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ROOT CAUSE ANALYSIS USING INTERNAL BENCHMARKING

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Abstract:
Nowadays, most companies are facing with many problems in production. One of them is the companies cannot balance the quantity produced to flow smoothly during processes. It causes more work in process and waiting time during process. The objective of this research is to analyze the efficient performance, to find the actual root-cause, and to improve the production line. In this article, textile spinning company is a case. This research analyzed the performance of each station by using internal benchmarking methodology that is referred to Hopp and Spearman (2000) by specifying Cotton SEMI-Comb line which makes a big profit to an organization. It can be found that the production line was inefficient operating because there were more work in process and it spent more time in the system during May to July, 2010. As a result, the inefficient stations were Roving Station and Winding Station. The improvement of Roving Station is reduction of work in process and cycle time. For Winding Station, the improvement is increasing throughput. This principle can be applied to production planning in order to set the layout and to improve the ability of an organization to deliver the products as customer requirements.

Keywords: internal benchmarking, little's law, constant work-in-process.

1. INTRODUCTION

Benchmarking is a tool that measures the performance efficiency by comparing one's business processes and performance metrics in comparison with industry leader and/or best practices from other industries. The difference in performance is used to lead an adjustment of production process to achieve better effectiveness and efficiency. Common performance measures are often related to quality, time, and cost. There are types of benchmarking as following: 1) Internal Benchmarking, 2) Competitive Benchmarking, 3) Cooperative Benchmarking and 4) Strategic Benchmarking. For this research work, we emphasize on evaluating actual line performance in comparison with theoretical performance called "Internal Benchmarking" (Hopp and Spearman, (2000). Using basic production line performance measures such as throughput, cycle time and work-in-process (WIP) as key performance indicators, these measures are compared with theoretical performance references. The differences between actual and theoretical performance help in root-cause-analysis and improvement of the production line. Unlike other benchmarking technique, internal benchmarking is convenient in data collection since the data is gather in company own process, while other techniques collect data from other companies where processes and unit of measures may be difference.

For this research, internal benchmarking technique is used as a tool for identifying area that needed to be improved in spinning company (part of textile industry). Since the production process of spinning company is quite extensive and linked as assembly line; starting from blowing process, carding process, drawing process, simplex process, ring spinning process, and finishing with Winding process. Some processes cannot produce enough to feed next station so the machine which is next process has to be stopped and wait for input to fill in. Some stations can produce much more than next station which caused bottleneck and traffic jam in the assembly line. As a result, the production rate is inconsistency in assembly line. Therefore, the spinning company decides to use internal benchmarking as a tool to analyze the production efficiency and identify area to be improved.

2. BACKGROUND

Bogan and Callahan, (2001), McNair and Leibfried, (1992); Spendolini, (1992). Many definitions have been proposed for benchmarking. Bogan and Callahan (2001) argue that benchmarking is a universal management tool that can be defined as the systematic process of searching for best practices, innovative ideas, and effective operating procedures that lead to superior performance. He classified the types of benchmarking are competitive benchmarking, cooperative benchmarking, collaborative and internal. According to McNair and Leibfried (1992), benchmarking is simply an external focus on internal activities, functions, or operations in order to achieve continuous improvement. Spendolini (1992) defines benchmarking as a continuous and systematic process for evaluating the products, services, and work processes of organizations that are recognized as representing best practices for the purpose of organizational improvement. Stevenson, (1996) described that benchmarking is simply the process of measuring the performance of one's company against the best in the same or another industry. Benchmarking is not just making changed and improvements for the sake of making changes, Benchmarking is about adding value. No organization should make change to their products, process or their organization if the changes do not bring benefits. When using benchmarking techniques, an organization must look at how processes in the value chain are performed. Boxwell, (1994) described that there are three reasons that benchmarking is becoming more commonly used in industry. They are:

1) Benchmarking is a more efficient way to make improvements. Managers can eliminate trial and error process improvements. Practicing benchmarking focuses on tailoring existing processes to fit within the organization, 2) Benchmarking speeds up organization's ability to make improvements, 3) Benchmarking has the ability to bring corporate America's performance up as a whole significantly. If every organization has excellent production and total quality management skills then every company will have world class standards

The Pittsburgh (PA) Police Bureau has been using internal Benchmarking for several years. In 1997 the city of Pittsbutgh entered into a consent decree with the U.S Department of justice to settle a suit over excessive force. The consent decree mandated the creation of and early intervention system, which is now known as the police Assessment and Review System (PARS). The PARS system includes data on 24 different officer performance indicators. Commanders review the data and compare the performance data of officers with other officers working similar assignments.

Jan Carlzon (1987), President of Scandinavian Airlines, described a method of internal benchmarking used to monitor the performance of the company's cargo operations (Called QualiCargo). The performance measures used included the speed with which telephones were answers; the frequency with which promised deadlines were met; the frequency with which the cargo actually traveled on the plane on which it had been booked; and the time-lapse between an aero plane landing and cargo being ready to be collected by the customer. A significant aspect of the QualiCargo monitoring system was the production of a monthly performance ranking. The different cargo terminals were compared, first against their own individual targets, and then with one another. The monthly report showed which terminal had the best and which had the worse performance. Those which achieved their objectives and 80% of deliveries had arrived on time. After its introduction, the figure rose to 92%

According to Little's Law (Little, 1961), it says that under steady state conditions, the average number of items in a queuing system equals the average rate at which items arrive multiplied by the average time that an item spends in the system where L =average number of items in the queuing system, W = average waiting time in the system for an item, and λ =average number of items arriving per unit time, the law is

$$L= \lambda W \tag{1}$$

This relationship is useful when conducting any process analysis of queuing systems, inventory control, and supply chain management. Hopp and Spearman, (2000) who applied Little's Law as:

$$WIP = TH \times CT \tag{2}$$

where they define throughput (TH) as "the average output of a production process (machine, workstation, line, plant) per unit time," work in process (WIP) as "the inventory between the start and end points of a product routing," and cycle time (CT) as "the average time from release of a job at the beginning of the routing until it reaches an inventory point at the end of the routing (that is, the time the part spends as WIP)." They note that cycle time is also referred to as flow time, throughput time, and sojourn time, depending on the context. However, there is a more fundamental difference between (1) and (2) in that the law is stated in terms of the average output or departure rate for the system, rather than the arrival rate. This reflects the perspective of a typical operating system, especially a manufacturing operation. As stated, we see that any increase in output requires either an increase in work-in-process inventory or a reduction in cycle time or both.

Hopp and Spearman, (2000) proposed three main performance references: 1) the best case 2) the worst case and 3) the practical worst case. In best case, it directly comes from little's law as show below:

The minimum cycle time for a given WIP level *w* is given by

$$CT_{best} = \begin{cases} T_0 & \text{if } w \leq W_0 \\ \dfrac{w}{r_b} & \text{otherwise} \end{cases} \qquad (4)$$

The maximum throughput for a given WIP level w is given by

$$TH_{best} = \begin{cases} \dfrac{w}{T_0} & \text{if } w \leq W_0 \\ r_b & \text{otherwise} \end{cases} \qquad (5)$$

In worst case, it assumes the longest possible cycle times for the system and somehow increase the waiting time without changing the average processing time (otherwise r_b and T_0 would be changed). The maximum cycle time for a given WIP level w is given by

$$CT_{worst} = wT_0 \qquad (6)$$

The minimum throughput for a given WIP level *w* is given by

$$TH_{worst} = \frac{1}{T_0} \qquad (7)$$

Since both best and worst case above do not involved with uncertainty and variation which commonly found in typical production line. Hopp and Spearman, (2000) establish another reference called "Practical Worst Case" which involves randomness. The practical worst case can be regarded as the maximum randomness case causes every possible to occur with equal frequency. When randomness is introduces into a line, more scenarios become possible.

In order for all states to be equally likely, three special conditions are required: 1) The line must be balance, 2) all stations must consist of single machine, and 3) process times must be random and occur according to a specific probability distribution known as exponential distribution. As a results, the practical worst-case (PWC) cycle time for a given WIP level *w* is given by

$$CT_{pwc} = T_0 + \frac{w-1}{r_b} \qquad (8)$$

The PWC throughput for a given WIP level w is given by

$$TH_{pwc} = \frac{w}{(W_0 + w - 1)} x\, r_b \qquad (9)$$

The throughput and cycle time of practical worst case are always between those of the best case and worst case. As such, the PWC provides a useful midpoint that approximates the behavior of many real systems. By collecting data on average WIP, throughput, and cycle time for a real production line, we can determine whether it lies in the region between the best case (green line) and practical worst case(blue line); best region, or between worst case (red line) and practical worst case; bad region, those like in Figure 1 and Figure 2. Systems with better performance that the PWC are good and systems with worse performance are bad. It makes sense to focus our improvement efforts on the bad lines because they are the ones with room for improvement.

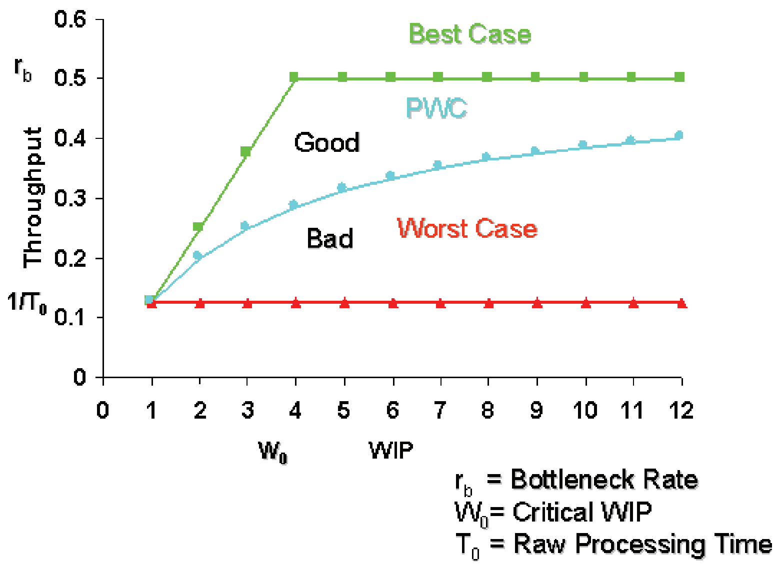
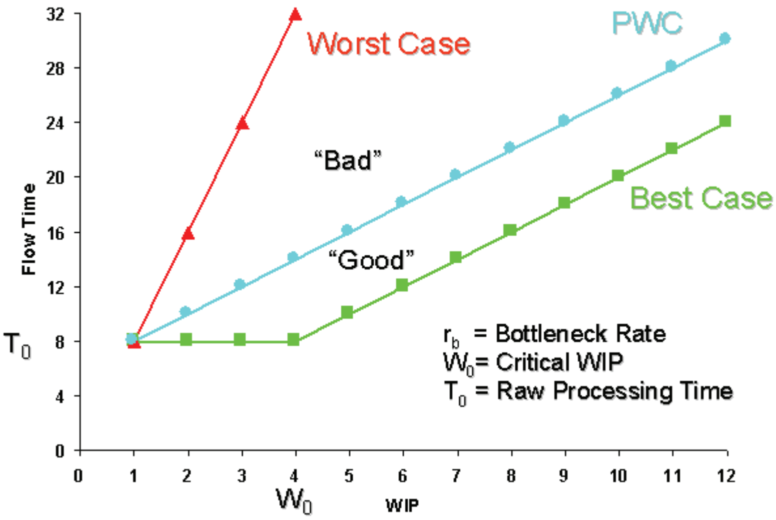


Figure 1: Relationship between Throughput and WIP for all three reference cases

Figure 2: Sample of relationship between Cycle time and WIP for all three reference cases



3. DATA COLLECTION AND ANALYSIS

Data collected the actual performance during May-July 2011. It combined the actual throughput 327.19 lbs/hr, actual cycle time 48 hr or 2 days and actual WIP level 15,705 lbs. The capacity and performance of the yarn spinning line is shown in Table 1 which is the average process rate (lbs per hour) and average process time (hours) at each station. From the table, the bottleneck rate is the smallest capacity of the process that is blowing process with r_b = 437.33 lbs/hr. The law process time is the sum of the process times with T_o = 0.105 hr.

Table 1: The capacity Data and actual performance for Spinning Process at Semi-comb line

Stations	Rate/Machine (Lbs/Hr)	No. Machines per Station	Process Times (Hr)	Capacity (Lbs/Hr)	W_0 (lbs)	TH_{actual} (lbs/hr)	CT_{actual} (hr)	WIP (lbs)
Blowing	437.328	1	0.002	437.33	1	428.656	0.003	1.14
Carding	75.447	8	0.013	603.58	8	599.651	0.015	9.19
Drawing1	316.050	2	0.003	632.10	2	429.848	0.004	1.77
Drawing2	167.321	3	0.006	501.96	3	427.225	0.004	1.87
Roving	186.629	4	0.006	746.52	4	495.238	0.022	10.90
Ring Spinning	15.296	35	0.065	535.37	35	422.934	0.053	22.52
Winding	103.746	6	0.010	622.47	6	327.190	0.024	7.85
		Process Times	0.105					

3.1 Overall Process Performance Analysis

From above table, the critical WIP (W_0), Throughput of the best case (TH_{best}), Throughput of the worst case (TH_{worst}), Throughput of the practical worst case (TH_{PWC}), Cycle Time of the best case (CT_{best}), Cycle Time of the worst case (CT_{worst}) and Cycle Time of the practical worst case (CT_{PWC}) for general production line can be calculated as shown in Figure 3 and 4.

Figure 3: Relationship between throughput and Work in Process of Spinning Plant

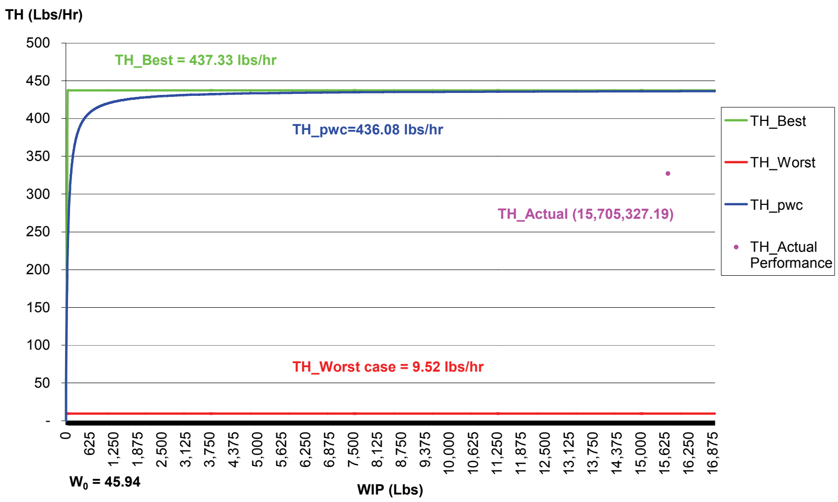
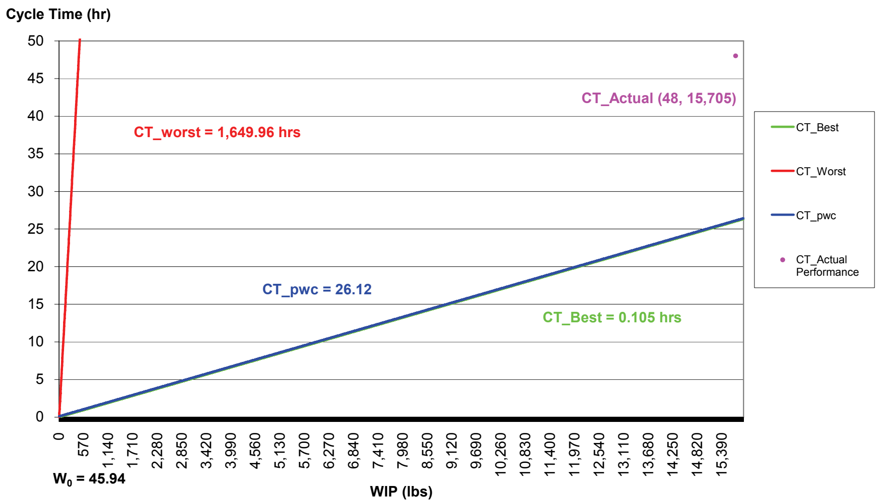


Figure 4: Relationship between Cycle Time and Work in Process of Spinning Plant



According to Figure 3, it shows that the actual throughput = 327.19 lbs/hr and WIP = 15,705 lbs are well into the "bad" region between practical worst case and worst case. Clearly, this line performance is not good operating in throughput term. In addition, Figure 4 was created by putting the calculations in graphical term. It shows that the line performance is bad because the actual WIP and actual cycle time pair of (15,705, 48) are laid between the worst case line and the practical worst case line. Therefore, this line performance is not good operating. Clearly, the performances both throughput and cycle time of this production line are not efficient performance because the actual cycle time spent more time than the practical worst-case cycle time and the actual throughput which is the average output of production process per hour less than practical throughput. Therefore, this production line should be improved because it has maximum cycle time and minimum throughput.

3.2 Individual Workstation Performance Analysis

In order to identify problem area, individual workstation is analyzed for its performance measures: cycle time, throughput rate and work-in-process according to equations (4) to (9) as shown in Table 2.

Table 2: Summary all calculations and the Result of Performance

Stations	Capacity (lbs/hr)	No. of M/C	TH_{actual} (lbs/hr)	TH_{best} (lbs/hr)	TH_{worst} (lbs/hr)	TH_{PWC} (lbs/hr)	CT_{actual} (hr)	CT_{best} (hr)	CT_{worst} (hr)	CT_{PWC} (hr)	WIP (lbs)	Result
Blowing	437.33	1	428.656	437.33	437.33	437.33	0.0026	0.00228	0.00261	0.00261	1.14	Good
Carding	603.58	8	599.651	603.32	75.41	342.48	0.0153	0.013	0.12	0.03	9.19	Good
Drawing1	632.10	2	429.848	632.1	316.05	403.9	0.0041	0.0032	0.006	0.0044	1.77	Good
Drawing2	501.96	3	427.225	501.96	167.32	242.49	0.0044	0.006	0.011	0.0077	1.87	Good
Roving	746.52	4	495.238	746.52	186.63	585.34	0.022	0.0054	0.0058	0.0186	10.90	Bad
Ring Spinning	535.37	35	422.934	535.37	15.30	231.29	0.053	0.65	1.472	0.1181	22.52	Good
Winding	622.47	6	327.190	622.47	103.75	380.31	0.024	0.01	0.076	0.0206	7.85	Bad
Overall		45.94	327.190	437.33	9.52	436.08	48	0.105	1,649.96	26.12	15,705	Bad

From Table 2, it indicates that there are 2 stations that's affected to the production performance: Roving Station and Winding Station. At Roving and winding department, they have a lot of machine that's made high productivity which is not aligned to other processes. See circle at Table 2, the capacity at Roving station is 746.52 lbs/hr and TH actual is 495.238 lbs/hr. Both capacity and actual throughput are 33.66% different which it is not necessary to operate the capacity more than 500 lbs/hr. For the capacity at winding station is 622.47 lbs/hr, TH actual is 327.19 lbs/hr. The difference is 47.43% that it is not necessary to operate more than 400 lbs/hr. It is directly impact to overall production efficiency, waste time for producing as well as it is hard to control the quality. Details below are reasons that concern to production efficiency.

Roving Station: WIP is the problem for this station. The reasons are following:

- Lack of material: Because lack of material, the manager plant need to use the low quality of fiber instead of good quality of fiber and hence the output (sliver yarn) is less volume due to often broke and need to stopped machine in order to tie the sliver.
- Stopping cleaning: since low quality of material, thus there is dust of fiber put on the machine that it has effect on quality of sliver yarn.

Proposed Improvement at Roving Station: This station has more WIP than critical WIP, hence cycle time reduction can be improved the production. Actions for cycle time reduction are shown as detail below:

- Plan for machine cleaning; before finishing each work.
- Improve quality of raw materials.
- Reduce the number of machines from 4 to 3.

Winding Station:

- Machine breakdown: clean the machine
- Setting up the machine
- Controlling quality: because the machine has "yarn clearing" part in order to cut defect yarn off, because we require the smooth of yarn surface. But since these machines are not auto machine, thus yarn is tied by worker. And this period, we use low quality of fiber, thus yarn often found broken. Because yarn often broke, the worker cannot tie the yarn completely. Meanwhile, the worker must fill the sliver yarn in order to run process continuously. The worker should control 2 machines per worker. (1 machine = 50 candles)

Proposed Improvement at Winding Station: The throughput time effects to production, thus productivity can be increased by following:

- Plan for the machine cleaning; before finishing each work.
- Improve quality of raw materials.
- Reduce the number of machines from 6 to 4. The reduction of number of machines causes the time of worker is reduced. There is more time for the worker to concentrate on machines
- Arrange training course for new comers and do re-training operators

4. CONCLUSION

The spinning yarn consists of 7 stations: Blowing, Carding, drawing1, drawing2, roving, ring spinning, and winding. Since the production lines were unbalance with multi-machine station and the workstations have different number of machines and processing time. Thus, we used the internal benchmarking methodology to compare the production line by using the method developed by Hopp and Spearman (2000).

From this research, it is found that this production line was not good since there were more WIP and it spent more time in the system. The analysis was made in each process to find the problem that effected on performance among WIP, Cycle Time and Throughput. As a result, the inefficient stations were Roving and Wingding.

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