the significance of the SME sector in strengthening their economies. Such enterprises also hold important functions in the global supply chains of large companies. Additionally, SMEs can contribute to a more sustainable future through responsible business practices. Individually, SMEs have a relatively small environmental and social impact, however, as they account for approximately 90% of all businesses, SMEs have a much larger collective influence. This raises the importance of sustainability reporting in the context of SMEs which provide a major contribution to the development and competitiveness of the economy (Mahmood et al. 2017).

Due to financial, human resources, and facility restrictions, the survival and development of SMEs must be much more carefully managed compared to large enterprises. Significant global events such as plummeting crude oil prices and the spread of the Coronavirus disease 2019 (COVID-19) are largely out of the control of SME owners and management. Such enterprises also face threats located within the business itself. Inadequate internal control systems and risk assessment are issues which fall within the control of management (Germann and Manasseh, 2017). As such, internal management systems must be strengthened. Mechanisms of internal control work to monitor the human resource activities of SMEs. Such activities are vital for the protection of physical and intangible resources, contributing to the efficiency and functionality of the business (Çika, 2018). Leveraging human resource management capacity can also be a source of competitive advantage for SMEs. Methods to manage manpower to adapt to a surge in orders are rarely discussed in the current literature. While a warm connection among employees and management provides significant advantages in the daily operations of SMEs, over-reliance on manual management and a lack of effective management systems fail to meet the needs of expanding enterprises.

A multi-objective optimization model provides a scientific and objective approach to the management of SMEs, particularly for daily operations scheduling. Scheduling is a decision-making process employed in numerous manufacturing and service sectors including production, health, tourism, hospitality, and transportation. Timetabling problems involve a number of activities, persons, materials, or capital that are assigned to predefined time periods under certain constraints (Taghizadehalvandi and Ozturk, 2019). This work takes a small to medium manufacturer facing a sudden increase in orders and employees as the research focus. A work attendance problem-solving process that employs a multi-objective optimization model to replace the previous manual work shift scheduling is presented. To determine a solution for the multi objective problem, the objective functions are first scalarized. The proposed mathematical model is scalarized with different weights by assigning the shift and different processes typed in the production line. To illustrate the contribution of this study, numerical outcomes of the model are compared with the previous manual shift scheduling system.

The remainder of the paper is organized as follows. In Section 2, a literature review of the application of multi-objective optimization for daily operations of SMEs is given. In Section 3, proposed solutions are presented, while Section 4 provides numerical results and discussion. Finally, the conclusions are presented in Section 5.

II. Literature Review

Several approaches have been developed in past literature to address shift scheduling and multicriteria shift scheduling problems. However, there are relatively few studies exploring SME shift scheduling by multi-objective programming method. In this section, studies employing multiple objective optimization structures are considered and various solution approaches are discussed, particularly multi-objective methods.

Numerous scholars have explored job scheduling problem-solving; however, most are focused towards work process optimization. Qian et al. (2006) proposed a modified method for solving multi-objective job shop scheduling problems. The trend of working from home was explored by Wang et al. (2014), who investigated data storage process scheduling issues to meet the needs of independent workers. Hosseinabadi et al. (2015) studied the maximum makespan of SME manufacturing firms. They also analyzed the average workflow and latency time of parts which are considered the objectives of scheduling and compatible with the philosophy of on-time production and supply chain management goals. The objectives of the study were to optimize resource utilization, minimize inventory turnover, and improve commitment to customers, and the simultaneous control of these objectives improved system performance. Vallejos-Cifuentes et al. (2019) presented an approach to the energy-aware flow shop scheduling and energy-aware job shop scheduling problem by considering process speed as the main energy-related decision variable in an SME. Ghiyasinasab et al. (2020) determined that small companies which prefabricate parts for the construction industry in the context of engineer-to-order systems often encounter production issues as they generally do not systematically optimize their planning. As illustrated, the main objective present

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in the proposed models is cost reduction.

The optimization of the manufacturing process is certainly important, particularly as SMEs are limited by manpower and financial resources. However, existing literature seldom explores a more reasonable allocation of manpower and shifts, especially for periods of rapid increase in production demand. Incorrect management at this time may lead to more serious losses, whether arising from customer claims or legal disputes with an employee. Yao and Zeng (2019) noted that a sense of fairness in salary distribution and organizational commitment can effectively reduce employee turnover, and that perceived external job opportunities moderate this inhibition. As distribution of shifts affects the salary income of workers in the assembly line, a feeling of 'relative fairness' is key to increasing retention rate. Similarly, Park et al. (2019) recognized that developing a collaborative organizational culture helps SME talent retention. A study by Swalhi et al. (2017) further demonstrates that overall justice has a greater effect on affective employee commitment than specific dimensions of justice, and that this 'justice' is highly related to fairness and affective commitment.

The literature review highlights that workload balance of the employees and their preferences for days-off have not been simultaneously taken into consideration in previous studies. In addition, scalarization techniques have not been intensively employed to determine a solution to this multi-objective problem. In this work, both workforce balance and employee satisfaction are considered. The adjusted labor laws allowing for flexible work hour arrangements are used first in the solution of multi objective workforce scheduling problem taking into account the needs of employees and enterprises.

III. Multi-objective Optimization Model for Staff Scheduling

A shift scheduling problem encountered in an SME manufacturer is discussed in this work using the example of Firm X, a leading medical material company with excellent experiences. To improve response to the huge demand for medical and surgical face mask products during the early outbreak of COVID-19 in January 2020, management immediately decided to increase productivity at their manufacturing facility and recruit more assembly line workers. To re-activate idle mask production equipment, Firm X also recruited 70 short-term employees as machine operators, handlers, and packers.

This was the first time Firm X has encountered such urgent production demand. To achieve the huge production requirements for face masks, according to labor negotiation and the Labor Standards Act, Firm X employed new flexible working hours from February 2, 2020, that allowed six working days per week and 12 working hours (eight hours in a typical shift and four hours of overtime) per day for the subsequent eight weeks. Firm X initially launched a manual attendance table for the new manufacturing plans, but this failed to satisfy supervisors and staff in the production line. After a series of discussions, the company decided to employ multi-objective programming for rescheduling attendance tables in the upcoming weeks.

The shift plans were prepared weekly for the production line for a total of 75 staff which included five foreman and 70 employees working in two 12-hour shifts between 7am to 7pm and 7pm to 7am every day. The 7am to 7pm shift was called 'day shift' and the 7pm to 7am shift was called the 'night shift'. Each employee could only arrange one shift a day and had the right to take two days off every seven days. There were also five different processes for workers to be scheduled in the face mask production line (1. Material feeding; 2. Welding; 3. Forming and cropping; 4. Packaging; 5. Supervising).

The weights of the processes are not the same due to the type of face mask product sold and customer

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demands. A weight was thus assigned to each department by the factory manager, aiming to balance the total department load rather than the total number of departments to which the employees were assigned. As this issue was not recognized initially, unbalanced assigned workloads created dissatisfaction among the employees. In the current case, monthly shift schedules were prepared by the factory manager in at least one day in advance.

The conditions mentioned above are compulsory restrictions of the system. In this study, a balanced workload was obtained for all employees while simultaneously minimizing the shift assignments to unwanted days-off. In this section, a two-objective mixed integer mathematical model is first developed for the current shift system of the application site. The constraints and objective functions in the proposed model were then determined by interviewing the Firm X factory manager and employees.

Set of parameters:

i index of staffs, *i*=1,…, 75
i=1~5 (foreman); *i*=6~75 (operator)
*d*index of days, *n*=1~7
*t*index of attendance shift, *t*=1~2
t=1 (7 a.m.-7 p.m.), *w*=1
t=2 (7 p.m.-7 a.m.), *w*=2
j index of job category, *j*=1~5
j=1 (Material feeding)
j=2 (Welding)
j=3 (Forming and Cropping)
j=4 (Packaging)
j=5 (Supervising)
*pjt*number of staffforjob category at attendance shift

Decision variables:

$$x_{idjt} = \begin{cases} 1, \text{if staff } i \text{ is assigned to day shift } t \text{ at day } d \\ 0 \qquad\qquad\qquad o.w. \end{cases}$$

$$y_{idj} = \begin{cases} 1, \text{ if staff } i \text{ is start working from a day } d \\ 0 \qquad\qquad\qquad o.w. \end{cases}$$

min Z
subject to

$$\sum_{d=1}^{7}\sum_{t=2}^{2}\sum_{j=1}^{5} w_k x_{idjt} \le z\,, \quad (1)$$

$$\sum_{i=1}^{75} x_{idjt} = pjt, \ \forall \text{d}, \forall \text{t}, \forall \text{j} \, (2)$$

$$\sum_{i=1}^{5}\sum_{j=1}^{4} x_{idjt} = 0, \ \ \forall \text{d}, \ \forall \text{t} \ \ (3)$$

$$\sum_{i=6}^{75}\sum_{j=5}^{5} x_{idjt} = 0 \ \ \forall \text{d}, \ \forall \text{t} \, (4)$$

$$\sum_{j=1}^{5}\sum_{t=1}^{2} x_{idjt} \le 1, \ \ \forall \text{d}, \forall \text{t}$$

(5)

$$\sum_{j=1}^{5} x_{idjt} + x_{idjt} \le 1, \ \forall \text{t}, \forall \text{d}$$

(6)

$$\sum_{\text{d}=1}^{7}\sum_{t=1}^{2}\sum_{j=1}^{5} x_{idjt} \le 6, \ \forall \text{i} \qquad\qquad (7)$$

$$-1 \le \sum_{d=1}^{7}\sum_{t=1}^{2} w_t \times \left(x_{idjt} - x_{idjt} \right) \le 1, \ \text{i=1~4}, \ \text{j=5} \quad (8)$$

$$-1 \le \sum_{d=1}^{7}\sum_{t=1}^{2} w_t \times \left(x_{5djt} - x_{1djt} \right) \le 1, \ \text{j=5}$$

(9)

$$x_{idjt} = 0 \text{ or } 1 \ \in \ \text{I}, \forall \text{i}, \forall \text{d}, \forall \text{k} \ \ (10)$$

$$y_{id} = 0 \text{ or } 1 \ \in \ \text{I}, \forall \text{i}, \forall \text{d}, \forall \text{k}$$

(11)

Constraint definition:

Constraint (1) is the objective function that is minimized for all persons and balanced load assignment is performed.
Constraint (2) ensures the number of assigned staff to day shift at day *d* in each job category *j* is equal to the total number of staff at attendance shift *t* in each job category *j*.
Constraint (3) ensures staff *i* 1-5 will not be assigned job category *j* 1-4.

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Constraint (4) ensures staff *i* 6-75 will not be assigned job category *j* 5.
Constraint (5) means each staff member *i* will only be assigned to a shift in each working date.
Constraint (6) ensures if staff *i* attends night shift *t*2, this staff member will be assigned to the same shift in the next working date.
Constraint (7) means all staff *i* can rotate up to six days a week.
Constraint (8) draws up staff *i* 1-5 minimum number of rotations and shifts of job category *j* 5.
Constraint (9) draws up staff *i* 1-5 minimum differentiation in number of rotations and shifts of job category *j* 5.
Constraint (10) and (11) are the range of decision variables, '1' means proceed while '0' means not proceed.

IV. Numerical Results

At its original size, manual scheduling is more convenient for Firm X as the number of employees is small. However, this scheduling style is unable to adapt to the situation of increased productivity due to the major problem of 'attendance and furlough fairness' among staff in the production line. Compared to manual scheduling, the multi-objective optimization programming presented in this study demonstrates highly consistent results. For example, the weekly average five attendance shifts per staff includes foreman and operators, and also facilitates the scheduling of statutory leave. This model also assures the shifts scheduled for each staff member will not cause confusion to their circadian clock. The optimization analysis results of Firm X's staff attendance are provided in Table 1.

Table 1. optimization analysis of multi-objective programming for staff weekly attendance

j=1	74	75	76
weights	No solution	8	8
Number of rotations	No solution	5	4-6
Average weights of supervisors	No solution	8.6	8.6
Average weights of operators	No solution	8.7	8.2

Relative to the original manual weekly staff attendance schedule, the advantages of multi-objective programming are detailed as follows:

1. Each weight value in the face mask manufacturing shift is consistent. The physical and psychological adjustment of the employee is also considered, and holidays can be arranged more reasonably. Thus, staff feelings of deprivation are reduced while earning due compensation.

2. Most importantly, workload fairness is ensured while adhering to labor laws which avoids many unnecessary management costs. The results of the manual weekly staff attendance schedule show that some employees must take turns of 11 shifts a week on average for each manufacturing staff member, while other staff are only given eight shifts. This inconsistency can lead to numerous management problems including nepotism or workplace bullying. Conversely, the attendance schedule by multi-objective programming provides higher fairness and rationality.

3. Multi-objective programming is conducive to the establishment of a management system which works to avoid cronyism in SMEs. Previous manual staff attendance scheduling predominantly relies on the subjective awareness of managers. This is based on the premise that the number of working members is relatively small, most of whom are family or founding members who can easily coordinate with each other. Once the scale of business expands, such management style and systems are highly prone to problems and can seriously hinder the development of an enterprise. Table 2 illustrates the differences between manual and multi-objective programming staff attendance scheduling.

Table 2. Differences between optimization model and manual scheduling

Item	Multi-objective	Manual staff	Differences

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	optimization model	scheduling	
Workload (shift) per staff	9	8-11	1-2
Supervisor weekly attendance times	5	4-6	±1
Operator weekly attendance times	5	3-5	±2
Processing time (seconds)	236	>1600	1364
Main benefits	Multi-objective optimization model has saved 22.7 minutes process time, and fully consideration of lawfulness and fairness		

V. Conclusions

An SME employee shift scheduling problem under a period of increase demand was explored in this paper. A sound management system is of utmost importance to SMEs. In addition to workplace hardware conditions, software conditions such as workplace atmosphere or harmonious communication has also been determined to play a critical role in daily management affairs, especially in the case of a large increase in purchase orders. To address this problem, a multi-objective optimization model is employed to establish an initial schedule that is robust to workload stability, furlough fairness, and lawfulness.

This study only focused on short-time staff in manufacturing sector assembly line work. Various avenues for further research include how to determine annual leave that will gradually increase with employee seniority or the problem of shifts arising from sudden leave. The impact of such factors on job scheduling in other industries also requires further analysis.

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