TAKT TIME & LINE BALANCING

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IMPROVE

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**WASTE ELIMINATION**
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Takt Time & Line Balancing

Definition:

**Takt Time** is the rate at which products or services should be produced to meet the rate of customer demand. It is derived from the German word, *Taktzeit*, which is often referred to as the heartbeat or drumbeat of production in Lean Manufacturing.

The value, in conjunction with the current *loading* (production) rates, is used to analyze process loads, bottlenecks, and excess capacity. The study will indicate which operations are ahead of the demand rate and which are not, both can have opportunities for improvement.

Use the Takt Time to compare to the measured "loading" to quantify whether an operation meets the customer demand rate, or exceeds, and by how much.
Takt Time has:

1. **Unit of time in the numerator (seconds, minutes, hours, day) per unit of time**
   - Such as seconds per day, minutes per shift....

2. **Customer Demand in number of pieces per unit of time in the denominator**
   - Such as pieces per day, pieces per shift...

The demand must have the same unit of measure as in the numerator. If the time available is in hours, then the demand must represent the pieces needed in hours.

The answer will be in time/part such as **seconds / piece** or **minutes / unit**.

The takt time represents the customer demand rate based on the **available** time the process has to produce the demand. This has nothing to do with the actual performance of a process. It represents the rate the process needs to perform to keep up with the customer demand rate.
Takt Time & Line Balancing

Formula:

\[
Takt\ Time = \frac{Available\ Time\ per\ Unit\ of\ Time}{Customer\ Demand\ per\ Unit\ of\ Time}
\]

Reminders: The answer will be in a “unit of time / piece”.

*The “Unit of Times” must be the same in the numerator and denominator*
Let’s discuss ‘Available Time’. The available time does not include planned downtime, to the process or machine, such as time planned for:

- Shift Huddles
- Safety Talks
- Breaks
- Lunch
- Meetings

If an 8 hour (480 minutes) consist of 30 total minutes of planned downtime and the machine or process is down during that time, the only 450 minutes are available and use in the numerator.

If the machine is supposed to run during these employee breaks then that time does need to be included. If the process is employee dependent and will be down during these breaks, then the time must be removed (available time should not include downtime).
EXAMPLE:
In one 8 hour shift, there were the following planned breaks and figures:
Shift Safety Huddle: 10 minutes | Break #1: 15 minutes | Lunch: 30 minutes | Break #2: 15 minutes
From analyzing the production sheets filled out by the operator, there was a total of 67 minutes of minor stoppages. The operator scrapped 2,779 pieces out of 86,234 total pieces produced. The ideal speed of the machine is 265 pieces/minute. The customer demand of this unit per shift is 90,000 pieces.

Calculate the Takt Time
Sometimes there is more information that necessary. Sort through the information provided and find the applicable inputs to calculate the Takt Time. We will use the other information to examine the Loading in a later example.
Takt Time = Available Time / Customer Demand Rate
Available Time = (8 hour shift) 480 minutes – 10 – 15 – 30 – 15 = 415 minutes

Takt Time = 415 minutes per shift / 90,000 pieces per shift
Notice that both the numerator and denominator are in the same unit of time – “per shift”

Takt Time = 0.004611 minutes per piece.
Since this is difficult to understand, let’s convert to seconds per piece. 415 minutes = 24,900 seconds

Takt Time = 24,900 seconds per shift / 90,000 pieces per shift = \textbf{0.2767 seconds per piece (or 3.614 pieces per second)}
Line Balancing involves balancing the workload (loading) among the sub-processes of the process where the takt time of each sub-process are met yet without leaving excess capacity (which could lead to one of the 7-Wastes of Waiting).

Most processes to produce a product or service involve sub-processes. Therefore the takt times and loading of each process must be analyzed. Usually the two metrics (Takt Time and Loading) are used in conjunction to analyze bottlenecks, extra capacity, and the degree of the bottleneck or extra capacity. Each metric by itself provides limited information.

The Loading must be calculated in the same units as the Takt Time answer. If the Takt Time was determine in seconds / piece, then the Loading must be calculated in seconds / piece.

The Loading is the actual performance of the machine (or process).
EXAMPLE ONE (same information as in the Takt Time example earlier – Page 1 of 3):
In one 8 hour shift, there were the following planned breaks and figures:
Shift Safety Huddle: 10 minutes | Break #1: 15 minutes | Lunch: 30 minutes | Break #2: 15 minutes
From analyzing the production sheets filled out by the operator, there was a total of 67 minutes of minor stoppages. The operator scrapped 2,779 pieces out of 86,234 total pieces produced. The ideal speed of the machine is 265 pieces/minute. The customer demand of this unit per shift is 90,000 pieces.

Calculate the Load Cycle (or Loading)
Sometimes there is more information that necessary. Again, sort through the information and find the inputs necessary to calculate the Loading of this process.

Recall, the Takt Time from the process earlier was 0.2767 seconds / piece (or the inverse, which says the same thing in a different way, is 3.614 pieces per second)

Loading represents that actual performance of the machine or process making acceptable parts. The information above is a short term sample which may or may not represent that long-term performance. Be careful when using short term samples to perform Takt Time analysis and balancing the workload off a sample that may not represent the long term performance.

Using just the data above, the machine (this process) made 83,455 acceptable pieces in 415 available minutes = 24,900 seconds. This equates to a Loading of 0.2984 seconds / piece.
Now, we have the Takt Time and the Loading performance

- Takt Time is 0.2767 seconds / piece
- Loading is 0.2984 seconds / piece

What does this mean?
The customer demand rate is quicker than the machine is performing. This means that extra time (probably overtime) will be needed, assuming nothing else changes, to meet the customer demand. This process is a bottleneck and constraint.

The Six Sigma team needs to find improvements through elimination of waste, find ways to increase machine speed, free up more available time, or otherwise reduce the loading by at least 0.0217 seconds / piece for the process to be in balance with the customer demand rate (takt time).

Now, this is just one process. This could be one sub-process in a process that have several sub-processes in order to make a final product for the customer. Perhaps there is extra labor from another sub-process that could be shifted to help on this process. Remember, within the 415 available minutes there were 67 minutes of speed losses or minor stoppages. The team should also direct attention for eliminating the 67 minutes of other downtime.
EXAMPLE ONE (same information as in the Takt Time example earlier – Page 3 of 3):

Now, we have the Takt Time and the Loading performance

• Takt Time is 0.2767 seconds / piece
• Loading is 0.2984 seconds / piece

How much downtime needs to be removed for the Loading to at least equal to Takt Time (assume the scrap pieces remains the same, unable to change breaks, huddles, and lunches, and the machine speed itself can not be increased)?

When the machine ran for 348 minutes on the shift, it produces 83,455 acceptable pieces which equals 4 pieces / second or 0.25 seconds / piece.

This is encouraging, because it proves that the machine itself is capable. If the 67 minutes of downtime are eliminated or reduced, the Loading will be lower than the Takt Time and the customer demand will be met!

But exactly how much downtime needs to be removed in order for the Loading to be at or lower than the Takt Time?
About 384 minutes or actual machine run time are needed to begin to beat the Takt Time. That means since, 415 minutes are available, the downtime has to be reduced from 67 minutes per shift to 31 minutes. The Six Sigma team must remove 36 minutes of downtime (in other words add 36 minutes of run time) in order to balance this process with the customer demand rate, Takt time. The Loading will then be 0.2761 seconds / piece which is slightly better (lower) than the Takt Time.
Takt Time & Line Balancing

EXAMPLE ONE - discussion

Caution: Another shortfall is the variance is not considered with Takt Time or Loading. There is variation with customer demand and there is variation with process performance. Both of these can create problems if the inputs are not rationalized with human thinking about the variation from shift to shift, day to day. Level loading is ideal and therefore the data used for the customer demand rate and the loading calculation of the process should be long term representative figures.

Loading usually involves only a measure of central tendency such as the mean, median, or mode. Two processes may have the same measure of central tendency but the processes with low variation will be the easiest to line balance with some degree of success. Balancing a line with processes that have extreme performance variation is not possible in the long term.

Another thing to look for is the scrap (or rework). If there is a lot of scrap, the acceptable pieces value is knocked down thus making it more difficult to achieve the takt time, or even if the process does meet the takt time, it is possible to free up more capacity for new business or to shift tasks to another process to help it achieve its takt time. Excessive scrap is a waste and it creates a lot of problems (from cost of extra raw material, tools, labor, lost capacity, extra machine hours which means more oil, maintenance, etc.) but also represents opportunity to the Six Sigma team to improve.

Every process (or sub-process) has a Takt Time and Loading value. Use both values of each process to look for bottlenecks or excess capacity. The team should begin with the biggest constraints. Some improvements will likely help all processes.
EXAMPLE TWO – Multiple sub-processes in one process (Page 1 of 5)

Most often there are several steps (sub-processes) into making a final product. Let’s say the Six Sigma Black Belt has compiled the following data for a five step process involved in making a complete unit. Each of the five sub-processes has 22.5 hours of available time per day to produce 55,000 pieces needed per day.

The Takt Time of each process = 1.473 seconds / unit
The Loading of each process is shown at the bottom

Which sub-processes are meeting and which are not meeting the customer demand rate, Takt Time? Like with most groups of data it can be easier to illustrate the situation with graphs or visual management techniques.
The data from the previous slide is charted below. Be improved to absorb some of the workload.

**Process 1:** Taking much longer than Takt time. Overtime is probably used to make up production and is the #1 constraint.

**Process 2:** Exceeding the Takt time, probably a lot of waiting and the excess capacity can be filled by absorbing some of the work from Process 1 and/or Process 4.

**Process 3 & 5:** Very close to meeting Takt time, not a focus area but possibly some best practices and application of LEAN tools can improve these loading rates. Improvement in these areas could be used to share workload from constraint processes.

**Process 4:** Taking longer than Takt time. Again, overtime is probably used or there are late deliveries, high expediting costs, and unhappy customers. Apply Lean Manufacturing principles and try to alleviate workload to Process 2 or others that may be able to

Processes 1 and 4 are the priorities – these are constraints (bottlenecks) that are most likely impacting the customer.
EXAMPLE TWO – Multiple sub-processes in one process (Page 3of 5)

Examine all the specific activities occurring in each process. Time studies, motion studies, spaghetti diagrams and other Lean tools often provide most the ideas for improvement.

Develop a plan for immediate, low-cost improvements. Ideas like professional signage, advanced comprehensive training and capital investments are not needed yet. They can be put on the long-term action register of improvements.

Run studies to determine the potential LOADING improvements. There is most likely not much that can be done to change the Takt time; focus on improving the LOADING (production rate).

Improving the LOADING, even in non-constraint operations is desirable, but the top priority is relieving constraint operations.
EXAMPLE TWO – Multiple sub-processes in one process (Page 4 of 5)

**Improvements**

• Visual Management tools were added to reduce complexity and improve consistency of units produced.
• Standard Operating Procedures (SOP’s) and training were done for all operators.
• SMED activity was done on all operations with focus on Process 1.
• Point-of-use tooling and shadow boards were created by the operators.
• Kanban bins with mins/maxs were established for materials.
• Some steps in each process were eliminated as former paradigms and rules were challenged.
• The machines in a couple operations received upgrades and overdue minor rebuild and were added to a TPM program. The speeds were dramatically improved (the "performance" component of OEE).
• Error-proof jig to prevent defects and rework was implemented.
• And/on lights were added as communication signals.
• 5S event held with key stakeholders.
EXAMPLE TWO – Multiple sub-processes in one process (Page 5 of 5)

After the improvements were made the new Loading calculations were done for each process. There were gains...and the success was to the point where there was excess capacity. All the activities could now be completed in four processes. Floor space was gained and excess older and fully depreciated equipment were sold for cash. A new loading study was done and the results are shown below.

Recall, the goal of Line Balancing is to have the loading rates meet the Takt time and this is accomplished as the chart indicates.
Bottlenecks
Bottleneck operations are *constraints*. These are operations or processes where the:

\[
\text{Loading} > \text{Takt Time}
\]

Usually operators and those closest to the process already know which operations have capacity and which are the constraints but it is not known to what degree and amount compared to the other processes. The numerical analysis of both allows those to see the extent of the bottleneck, or the extent of the extra capacity and compare it to other processes. This allows the team to prioritize the improvements.

In order to consistently meet the delivery demands of the customer each bottleneck will need to be resolved so the loading is faster than the Takt time.
**But where do you focus your efforts first?**

The study will only provide numbers. As a Six Sigma Project Manager you can only present the numbers but also offer up what is NOT in the numbers that could shift priorities. Ask “What is affecting the customer the most”. Usually, this answer resides in the bottlenecks (constraints)....those are priority.

A small constraint in one area due to high scrap or the root cause of customer complaints may be much costlier overall than a larger time constraint in another area.

These numbers along with reasoning on costs, scrap, and other subjective measures are for the team to determine the priorities for the improvements. This is why a Finance professional and key stakeholders must contribute to the team.

The goal is to get the entire line balanced after removing waste. Waste reduction (rework, scrap, over production, and other 7-Wastes) should be targeted aggressively and then a loading study should be done prior to significant investments into line balancing.
Takt Time Calculator – click here to find Templates and Calculators, including an Takt Time calculator. An example is also included with the template to help illustrate the proper way to use the calculator.

### PROCESS 1

**Available Work Time**
Assume the process is scheduled to run 24 hrs/day on 3 shifts.

The Total Time Available
- 24 HRS/DAY
- 1440 MINUTES/DAY
- 86,400 SECONDS/DAY

Assume each shift gets a 20 minute break
- 1 HR OF BREAKS/DAY
- 60 MINUTES OF BREAKS/DAY

**Subtract** 1,600 SECONDS OF BREAKS/DAY

Assume there is a Mandatory Production/Quality/EHS Review at the start of each shift that last 10 minutes.
- 0.5 HRS / DAY MEETINGS
- 30 MINUTES / DAY MEETINGS

**Subtract** 1,800 SECONDS / DAY MEETINGS

**Available Work Time / Day** = 86,400 - 3,600 - 1,800 = 81,000 SEC / DAY

**Customer Demand Rate**
Historical demand (or a forecast, or provided amount from customer)
The daily demand
- 275,000 PARTS/WEEK
- 5 DAYS/WK SCHEDULED TO WORK

**Demand Rate**
- 55,000 PARTS / DAY
- (275,000/5)

**Takt Time for PROCESS 1**

\[
\text{Available Work Time / Customer Demand Rate} = \frac{81,000 \text{ SEC/DAY}}{55,000 \text{ PARTS/DAY}}
\]

**Takt Time equals** 1.473 SECONDS / PART

Note: The numerator and denominator have same rate unit (DAY). It does not have to be “per day” but the time units must match so they cancel out in the takt time calculation.