Operations management tools to be applied for textile

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Abstract. In this paper, basic concepts of process analysis such as flow time, inventory, bottleneck, labour cost and utilization are illustrated first. The effect of bottleneck on the results of a business are especially emphasized. In the next section, tools on productivity measurement; KPI (Key Performance Indicators) Tree, OEE (Overall Equipment Effectiveness) and Takt Time are introduced and exemplified. KPI tree is a diagram on which we can visualize all the variables of an operation which are driving financial results through cost and profit. OEE is a tool to measure a potential extra capacity of an equipment or an employee. Takt time is a tool to determine the process flow rate according to the customer demand. KPI tree is studied through the whole process while OEE is exemplified for a stenter frame machine which is the most important machine (and usually the bottleneck) and the most expensive investment in a finishing plant. Takt time is exemplified for the quality control department. Finally quality tools, six sigma, control charts and jidoka are introduced. Six sigma is a tool to measure process capability and by the way probability of a defect. Control chart is a powerful tool to monitor the process. The idea of jidoka (detect, stop and alert) is about alerting the people that there is a problem in the process.

1. Basic concepts

Every business has the aim to maximize profits. Operations management tools are applicable for any business and any industry in order to help to maximize profits by means of both high productivity and high quality. In this paper, several operations management tools are introduced and applied for a finishing plant to measure operational performance. By the way, an effective toolset, serving scientific management, is provided for the managers of textile operations.

To start with, basic concepts of process analysis are illustrated following which operations management tries to improve results of these:

Flow time: The time needed for a unit of product or service to be produced. By the way, this is the time from the start to the end of the process for one unit.

Flow rate: Units to be produced per certain time. The reciprocal (1/x) of flow time.

Inventory: The total amount of units in a process. Raw, semi or final products are considered.

Bottleneck: The work station which has the least capacity. Having least capacity, the bottleneck is the step driving the production. By the way, the capacity of the process, maybe even the capacity of the business, is the same of the capacity of the bottleneck. In a finishing plant, the bottleneck is usually the stenter frame machines. So in this paper, these machines would be mentioned more frequently.

Direct labor cost: The cost of directly workers' pay for the production of one unit.

Utilization: The percentage of working time over the total time paid for.

2. Operations management tools for textiles

Strategic initiatives allows companies to shine in their respective arenas. These include (a) business process reengineering, (b) just-in-time manufacturing and purchasing systems, (c) time-based competition, and (d) competing quality [1].

Efficient production of goods and services requires effective applications of the concepts, tools and techniques of operations management. Productivity and quality are two legs of a business running together. Operations management serves many tools on productivity and quality in a process. In this paper is exemplified six different tools, three of which is in service of productivity mostly, while the other three is quality biased. It should never be neglected that any tool helps also the other side to go forward. These tools are *KPI (Key Performance Indicators) tree*, *Overall Equipment Effectiveness* and *Takt Time* for productivity and *six sigma and process capability*, *control charts* and *jidoka* for quality. Many more are available and can be adopted textile business.

2.1. KPI tree

KPI tree, where KPI stands for "key performance indicators", is a tool that visualizes the relationship between operational variables and financial variables.

Profit, being one of the most important numbers in a business, is the main branch of the KPI tree in figure 1. It is executed from the difference of the revenue and the costs. The revenue is driven by the flow rate multiplied by the price ($/meter). The flow rate would be the minimum of the demand and the capacity. The flow rate would be equal to the capacity of the plant when demand exceeds the capacity and the capacity of the plant would be equal to the capacity of the bottleneck where the bottleneck is generally the stenter frames in a finishing plant. On the other hand, costs are the sum of fixed and variable costs accumulated by the flow rate multiplied by the operating costs of workstations added up.

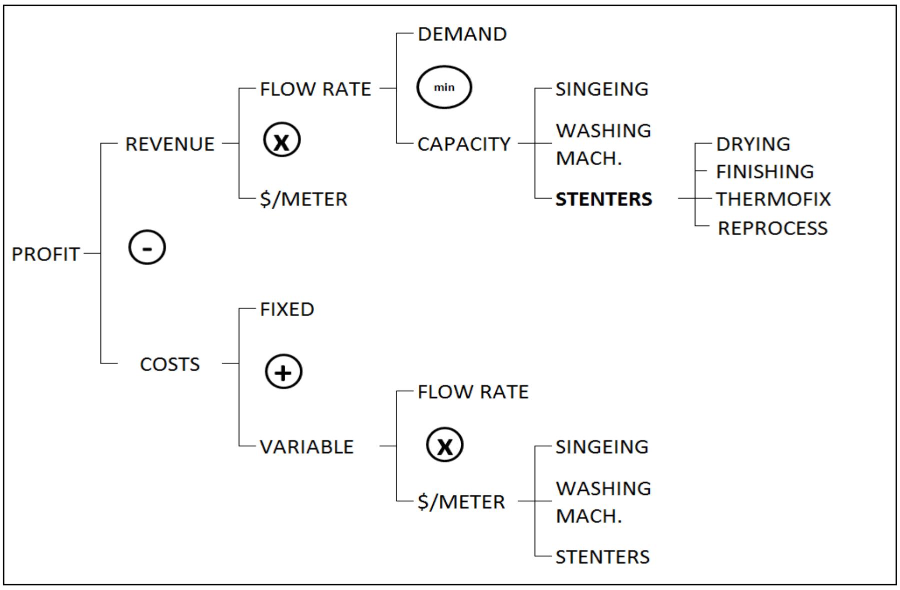

Figure 1. A KPI tree for a finishing plant.

A KPI tree visualizes the relationship between the operational and financial variables from branches to the leaves. Figure 1 shows an example of a KPI tree. Leaves of the tree are easier to treat but have less impact on the results while the branches are harder to treat but have more impact. A KPI tree is a good start point for sensitivity analysis to see which operational variables yield the biggest financial improvements [2].

2.2. Overall Equipment Effectiveness (OEE)

Companies purchase expensive machines for example stenter frames. Such machines should be fully utilized in order to pay back. But unfortunately, a stenter frame machine might be utilized less than 50%. Overall Equipment Effectiveness (OEE) is a powerful tool that helps to analyze the utilization and downtime of a machine and to see the potential for productivity improvement.

Through a ‘working hours’ spreadsheet of a machine, OEE diagram can be prepared. The diagram shows the effective time of the machine and downtime reasons dramatically. By the diagram of a machine, managers see where improvements can be provided faster and easier and more results are obtained. Different machines can also be compared to set a start point.

In figure 2 is an OEE diagram of a stenter frame machine. Time losses are shown in order of downtime losses, speed losses and quality losses. By adding on, total time loss is 43% and true value add time is 57% of total planned time. It means there is an extra 43% potential capacity.

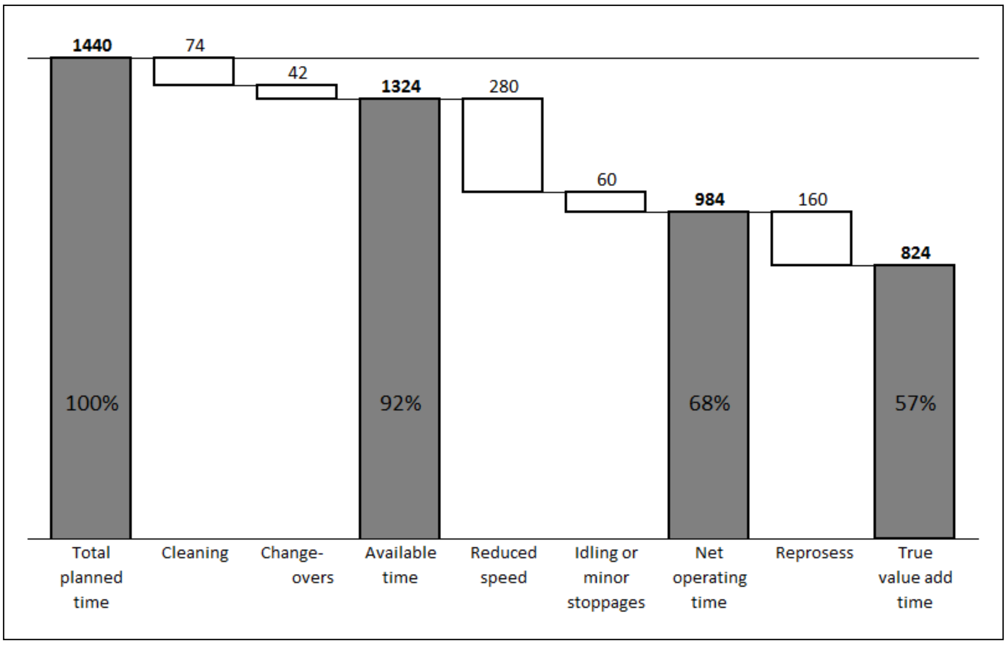

Figure 2. An OEE diagram of a stenter frame machine.

2.3. Takt time

Due to market instability and the frequent introduction of innovations in processes and technologies, operating managers are facing the need to continuously adapt the system architecture and the operational parameters to meet profitable operating conditions and remain competitive in the global market [3]. Changing even hourly in some industries, demand changes seasonally in textiles. The same company can produce one million meters of fabric in September, half million in December. Thus, company should make resource planning by months in order to reduce direct labor costs and increase the utilization.

Takt time is a concept telling the time period during which a unit has to be produced according to the demand. When one worker is needed for takt time 5 minutes, then 5 workers would be needed for takt time is 1 minute. The shorter the takt time is, the faster the production should be. This is possible by leveling the production first and then employing “staff to demand”.

Having leveled the production, the quality control department of a finishing plant should inspect one thousand meter fabric in 43,2 minutes for one million meters in a month, in 86.4 minutes for half million. Takt time is 43,2 and 86,4 minutes for September and December respectively. In order to employ the staff to the demand, the number of inspectors for that month can be calculated accordingly (Figure 3).

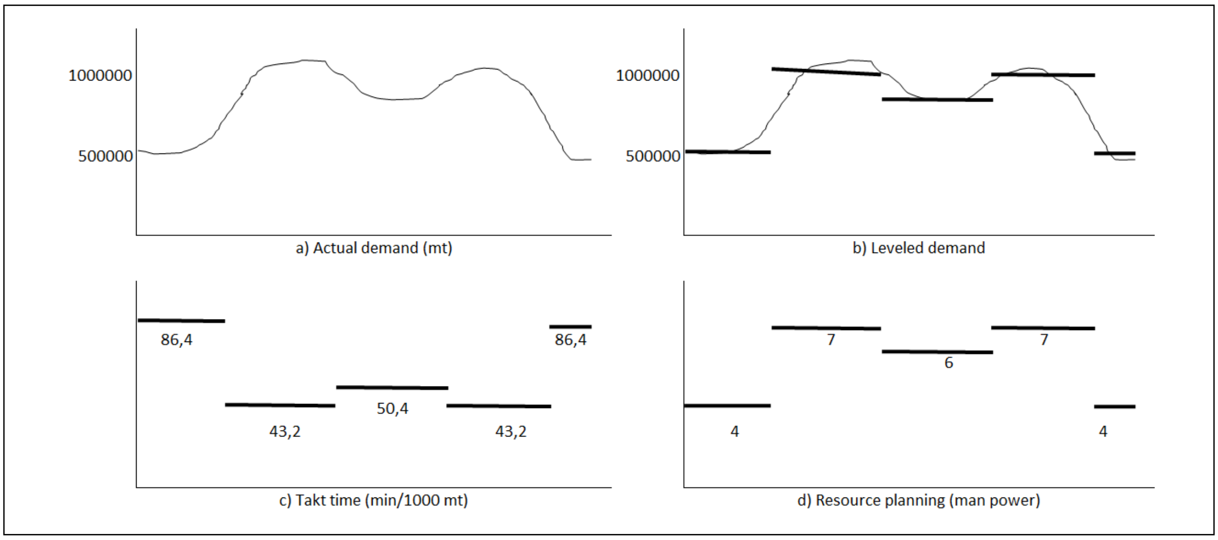

Figure 3. Resource planning through demand levelling and takt time.

2.4. *Six Sigma and Process Capability*

The term “Six Sigma - 6σ” refers to a quality level where specification limits are between ± 6 standard deviations. It means %99.9999998 of the production is in specification and just 2 defects are produced per billion. This is a rational objective such industries as aerospace, health. However, most manufacturing companies aim 3 sigma level rationally.

Besides, process capability increases as the sigma level increases. The capability index (C_p) of a process is the assessment of whether the natural tolerance (6σ) of a process is within the specification limits. When upper and lower specification limits (USL – LSL) and standard deviation known, capability index (C_p) can be calculated as:

$$C_p = \frac{allowable\ process\ spread}{actual\ process\ spread}$$

$$C_p = \frac{USL-LSL}{6\sigma} \tag{1}$$

Table 1. Sigma levels, process capability and related defect probabilities and defect numbers per million.

zσ	Cp	P{defect}	ppm
1σ	0.33	0.317	317,000
2σ	0.67	0.0455	45,500
3σ	1.00	0.0027	2,700
4σ	1.33	0.0001	63
5σ	1.67	0.0000006	0.6
6σ	2.00	2x10-9	0.00

A C_p of 1.0 indicates that process is judged to be “capable”. This is ±3σ level. [4]

An example on process capability: Consider that USL = 141.0 cm and LSL = 139.0 cm for a fabric width where average width and standard deviation are 140.4 and 0.6 respectively.

C_p was calculated by equation (1) and found 0.56 which is less than 2σ for this specification. Being the average 140.4 not the middle of upper and lower specification limits, it can be calculated –thanks Excel- that 15.9% of the production would exceed 141.0 cm and 1.0% would go below 139.0. Due to the high defect probability, such a deal might not be profitable for marketing.

2.5. Control charts

Control charts are powerful tools for statistical process control. A finishing plant could monitor many process and product parameters by control charts and catch any problems about machine settings and product specifications. It is as easy as plotting measured data on a graph and add on.

On the control chart in figure 4, besides upper and lower specification limits from the example above, upper and lower control limits are set using equations following [5].

$$Upper\ Control\ Limit\ (UCL) = \bar{\bar{x}} + z\sigma \tag{2}$$

$$Lower\ Control\ Limit\ (UCL) = \bar{\bar{x}} - z\sigma \tag{3}$$

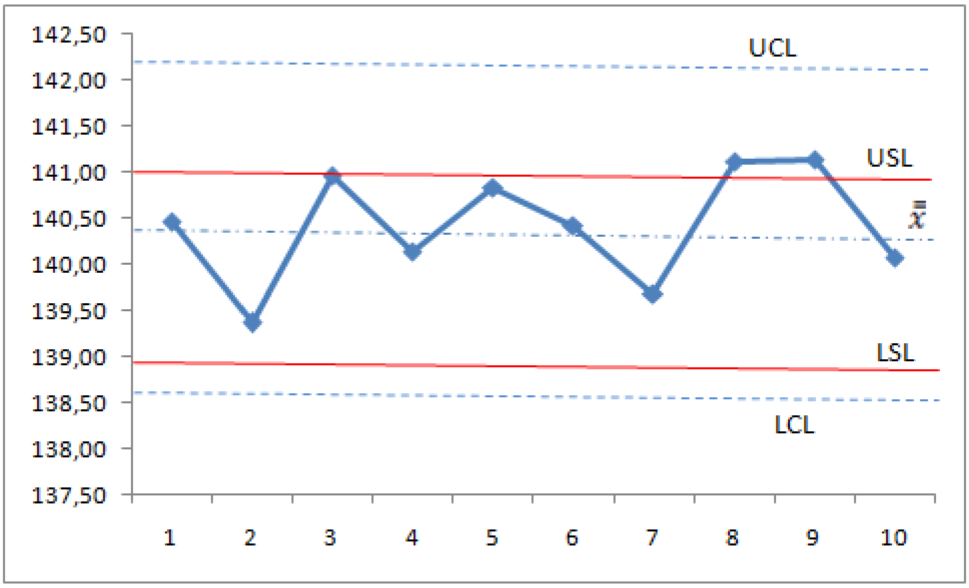

Figure 4. Control chart of the width mentioned in the previous section. Each data is the average of five samples.

Control charts help the operations managers to trace the defects and causes of the defects. They also show trends when a specification goes upwards or downwards in a period of time. It means the specification would exceed upper or lower limits soon. Another utilization of control charts is the visualization –roughly- of the process capability within specification limits.

2.6. Jidoka

Catching defects is critical for especially two reasons: Defects lead to further defects and secondly when defects reach the bottleneck the capacity of the plant is wasted. Finishing plants occasionally experience those.

Toyota Motor Company have introduced a detect-stop-alert system called *jidoka*. The basic steps of jidoka are to: (1) detect the problem, (2) stop the process, (3) restore the process to proper function, (4) investigate the root cause of the problem, and (5) install countermeasures. Each worker at Toyota is empowered to stop the assembly line [6]. This quality tool have still been used in Toyota plants all over the world via an andon cord accompanying the assembly line. When a worker catches a defect, he/she pulls the cord to stop and alert whole plant. Plant stops. Managers, engineers and workers come to the incidence scene –*gemba* in Japanese. The plant would only run after the problem is solved and root causes are eliminated in order not to experience such a defect again.

The system had been developed initially for weaving looms of Toyota before Toyota was a motor company. Weaving machines have still got those lights to alert people when stop due to a defect.

3. Conclusion

There is so fierce competition in textile industry as every business. The one and only way of success is "scientific management" in a highly competitive business world.

This paper shows that a finishing plant can employ practically at least six effective tools in order to serve scientific management and measurable operations instead of rule of thumb. These tools and more tools alike can be applied simply and easily by textile managers. Some of them like control charts and *jidoka* could even be applied by workers. Harmony, cooperation, high efficiency and maximum output would take place by such an operations management.

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