The stimulation of the consequences of applying "DBR mechanism" to a product line performance (Case study: rocker arm production line in IDEM co.)

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Abstract. Applying the theory of constraints in production, increases production output and the efficiency of the system. In this theory, whatever that prevents the system from achieving a higher level, is called a constraint. The constraints of a system is what determines the maximum performance or efficiency of that system. The theory of constraints in production systems uses a controlling mechanism called DBR in order to balancing the flow of production line.

In this survey, a case study has been conducted on a product line in automotive industry. As the initial level, the application of DBR system for this product line has been stimulated and then it has been compared to a ordinary production line. Then, the effects of shift of bottleneck on four key measures was estimated both for normal and for DBR applied systems. The measure are waiting times, work-in-progress, throughput and delivery time. The results show that as we get away further from the bottleneck, the indicators are being lower but in DBR system the slope of the shift line is lower than the ordinary system.

Keywords: Theory of Constraints, DBR, production line performance, simulation

INTRODUCTION

The increased competition in the industry will pay more attention to the continuous improvement of the efficiency of production systems and is trying to eliminate any waste. The theory of constraints (TOC) is an overall management philosophy introduced by Eliyahu M. Goldratt in his 1984 book titled "The Goal" that is geared to help organizations continually achieve their goals. It focus on Identify the system's constraint to increase Throughput in the factory. The theory of constraints holds that every system has at least one constraint. Each constraint indicates the potential for growth and effective change. Drum-buffer-rope, so called "DBR", is the Theory of Constraints production application in manufacturing systems. Drum-Buffer-Rope (DBR) is a method of synchronizing production to the constraint while minimizing inventory and work-in-process. Using DBR can improve the efficiency of production line. DBR method is used to the synchronizing production process. The purpose of the synchronizing is the possible smooth and continuous flow of materials, components and semi-manufactured inventory in production systems. The Drum is the bottleneck Schedule. Based on the limited capacity of the bottleneck, the demand of the market and the delivery of goods will be determined. The purpose of the Buffer Stock bumpers Embed station production bottlenecks and hot spots support the output of the system.

Rope argument also implies that if other stations with imaginary ropes attached to the throat. And materials and parts by the rope is guided in the throat, in the move. The other stations on program schedule will be determined when the throat. When the raw material is injected into the system and station before the throat,
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throat and processed according to the schedule set backward. And schedule station bottleneck after bottleneck and delivery products based on the schedule and in accordance with a defined process forward. The planning system ensures that the bottleneck never be idle for lack of materials and parts required. And parts out of the bottleneck without delay to the next station reach the end of the line.

The aim of this study was to compare the two systems drum-buffer-rope and conventional production systems and the effect of the physical location of bottlenecks on the lines of performance indicators system. And secondary objectives of the study are to determine the buffer size appropriate for the implementation of DBR model for the system, measured by indicators of throughput, work-in-process, the waiting time and the time of delivery in the current system, measuring the parameters listed in the DBR method, And the effect of bottleneck Shifting on the criteria mentioned above.

The research questions are as follow:

1. What is the effect of Executing DBR method on the performance indicators in production system?
2. What is the effect of bottleneck Shifting on the performance indicators in normal situation of production system?
3. after the implementation of DBR method, What is the effect of bottleneck Shifting on the performance indicators in production system?

LITERATURE REVIEW

DBR method as applied model Theory of Constraints to improve production systems:

New systematic approach of theoretical limits can be called the thinking process. Restrictions theory focused on the achieved organization, created a new paradigm, which causes a change in attitude to the concept and strategies for improving soil productivity. And the chance to exert an efficient and effective change significantly. Attitude to the theory of constraints, resulting in material flow balance in the whole system is possible. And the cycle is repeated breaking boundaries and finding new leads in the system. And specificity of continuous improvement achieved has come to be optimized for the entire organization.

Since the real capacity of the plant is to determine their throats. Understanding them is the first step would be to accept the changes due to theoretical limitations. One of the most important applications of the theory of constraints, DBR method is the production system. By Golder was introduced. DBR set of rules to identify constraints) throat (and taking advantage of it in order to implement the Theory of Constraints, is provided.

DBR method components include:

DRUM

Constraints or bottlenecks; determine the overall speed of the system. In many cases, DRUM contains a detailed schedule for the constraints, in order to maximize utilization of bottleneck. It should be noted that a bottleneck which is always busy, is not necessarily utilized completely. (Schragenhiem & Ronen, 1990)

BUFFER

Because random disruptions are inevitable in any organization, 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.
Three types of T-B are used in buffer management:

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. (Mahapatra & Sahu, 2006)

   The buffer used in this study is Constraint buffer.

ROPE

Rope is a schedule for a release of material into the production line. So that buffer guarantees that no new work in the system not able to be released until it is needed at the constraint. In fact, the application of the rope is to release appropriate materials into the production system at the right time. In DBR mechanism, This can be achieved through providing a detailed schedule for the release of raw materials into the system. (Wu et al, 1994)

The Indicators of manufacturing system:

the Indicators of manufacturing system that have been studied in this research are:

- Work in process: "WIP" refers to all materials and semi-finished products that are at various stages of the production process.
- Waiting time: The total time that a semi-finished product is waiting to enter the following work station.
- Throughput: The output of the production system at a given time.
- Delivery Time: the total time elapsed since the raw materials arrival at the facility to the final product release to the warehouse

PLANT TYPES

There are four primary types of plants in the TOC lexicon. They specify the general flow of materials through a system, and they provide some hints about where to look for typical problems.

- I-Plant: Material flows in a sequence, such as in an assembly line. The primary work is done in a straight sequence of events (one-to-one). The constraint is the slowest operation.

   The plant used in this study is I-Plant

- A-Plant: The general flow of material is many-to-one, such as in a plant where many subassemblies converge for a final assembly. The primary problem in A-plants is in synchronizing the converging lines so that each supplies the final assembly point at the right time.

- V-Plant: The general flow of material is one-to-many, such as a plant that takes one raw material and can make many final products. Classic examples are meat rendering plants or a steel manufacturer. The primary problem in V-plants is "robbing" where one operation (A) immediately after a diverging point "steals" materials meant for the other operation (B). Once
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the material has been processed by A, it cannot come back and be run through B without significant rework.

- T-Plant: The general flow is that of an I-Plant (or has multiple lines), which then splits into many assemblies (many-to-many). Most manufactured parts are used in multiple assemblies and nearly all assemblies use multiple parts. Customized devices, such as computers, are good examples. T-plants suffer from both synchronization problems of A-plants (parts aren't all available for an assembly) and the robbing problems of V-plants (one assembly steals parts that could have been used in another). (Fawcett and Pearson, 1991)

THE METHODS OF UNBLOCKING BOTTLENECK:

The following methods can be used for unblocking bottleneck without changing the layout:

- Efforts to reduce start-up time
- Eliminating the unnecessary measures
- Timing shift and rest to avoid the restrictions unemployed
- Training of personnel to increase efficiency
- Prevent low quality products to the bottleneck
- Improvement of machinery and equipment manufacturing bottleneck station
- Preventive maintenance

DBR METHOD PERFORMANCE:

More research in the field of DBR method implementation has been done. Shin Woo and colleagues in their paper a hypothetical system furniture production are considered. And using a methodology DBR to its timing and the use of simulation, the construction of the whole system in this case have been compared with the normal mode. The results indicate that the processing of orders in the normal average is 30 percent longer than the DBR. (Wu et al 1994)

Shragenhiem & Ronen three-step timing constraints, the size of the buffer and the Rope scheduled to run DBR methodology introduced in the production line. And these steps in the implementation of DBR in a production system with a six-workstation using simulation method are used. (Shragenhiem & Ronen, 1990)

Chakravorty in a study compares the DBR system, upload an unlimited adjusted And the immediate release as for two laws, "first come, first served" (FCFS) and the "shortest processing time" (SPT). he states that although previous studies, shows the good performance of the modified unlimited loading system, But the DBR system is considerably better than it acts. He shows that using the shortest processing time improves DBR system performance. (Chakravorty, 2001)

Mahapatra and colleagues using simulation techniques and neural networks in a process system to compare the methodology of DBR, production systems have been common. In addition, the displacement of the throat, change the buffer size, the average processing time for a change in number of cars throughput on both systems are also examined. (Mahapatra and Sahu, 2006)

Kadipasaoglu with respect to an imaginary line with four workstation, the effects of displacement and restrictions on the parameters that are used in the protective capacity building, waiting time and have the
time. In each experiment, changes in unemployment station processing time are considered as a variable. After running the simulation to investigate the interaction of these factors are discussed. (Kadipasaoglu et al, 2000)

**METHODOLOGY:**

The purpose of this research is to implement the Theory of Constraints approach in a real production system in comparison with conventional systems to study the effects of shift of bottleneck. In this study, a real production line has been selected. Automotive industry have been selected for this purpose due to their special contribution in manufacturing industry. In this research the rocker arm production line in IDEM.CO in Tabriz is selected.

After studying production systems, the buffer size is achieved by using simulation. The right size, using an initialization and change this value to optimize the parameters obtained in this study. Then the implementation of DBR approach is in the system. To this end, we will collect data on the production line we needed.

Data such as line drawings, the number and sequence of stations, the processing time at each station with proper probability distribution, identify stations that have the capacity bottleneck And times of failure and repair stations.

Given the above, we have obtained the data necessary to run the simulation. Then run the computer simulation and the effect of the mentioned variables on the performance of the system during a period to be determined. In the current state of DBR system and has been in the software simulation.

It is selected in line with the conditions and characteristics of the line, 3 stations as the stations that have been selected to become the bottleneck capacity. The comparison between the current system and drama, Rope buffer and the effect of any measures on work-in-process waiting time, throughput and delivery time with respect to the effects of the bottleneck physical location is examined.

Thus, different states, and each state simulation, action simulation was repeated for 10 times. Then, the results of simulation times were analyzed with SPSS software. And at the end of the conclusions and recommendations have been discussed.

The data in this study is done using simulation software ARENA.
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Analysis of data:

the rocker arm production line in IDEM.CO is Consists of 9 stations. The map of production process and processing time for each station is shown in the following figure. The mean and variance of the processing time in each of the stations is displayed.

Due to this, in the current system, the third station with the highest processing time is to be determined as a system bottleneck. To investigate the effect of shift of bottleneck on the production system, according to the conditions and characteristics of the production line, stations 1, 4 and 8, which had a greater capacity for the throat. The new location was chosen as a bottleneck. And performance indicators mentioned in the case of each of these stations have been measured the system bottleneck. The real bottleneck is the third station at the time of the study. Assumed that the bottleneck in accordance with procedures provided in the literature, with increasing force and equipment, improve the machine or increase shifts improves. And the state of the bottleneck is removed. And throat transferred to another station. The next step for information on times and failures and maintenance stoppages during the past year collected all workstations. And distribution of potential failures and maintenance times for each work station using the software Arena Analyzer Input has done. This tool is a set of data, distribution right time and with the lowest allocation error. Also a time with uniform distribution (UNIFORM[1, 2] to transfer parts between stations is considered.

All times they were stated after the introduction and distribution of software simulation for a given period of time and the results have been analyzed.

Time simulation in this study, 3 months, each month 30 day 8 hour shift per day is 2. In other words, the production line has been simulated for the duration of 86400 minutes. The simulation was repeated 10 times for each mode.

Simulation of the problem in DBR state

In the DBR after identification of bottlenecks and determine production rates, the need to allocate a certain amount of inventory is stored at the back of the throat station. That being unemployed to avoid the bottleneck station is assigned. The Rope communication mechanism should be based on the production rate of the bottleneck station and allocated buffer. Login parts into the timing system. For the simulation, we first define the system bottleneck. And then optimize the size of the buffer, using the simulation achieved. To determine the optimal size of the buffer should be defined as the number of components in the system before the bottleneck station between the station and throat are dumping raw materials) the sum of the parts
in the queue and processing (must be less than or equal buffer. The different amounts allocated to the buffer and the amount of buffer system simulation results is observed. This operation has been started from a lower to a buffer. For different values so that the indicators discussed in this study) work-in-process, Waiting time, throughput and delivery time (the best of it, continues. Therefore in system, the number of components in the system before the bottleneck station should be lower than the optimum. If the number of parts to be optimized, the new pieces will not entrance into the system, unless it is a piece out of the bottleneck station (DBR mechanism).

After determining the optimal buffer and define the mechanisms Rope, process simulation work for a period of 3 months work 7 days a week and two 8-hour shifts per day, with 10 repetitions performed.

In the following charts, the results are similar in the two DBR and normal to above four indicators, taking into account the effect of changing physical locations is a bottleneck.

**Table 1.** Comparison of the current system and DBR system based on work in progress (WIP).

<table>
<thead>
<tr>
<th>bottleneck</th>
<th>current system</th>
<th>DBR system</th>
</tr>
</thead>
<tbody>
<tr>
<td>station 1</td>
<td>562.14</td>
<td>248.23</td>
</tr>
<tr>
<td>station 4</td>
<td>579.87</td>
<td>365.62</td>
</tr>
<tr>
<td>station 8</td>
<td>2135.28</td>
<td>574.39</td>
</tr>
</tbody>
</table>

**Figure 1.** Diagram of the current system and DBR system based on work in progress (WIP).

**Table 2.** Comparison of the current system and DBR system based on waiting time.

<table>
<thead>
<tr>
<th>bottleneck</th>
<th>current system</th>
<th>DBR system</th>
</tr>
</thead>
<tbody>
<tr>
<td>station 1</td>
<td>210.67</td>
<td>94.67</td>
</tr>
<tr>
<td>station 4</td>
<td>202.44</td>
<td>121.52</td>
</tr>
<tr>
<td>station 8</td>
<td>905.38</td>
<td>198.72</td>
</tr>
</tbody>
</table>
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Figure 2. Diagram of the current system and DBR system based on waiting time.

Table 3. Comparison of the current system and DBR system based on throughput

<table>
<thead>
<tr>
<th></th>
<th>DBR system</th>
<th>current system</th>
<th>bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>station 1</td>
<td>210.88</td>
<td>211.37</td>
<td>station 1</td>
</tr>
<tr>
<td>station 4</td>
<td>209.89</td>
<td>210.11</td>
<td>station 4</td>
</tr>
<tr>
<td>station 8</td>
<td>205.32</td>
<td>203.19</td>
<td>station 8</td>
</tr>
</tbody>
</table>

Figure 3. Diagram of the current system and DBR system based on throughput.
Table 4. Comparison of the current system and DBR system based on delivery time.

<table>
<thead>
<tr>
<th>DBR system</th>
<th>current system</th>
<th>bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.08</td>
<td>222.18</td>
<td>station 1</td>
</tr>
<tr>
<td>150.34</td>
<td>230.77</td>
<td>station 4</td>
</tr>
<tr>
<td>221.74</td>
<td>950.67</td>
<td>station 8</td>
</tr>
</tbody>
</table>

As can be seen in the charts and tables, for work-in-process by changing the location of the throat from Station 1 to 8, the index is higher in December of feed. In the conventional system, the first in the first and fourth stations, the process is constant. And then it will be increased.

The waiting time for the index, in the current absence of significant changes in wait times in primary stations are facing a sharp increase in the next station. And in the case of DBR, the bottleneck ahead is the location, the amount of waiting time increases. The increase in the index of DBR has a lower slope than the conventional method.

Of throughput in both ways away from the source of production bottlenecks reduced the slope is more severe reduction in the normal way. The bottleneck is away from the source of the difference in throughput in the way of DBR as compared to normal increases.

The delivery time’s index is the primary bottleneck station has no significant effect on the index delivery time. But at the next station a significant slope increases. In January of RSS, we see a lower slope. Still, seeing the deterioration of the index away from the source of the bottleneck where we are.

A comparison of performance indicators hypothesis testing product line in both the normal and the DBR:

In order to compare the results of the performance indicators in the normal way and the DBR of ANOVA test using SPSS software is used. The results are visible in the following tables.
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Table 5. The significance level for the indicator work in process (WIP).

<table>
<thead>
<tr>
<th>Sig.</th>
<th>bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.042</td>
<td>station 1</td>
</tr>
<tr>
<td>0.035</td>
<td>station 4</td>
</tr>
<tr>
<td>0.048</td>
<td>station 8</td>
</tr>
</tbody>
</table>

Table 6. The significance level for the index of waiting time.

<table>
<thead>
<tr>
<th>Sig.</th>
<th>bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.049</td>
<td>station 1</td>
</tr>
<tr>
<td>0.035</td>
<td>station 4</td>
</tr>
<tr>
<td>0.021</td>
<td>station 8</td>
</tr>
</tbody>
</table>

Table 7. The significance level for the index throughput.

<table>
<thead>
<tr>
<th>Sig.</th>
<th>bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.074</td>
<td>station 1</td>
</tr>
<tr>
<td>0.081</td>
<td>station 4</td>
</tr>
<tr>
<td>0.043</td>
<td>station 8</td>
</tr>
</tbody>
</table>

Table 8. The significance level for the index delivery time.

<table>
<thead>
<tr>
<th>Sig.</th>
<th>bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.038</td>
<td>station 1</td>
</tr>
<tr>
<td>0.025</td>
<td>station 4</td>
</tr>
<tr>
<td>0.012</td>
<td>station 8</td>
</tr>
</tbody>
</table>

As can be seen in the indicators used in the process, waiting time and delivery time, better methods of DBR, compared to normal levels of confidence in the table have accepted. But in the case of throughput, is no significant difference in the two methods.

In explaining this case we can say that the system of DBR, because the purpose of synchronization in parts and raw materials to the system performance bottleneck is the station. In cases where the arrival of parts to the system disrupts the function of the station is the bottleneck. It took out a piece of the throat delays honor. Therefore, the method of DBR input is less than the normal way we encounter. But with less input, output similar compared with normal practice derived. The reason for this is that work-in-process and waiting times and delivery time will be reduced in DBR mechanism and so despite the no difference between throughputs, the ratio of output to input increased. On the other hand, due to the reduction in the above parameters, the output achieved with much lower cost than the normal way. The improvement in the performance of production systems in drum-buffer-rope is clearly visible.

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CONCLUSION

As the effect of the implementation of DBR on performance indicators are compared with the current situation was observed in the production line. The indicators used in the process, waiting time and the time of delivery, a significant improvement in the way of DBR are observed. But the index is not significant throughput improvement. Statistical analysis was performed according to virtually zero equity means deemed accepted. And it is not considered as a significant difference in the two methods. The effect of shift of bottlenecks in the current system of DBR can be outlined as follows:

1) in general, both of the bottleneck in the production line is closer to the source, the indicators are better, and the farther from the source, the indicators are weaker.

2) The lower the index the stations closest to the source, the slope is gentle. But by far, takes a sharp slope. However, in January of R the index gentle slope than the normal method of change.

3) work-in-process indicators, the waiting time and the time of delivery, the bottleneck moved more major changes are throughput ratio.

4) The effect of shift of bottleneck on performance indicators of both normal and non-DBR in the primary stations of the production line is not very sensible. But in general, the bottleneck station closer to the source line, the better is the performance indicators.

REFERENCES


