

# Drum-Buffer-Rope: The Technique to Plan and Control the Production Using Theory of Constraints

Arvind Bhardwaj, Ajay Gupta, Arun Kanda

**Abstract**—Theory of Constraints has been emerging as an important tool for optimization of manufacturing/service systems. Goldratt in his first book “The Goal” gave the introduction on Theory of Constraints and its applications in a factory scenario. A large number of production managers around the globe read this book but only a few could implement it in their plants because the book did not explain the steps to implement TOC in the factory. To overcome these limitations, Goldratt wrote this book to explain TOC, DBR and the method to implement it. In this paper, an attempt has been made to summarize the salient features of TOC and DBR listed in the book and the correct approach to implement TOC in a factory setting. The simulator available along with the book was actually used by the authors and the claim of Goldratt regarding the use of DBR and Buffer management to ease the work of production managers was tested and was found to be correct.

**Keywords**—Drum Buffer Rope (DBR), Optimized Production Technology (OPT), Capacity Constrained Resource (CCR)

## I. INTRODUCTION

THEORY of constraints is the result of pioneering work of Dr Eliyahu Goldratt [1]. Initially, Goldratt presented his rules of production scheduling in the form of software called Optimized Production Technology (OPT). Later on, he presented his ideas of production Management in the form of a book “The Goal”. Goldratt [1] highlights the difficulties faced by most of the production managers in their day-to-day work. Goldratt presented some of the unorthodox methods to solve these problems. Goldratt presented the drawbacks of conventional measurement systems and suggested three measurement yardsticks to gauge the performance of a system. These yardsticks are defined below:

- a. *Throughput* It is defined as the rate at which a system generates money by the sale of goods and services which it produces
- b. *Inventory* It is the money that a system has invested in purchasing the things that it intends to sell.
- c. *Operational expenses* It is the money, which a system spends to convert inventory into throughput.

Throughput is the money coming into the system; inventory is the money currently inside the system and operational

Arvind Bhardwaj is with Department of Industrial & Production Engineering, National Institute of Technology Jalandhar (India)

Ajay Gupta is with Department of Industrial & Production Engineering, National Institute of Technology Jalandhar (India)

Arun Kanda is with Department of Mechanical Engineering, Indian Institute of Technology, Delhi (India)

expenses is the money we have to pay to make the throughput happen. Therefore all the parameters can be defined in terms of money. Any activity that effects favorably at least one of the above three measures is productive. Otherwise it is unproductive.

Goldratt highlighted the reasons for buildup of inventory in the manufacturing organizations. Goldratt defined a bottleneck resource, the role of bottlenecks in determining the output of organization, method to identify and exploit bottlenecks. Goldratt also gave the steps for ongoing improvement. These steps are presented below

- a. Identify the system bottlenecks
- b. Decide how to exploit these bottlenecks
- c. Sub-ordinate everything else to the above decision
- d. Elevate the system bottlenecks
- e. If in the above process a bottleneck has been broken, go back to the first step. But do not allow inertia to cause a system constraint.

These steps have been explained in greater details by Goldratt [4] in his book “Theory of constraints”. For continuous improvement of an organization, these steps are to be repeated again and again. The Goal was a great success but according to Goldratt, although many managers around the globe read and recommended this book to the others but many of them could not apply it to their production situation. Because the book was written in the form of a novel and the steps to implement theory of constraints were not clearly mentioned. So, Goldratt [2] wrote this book titled “Production the TOC way” This book by using simulation, explains the fallacy of most commonly thought problems of most of the production managers, then it presents the Drum-Buffer-Rope and Buffer management techniques to effectively manage the production systems. In DBR, we identify the constraint and prepare the production schedule for the constraint (Drum). Then we subtract the constraint time buffer from it to determine the timing of release of material into the production system. The buffer in front of the constraint is monitored continuously. Any decrease in this buffer is called a hole. These holes are used to initiate corrective actions so that the planned results can be achieved.

## II. CORRECT APPROACH TO TEACH TOC

If we try to convince the practicing managers that TOC tools can be used to solve most of their day to day problems by giving the example of successful implementation in other companies, they will resist the idea by saying that the situation in their company is different from those companies and that

the problems which they are facing are unique and the solution of these problems is not in their hands. They will raise different kinds of objections. You address one objection, they will immediately raise another. This phenomenon will be present in every case, it does not matter whether the concerned employees are open minded and progressive or not. The progressive people resist the idea because; in most of the cases progressive people might have tried their level best to solve their problems but must have failed. But in that attempt they might have developed the feeling that the solution of the problem is not in their hands. Also, they will have a very strong inclination towards the solution developed by them and will not be open to any new idea. So, they too will resist the new idea and hence the change. Therefore, to cause them to seriously entertain your suggestions, you must cause them to stop believing in their conclusions. The right approach is to ask the managers why managing production is so difficult and note down the reasons suggested by them. Most of the managers generally quote the reasons like customers change their mind at the last moment, suppliers and employees are unreliable, existence of quality problems, maintenance problems, poor data availability, wrong policies etc. Then ask the participants to estimate the cost and feasibility of fixing each of these problems. They will agree that it is not feasible to fix all the problems or the resources required to fix many of the problems are exorbitant. They will all agree that managing production will be a piece of a cake, once all these problems are corrected. At this stage, the participants are presented with the simulator of a paradise plant, a plant where none of the above mentioned problems exist. There are confirmed orders, suppliers supply the quantity needed immediately, there is no absenteeism or quality problem and the plant has enough capacity to meet those orders. The participants are asked to plan and schedule the production according to their own methods, so that the customer demands can be met. The simulator indicates the raw material requirement for each product, cost of each material, selling price of each product, processing sequence for each product, set-up and processing time at each workstation. Thus it is a totally deterministic and fairly simple production situation. The participants prepare their plan and run the simulator accordingly. Once the simulator is run, it displays the net profit, return on investment, throughput, inventory, operating expenses, utilization level of each resource and order fulfillment at the end of the week. Most of the participants fail to achieve the results i.e. all the required products are not manufactured and shipped to the customers in time. Most of the participants find that the original plans had a very short life and they had to do lot of course correction. The main reason for this happening is that most of the people run the plant by observing it i.e. checking if all the resources are being used and as soon as a resource gets idle, we try to find a work that can be allocated to it. The core problem is that, in their attempt to manage well, the managers are guided by two contradictory objectives. One, to manage well, they must control the cost and the cost can be controlled by good departmental performance and high local efficiencies at each resource. Two, to manage well, they must achieve good plant performance measured by throughput i.e. to manufacture and ship the products according to the promised due dates. Good departmental performance and good

plant performance appears to be contradictory to each other. The actions that are absolutely necessary to achieve good departmental performance are devastating from the point of view of good plant performance and vice-versa. The mode of operation of most of the managers is of compromise between good departmental and good plant performance. This compromise is responsible for most of the undesired effects present in a production system. In the beginning of the month, the actions of the managers are guided by the cost world consideration of achieving high efficiency on utilization of each and every resource. To achieve this, many material items are released into the production system ahead of the schedule. It leads to confusion and a mix up of priorities. During the end of the month, customer due dates become more important. To meet the due dates, manager's resort to fanatic course correction and expediting. Actions like resetting the workstations to expedite the late material through them, working overtime etc are resorted to. The end result of this compromised way of working is that neither high efficiency nor good due date performance is achieved and the system carries high inventory and incurs high operating expenses. Fig 1. shows this conflict diagrammatically.

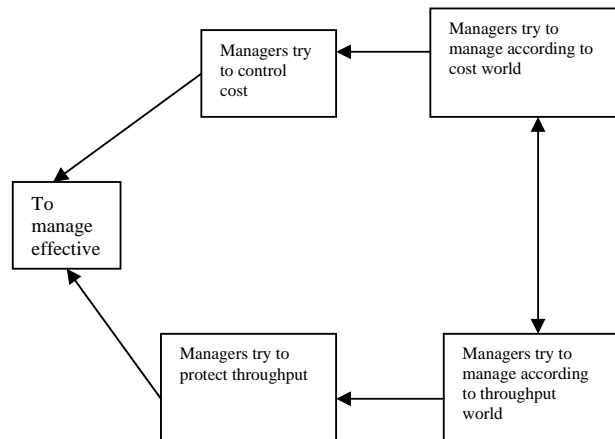


Fig 1. Basic conflict faced by managers

Efficiency syndrome is a behavior pattern present at all the levels in most of the organizations e.g. workers don't want to be caught standing idle, supervisors are always on look out for work for their sub-ordinates, managers strive to have high efficiency and most of the corporate head quarters will interfere if the efficiency figures of a plant are low. This efficiency syndrome is responsible for most of our difficulties in managing production and we must get rid of it because we cannot and should not have a perfectly balanced plant. So, for most of the plants, the capacity of most of the resources will be more than the demand placed on them. Now, if we strive to achieve high efficiency levels at all the workstations. We will have to release material ahead to time. This will increase the queue length in front of the workstations and manufacturing lead-time. Similarly, to achieve high efficiency, common parts meant for the production of one product may be diverted to manufacture other products. This further deteriorates the due date performance. Thus to meet the due dates, we resort to

fanatic course correction and expediting at the end of the month.

In cost world, good global result is assumed to be equal to sum of good local results. While in throughput world, good global results are not equal to sum of good local results. Cost world assumes that different links in the organization can work and can be measured independent of each other while throughput world says that the coordinated efforts of different links in the organization is essential to achieve good global results. Even if a single link fails to do its job, the global results get affected. Another wrong policy prevailing in most of the companies is batch size syndrome. Economic batch quantity is determined by a point where the sum total of setup cost and inventory carrying cost is minimum. Since most of the non-bottlenecks have spare capacity, reducing the total setup time by reducing the number of setups adds to the idle time only and does not result in any saving at all. Similarly, to ensure control and to minimize paper work, the items are moved from one workstation/department to other in batches. This also increases the production lead-time and effects the due date performance. Also most of the customer orders are not equal to our economic batch quantity, we will have to break the EBQ rule quite often to meet the customer orders. The most commonly stated reasons that makes management of production difficult adds fuel to the already existing fire only. The fire exists because of the wrong policies derived from the cost world. This fire consumes most of our ability to deal with disturbances and whenever we are faced with some disturbances, we have very little ability left to effectively deal with them and these disturbances makes us go crazy. When there is a general agreement among the participants that managing production is difficult not because of the causes mentioned by them but because of the wrong policies like efficiency, economic batch quantity etc. derived from the cost world, the concept of DBR is introduced to them and they are asked to plan and control according to DBR.

### III. DRUM-BUFFER-ROPE MECHANISM

- a. Identify the constraint.
- b. Prepare a schedule for the constraint (Drum).
- c. Determine the constraint buffer (in terms of time). In constraint buffer, we do not intend to keep specific number of specific parts in front of the constraint, rather we intend to keep specific number of hours of work, the type of parts that are held in the buffer will keep on changing according to the production schedule of the constraint
- d. Using the constraint schedule and constraint buffer, determine the timing of material release into the production system.
- e. Ensure that the constraint works strictly accordingly to the schedule prepared for it and correct deviations, if any, immediately.
- f. Put other resources on roadrunner ethics i.e. when there is material, work on it on a first come first serve basis, otherwise do nothing.
- g. For free goods, market demand is constraint. For these goods, subtract the shipping buffer from the customer due date to determine the material release timing.

- h. Prepare a plan of utilization of common parts. Common parts are the components required by more than one product. We must prepare a schedule for them, otherwise either no one will work on them or they may be diverted to manufacture something else rather than using them on the item for which they were originally released into the system and the manufacturing lead-time may be stretched unnecessarily.
- i. Material Release Point

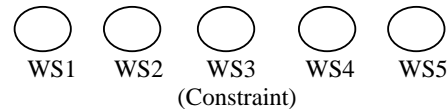


Fig. 2. Relative Location of Constraint & Material Release Point

If a constraint has to choose among two components to work on, both of which will ultimately be joined together to make a finished product, then it should first process the component requiring lesser per unit processing time and afterwards it should take up the second one. This will also help in reducing the number of delayed products at the end of the planning period or this will reduce the effect of disturbances on the due date performance.

When the simulated plant was run using DBR, customer due dates were met, we were able to manufacture all the items demanded by the customer. There was lesser inventory in the system. The only drawback was that the efficiency figures on the non-bottlenecks were low. The lead-time is also higher because of efficiency syndrome. Once we get rid off the efficiency syndrome, we can reduce the manufacturing lead-time to half of its previous value. A hole in the buffer means work which is scheduled to be done by the constraint workstation in the buffer time period has not yet reached in front of the constraint. If an upstream operation is holding two different materials for processing in front of it, both of which represents hole in the constraint buffer. Then it should first process the material which represents hole in the region 1, then process the material that is a hole in the region 2 and the material representing hole in the region 3 should be processed in the end. This way the burden of chasing down the delayed parts is transferred from the shoulders of a person in charge of constraint to the person in charge of upstream operations. For proper exploitation of constraint, it is important that the in charge of constraint operation should stay there only rather than chasing the delayed parts upstream.

#### A. Setting priority for maintenance work

Buffer management helps the maintenance manager in deciding the priority of the maintenance work e.g. if two or more persons approach the maintenance manager at the same time, complaining about two or more different breakdowns. The maintenance manager usually decides about the priority of attending them on the basis of volume of their shout. Buffer management provides him a rational basis to take a decision in such situations. He can decide about the priority based on the depth of penetration of holes created by these breakdowns, the workstation causing deeper penetration is to be attended first.

### B. Role of expeditors

In the buffer management, whenever a hole appears in the region 2, the expeditor is required to track the material and prepare an emergency action plan. The plan will be implemented only if the hole penetrates into region 1. When a hole penetrates into region 1, it becomes the top priority and such material has to be expedited to the constraint by stopping any other operation going on the upstream non-constraints workstation and processing the hole material immediately. Only a few of the region II holes will actually become region I holes. Therefore many of the emergency plans will never be put to work in actual practice. So, what is the use of all this tracking and emergency plans? Tracking of material that represents hole in the region 2, a number of times, will reveal that such materials are often found in front of only a few workstations. These workstations represent the area where the improvement efforts need to be directed immediately. Once these processes have been improved, the frequency of occurrence of holes in the region 2 will go down. Buffer management used along with Drum-Buffer-Rope doubles the results obtainable with DBR alone.

A particular workstation may not remain constraint forever and the constraint may change with the change in product mix or demand. The production manager will come to know about it very quickly. If some upstream operation becomes the new constraint, more and more holes in the constraint buffer will start penetrating into region 1 and this material will be traced lying in front of the new CCR (capacity constrained resource) and these holes will start penetrating into shipping buffer also. If an operation that is not upstream to the constraint operation becomes the new constraint, the holes will appear in the shipping buffer only. To start with, even if we arbitrarily choose a workstation as CCR, buffer management will quickly reveal the actual CCR.

### C. Measurement system

The performance of a department should not be measured by local efficiency of that department rather it should be measured by the number of region 1 holes generated by that department in the constraint or shipping buffer. Lesser the number of holes generated, better the performance and vice versa.

Drum-Buffer-Rope and buffer management can be applied with the same degree of success in any kind of manufacturing environment whether it is V A of T type of configuration. In T type of industries, different finished goods have many common parts. Working on the basis of efficiency has the highest devastating impact on such companies. Car industry and most of the electronic industry belongs to this category.

## IV. CONCLUSIONS AND SCOPE FOR FUTURE WORK

The people have a strong resistance about the utility of any new technique in solving their problems and they have a belief that their situation is different from the situation of the companies where that technique has been applied successfully. They also carry a list of probable causes of their problems in their mind. Till it is proved that their list does not contain the root cause of their problems, they will not listen to the applicability of new technique or existence of some other

cause. In the book, Goldratt, by using simulation, has proved that even managing a plant where the most commonly thought reasons of problems are missing is difficult. The root cause of the problems is a behavior pattern developed on the basis of efficiency-based approach. Once a manager changes this approach, he is able to achieve much better results with considerably less pain. The paper also explains the steps to implement Drum-Buffer-Rope mechanism in a factory. Although DBR has been successfully applied by many American and European companies but the utility of this mechanism needs to be established by applying it in some practical manufacturing situations in India as there is no reported application of this technique in India. Buffer management can also help in setting the maintenance priorities and setting up an appropriate measuring system.

### REFERENCES

- [1] E.M. Goldratt "The Goal: A process of ongoing improvements", North River Press, 1984
- [2] E.M Goldratt "Production The TOC way", North River Press, 2003
- [3] E.M Goldratt "It's not luck" North River Press, 1994
- [4] E.M Goldratt "Theory of constraints" North River Press, 1990
- [5] E.M Goldratt & R. E. Fox "The Race" North River Press, 1986
- [6] Chakravorty Satya S "An evaluation of DBR control mechanism in a job shop environment" Omega, Volume 29, 2001, pp. 335- 342
- [7] Duclos Leslie K, Spencer Michael S "The impact of a constraint buffer in a flow shop" International Journal of Production Economics, Volume 42, 1995, pp. 175- 185.
- [8] Chakravorty Satya S, Atwater J Brian "The impact of free goods on the performance of drum-buffer-rope scheduling systems" International Journal of Production Economics, Volume 95, 2005, pp. 347-357
- [9] Ribeiro M A, Silveira J L & Qassim R Y "Joint optimization of Maintenance and buffer size in a manufacturing system" European Journal of Operations Research, volume 176, 2007, pp. 405-413
- [10] Daniel V, Guide R Jr. "Scheduling with the priority dispatching rules and drum-buffer-rope in a recoverable manufacturing system" International Journal of Production Economics, volume 53, 1997, pp. 101-116
- [11] Wahlers James L, Cox James F "Competitive factors and performance measurement: Applying theory of constraints to meet customer needs" International Journal of Production Economics, volume 37, 1994, pp. 229-240
- [12] Mishra Nihikant, Parkash, Tiwari M K, Shankar R, Felix T S Chan "Hybrid Tabu- Simulated Annealing based approach to solve multi-constraint product-mix decision problem" Expert systems with applications, Volume 29, 2005, pp. 446-454
- [13] Radovitsky Zinovy D "A quantitative approach to estimate the size of Time buffer in the theory of constraints" International Journal of Production Economics, Volume 55, 1998, 113-119
- [14] Gerhard Plenert "Focusing Material requirement planning (MRP) towards performance" European Journal of Operations Research, volume 119, 1999, pp. 91-99
- [15] Michael Umble, Elisabeth J Umble "Utilizing buffer Management to improve the performance in a health care environment", European Journal of Operations Research, volume 174, 2006, 1060-1075W. D.