A Study of the Scheduling Simulation System of U-shaped Production Line with Multi-workers using eM-Plant

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Abstract: We have been concerned with a multi-stage flowshop scheduling problem using eM-Plant™. In this paper, we discuss a U-shaped production line with multi-workers. To perform a job efficiently, each worker is assigned one or more operations dynamically. As each operation is a work-in-progress, the model is complex. We analyze this kind of model by simulation software called eM-Plant™. One of the characteristics of a U-shaped production line is to be able to control the input and output in the same place. One worker often can do all the operations from input to output on the product. In this study, the authors focus on the feature extraction of this scheduling problem by using a model of a U-shaped production line for two workers and three processes using eM-Plant simulation software.

Keywords: *Simulation; Scheduling; eM-Plant*

1. INTRODUCTION

In recent years, there has been a tendency for the life cycle of a product to shorten. Therefore, a production system tends to reduce the production lot as much as possible to avoid the risk of the circulation stock turning into dead stock. Moreover, the latest production system tends to produce products for small inventory spaces. As far as the production line is concerned, the charge from a straight line to a U-shaped line enables the worker to be in charge of two or more processes.

In such a line, it is necessary to cope with a sequence change in the process and the number of people flexibly. A simulation technique has often been used to analyze this. To understand the features of the scheduling problem, a dedicated simulation program is usually coding for a model. It is necessary to change the program significantly if there is a change in the line and process. Moreover, the program works to add an animation function in order to visualize the simulation result which is not easy.

In this study, we focus on a feature extraction of this scheduling problem by using a model of a U-shaped production line for two workers and three processes using eM-Plant simulation software.

2. MODELING OF U-SHAPED PRODUCTION LINE SCHEDULING PROBLEM

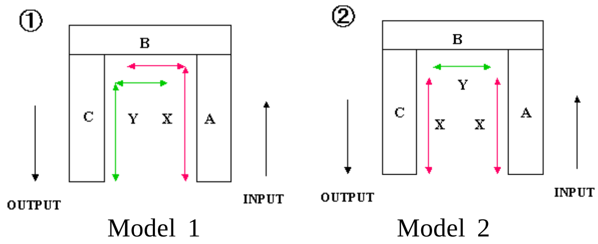

Figure 1. U-shaped production line model.

We use two models which depend on how the worker changes, as shown in Figure 1. (Model1, Model2)

These two U-shaped production lines have three processes, A, B, and C, and two workers. Worker X is in charge of process A and process B in Model 1, and worker Y is in charge of process B and process C. Worker X is in charge of process A and process C in Model 2, and worker Y is in charge of process B.

2.1 Parameters and Conditions in this Simulation

(1) All jobs consist of three processes (A, B, and C), and are processed in turn. The processing time of process A, process B, and process C of job i is assumed to be Ai, Bi, and Ci respectively.
(2) Workers consist of two people (X and Y).
(3) Each worker's processing performance is the same.
(4) The processing of all jobs begins from A on arrival.

(5) If the processing of each job is not completed, the following processing does not start.
(6) The worker cannot process other jobs while processing one job until the processing of the job ends.
(7) The movement time of the job is assumed to be 0. Therefore, the following job can be processed when the processing is completed.

2.2 Input Information needed for Analysis

Input information for analysis is as follows:
(1) Number of jobs
(2) Processing time of job in each process
(3) Number of maximum stocks between processes
(4) The sequence of a job

2.3 Output Information for Analysis and Evaluation

Output information for analysis and evaluation is as follows:
(1) The total duration time
(2) The amount of maximum work-in-progress between processes

3. CONSTRUCTION OF U-SHAPED PRODUCTION LINE MODEL

3.1 Generation of object

Using eM-Plant, the production line, can be modeled by using a standard basic object. The user can flexibly customize the object and construct the simulation model by using the object (Figure 2.).

3.2 Basic object

The basic objects used to construct the model in this study are as follows:

1.connector	8.exportor
2.ivent controller	9.entity
3.source	10.method
4.single process	11.valiable
5.drain	12.table file
6.baffer	13.comment
7. broker	14.gage

3.3 Method

The method for constructing the model is as follows:
(1) Reset
Initialization of variables and tables

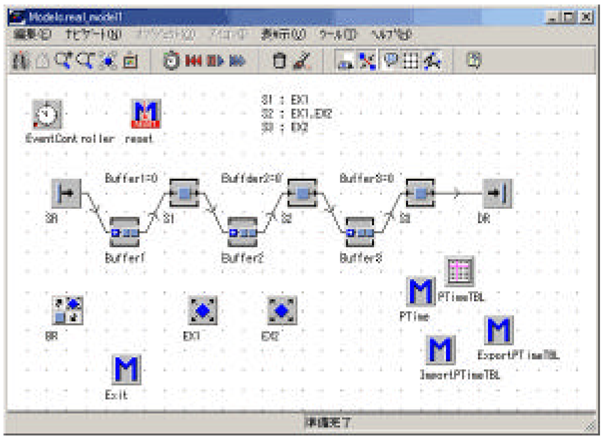

Figure 2. Example of a constructed model using eM-Plant

(2) PTimeTBL
The processing time is calculated when the job and the process are passed as a parameter argument, and it is returned as the processing time in the process. The identifier of the job is '@', and that of the process is '?'.
(3) ImportPTimeTBL
External data input to table file

The object and the method were combined and the model of Figure 2 was constructed. The model of the other type of Figure 1 was constructed comparatively easily by using the function of inheritance.

4. SIMULATION OF CONSTRUCTED MODEL

We analyzed the difference of the processing time in each process.

4.1 Simulation1:

The number of jobs is 20.
We simulated the cases where the number of maximum stocks between the processes are 20 and 1.
There are 13 combinations in all. (6+3+3+1)
However, symmetrical combinations are omitted here; therefore the total becomes eight as shown in the following Table 1.

Table1. Processing time in each process

O > O > O	O > O = O	O = O > O	O = O = O
Ai > Bi > Ci	Ai > Bi = Ci	Ai = Bi > Ci	Ai = Bi = Ci
Ai > Ci > Bi	Bi > Ai = Ci	Ai = Ci > Bi	
Bi > Ci > Ai			

4.2 Simulation results

4.2.1 Comparison of total duration time

In Model 1, there was no significant difference in the total duration time. It seems that the reason is due to the flexibility of the work responsibility of worker X and worker Y in process B.
In Model 2, the total duration time varied. It was confirmed that the total duration time shortened while approaching the condition of Bi≅Ai+Ci (Bi>Ci>Ai or Bi>Ai=Ci). (≒ : means nearly equal)

4.2.2 Comparison of maximum work-in-progress

It was confirmed that the work-in-progress between process A and process B stagnated easily if the value of Ai was smaller than that of Bi. This reason is that worker X is processing job A1, A2, ... , while worker Y is processing the first job B1.
It was confirmed that the work-in-progress did not stagnate between process B and process C because the large Ci value was not considered. Therefore, the simulation result is evaluated by the maximum work-in-progress in process A and process B hereafter.

4.3 Simulation 2:

Work-in-progress stagnates between process A and B when Ai is small. To avoid this, an extra job, B2, with the same processing time as B1 was assigned to worker X. The job which was the cause of the stagnation of the work-in-progress was removed.

The stock patterns are as follows:
1. The number of maximum stocks is 20 and includes no extra jobs (MAX20-nonextra).
2. The number of maximum stocks is 20 and includes extra jobs (MAX20-extra).
3. The number of maximum stocks is 1 and includes no extra jobs (MAX1-nonextra).

By considering the total duration time of the foregoing paragraph, we used the condition of Bi≅Ai+Ci (two kinds of (Bi>Ci>Ai and Bi>Ai=Ci)). Also, we then simulated it by changing the processing time, and evaluated it.
The number of jobs is 20.
The number of maximum stocks between the processes is three, as shown above.
The processing time in each process of the job.
The average of the processing time which is Bi≅Ai+Ci (Bi>Ci>Ai re-Bi>Ai=Ci) is assumed to be three kinds as follows:
i) Bi≅100, Ai≅10, Ci≅90
ii) Bi≅100, Ai≅30, Ci≅70
iii) Bi≅100, Ai≅50, Ci≅50

To determine the difference, random numbers which were subject to regular distribution were generated (Standard deviation: in the case of 3 and 5).

4.3.1 Rule to determine the order of job

The order of the jobs is determined by the following three rules.
Random (Depending on the order of the generated random numbers).
Johnson rule which uses Ai and Ci. (rule 1)
Johnson rule which uses Ai+Bi and Bi+Ci. (rule 2)
According to the argument above, the case considered by the simulation is two (model) x three (average value) x two (standard deflection) x three (arranging rule) x three (stock pattern) = 108 kinds.

5. SIMULATION RESULTS AND EVALUATIONS

5.1 Evaluation for total duration time

If we use either the Johnson rule of rule 1 or 2, we can shorten the total duration time. However, there was no difference betwe en the Johnson rule Ai and Ci and the Johnson rule Ai+Bi, and Bi+Ci for the total duration time.
The following has been confirmed for the case of Bi>Ci>Ai of Model 1 and Model 2.The total duration time of MAX20-nonextra was smaller than that of MAX20-extra and MAX1-nonextra.This reason is that a small job during the processing time is not be able to be processed in process A, and to stop in MAX1.
When the processing demand comes at the same time in process A and process B, worker X processes process A first. At this time, Bi is in a waiting status. This result is derived only from the pattern of Bi>Ai≅Ci. The same is true of Bi>Ci>Ai. The reason is that the balance of Bi≅Ai+Ci diminishes greatly because the difference of the processing time of Bi and Ci is large. The cause of this has to do with the difference of the operation rate between worker X and Y.

5.2 Evaluation for a maximum work-in-progress

When an extra job is given for Bi>Ci>Ai in Model 1 and Model 2, maximum work-in-progress is small. In MAX20, maximum work-in-progress increases as Ai becomes small. The maximum value at this time was 18. Maximum work-in-progress could be reduced to 13 by assigning an extra job.

5.3 Comparison between models

We compared Model 1 and Model 2 of three (average value) x two (standard deflection) x three (arranging rule) x three (stock pattern) = 54 kinds using the same condition. Model 2 was better than Model 1 with respect to the total duration time and the maximum work-in-progress. Figure 3 and Figure 4 are typical. The horizontal axis shows a combination of an average value and standard deviation for each graph.

In the maximum work-in-progress comparison, the vertical axis is the maximum work-in-progress between process A and process C. Horizontal axis (1) - (6) of Figure 3 shows the following:

(1) Bi≅100, Ai≅50, Ci≅50, and standard deviation 3
(2) Bi≅100, Ai≅50, Ci≅50, and standard deviation 5
(3) Bi≅100, Ai≅10, Ci≅90, and standard deviation 3
(4) Bi≅100, Ai≅10, Ci≅90, and standard deviation 5
(5) Bi≅100, Ai≅30, Ci≅70, and standard deviation 3
(6) Bi≅100, Ai≅30, Ci≅70, and standard deviation 5

The parentheses in the figure correspond to (1) Random, (2) Johnson rule (Ai,Ci), and (3) Johnson rule (Ai+Bi,Bi+Ci). The left stick shows Model 1 and the right stick shows Model 2.

In Model 2, because a worker's work place is determined, the amount of work is fixed. On the other hand, each worker's allocation balance in process B may worsen in Model 1. Here, Model 2 has a better result than Model 1.

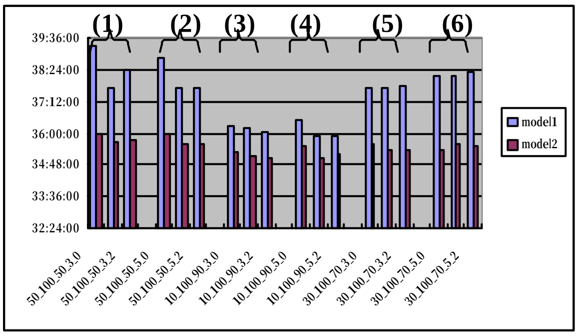

Figure 3. Comparison of the total duration time (MAX20-extra)

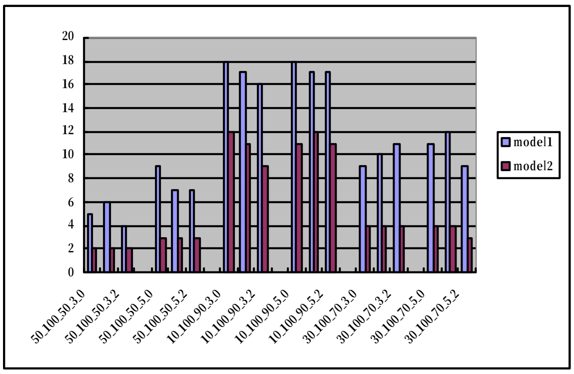

Figure 4. Comparison of the maximum work-in-progress (MAX20-noextra)

6. CONCLUDING REMARKS

Under the condition of Bi≅Ai+Ci (Ai+Bi+Ci = constant), Model 2 can produce a better schedule than Model 1. Johnson rules shorten the total duration time more than random in both Model 1 and Model 2. Maximum work-in-progress decreases by giving an extra job. However, the total duration time increases.

7. ACKNOWLEDGEMENTS

The authors express their appreciation to Japan Technomatics Co. Ltd. for their contribution to this paper.

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