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Application of Project Management Model with Theory of Constraints to Minimize Project Completion Time and Direct Labor Costs

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Abstract

Small and medium-scale manufacturing industries generally face difficulties in minimizing their operational costs. The company's Make-to-Order strategy causes fluctuations in the number of jobs received, so it minimizes fixed costs such as labor wages. This phenomenon occurs in rectifier panel manufacturing companies and various other companies. Companies minimize the number of permanent employees and recruit daily contract employees. Unfortunately, daily contract employees are recruited when orders are received (t=0) so that employees are still paid even though work is not yet available. This study attempts to determine the timing of recruiting daily contract employees that is adjusted to the scheduled work. The method used is a combination of project management with the theory of constraints. The study focuses on three things, namely: (1) Determining the number of workers based on the workload in each position. (2) Conducting project scheduling using the PDM (Precedence Diagram Method) project scheduling method. (3) Applying the Theory of Constraint (TOC) method at problematic workstations so that product flow is balanced. The results of the study show efficient performance, namely: the number of workers decreased from 24 people to 17 people, and the duration of the project decreased from 171 working days to 94 working days

1. INTRODUCTION

As a concept in corporate management, the theory of constraints is often combined with various other concepts such as project management, resource-based internal company capabilities, and others. Several studies that have combined the concept of the theory of constraints with various other theories include Cullen and Parker (2015), Parker et al. (2015), Izmailov et al. (2016), Liu et al. (2020), and Zohrehvandi et al. (2020). Parker (2015) developed the concept of the theory of constraints with project management in various industrial sectors. Cullen and Parker (2015) examined the benefits of integrating the theory of constraints with the concept of resource-based internal company capabilities, and Zohrevandi et al. (2020) examined the theory of constraints model with efficient project resources. Their research was conducted on a wind power plant project to achieve a more realistic project duration.

This paper explains the results of empirical research in medium-scale manufacturing companies that respond to consumer demand with a make-to-order strategy. Products made by the company include panel rectifiers, kWh meters, electrical panels (AC / DC Board, MDP / SDP), batteries, battery racks, traffic inverters, and converters. The variety of products made and made-to-order strategies in response to consumer demand confront the company in the matter of production planning and resource allocation. Late delivery of

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ordered goods will result in a fine fee, but at the same time, the number of machines and employees is minimal.

To minimize operational costs, the company also limits the number of permanent employees and, for a certain period, prefers contract employees in accordance with the number of orders received. Contract workers are employees who are employed with an employment agreement for a certain period of time. In fact, difficulties in making production planning lead to high contract employee costs. This time, contract employees are recruited when new orders are received (t = 0), while the employee's work will only appear next time. This phenomenon causes the high cost of contract employees.

Because the products are very diverse and the capacity of production machines is limited, this study proposes separate production planning for each product. The proposed production planning uses a project scheduling approach. Every product order received is treated as a project. Project scheduling is made as a reference in recruiting contract employees, so contract employees are not recruited at t = 0, but at the time the work will begin. Thus, employee recruitment is adjusted to the burden and type of work received. Recruitment in stages can minimize the total cost of labor costs.

In addition to production planning and contract labor planning, another difficulty faced by companies is the management of inventory in production activities. Work stations with the smallest production capacity will cause problems in the production process, including producing small output, resulting in bottlenecks in the production line. To minimize the buildup of work in process, production schedules made using the project approach are synchronized with machine schedules on the shop floor with TOC approach.

TOC is a management philosophy for continuous improvement processes (Goldratt, 1988). Various world-class companies have successfully applied TOC, such as 3M, Amazon, and Boeing (Watson et al., 2007). Activities in business organizations are a series of orderly processes (Bevilacqua et al., 2009), and TOC directs managers to focus on constraints that hinder the process, to then be improved so that the output can be better. TOC applied to project management is the top five theories from various journals published and reviewed by academics. Various other theories that are often applied with TOC are Actor Network Theory, Fuzzy Set Theory, Utility Theory, and Stakeholder Theory (Johnson et al., 2016). Goldratt (1997) explained the application of TOC in project management, and agreed on the critical path as the path that determines the duration of the project.

This research has objective to create production planning in the company with the project scheduling model. Every order is treated as a project. Project scheduling which is produce in this research will be use to determine the time hiring of contract employees. Thus, hiring of contract employees is carried out in stages, so that contract labor costs can be minimized. The second goal is to minimize the amount of work in process caused by work stations with the lowest output, called work station constraints. Minimization of the amount of work in process is done by synchronizing project schedules with machine scheduling based on the theory of constraints.

The research was conducted when the company received a panel rectifier order, so the proposed model was tried to be applied to the project panel rectifier scheduling. A rectifier is a tool to convert alternating electric current / AC (Alternating Current) into direct current.

2. PROBLEM FORMULATION AND RESEARCH FRAMEWORK

2.1 Problem Formulation

The manufacturing company where the research was conducted faced three challenges in its production system: production planning, determining the number of contract employees, and minimizing the amount of work-in-process on the production floor. This study sought solutions to these three challenges by integrating workload calculations, project scheduling models, and the TOC approach.

2.2 Research Framework

This study developed two algorithms to solve problems in the manufacturing company studied. The search for solutions was carried out to address three problems faced, namely an algorithm for determining the workload and an algorithm for determining the project schedule using the TOC approach. The workload determination algorithm begins with analyzing the type of work, production capacity and the number of workers required. The project schedule determination algorithm is carried out by creating a diagram of the relationship between activities, determining the critical path, determining the constraint workstation and creating a work release schedule using the drum-buffer-rope method. The complete algoritm is presented in the following steps.

1. Algorithm for determining the workload on the factory floor
   a. Calculate the number of parts/components to be processed, determine the process activities and the required processing time.
   b. Determine the operator qualifications required for each process.
   c. Determine the various work elements in each process.
   d. Calculate the time to complete the work for each work element to be performed.
   e. Calculate the workload for each work element by determining the operating frequency of the work element in each process.
   f. Calculate the number of workers required based on the workload calculated in step e.

2. Algorithm for creating a project schedule using the drum-buffer-rope method
   a. Create a project schedule using the PDM method, which consists of the following stages:
      a.1 Develop a Work Breakdown Structure.
      a.2 Create a diagram of the relationships between the project's activities.
      a.3 Create a project schedule and determine the critical path of the project.
      a.4 Allocate labor to each work process.
   b. Determine the constraint workstation (Drum), which is the workstation on the critical path with the smallest capacity.
   b. Calculate the buffer time to prevent the constraint workstation from being idle.
   c. Determine the work release time (rope) backward from the constraint workstation to minimize work in process.
   d. Determine the work completion time forward by adding the work completion time at the constraint workstation with the processing time at the workstation after the constraint workstation.
   e. Calculate the work completion time for the entire project.

3. APPLICATION OF ALGORITHM

The two algorithms developed in this study were applied to a manufacturing company that produces panel rectifiers. Panel rectifiers are instruments that can store power and will distribute the remaining power when the input from the power source is cut off. Panel rectifier products have two component parts, namely the panel part and the electronic circuit part that has been assembled inside. Panel rectifiers are described in Figure 1. As a case study, the company where the research was conducted is currently receiving a request from a consumer for 54 units with a contract period of 150 working days.In designing the Panel Rectifier production management system, three tasks are performed. Calculating the number of workers using a workload analysis approach, balancing product flow using the Theory of Constraints (TOC), and scheduling the project using the Precedence Diagram Method (PDM). The purpose of calculating the number of workers is to estimate labor requirements to avoid excess or shortages during the project.

Figure 1.
Panel rectifier

3.1. Algorithm for workload calculation

The data obtained from the calculations of algorithm 1 and algorithm 2 are presented in Table 1 and Table 2.

3.2. Research Procedure

The determination of workstation constraints and buffer time calculations are described in Figure 2. Validation of the research results was carried out by comparing the performance of project scheduling carried out by the company with the scheduling performance obtained from the developed algorithm. The comparison of the two performances is explained in Table 3. The approach used in placing the buffer time is the Drum-Buffer-Rope. What is meant by drum is a workstation limiter, because the work element determines the next product rate. Whereas rope is the information conveyed in the preparation of electronic components as a control of production flow. The location of the workstation where the bottleneck occurs is in the middle of the process. Therefore, the buffer will be placed before the limiting workstation. The positioning of the buffer aims to balance the product flow so that the limiting workstation utility is not more than 100%.

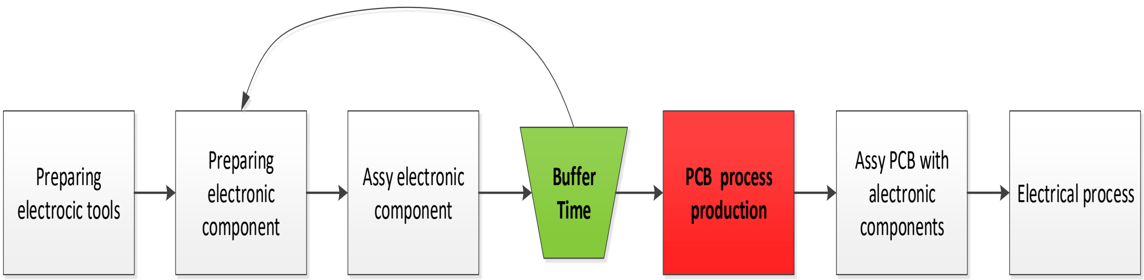

Figure 2.
Drum-Buffer-Rope Model

Table 1.
Data from the processing results of the algorithm steps 1

No	Employee qualification	Job Element	Time to process (minutes)
1	Employee for Cutting Tool process	Setting up the cutting machine	5
		Setting up material	1
		Cutting process	2
		Material Release	1
2	Employee for Pounce Machine	Setting up	2
		Setting up material	1
		Proses pounce	2
		Material Release	1
		cleaning	2
3	Employee for Sanding Machine	Setting up	3
		Processing	10
		cleaning	2
4	Employee for Bending Machine	Setting up	3,5
		Material Setting up	1
		Bending processing	5
		Material release	2
5	Employee for Drilling Machine	Setting up	5
		Material Setting up	4
		Boring processing	8
		Material Release	3
		cleaning	5
6	Employee for Welding Machine	Setting up	5
		Material setting up	10
		Welding Processing	90
		finishing	5
7	Employee for Electronic Assy	Setting up tools	10
		Setting up the component	15
		Assembly processing	130
		PCB processing	240
		Assy of PCB to component	30
8	Employee for Electrical assy	Setting up	5
		Material setting up	10
		processing	60
		Assy 1	15
		Assy 2	15
		Assy 3	5
9	Employee for QC	Visual inspection	10
		Functional inspection	30
10	Employee for Installation	Site Survey	30
		Setting up	120
		processing	360
		Functional inspection	180

Table 2.
Results of data processing in step 1 (e-f)

Workstation	Manpower
Cutting process	1
Pounce process	1
Sanding process	2
Bending process	1
Drilling process	2
Welding process	4
Electronic assy process	6
Electrical assy process	2
QC process	2
Installation process	2
Total	**23**

Table 3.
Comparison of performance criteria

No	Criteria	Existing	proposed	saving
1	Duration time of project	171 days	94 days	77 days
2	Number of workers	24 people	17 people	7 people
3	Direct labour cost	Rp399.500.000	Rp202.500.000	Rp137.000.000

4. ANALYSIS AND DISCUSSION

The project scheduled shows that allocating resources is more efficient. Cut and punch operators who have completed their work can be immediately allocated to become electrical operators. Work on electrical workstations does not require special skills, so operators can be allocated from the cut operators. Likewise, QC workstations will be managed by electronic operators because QC workers must have expertise in electronics. The installation work will be carried out by an electronic operator. This is because electronic activities and installations require the same work skills.

This study used three performance criteria: project completion time, required labor volume, and direct labor costs. The developed algorithm performed better than the company's existing method. This phenomenon occurred because the production planning process was carried out simultaneously with the planning of direct labor requirements for contract employees and the estimation of workstations that would become constraints. This mechanism was able to reduce the project's duration from 171 days to 94 days. Similarly, the number of direct labor hired was reduced from 24 to 17. This decrease in the number of employees could occur because contract employees were recruited when work that matched their qualifications was about to begin, and were not allocated to them at the start of the work contract. The project schedule can be used as a reference to regulate the recruitment time of contract workers, so that the recruitment is carried out in accordance with the needs of the production process.

5. CONCLUSION

Integration theory of constraints with project management has proven to be a solution for problems in determine the production schedule, calculate the number of contract workers needed and estimate the recruitment time as well as minimize the number of idle parts at each work station. An algorithm can minimize the project completion time, minimize the number of contract workers, and minimize the number of work in process simultaneously.

In this research, data and information are deterministic in nature. The two developed algorithms were proven to reduce the project's processing time, from 171 days to 94 working days. The reduction in working days occurred due to high workstation utilization as a consequence of the time buffer at the constraint workstation. The use of the drum-buffer-rope method also made work at each workstation more effective and efficient due to the backward release time determination from the constraint workstation and the forward completion time determination from the constraint workstation. The reduction in the number of contract workers from the original 24 to 17 people occurred because each contract employee was only recruited when the type of work was about to begin processing. Therefore, each employee was contracted for a different length of time, according to the predetermined project schedule. This automatically reduced direct labor costs, which were calculated from contract workers. Further research needs to consider order data, which is dynamic and probabilistic, so that it is more like a real manufacturing system

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