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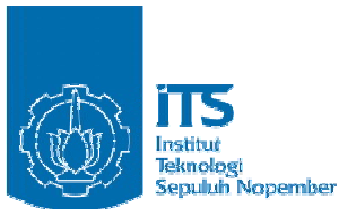
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The Effect of Product Structure Complexity and Setup Time-Run Time Ratio (R) on Makespan in Multilevel Product Scheduling

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Abstract. *The makespan in multilevel product scheduling is affected by product structure complexity and process routing complexity. This study was a part of long term study in multilevel product scheduling done by Production System Laboratory of UAJY. The objective of the study is to find a short-cut justification of lot size decision giving minimum makespan, based on some parameters of product structure complexity and process routing complexity. This paper presents a preliminary result of the study, i.e. the effect of product structure complexity and setup time-run time ratio (R) on makespan. The analysis was based on a set of hypothetical data. Product structure complexity was limited up to 5 levels and up to 5 parts in one level. Process routing complexity was limited up to 3 machines and up to 5 operations. Forward scheduling was used to compute the makespan. Different R was employed to find the minimum makespan. The R giving the minimum makespan was called optimum R. The result showed that the values of average optimum R varied from 0.198 to 0.455. This study is still underway for analyzing further the effect of product structure complexity and process routing complexity.*

Keywords: *short-cut justification, multilevel product scheduling, setup time-run time ratio, makespan*

1. INTRODUCTION

Recent researches about lot size and lot sizing were done related to recent issues such as lean manufacturing, agile manufacturing, and supply chain management. Munson et al (2003), Tang et al (2004), and Jiang et al (2006) are some examples of those. Most of them concerned to cost minimization, as well as the previous researches such as Anwar and Nagi (1997), Lovell (2000), Friend et al (2001), Ghomi and Torabi (2001), Chubanov et al (2006), Marinelli et al (2007), and Liu et al (2008), or mathematical models and approaches such as Ghomi and Torabi (2001), Friend et al (2001), Loparic et al (2003), Tang et al (2004), Guan et al (2006), Beraldi et al (2006), Vyve (2006) Chiu et al (2006), Hwang (2007). For practical purposes, time minimization and short cut justification for immediate decision making is important. This paper concerns to find a short-cut justification of lot sizing in the term of time minimization for scheduling of multi-level products, in make-to-order and job shop environment.

The material discussed here is a part of a study done by Production System Laboratory of Universitas Atma Jaya Yogyakarta (UAJY). A preliminary study showed that the makespan in multilevel product scheduling is affected by several parameters: product structure complexity (level, number of parts in one level, total number of parts) and process routing complexity (setup time and run time). Erawati (2006), Patria (2006), and Rinawati (2007) had conducted case studies in several manufacturing companies. Their studies had shown that there was a specific lot size resulting minimum makespan for a specific case.

Scheduling problems are NP-hard problems (Pinedo, 2002), especially in job shop environment. It is difficult to justify the scheduling result before creating the schedule itself. In the other hand, it is important to decide scheduling or planning parameters such as lot size as soon as possible to immediately respond to the orders. The main objective of the study is to find a short-cut justification of appropriate lot size decision based on some parameters of product structure complexity and process routing complexity. The

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expected result of the study is a general empirical formula to decide an optimum lot size, i.e. a lot size giving minimum makespan, to help a production planner deciding the production lot size immediately and simply. This paper presents a preliminary result of the study.

2. METHODOLOGY

2.1 Concept and Idea

A preliminary study showed that the makespan in multilevel product scheduling is affected by several parameters of product structure complexity (level, number of parts in one level, total number of parts) and process routing complexity (setup time and run time). It is hypothesized that other routing complexity parameters such as number of operations and number of machines will also affect the makespan. If:

L_s = optimum lot size,
 H = level of product structure,
 W = maximum number of parts in one level,
 N = total number of parts,
 T_s = average setup time of all the operations,
 T_r = average run time of all the operations,
 P = maximum number of operations in part routings,
 M = maximum number of machines used,

the main objective is to find a general empirical formula:

$$L_s = f(H, W, N, T_s, T_r, P, M) \quad (1)$$

From a study about the effect of setup time and run time to makespan, it could be identified that the lot size decision actually depends on the ratio of setup time and run time, not on the value of the time itself. Several experiments using different values of setup time and run time gave similar optimum lot sizes if the ratios of setup time to run time are similar. An un-dimensional number called setup time-run time ratio then generated as follows:

$$R = \frac{T_s}{L_s \cdot T_r} \quad (2)$$

The function presented in equation (1) then could be re-formulated as:

$$R = f(H, W, N, P, M) \quad (3)$$

2.2 Scope and Design of The Study

The main objective of the study is to find a short-cut

justification of appropriate lot size decision based on some parameters of product structure complexity and process routing complexity. To achieve that objective a limited study evaluating product structure complexity was designed up to 5 levels and up to 5 parts in one level. The scope of the study is shown in Table 1. The darkened area indicates the studied area completed so far.

Table 1: Scope of Study

		Maximum Number of Items in Each Level				
		1	2	3	4	5
Number of Levels	2	A	B	II		
	3	I	III	IV		
	4					
	5					

The study was divided to several sub-studies. Each of those was conducted by different co-researchers who created their own hypothetical cases. That is why several controlled variables still could not completely be controlled. So far, there are four completed sub-studies:

1. Area I, with the number of item in each level is 1, number of level is up to 5, item to produce is 24 units.
2. Area II, with the number of item in each level is up to 5, number of level is 2, item to produce is 30 units.
3. Area III, with the number of item in each level is up to 2, number of level is up to 5, item to produce is 20 units.
4. Area IV with the number of item in each level is up to 3, number of level is 3, item to produce is 32 units.

While Area A and B is the intersection between Area I and II and Area II and III respectively.

Analysis steps for each cell (intersection between Number of Level and Number of Item in Each Level) is shown in Figure 1.

Different number of BOM for each cell was generated because each cell has its own characteristic. Total of 35 BOM had been generated (4 for Area I, 5 for Area II, 20 for Area III, and 6 for Area IV). The example of generated BOM can be seen in Figure 2.

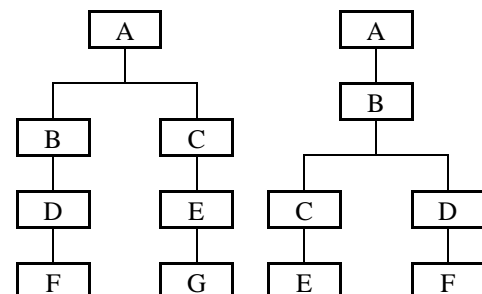


Figure 2: Examples of Generated BOM for 4 Levels and 2 Items in Each Level

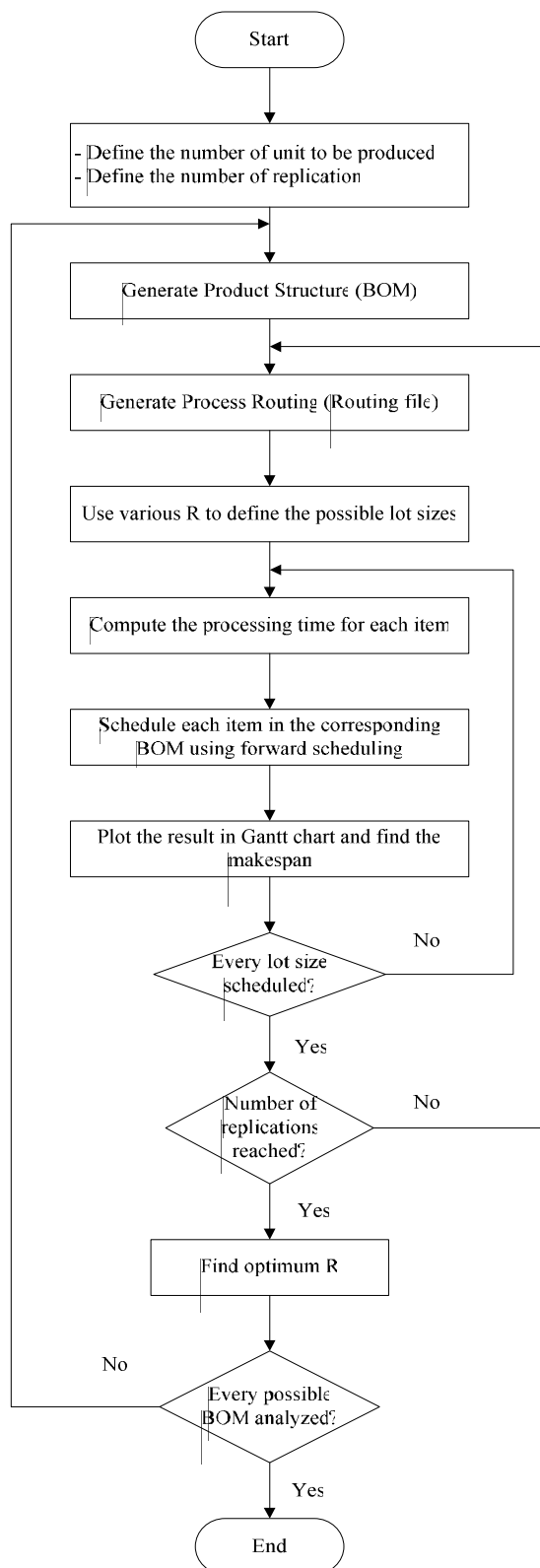


Figure 1: Analysis Steps for Each Cell

Process routing complexity was limited up to 3 machines and up to 5 operations. A minimum of three replications of routing file were generated for each BOM with the setup time varied between 6 to 10 minutes for each lot and run time varied between 1 to 5 minutes for each unit. The example of generated routing file can be seen in Table 2.

Table 2: Example of Generated Routing File

Item	Machine	Setup time (minutes/lot)	Run time (minutes/unit)
A	Y	7	5
	Z	6	2
	X	9	3
	Y	6	5
	Z	6	1
B	X	6	3
	Y	10	1
	Z	8	1
	X	8	2
	Y	8	3
C	Z	6	5
	Y	10	1
	X	7	2
	Z	9	2
D	X	6	4
	Z	8	3
	Y	7	2
E	X	8	2
	Z	7	3
	X	6	4
	Y	9	1

Using the generated routing files, we use different R to define the various lot sizes possible for each cell. For example, refer to Table 2, the unit to be produced is 30, the average of setup time is 7.476 minutes, and the average of run time is 2.619 minutes. The possible lot size to be used for specific R can be seen in Table 3:

Table 3: Possible Lot Size for Various R

R	Lot Size	Possible Lot Size
0.1	28.54525	30
0.2	14.27262	15
0.3	9.515082	10
0.4	7.136312	
0.5	5.709049	
0.6	4.757541	5
0.7	4.077892	
0.8	3.568156	
0.9	3.171694	3

From Table 3, for the 30 units to be produced, we scheduled using 5 lot sizes, 3, 5, 10, 15, and 30.

The number of BOM variations, the number of lot size variations, and the number of replications for each cell is presented in Table 4.

Table 4: Number of BOM variations/Number of Lot Size variations/ Number of Replications

		Number of Items in Each Level				
		1	2	3	4	5
Number of Levels	2	1/5/7 and 1/5/5	1/5/5 and 1/4/3	1/5/5	1/5/5	1/5/5
	3	1/5/7	3/4/3	6/4/5		
	4	1/5/7	6/4/3			
	5	1/5/7	10/4/3			

One of possible objective function to be minimized is makespan. Assume that all the ready time are at time zero, makespan is equivalent to the completion time of the last job to leave the system. A minimum makespan usually implies a good utilization of the machine(s) (Pinedo, 2002). The R that yields the minimum makespan is called optimum R. To find the minimum makespan in each BOM and each replication, we use these steps:

1. Compute the processing time for each item:
2. Processing time = setup time (minutes/lot) + run time (minutes/unit) x lot size (unit).
3. Use forward scheduling to schedule each item in the corresponding BOM, starting from the lowest level. Forward scheduling assumes that procurement of material and operations start as soon as the requirements are known. The events or operations are scheduled from this requirements point of view (Narasimhan et al., 1995).
4. Plot the result in Gantt Chart, the example is shown in Figure 2.
5. Find the makespan and identify which lot size that

yields minimum makespan.

6. Find the optimum R using equation 2.

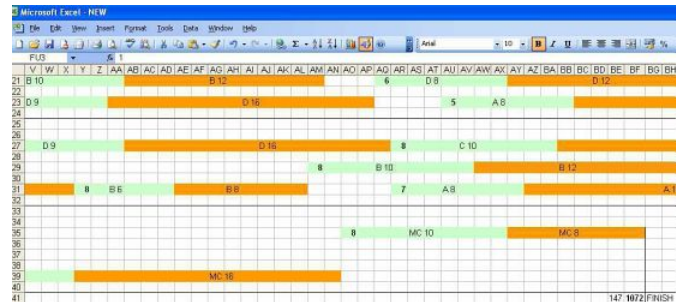


Figure 2: Part of Gantt Chart

3. RESULT

The lot size that yields minimum makespan identified from the analysis for each BOM then is used to find the optimum R. The optimum R obtained for each BOM is the average value of all the replications. The optimum R for each BOM is shown in Table 5.

Table 5: Optimum R for Each BOM

		Number of Item in Each Level				
		1	2	3	4	5
Number Of Level	2	0.296	0.251	0.261	0.259	0.237
		0.274	0.145			
	3	0.371	0.224	0.228		
			0.216	0.255		
			0.155	0.175		
				0.276		
				0.230		
				0.160		
	4	0.455	0.200			
			0.187			
			0.230			
			0.185			
			0.090			
	5	0.414	0.152			
			0.213			
			0.188			
			0.209			
			0.128			
			0.159			
			0.203			
			0.118			
			0.142			
			0.209			

Average optimum R for each cell is shown in Table 6.

Table 6: Average Optimum R

		Number of Item in Each Level				
		1	2	3	4	5
Number Of Level	2	0.285	0.198	0.261	0.259	0.237
	3	0.371	0.198	0.220		
	4	0.455	0.173			
	5	0.414	0.172			

ANOVA could not be used because the area hasn't been completed yet. From table 6 we can see that average optimum R is varied from 0.198 to 0.455. The study hasn't encountered optimum R either below 0.05 or over 0.5.

4. CONCLUSION

4.1 Conclusion

The objective of the study is to find a short-cut justification of appropriate lot size decision based on some parameters of product structure complexity and process routing complexity. Scenarios were developed and a set of hypothetical data for each scenario were generated. From the scenarios, it was found that each BOM has its own optimum R. There were any weaknesses in our scenarios, but from this preliminary study we never experienced average optimum R below 0.198 or above 0.455.

4.2 Further Study

The scope of the study has not been completed yet, there are still many blank areas. This study is still underway to complete the area to gain a better perspective of optimum R. The next study will be focused on process routing complexity.

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