Application Of Theory Of Constraints On Scheduling Of Drum-Buffer-Rope System

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ABSTRACT: *The successful enterprises deliver products and services in shorter throughput time and turnover inventory as quickly as possible. Three important approaches to achieve these goals are Materials Requirements Planning (MRPI, MRPII), Just-in-Time (JIT) and Theory of Constraints (TOC). TOC is systematic management approach that focuses on actively managing those bottlenecks that impede a firm's progress toward its goal of maximizing profits and effectively using its resources. TOC seems to be a viable proposition because it does not require costly affair of system change; rather it is simply based on scheduling of the capacity constraint resources. The scheduling system of theory of constraints (TOC) is often referred as drum-buffer-rope (DBR) system. DBR systems operate by developing a schedule for the system's primary resource constraint. This paper describes the basic overview of application of TOC on scheduling of drum-buffer-rope system and the previous work carried by researchers along with brief review. Elimination of bottleneck resources by DBR scheduling it is possible to improve profit by improving throughputs, reduction in WIP inventories; improve on time delivers and better utilization of constraint resources. TOC is applicable to any kind of industry for scheduling.*

*Keywords***:** *Bottlenecks, DBR scheduling, Primary Resource Constraint, Throughputs, TOC.*

I. Introduction

The objective of any manufacturing system is to convert the raw materials into finished products in a shop floor. Synchronous manufacturing system (SMS) is a manufacturing management methodology that consists of certain techniques and principles where every action is evaluated in terms of common global goal of the organization. SMS helps to achieve better performance and efficiency in a manufacturing organization. SMS introduces the concept of drum buffer rope (DBR) approach, which is generalized system and states how it satisfies and solves most of the problem of inventory levels in manufacturing environment. Reducing Work in Process (WIP) inventory to improve cycle time, delivery and product quality has become the key for maintaining the profitability. There are various techniques like Material Requirement Planning (MRP), Just In Time (JIT) and Line Balancing etc. These techniques are used for performance improvement and eliminate wastage but installation period is high, while in line balancing cost of adding capacity is high. A relatively new approach called theory of constraint (TOC), introduced by Dr.Eliyahu Goldratt in the mid-1980s [11], could overcome the above problems. Theory of constraint (TOC) also known as constraint management (CM) or synchronous manufacturing (SM) [8], is global managerial methodology, which tries to concentrate on the most critical issues of the system. These constraints should be identified and logically solved to improve the performance of system. The scheduling system theory of constraints (TOC) uses is often referred to as drum-buffer-rope (DBR) system. DBR systems operate by developing the schedule for system's primary resources constraint. The implementation of TOC-DBR in V-plant operation improved the annual sales, reduced late orders and reduced finished product inventory [6]. On the basis of TOC methodology to developed the dispatching rules for scheduling by taking into account the presence of bottleneck machines [9].

This shows study of critically components in manufacturing organization, which act as bottlenecks by applying Theory of Constraint (TOC) the efforts have been directed to increase the system performance [2].

II. The Concept Theory of Constraint

The concept of the TOC can be summarized as:
Every system must have at least one constraint. If it were not true, then a real system such as a profit making organization would make unlimited profit. A constraint therefore is anything that limits a system from achieving higher performance versus its goal.
The existence of constraints represents opportunities for improvement.

Contrary to conventional thinking, TOC views constraints as positive, not negative. Because constraints determine the performance of a system, a gradual elevation of the system's constraints will improve its performance [2].

The TOC has two major components. First a philosophy which underpins the working principle of TOC. It consists of the five focusing steps of on-going improvement, the drum-buffer-rope (DBR) scheduling methodology, and the buffer management information system. These ideas are usually referred to as TOC's "logistics" paradigm. The second component of TOC is a generic approach for investigating, analysing, and solving complex problems called the thinking process (TP).

2.1 Philosophy

The principle of Theory of Constraint consists of five focusing steps.

Step 1: Identify the systems constraint or bottleneck.

> Identify the operation that is limiting the productivity of the system. This may be a physical or policy constraint

Step 2: Decide how to exploit the bottlenecks.

> Achieve the best possible output from the constraint. Remove limitations that constrain the flow, and reduce non-productive time, so that the constraint is used in the most effective way possible

Step 3: Subordinate everything else to the above decision.

> Link the output of other operations to suit the constraint. Smooth work flow and avoid build up of work-in-process inventory. Avoid making the constraint wait for operation.

Step 4: Elevate the system's bottlenecks.

> In situations where the system constraint still does not have sufficient output invest in new equipment or increase staff numbers to increase output.

Step 5: If in a previous step a bottleneck has been broken go back to step 1.

> Assess to see if another operation or policy has become the system constraint.

2.2   Thinking Process Of Theory Of Constraint

The TOC is thinking processes are more useful in deciding what to change, to what to change and how to cause that change to occur. It is also called as problem solving methodologies. In much the same way as the five focusing steps focus on the constraint, the thinking processes focus on the factors that are currently preventing the system from achieving its goals. First identifying the symptoms within the system, which provide evidence that the system is not performing as well as desired. Working from there, the various TOC thinking process tools are then used to deduce what the causes of those symptoms are, what needs to be done to correct those causes and such corrective actions could be implemented.

III. DBR Approach

There are two fundamental issues that can be addressed while developing a synchronized product flow.

1.   The ability of plant to execute the planned product flow over a given period of time.
2.   The impact an ever present deviations on the planned product flow.

The DBR approach explicitly consider both issues in manufacturing organization, a preliminary production plan has to be established and the next step is to develop detail schedule to the capacity constraint resources (CCR), which are resources that, if not properly scheduled and managed are likely to prevent the product how to deviate from the planned flow.

IV. Drum-Buffer-Rope and Buffer Management

The logistics paradigm of the TOC has evolved from the scheduling software called Optimized Production   Technology (OPT) which in turn, is based on the following nine rules:

1. Balance flow, not capacity.
2. The level of utilization of a non-bottleneck is not determined by its own potential but by some other constraint in the system.
3. Utilization and activation of a resource are not synonymous.
4. An hour lost at a bottleneck is an hour lost for the total system.
5. An hour saved at a non-bottleneck is just a mirage.
6. Bottlenecks govern both throughput and inventories.
7. The transfer batch may not, and many times should not, be equal to the process batch.
8. The process batch should be variable, not fixed.
9. Schedules should be established by looking at all the constraints simultaneously. Lead times are the result of a schedule and cannot be predetermined.

DBR methodology provides a mechanism for protecting total throughput of the system by the use of Time-buffers (T-Bs). Time-buffers contain inventory and protect constraint schedule from the effects of disruptions at

non-constraint resources. The use of T-Bs as an information system to effectively manage and improve throughput is referred to as buffer management. It provides information based on planned and actual performance and is used for monitoring the inventory in front of a protected resource to compare its actual and planned performance.

Three types of T-B are used in buffer management [12]:

1)   Constraint buffers: contain parts which are expected to wait a certain amount of time in front of a capacity constraint resource (CCR), thus protecting the constraint's planned schedule.

2)   Assembly buffers: contain parts/subassemblies which are not processed by a CCR, but need to be assembled with CCR parts.

3)   Shipping buffers: contain products which are expected to be finished and ready to ship at a certain time before the due date, thus protecting delivery date performance.
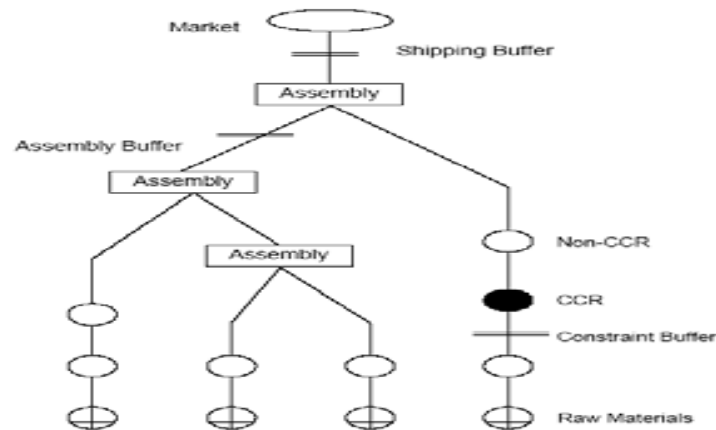

Fig.1 Different types of buffer

(Fig.1) shows the locations of these three time buffers. Notice that an assembly buffer is not required before every assembly operation. It is required only before assembly operation that is fed by both CCR and non-CCR parts. The constraint buffer is located in front of throughput orientation construct and empirically testing the hypothesis .Future research could be directed towards the simulation of the case studies of organizations by identifying the bottleneck stations and developing a detail schedule for it with the application of finite scheduling method
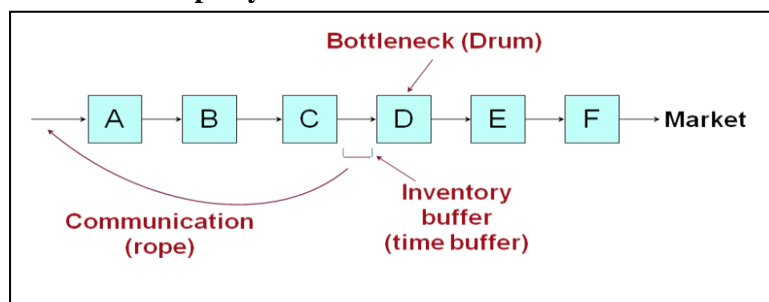
V. Drum-Buffer-Rope System

Fig. 2 Drum-Buffer-Rope (DBR) technique.

The Drum-Buffer-Rope principle (DBR) is scheduling technique of TOC that can visualise the systems constraints (Fig. 2). Every production system needs some control points or points to control the flow of product through the system. The Theory of Constraints argues that the best place for control is at the bottleneck. This control point is called the drum. A buffer can be used in front of the bottleneck, to make sure the bottleneck always has something to work on. Because it is a bottleneck, its output determines the throughput of the system. Communicating back upstream to A, what D has produced so that A provides only that amount, is called the rope. It keeps inventory from building up.

The assumptions of DBR is,

1.   The master production schedule (MPS) should be developed so that it constraint with the constraint of the system (Drum).
2.   The throughput of the system must be protected from minor occupations through time buffers at critical point of the system (Buffer).
3.   The protection at each resource should be tied to the drumbeat (Rope).

VI. Theory of Constraint Performance Measures

1. Financial measures
1.1   Net profit: An absolute measurement in rupees.
1.2   Return on investment (ROI): A relative measure based on investment.
1.3   Cash flow: A survival measurement.
2. Operational measures
2.1   Throughput (T): The rate at which the system generates money through sales.
2.2   Inventory (I): All the money invested in purchasing things needed by the system to sell its products.
2.3.   Operating Expenses (OE): All the money the system spends, turning inventory into throughput.

VII. Applications of Theory of Constraints DBR Scheduling

1.   Application of Theory of Constraints to a Service Firm (Christopher Olson, 1998) [3]. Before implementation of TOC, it was observed that the company was well behind the schedule and not meeting marketing's promises. More than 20% of the orders were unsatisfied in each month. It is observed that after implementation of TOC, throughput of the firm is increased by 25% along with considerable reduction in inventory.
2.   Due-date performance improvement using TOC's aggregated time buffer method at a wafer fabrication factory (Tsai-Chi Kuo et.al 2009) [7]. The findings reveal that applying aggregated time buffer control system improved the overall due-date control, in terms of on-time delivery rate, average tardiness and variances in average tardiness and lateness.
3.   Applications of TOC in a small   manufacturing Indian industry (L.S. Murty, 2000) [1]. After application of TOC, throughput increase about 50% without any additional investment. Besides this, there is considerable reduction in work in process inventory and increased machine utilization.
4.   Implementing the Drum-Buffer-Rope (DBR) in V-plant operation (S.S.Chakravorty, 2002) [6]. The annual sales and performance measure before, during and after implementation of DBR are compared. It is found that the annual sales are increased by 4% inventory of finished window unit decreased by 67% and percentage of the orders reduced by 63%.
5.   Implementation of TOC-DBR in a food industry (Umble et. al 2000) [5]. Discussed so as to clearly demonstrate how TOC-DBR can be effectively implemented. The TOC-DBR implementations eliminated many of the previously observed problems. The controls established by DBR result in reduction in work in process inventories and improved make-to-order response time. This effectively resulted in increased level of system throughput and improved product quality.
6.   Effect of Drum-Buffer-Rope approach principal on the performance of synchronous manufacturing by conducting a case study in a small scale industry (R.Sivasubramaniam et.al 2000) [8]. The optimum production rate at each work centre is computed.
7.   Although Theory of Constraint is often associated with manufacturing, it is also used in logistics, supply chain (Horng-Huei et.al 2010) [10], healthcare industries and product development.
8.   Presently authors are working on elimination of bottleneck resources by application of Theory of Constraints on scheduling of Drum Buffer Rope (DBR) system in the medium scale industry. The housing product manufacture on housing production line. The demand of housing product 1200 housings per month but current output is 1000 housings per month. Thus, there is need for proper scheduling of resources and increase the productivity of housing production line. The company is offering this problem by elimination of bottlenecks resources through proper scheduling and improve productivity of targeted housing production line. It is proposed to apply Theory of Constraint approach to this problem by DBR scheduling of bottleneck resources in the selected housing production line and improve the productivity of the housing production line.
        Process layout of housing production line is shown in (fig.3).
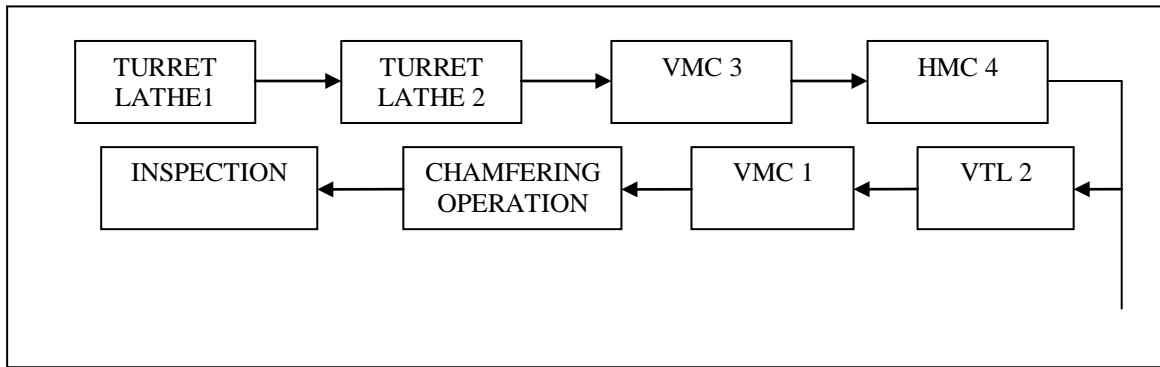
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Fig.3 Process layout of housing product

8.1 Problem Associated With Company's Existing Scheduling Technique

8.1.1 Problems associated with dispatches.

The company has to carry the housing product dispatch depends machine dispatch date. At the same time there is very little difference in the manufacturing lead time of entire housings.

The analysis of housing product dispatch is carried out and found that the percentage of on time delivers of housing product is are very less.

The dispatches of housing product of last six month is shown in table 8.1.1

Table 8.1.1 Average % on time deliveries before DBR scheduling

Products	June 12	July	August	September	October	November
Housings	87%	84%	86%	89%	91%	88%

From above table we clearly see that the average percentage of on time deliveries per month is less. The average the average percentage of on time of last six months is 87%.

8.1.2 Problems associated with Work-in-process inventory.

The company recesses the whole lot of the particular housing product into the particular housing production line. Hence there is no difference between the size of process batch and transfer batch, thus the process batch is not spilt different number of small sized transfer batches. Due to reason, the company has no control over the amount of WIP inventory present in housing production line. Hence, all machines in the housing production line are tied huge amount of WIP inventory.

The average amount of Work-in-process inventory of last six month is shown in table 8.1.2

Table 8.1.2 Average Numbers Of WIP inventory Before DBR Scheduling

Products	June 12	July	August	September	October	November
Housings	205	210	203	197	195	200

From above table we clearly see that the average amount of Work-in-process inventory of last six months is more. The average numbers of WIP inventory before DBR scheduling is 202 housings.

8.1.3 Problem Associated with Overtime.

As the company is not meeting require due dates of dispatch, the company has to go for the overtime. Most of times 35% of operators have to come for the overtime on the weekly one day. Despite of this huge amount of overtime, company fails to meet the dispatch due-dates.

The average amount of overtime cost of last six month is shown in table 8.1.3

Table 8.1.3 Average Amount In Rs. Before DBR Scheduling

Products	June 12	July	August	September	October	November
Housings (Rs)	20000	21000	19800	18900	18700	19600

From above table we clearly see that the average amount of overtime cost of last six month is more. The average amount of overtime cost of last six month is Rs. 19667

There is need of proper scheduling of resources in selected housing production line and improving performance as well as productivity of housing production line by improving on time delivery rate, reducing work in process inventory and reducing cost of overtime.

8.2   Scheduling In DBR At Housing Production Line

8.2.1   Pre-implementation analysis of various performance measures of the system such as work in process inventory, throughput and percentage of on time deliveries etc.

8.2.2   Determination of available capacities of each resources and demand placed on each resources of system using stopwatch time study.

8.2.3   Identification of bottleneck resources of the system on the basis of capacity to the demand ratio of each resource and WIP inventory in front of each resource. In this study HMC 4 is found to be bottleneck machine. Bottleneck resource HMC 4 is having limited capacity, huge WIP inventory and also facing maintenance related problem.

8.2.4   Analysis by Drum-Buffer-Rope (DBR) technique.

8.2.5   Implementation of Drum-Buffer-Rope (DBR) technique by scheduling the constraint resource for maximum utilization and scheduling the nonconstraint resources for serving the constraint resource.

8.2.6   Performance measurement of system due to DBR scheduling.

VIII. Benefits Of Theory Of Constraint

The most significant benefit of TOC is to improve the responsiveness of the firm to the changes in the marketplace thus providing an advantage in competition. The benefits are:

1.   Product Cost: is greatly reduced due to reduction of manufacturing cycle time, reduction of waste and inventories and elimination of non value added operations.

2.   Quality: is improved because of continuous quality improvement programmes.

3.   Design: Due to fast response to engineering change, alternative designs can be quickly brought on the shop floor.

4.   Productivity improvement.

5.   Higher production system flexibility.

6.   Administrative ease and simplicity.

IX. Conclusion

Inventories are used to give the impression of good control and maximum equipment utilization but much were inventories same times accumulates more investment of the organisation and this concept keeping inventory was traditionally used in proven new industry. DBR scheduling proves the above traditional logic wrong. The DBR scheduling provides reduction in average WIP inventory, increasing in percentage of on time delivers, reducing in average overtime and reducing in average raw material inventory.

Also because of DBR scheduling reduce WIP and raw material inventory were space availability in the store as well as production shop and improving the quality of product due to better control over operation of constraint resources. The ideal time of non constraint resources are utilized by other purposes e.g. developments work.

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