Application of Theory of Constraints in Bottleneck Work Stations Optimization

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Abstract. Manufacturing industries engaged in making of instant noodles in Medan city have problems in production planning. The process studied is the manufacture of GCGEP, GCST and G-1000GSP products. The constraints faced by the company are the presence of bottlenecks on mixing and cooking work stations due to differences in capacity between the work station and the previous work station, namely the sieving work station and dough forming work station. Bottleneck work stations happens in mixing work stations in January, February, March, May, June, July and August 2014 as well as cooking work stations in January, May and July 2014. This study uses the principle of continuous improvement of Theory of Constraints (TOC) to eliminate constraints on bottleneck work stations and to facilitate the overall production flow. In applying TOC, to optimize the production master schedule and to know the maximum advantage cost, linear programming method is used. After the optimal master schedule results are known, revisions to rough cut capacity planning are carried out and the result shows that the bottleneck work station found has become a non-bottleneck work station.

1. Introduction
In an industry both manufacturing and service industry, the process of preparing a good scheduling is an important thing. This is because a good scheduling will increase the effectiveness and efficiency of the industrial production system which is ultimately reduce production costs. Scheduling is a decision-making process whose role is very important in the manufacturing and service industries, namely allocating existing resources and the goals and objectives more optimal than before for the company. The purpose of scheduling activities include increasing the resources or reducing waiting time and the total processing time can be reduced and productivity increases or reduces the number of delay activities in the queue when the existing resources are still working on the other tasks [1] [2].

The development of the manufacturing industry today leads to manufacturing systems produces variation of products type with the quantity of products per type being smaller. Product specifications tends to adjust the customer demand. The product life cycle tends to be shorter, and this condition causes companies to work with shorter lead time to stay competitive and maintain their survival. The manufacturing industry often experiences bottleneck constraints during the production process. This is causes the production process between work stations do not work properly [3].

In the manufacturing industry several common ways to handle bottleneck work stations are the additional of machines, equipment, or employees, improvement of work methods and the additional of overtime. However, these methods requires the large capital and long time sometimes it is not possible. For this reason, a problem solving approach is needed, namely by optimizing the resources in the factory and managing the constraints exist in the factory properly. The company is engaged in the manufacture of instant noodles consisting of six work stations, namely sieving work stations, mixing
work stations, dough forming work stations, cooking work stations, packaging work stations, and packing work stations. Based on observations, it can be seen that not all production flows run clearly. One of the problems happened was the presence of bottlenecks on the production floor, especially at the sieving and mixing work stations due to differences in capacity between the two work stations. The production capacity of the sieving work station is greater than the production capacity at the mixing work station. This causes a difference in capacity the capacity. Thus, bottlenecks happen at mixing work stations which is delays in the production process and decrease in the number of products produced by the company.

One method that can be used to analyze production planning problem is using Theory of Constraints (TOC). TOC is a method which has a well developed research apparatus referred to as the Thinking Process [4]. The TOC was developed during the 1980s by a physicist who had an outstanding knowledge of systems. However, the origins of the TOC relate to the development of a software production schedule during the 1970s, known as Optimised Production Technology also designed by Goldratt [5]. Theory of constraints is defined by Dr. Eliyahu M. Goldratt which claims that each system has at least one constraint. TOC has now developed into a theory of management [6]. The assumptions of the TOC, as introduced by an Israeli physicist Dr. Moshe Eliyahu Goldratt, were first published in the 1984 book The Goal: Excellence In Manufacturing which offered comprehensive solutions for production management. Theory of Constraints focuses on system improvement which is defined as a series of independent processes [7].

Many previous studies have been carried out in handling bottleneck problems and production scheduling using the Theory of Constraints method. Rotstein (2002) present a retrospective study of whether or not the bottleneck in a particular emergency department had been the physicians, to evaluate under what conditions adding medical staff would be a valuable strategy. This is a contribution, though probably not very generalisable to the first step of the process of ongoing improvement: identifying the bottleneck. The marginal benefit of shortening non-trauma patients' length of stay during a period when a physician in the evening shift had been added was examined for different patient volumes. The study showed that the physician could only be regarded as the bottleneck within the 80-119 patient volume range [8]. Another studies have been carried out by Gupta and Kline (2018) applied the TOC method to eliminate bottlenecks on Chemical Industry. The application of TOC’s process of ongoing improvement to a Chemical Dependency unit within a community mental health center. In identifying the constraint, wait times are taken as a clue to spot psychiatrists as the primary constraint of the system, and the therapists as the secondary. In the later steps of subordinating the system to the constraints, it is revealed that the clinical support function also demonstrates inadequate capacity. As a result, the no-show rate for Psychiatric Evaluation appointment fell from 43% to 20%. Other recommendations regarding increasing pay of clinical staff support await agency action at the executive level. It was advised that the patients with a certain number of missed appointments per year should have their cases closed [9]. The application of TOC is an effective method to eliminate waste and it does not interrupt the production.

2. Methodology
The research was conducted on one of the instant noodle industries in Medan city where the object studied was the production process and cycle time happened at each work station in the process of making noodles. The research begins with making observations directly to the factory to collect information related to the production process. The activity carried out at this stage is to identify the description of the production of all work stations. After observation, then data collection on the number of demand for 3 types of products over the past 1 year. After that, do forecasting the product demand for the next 1 year. Data collected based on consumer demand. After forecasting, then the master production schedule is arranged. After the preparation of the master production schedule, Rough Cut Capacity Planning (RCCP) was calculated to determine the capacity needed by each work station capable to produce products according to the forecasting results. Identification of bottleneck and non bottleneck work stations is done after RCCP calculation. The master schedule of production is carried out again based on the principle of Theory of Constraint.TOC is defined as a management philosophy that provides a focus for continous improvement that results in enhanced organizational
performance. TOC by analysing Operations Management and obtained the following four findings. First, the TOC offers a new paradigm in Operations Management that replaces an outdated consensus to seek to achieve efficiency in the company, and thus the pursuit of the goal from a global perspective is more consistent with this new paradigm in Operations Management. Second, the TOC offers approaches to decision making in operations that can optimise company activities. Third, the TOC provides a criteria framework for Operations Management, but more empirical tests are needed to validate its operational practicality. Finally, the TOC can provide a unified theme or theory in Operations Management, thus offering new insights for researchers and practitioners.

3. Result and Discussion

3.1. Forecasting of Product Demand

Forecasting the number of product demand is carried out on 3 types of products, namely GCEGP, GCST and G-1000GSP products. Forecasting the number of demands carried out from January to December 2013. Forecasting is carried out for the next 1 year. The results of forecasting GCGEP, GCST and G-1000GSP products can be seen in Figure 1.

![Figure 1. Forecasting of GCEGP, GCST and G-1000GSP of January-December 2013](image)

From the table above it can be seen that the demand for GCEGP, GCST and G-1000GSP products decrease continuously every month. This is caused by the interruption of the stations between production which is resulted in the capacity of available products being small.

3.2. Calculation of Rough Cut Capacity Planning (RCCP)

Calculation of the required capacity is done to determine the capacity needed for each work capable to produce products according to the results of forecasting. Next stage, the results of rough cut capacity planning are used to determine the bottleneck and non-bottleneck work stations. Calculation of rough cut capacity planning is carried out based on the required capacity (CR) and available capacity (CA) on 2 production stations namely mixing and cooking work station. Results the calculation of work stations experiences bottleneck can be seen in Table 1.

| Work Station | Month     | CR (second) | CA (second) | Workload Percentage (%) | Category   |
|--------------|-----------|-------------|-------------|-------------------------|------------|
| Mixing       | January 2014 | 2100208     | 1793456     | 117,2                   | Bottleneck |
|              | February 2014 | 2029932     | 1992729     | 101,86                  | Bottleneck |
|              | March 2014   | 2021898     | 1992729     | 101,46                  | Bottleneck |
|              | May 2014     | 2133331     | 1793456     | 118,96                  | Bottleneck |
|              | June 2014    | 2197192     | 2092365     | 105,02                  | Bottleneck |
From the table above it can be seen that there are bottlenecks at mixing and cooking stations. This is because available capacity does not meet the required capacity.

### 3.3. Calculation of Proposed Capacity Using Theory of Constraints Method

These two bottleneck work stations have constraints must be eliminated to maximize the company income. The principle of continuous improvement of theory of constraints (TOC) is applied to optimize capacity planning and there is no bottleneck at work stations anymore. By using the linear programming method, the revision of the master production schedule is done by adjusting the capacity of the mixing and cooking work station. Rough cut capacity planning (RCCP) revisions are carried out to see if there is still a bottleneck work station or not after the revision of master production schedule is carried out. Improvement is carried out by reducing the capacity needed on bottleneck work station.

### 4. Conclusion

From the results of rough cut capacity planning, it was found that mixing work stations in January, February, March, May, June, July, and August 2014 and cooking work stations in January, May, and July 2014 were bottleneck work stations were same. After setting the optimal master production schedule, applying the principle of theory of constraints and using linear programming methods, it is found that the mixing station and cooking station becomes non-bottleneck work stations. The bottleneck problem has resulted in a significant decrease in product sales and consumer demand every month.

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