Research on Personnel Allocation Strategies of Reducing Workers in Divisional Seru

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Abstract. With the diversification and individual development of the economy, enterprise competition tends to be international, and traditional production line has disadvantages in terms of efficiency and labor costs. This paper considers reducing workers to reduce labor costs in line-seru. It also considers reducing the number of workers without increasing the manufacturing period of the product to ensure timely delivery. This paper proposes a multi-objective model to solve the problem of reducing the number of workers and not increasing the manufacturing period. The variable length coding heuristic algorithm is used to solve the model. This algorithm is not only suitable for the case of fewer workers, but also has good applicability to medium and large-scale problems.

Keywords: divisional seru, reducting workers, heuristic algorithm.

1. Introduction
With the rapid development of the economy, the cycle of providing products by enterprises is continuously shortening, labor costs are increasing, and the requirements for optimization of production methods are becoming higher and higher. Enterprises must enhance their competitiveness. Therefore, it is urgent to transform the production efficiency of the original assembly line.

The divisional seru is a short line with several cross-trained workers. The process in a divisional seru is divided into different parts. Each section is operated by one or more workers. The divisional seru production system has the idea of integrating lean production and agile manufacturing[1]. Therefore, line-seru conversion can improve the productivity and competitiveness of enterprises. Completing the line-seru conversion is a complex decision-making problem[2], which requires the number of decision-making units. In each cell, the number of workers and the arrangement of workers' positions are allocated according to the skill level of the workers. In addition, the evaluation of unit performance after line-seru conversion is also an important decision issue.

Kaku et al, built two goals in the model (total production time and total man-hours), and experiments based on numerical simulations were performed to analyze the effects of various operating factors on the line-battery conversion [3]. Reducing workers can address labor costs. Canon has cut a large number of employees to cope with high labor costs. Sony Kohda used line-seru conversion to reduce TTPT by 53%[4]. The production line-seru conversion that minimizes the manufacturing period is studied. Subsequently, Yu extended the research on the line-seru conversion model, which reduced both the number of workers and the manufacturing period. They said that the number of workers and the
production period can be reduced at the same time by changing the production line. However, when considering these two goals at the same time, the Pareto optimal solution may save manpower but increase the validity period. At the same time, the algorithm is suitable for use when the workers are small[5].

Therefore, according to the actual needs of enterprises, this paper reduces the number of workers without increasing the manufacturing period, and uses a heuristic algorithm to solve the model. This solution method is also applicable to actual production with a large number of workers.

2. Divisional seru reduce workers without adding build-time models

2.1. Assumption

The following assumptions are made for the divisional seru manufacturing system: the type and batch of the product are known; the cost of new equipment and tools is ignored; in the assembly line, each worker performs only one process, so the number of workers (W) is equal to the number of processes; The number of workers in different seru can be different; The assembly tasks in each divided seru are the same as the assembly tasks in the assembly line; The interval between adjacent batches of different types of products is heavy. Set time, the interval between adjacent batches of the same product is 0.

2.2. Indices

\( i \) index of workers \((i = 1, 2, \ldots, W)\); \( j \) index of serus \((j = 1, 2, \ldots, J)\); \( n \) index of product types \((n = 1, 2, \ldots, N)\); \( m \) index of product batches \((m = 1, 2, \ldots, M)\); \( l \) indicates the process number on the assembly line \((l = 1, 2, \ldots, L)\); \( k \) indicates the serial number of the product batch assembled in the seru; \( V_{mn} \) indicates the standard processing time of the first operation of the products of the category; \( T_{nl} \) indicate the proficiency of workers in the operation of the process; \( \gamma_{il} \) indicate the preparation time of the product type during the production of the tour seru; \( S_{tn} \) indicate the preparation time of the product type in the production line; \( SL_n \) indicate the skill level of the worker's processing type products; \( \beta_{ni} \) indicates the upper bound of the number of effective operations by the workers; \( \eta_i \) indicates the degree of influence of the worker on the execution of multiple processes. \( C_i \) represents the capacity factor when the first worker operates multiple processes, as shown in Equation (1); \( TT_m \) indicate the processing time of a product in a batch in a process in the seru, as shown in Equation (2); \( TS_m \) indicating the batch At the preparation time for the start of seru processing, as shown in Equation (3); \( TF_m \) indicate the circulation time of the products in the batch, as shown in Equation (4); \( TB_m \) is the start processing time of the batch of products in the seru as shown in Equation (5).

Decision variables: \( X_{ij} \) means 1 when workers are assigned to the unit, otherwise 0; \( Z_{mjk} \) means 1 when the first batch of products is allocated to the seru and the first production is scheduled, otherwise 0;

\[
C_i = \begin{cases} \{1 + \epsilon_i(W - \eta_i), \ & W > \eta_i \\ 1, \ & W \leq \eta_i \end{cases} \quad \forall i \quad (1)
\]

\[
TT_m = \frac{\sum_{n=1}^{N} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} V_{mn} T_{nl} \gamma_{il} X_{ij} Z_{mjk}}{\sum_{i=1}^{W} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} X_{ij} Z_{mjk}} \quad (2)
\]

\[
TS_m = \sum_{n=1}^{N} S_{tn} V_{mn} \left(1 - \sum_{m=1}^{M} V_{nm} Z_{j(k-1)m'})\right), \quad \{j, k\}/Z_{mjk} = 1, \forall j, k \quad (3)
\]

\[
TF_m = \frac{b_{m} TT_m}{\sum_{i=1}^{W} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} X_{ij} Z_{mjk}} \quad (4)
\]

\[
TB_m = \sum_{q=1}^{m-1} \sum_{j=1}^{J} \sum_{k=1}^{K} (TF_q + TS_q) Z_{mjk} Z_{qj(k=1)} \quad (5)
\]

2.3. Model

Objective functions:
\[
\min \left\{ \sum_{j=1}^{J} \sum_{i=1}^{I} X_{ij} \right\} 
\]

Subject to

\[
\min \left\{ \max_{m=1}^{M} (TB_m + TF_m + TS_m) \right\} 
\]

\[
1 \leq \sum_{i=1}^{I} X_{ij} \leq W, \ \forall j
\]

\[
\sum_{j=1}^{J} X_{ij} \leq 1, \ \forall i
\]

\[
\sum_{j=1}^{J} \sum_{i=1}^{I} X_{ij} < W
\]

\[
\sum_{j=1}^{J} \sum_{i=1}^{I} Z_{ijk} = 1, \ \forall m
\]

\[
\sum_{m=1}^{M} \sum_{k=1}^{K} Z_{ijk} = 0, \ \forall j / \sum_{i=1}^{I} X_{ij} = 0
\]

In equations (6) and (7), the objective function of the model is to minimize the total number of managers and workers and minimize the maximum manufacturing period. In the constraint conditions, Equation (8) is to ensure that each seru contains at least one worker and ensures that each seru contains at least one process and at most one sequence.; Equation (9) means that in a line-seru conversion for the purpose of reduction, workers must either stay in the divisional seru or be removed; Equation (10) indicates that the total number of workers after the reconfiguration is less than the total number of assembly line workers; Equation (11) indicates that a product batch can only be allocated to a divisional seru; (12) indicates that at least one worker is responsible for processing Batch.

3. Variable-length encoding heuristics
This paper proposes a novel variable length coding heuristic algorithm (VLEH) to solve the model. For a line with workers, we use a vector of less than to represent a reduction of workers. In the vector, the number of elements representing a worker is less than, which means that the workers are reduced. The variable length coding solution for reducing workers is to delete one or more elements representing workers based on the original solution. Variable-length encoding is used to generate the initial solution. In order to further find a feasible solution with fewer workers, a method is proposed that can reduce one worker of the variable-length coding solution that has been generated. The way to reduce 1 worker in a given solution is to remove any element that represents the worker.

We use an improved neighborhood strategy for searching for improved neighborhood relationships for better manufacturing-time constraints, that is, swapping workers in the seru with any elements not in the seru. The process of the variable length coding heuristic (VLEH) is as follows, VLEH first generates an initial solution set (s) based on variable-length encoding. For each initial solution (\(S_i\)), VLEH obtains the neighborhood with the shortest span as the new \(S_i\) by searching locally based on the initial solution \(S_i\) considering the manufacturing period. Then, for \(S_i\) HLEH obtains the neighborhood with the shortest span as \(S_h\) through local search. Based on reducing 1 worker of the generated variable-length coding solution, deleting any element representing the worker reduces 1 worker of the generated si. If \(S_h\) is better than \(S_i\), set \(S_i\) to \(S_h\), and continue to search for the next better \(S_h\) than \(S_i\) by searching 1 less workers locally, otherwise, continue to search for better \(S_h\) than \(S_i\) until termination condition. In a loop, if \(S_i\) is a better solution than the optimal solution (OPT), set OPT to \(S_i\).

4. Example analysis
In order to verify the effectiveness and feasibility of the model proposed in this chapter to reduce the number of workers without increasing the manufacturing period, this section will use a calculation example to verify the model using a variable length coding heuristic algorithm. Converting the pipeline to segmented units to reduce workers’ decisions includes two NP-hard puzzles (ie unit formation and unit scheduling). For simplicity, FCFS rules are used in cell scheduling.
In this case, assuming that a batch is processed in one seru, the experimental data used can be found in Tables 1 and 5 of Yu et al[6]. And Tables 1 and 2 of Yu et al[7]. In the case, the following parameters will be used: \( |S| = 10, m_t = 20, \text{maxIter}_t = 5, \text{maxIter}_r = 3 \). \( |S| \) indicates the number of initial solutions; \( m_t \) indicates the number of neighborhoods to search for a better manufacturing period; \( \text{maxIter}_t \) is the maximum number of iterations during which the manufacturing period is constant; \( m_r \) is to reduce the number of adjacent workers; \( \text{maxIter}_r \) is the maximum number of iterations for a work program where the number of workers is constant; \( WR \) indicates the number of workers reduced without increasing the manufacturing period. Table 1 shows the solution without increasing the manufacturing period when the number of workers is 12. It is found that there is no any plan to reduce more than 3 workers without increasing the manufacturing period. Therefore, for the 12 workers in the case, one, two, or three workers can be reduced without increasing the manufacturing period. They are listed in Table 1.

**Table 1.** Number of workers for 12 cases.

| NO. | Makespan   | Solution                                      |
|-----|------------|-----------------------------------------------|
|     | Reduced 1 worker without increasing makespan |                                               |
| 1   | 3269.468   | \{\{1,261,134\},\{8,710,519\}\}             |
| 2   | 3287.66    | \{\{1,261,134\},\{2,710,519\}\}             |
| 3   | 3295.144   | \{\{24\},\{1019\},\{5,381,112\},\{6\}\}   |
| 4   | 3302.872   | \{\{3,811,912,415\},\{762\}\}              |
| 5   | 3305.224   | \{\{1,261,174,135\},\{8109\}\}             |
|     | Reduced 2 worker without increasing makespan |                                               |
| 1   | 3577.753   | \{\{11\},\{15,436\},\{781,012\}\}         |
| 2   | 3595.455   | \{\{119\},\{15,436\},\{71,012\}\}         |
| 3   | 3597.484   | \{\{119\},\{15,436\},\{7812\}\}           |
| 4   | 3597.484   | \{\{119\},\{15,436\},\{81,012\}\}         |
| 5   | 3621.732   | \{\{12\},\{311\},\{48\},\{156\},\{710\}\}|
|     | Reduced 3 worker without increasing makespan |                                               |
| 1   | 3968.37    | \{\{4,816,115\},\{3912\}\}                |
| 2   | 3974.318   | \{\{12,463\},\{112,918\}\}                |
| 3   | 3974.318   | \{\{12,463\},\{1,129,101\}\}              |
| 4   | 3975.881   | \{\{11\},\{61,354\},\{12,810\}\}         |
| 5   | 3979.512   | \{\{12,463\},\{1,121,018\}\}              |

5. Summary

This chapter studies the problem of reducing the number of workers by converting pipelines into divisional seru without increasing the manufacturing period. A reduction model considering the skill level of workers is established, and a heuristic algorithm of variable length coding is designed for solving. The analysis of examples shows that the more workers in the assembly line, the more workers can be reduced without increasing the manufacturing period. The least skilled workers are more likely to be cut without increasing duration.

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