Optimization in Critical Work Center Using Theory of Constraints

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Abstract. Many companies experience problems or problems in the production process. One of the problems disturbing the production process is the bottleneck. The pellet industry has problems in pellets production. The capacity imbalance available between the drying station and the milling station causes the pellets making process to accumulate resulting in a bottleneck. Therefore, an analysis can be done to overcome these problems by overtime. Overtime is carried out for 1 hour on each shift and 2 hours on certain shifts in July 2019 period and September 2019 and the number of working hours becomes 18 working hours and 19 working hours from the previous one which is only 16 working hours at the milling work station because it is seen from a negative variance value and the percentage of load is below 100%. This shows that overtime can be effective to eliminate constraints.

1. Introduction

The development of the industrial world at this time requires companies to produce perfectly. This is because in the increasing of industrial world competition, productivity is one of the factors determines a company to be successful [1]. However, in reality many companies experience problems in the production process such as in the pellet industry.

Pellet industry produces products through five work stations including drying, milling, mixing, pelleting and packing work stations. The five work stations have different production capacities. Drying work stations have a greater production capacity compared to milling work stations which is cause bottleneck. The bottleneck occurs will result in delays in the production process and have an impact on the company's performance. Therefore, this problem must be resolved and work stations can be optimized and bottleneck does not happen.

Bottleneck is defined as a problem that occurs at work stations that limits the efficiency of the entire process [2]. This can lead to situations where the work station before the bottleneck can complete processing so that it cannot continue the material, because the works that follow it are still involved in the previous processing [3]. This problem must be solved in order to increase work productivity and production profits. Bottlenecks occur if the capacity available in an industry is insufficient to meet product demand from consumers [4]. Bottleneck problems overcome by various methods, one method is theory of constraint.

Theory of Constraints (TOC) was first known as the Theory of production introduced by Goldratt and Cox [5,6]. TOC is basically eliminating the restrictions of the system (or bottlenecks) that prevents production flow from completing the process according to demand [7] TOC is a method that
is concerned with limiting capacity in manufacturing processes by its capacity-constraints resources. TOC can be used in both manufacturing and service companies and in several managerial areas, such as: project management, quality management, information systems. This method is especially widespread in production planning [8]. There is several strengths of TOC method that is in contrast to other improvement approaches that tends to optimize performance in each area of the system (such as TQM, Six Sigma and Lean) a that is on the basis of systemic thinking, focusing efforts on increasing the important components of the system [9].

Many research has been done in overcoming bottleneck problems. Imam and Andrie (2013) conducted a study by analyzing capacity constrained resources using the theory of constraint approach to optimize production flow. The use of Theory of Constraint in this research is used to remove constraints by maximizing the area of the work station constraints, optimizing resources, increasing production performance and making the optimal number of product combinations [10]. Another study was also conducted by Ercument et al. (2015) in optimizing production in the furniture industry [11]. The purpose of this study is to provide a solution to the contrains that occur in the work station to be able to complete their targets so that by increasing the profitability of the company. The theory of constraints has been carried out on furniture companies operating in the Mediterranean Region. The result is that, there are capacity constraints that occur in the production process in the company and profitability will increase by 42% after the elimination of these constraints. However, this research is closely related to the optimization of resources in increasing company productivity. This study aims to optimize resources in overcoming bottlenecks that disturbs industrial productivity.

2. Methodology

The research was conducted in one of the pellet manufacturing industries located in Medan City. The research was conducted by observing the real conditions in the industry. From the results of direct observation, the formulation of the problem is determined according to the conditions and the research objectives can be applied. The research objectives determined are as a solution to the problems that happen. Furthermore, data collection is needed as input in solving bottleneck problems. Data is obtained through observations on the pellet production process and the results of interviews with workers and employees in the pellet industry. Based on these data, an analysis of the problems that occur is done by optimizing resources to eliminate bottlenecks. The analysis is carried out with several stages, namely forecasting product demand and calculating product capacity with rough cut capacity planning. Forecasting is done with the aim to estimate the amount in the next period. Calculation of forecasting is done by the time series method and consider the estimation of errors. While the calculation of capacity with rough cut capacity planning is done to see which work stations have bottlenecks. After it was discovered that the work station had a bottleneck, then a problem was solved by using theory of constraint. Overall, the philosophy of TOC management is directed at helping organizations sustainably achieve their goals.

The underlying three measures are: throughput, operating expense, and inventory [12]. TOC is carried out in several stages starting with identifying company constraints. In this case the constraints in question are in the form of identifying a bottleneck work station. Next is the exploitation of binding constraints. At this stage alternatives that can solve problems so that they can optimize work stations that experience bottlenecks. The final step is the subordination of solutions to overcome existing constraints [1]. With these stages, a solution will be obtained to overcome the bottleneck problem that is currently an obstacle in the industry.

3. Result and Discussion

3.1. Forecasting of Product Demand

Forecasting the number demand of pellet products for the next one year is based on demand data from January 2018 to December 2018 with the time series method. Forecasting results are selected
based on the smallest error estimates. The results for the number of pellet demands can be seen in Figure 1.

![Demand Forecasting of Pellet](image)

**Figure 1. Result of Pellet Products Forecasting**

Based on the figure 1, it can be seen that product demand are fluctuating for each order period. For this reason, it is necessary to calculate the capacity needed to fulfill the demand and the bottleneck can be avoided.

3.2. **Determination of Rough-Cut Capacity Planning**

Rough Cut Capacity Planning is used to calculate the capacity requirements roughly and compare them with available capacity [13]. Calculations for the capacity needed are carried out in determining the capacity needed by each work station that is able to complete the product according to the forecasting results Calculation of rough-cut capacity planning is carried out based on the required capacity (CR) and available capacity (CA) on milling work station. Results the calculation of work station experiences bottleneck can be seen in Table 1.

| Work Station | Category       |
|--------------|----------------|
| Drying       | Non Bottleneck |
| Milling      | Bottleneck     |
| Mixing       | Non Bottleneck |
| Pelleting    | Non Bottleneck |
| Packing      | Non Bottleneck |

Based on the table 1 above, it can be seen that at the milling station there is a bottleneck and the capacity improvement is needed.
3.3. Recommendation Using Theory of Constraint
Recommendation is done using theory of constraint. Improvement starts by problem identification and done by bottleneck work station identification. Based on the result of identification obtained that bottleneck happen at milling station as in Table 2.

Table 2. Recapitulation of RCCP Calculation on Bottleneck Determination

| Work Station | CR (second) | CA (second) | Variance | Workload Percentage (%) | Category |
|--------------|-------------|-------------|----------|--------------------------|----------|
| Mixing       | 2728872     | 3720039     | -991167  | 0.73                     | Bottleneck |
|              | 2728872     | 3720039     | -991167  | 0.73                     | Bottleneck |
|              | 2728872     | 3863117     | -1134245 | 0.71                     | Bottleneck |
|              | 2730231     | 3720039     | -989808  | 0.73                     | Bottleneck |
|              | 2730231     | 3863117     | -1132886 | 0.71                     | Bottleneck |
|              | 2731590     | 3720039     | -988449  | 0.73                     | Bottleneck |
|              | 2732949     | 3576960     | -844011  | 0.76                     | Bottleneck |
|              | 2732949     | 3720039     | -987090  | 0.73                     | Bottleneck |
|              | 2732949     | 3576960     | -844011  | 0.76                     | Bottleneck |
|              | 2731590     | 3720039     | -988449  | 0.73                     | Bottleneck |
|              | 2732949     | 3576960     | -844011  | 0.76                     | Bottleneck |
|              | 2731590     | 3720039     | -988449  | 0.73                     | Bottleneck |
|              | 2731590     | 3720039     | -988449  | 0.73                     | Bottleneck |
|              | 2731590     | 3863117     | -1132886 | 0.71                     | Bottleneck |

Based on the table above, it can be seen that the milling station has a bottleneck due to insufficient capacity available to produce in accordance with the required capacity and alternatives are needed to overcome these problems. Alternative solution to optimize the bottleneck work station is overtime. *Overtime* is done for 1 hour on each shift and 2 hours on certain shift in July 2019 period and September 2019 the number of working hours are 18 hours and 19 hours of working hours from the previous working hours only about 16 hours. Result by using overtime shows that there is no bottleneck on bottleneck work station because it seen from negative variance value and load percentage below to 100%. This condition shows that using overtime can be an alternative to eliminate constraint.

4. Conclusion
Manufacturing industry of pellet experienced a bottleneck at the mixing station due to the capacity imbalance available at the industry. Problem solving is done by using theory of constraints principle with solution alternative of *overtime* for 1 hour (9 hours/shift) and 2 hours on certain shift. This solution results non-bottleneck work station in all of period and shows that overtime can be an alternative to eliminate constraint.

Acknowledgement
The author would like to thank the Universitas Sumatera Utara for supporting finance in publishing this article and the pellet company that is willing to be the object of this research. We appreciate the efforts of all participants in conducting this research.

References
[1] Anita M and Dodo A 2017 *Seminar dan Konferensi Nasional IDEC* (Surakarta, 8-9 Mei)
[2] Betterton C E and Silver S J 2012 *International Journal of Production Research* **50** (15), pp 4158-4174
[3] Mateusz K 2016 *Economic and Management* **8**, pp 103-122
[4] Himanshu K and Ashish S 2014 *International Journal of Mechanical Engineering and Robotics*
Research

[5] Goldratt E M and Cox J 2014 *The Goal: A Process of Ongoing Improvement* (New York: North River Press)

[6] Radoslaw W, Bozena S Z, and Michal Z 2017 3rd *International Conference on Social, Education and Management Engineering*

[7] Gupta M and Snyder D 2009 *International Journal of Production Research* 47 (13), pp. 3705–3739

[8] Alsmadi M, Almani A, and Khan Z 2014 *International Journal of Quality & Reliability Management* 8, pp. 906-920

[9] Victor G A E, Pedro G V, and Maria M G Z 2016 *European Research on Management and Business Economics* 22, pp. 139–146

[10] Imam S and Andrie W A 2013 *Analisis Capacity Constrained Resources Guna Mengoptimalkan Aliran Produksi Dengan Pendekatan Theory Of Constraints* (Yogyakarta: IST AKPRIND)

[11] Ercument O, Ata K, and Jekaterina K 2015 *Intellectual Economics* 9, pp. 138-149

[12] Trojanowska J and Pajak E 2010 7th *International DAAAM Baltic Conference* (Estonia: Tallinn, 22-24 April)

[13] Sukaria S 2009 *Perencanaan dan Pengendalian Produksi* (Yogyakarta: Graha Ilmu)