

HOW TO IMPROVE PRODUCTIVITY BY 160%

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Abstract: There is a large capacity increase potential in Swedish industry through increasing productivity of existing resources without investing in more machines or personnel. This article presents a case study where the capacity could increase more than 160% percent. This was proven by a test in running production. This tremendous increase was made possible through standardization and time setting of all work tasks. A new scheduling system was made up of product activity sequences based on a vast library of over 800 standardized generic activities.

Keywords: Standardization, Planning, Capacity, Productivity

1. INTRODUCTION

On previous SPS conferences have results from the PPA (Productivity Potential Assessment) studies been presented (Almström and Kinnander, 2008 and 2009). It has been established that the average OEE (Overall Equipment Effectiveness) (Nakajima, 1994) of Swedish manufacturing companies is around 60%. Given that the best companies have an OEE of over 90%, we can draw the conclusion that the average productivity increase potential is about 50% $((90-60)/60 = 50\%)$. To increase OEE to that level is of course very demanding, but several important factors have been highlighted. The direct causes for low OEE are breakdowns, setups, ramp up, scrap rate etc. These causes in turn depend on different issues and one very important issue is the operator work.

The PPA studies have further shown that the competence and interest in studying manual work is very low. Managers argue that the machines are creating value and the operators are only there to keep the machines running and therefore are not relevant to study, nothing could be more wrong when in fact the operators' actions or lack of actions creates low OEE. The problem is not the operators, it is the managers that don't realize the importance of this question for realizing the productivity potential into real productivity increase that in turn can be harvested as either lower costs or higher capacities.

Operators affect losses in many different ways, for example an operator is needed for handling disturbances, the operator performs the setup work and the machine might be waiting while the operator attends another machine. Therefore it should be very important for the companies to study the operators' work and try to improve to, in turn, improve OEE and the real capacity of the production.

2. FRAME OF REFERENCE

Commonly, production capacity is increased by investing in new resources, for example new or improved machines or hiring additional operators. But capacity can also be increased with only the available resources. If that is going to happen the productivity must increase.

Real capacity and ideal capacity are depicted in figure 1 (Sundkvist, 2014). The ideal capacity (for a sub-system and a specific product) is determined by the intended or designed method (M). The work standards are increased

in increments through improvements of existing methods and equipment or investments in new equipment and machines. To get a high real capacity (i.e. to get it close to the ideal capacity) the Performance (P) and Utilization (U) need to improve. The performance (P) is determined by the speed that the standard is carried out at and is typically decreased after radical method improvements (figure 1). The utilization (U) represent how large part of the planned production time that is spent on the intended method and is affected by disturbances and other losses (Table 1).

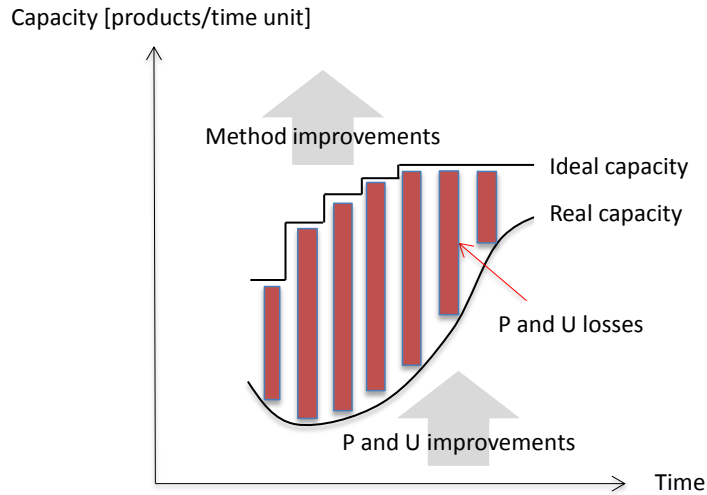


Fig. 1. Ideal capacity and Real capacity (based on Sundkvist, 2014).

The P and U are broken down into sub-categories to more clearly define what factors that influence the parameters and how to measure them (Table 1). The relation between productivity increase and the factors are given by Equation 1. The M factor is measured as the inverse of the ideal (designed) cycle time for a specific activity. The P and U factor are expressed as percent.

$$\text{Productivity} = M \times P \times U \quad (1)$$

The purpose of this article is to present facts that support the MPU model for productivity and capacity increase and to show the benefit of standardizing operator work for long cycle work tasks.

Table 1. Productivity factors (Almström, 2013).

	Variable	Definition
P	Personal performance rate (P_P)	The personal performance rate is affected by the individual's physical ability and his or her motivation to work at a high speed (relative the MTM norm), independent of work task.
	Skill based performance rate (P_S)	The skill based performance rate is the individual's speed at performing a specific work task depending on the training and the experience the individual has for the task.
U	Need based utilization rate (U_N)	The need based utilization rate depends on the need for relaxation and personal time. It is often regulated by agreements at the work place. It includes paid breaks and losses before and after a break.
	System design utilization rate (U_S)	The system design utilization rate is defined as the balance losses designed into the system. It can be balance losses on an assembly line as well as losses in a semi-automated work station.
	Disturbance affected utilization rate (U_D)	Disturbance affected utilization rate corresponds to the losses caused by different random disturbances. It includes the lost time from discovery of the disturbance until the work is performed at full speed again.

To be able to define the M factor there must be a work standard and that standard need to have a set time. There are several motivations for having timed work standards. Improvements made without any standard stated will not work, because it is impossible to say if the randomness from the unstandardized work was improved or if just another way of performing a specific task was added (Liker and Meier, 2006). Further, without a standardized work method it is hard to make an accurate schedule (Bishop, 2001). Standardized work methods are not only beneficial for the management in a company. If the measurement of the standardized work task is properly

performed it will be beneficial for the employees as well, because the expectations from the company will be clearly stated (Bishop, 2001).

When developing standard times it is vital to consider the cycle time for the operation that is to be standardized. Depending on the length of the cycle time there are different measurement approaches which are suitable to use (Smith, 2001). Smith divides work into short, medium and long cycle times. Short cycle times are defined as up to 20 seconds long and highly repetitive and often performed in a limited area with most of the required equipment within arm's reach. Medium cycle times are in the range of 20 seconds to 20 minutes and can involve several work stations and may or may not involve repetitive work tasks. Long cycle times are in the range of 20 minutes to 1000 hours or more and often contain long distances between different work areas (Smith, 2001).

Work within the range of short cycle times are preferably measured with direct measurements. Direct measurements implies that the measured time for a certain action is only used for that specific action and are not to be reused in any other operation. For work classified as medium cycles, standard data is a suitable method to use. Standard data elements are composed by well-defined sub-activities, which should be adjusted to the specific work task regarding size, content and number of sub-activities used (Smith (2001)). According to Connors (2001) standard data sub-activities can exist in different levels where in the lowest level a sub-activity typically is represented by a few fundamental motions performed by a human. Each sub-activity represents a standard time, which either could be measured with a measurement tool or stated by a predetermined time system (PTS) (Connors (2001)). Work belonging to the longest cycle time category has a third approach when it comes to stating standard times. For this kind of work a PTS is a suitable tool to use (Smith (2001)).

3. THE CASE

The facts are collected from a case that was carried out as a master thesis project and took place at a manufacturing company in the chemical business. The factory had around 150 employees and was a part of a large international group. Even though chemicals are produced, they were made in batches and the final products were sold as discrete products in jars. The raw material was received as liquids or powders. The bulk fluid was added by hoses from large tanks, but all other ingredients were added by hand from bags or bins. Each product was described by a recipe where the chemicals were specified and a work procedure was described.

The factory and the selected work area had very large improvement potentials. The machine utilization was very low due to several factors: lack of planning, high variations, quality issues etc. There were no established standard times for activities or lead times for batches. And as an effect of that there were no possibilities to make schedules for balancing machines and operators. The operators were given a weekly batch plan based on experience of the capacity, and then it was up to the operators to plan their time and try to utilize the machines as much as possible. Each batch took several hours to produce, and the manual time was typically around an hour, but differed a lot between products. The company, its products and the present production system is presented more thoroughly in the master thesis (Hansson and Samuelsson, 2014).

Hansson and Samuelsson had first-hand experience from the production, since they had been working at the department during previous summer. The thesis subject was their proposal and the management at the company supported the project. The fellow operators were also willing to cooperate to improve the production; they were as frustrated as the management by the lack of plans and standards. Since the problem at large was known a priori, there was no need to make a comprehensive pre-study. The initial question that the managers wanted to get an answer to was: "How long is the ideal leadtime for a batch?" A consequence of that question is obviously to compare the ideal lead time for a batch or the ideal capacity with the real capacity and try to find means to close the gap by improving P and U (Figure 1). Because of the lack of standards and a lot of small improvement potentials in the present way of working, there were no point of calculating an M factor for the present state.

4. STANDARDIZATION

The first task was to set standards for all activities including a time down to fractions of seconds. This was made using movie technique and the software AviX. AviX was used to identify activities and order them in hierarchies. The PTS MTM-SAM (MTM, 2004) was used for setting synthetic times for all suitable activities. Times for activities depending on machines or materials were set using an average of several stopwatch studies. Machine times were also standardized by introducing measures to make the quality outcome reliable and predictable. All-in-all over 800 activities were identified and timed. Some examples of activities are given in table 2 to give the reader a notion of the level of detail in activity descriptions and times.

Table 2. Examples of standard activities with standard times.

Charge one powder bag (PX1, 15Kg, DS7)	36.2 s
Fetch plastic bag and mount it next to DS17	0.9 s
Take out plastic bag from storage	0.9 s
Grab handlebar and start driving	2.0 s
Prepare powder charging at DS17	67.7 s
Fix pan under DS4 2nd time	70.4 s
Remove lid off pan at liquid pre-batching and stash it then return to pan (or vice versa)	7.4 s
Place container above pan and ready for charging	9.4 s
Place/fetch tool within reach	0.9 s
Prepare charging of drum with forklift	77.0 s
Reattach bucket lid onto bucket	16.9 s
Open bucket lid with tool	30.5 s

5. NEW SCHEDULING SYSTEM

The old scheduling system was not a “system” it was more of a guideline for the products that needed to be produced for the coming week (Figure 2). All products were ordered according to forecasts and stock levels. The operators had freedom to produce the batches in an order of their choice. Rework was very common due to lack of standardization and variation in incoming materials. The rework was not scheduled.

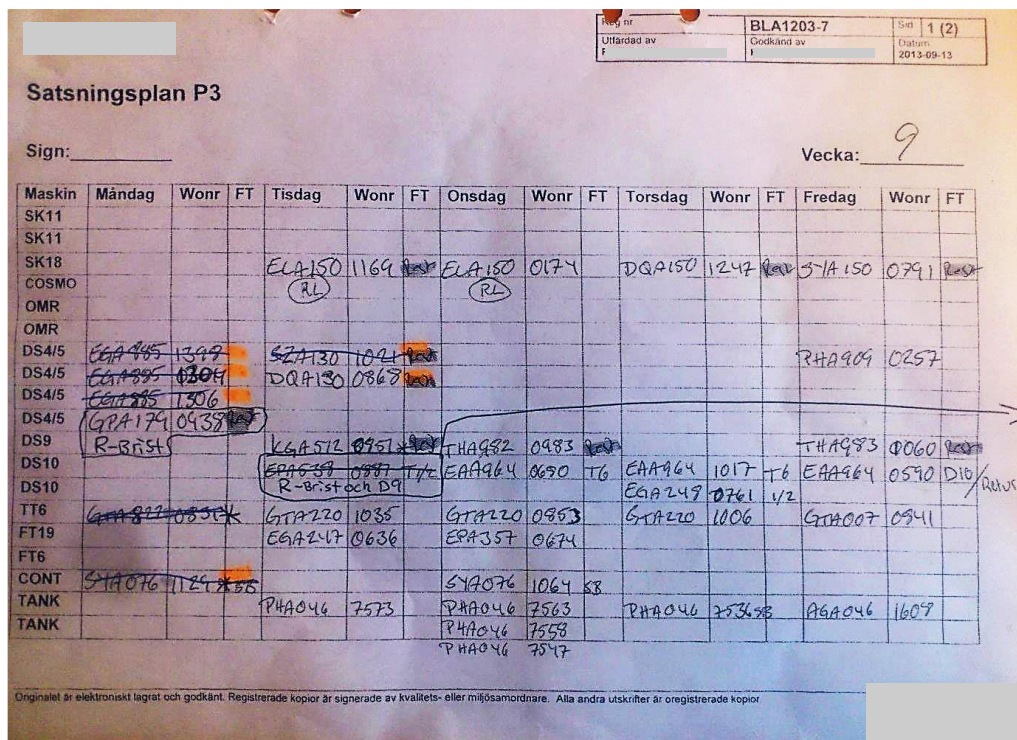


Fig. 2. An example of the old production schedule for a week.

The standard times were put in a library in AviX and then were 61 products, representing over 94% of the production for the previous 4 years, prepared by combining activities from the library based on the recipe for each specific product. These product specific combinations of activities were represented as staple bars (Figure 3). The colours coding was:

- Green: Machine time (the machine is running)

- Yellow: Operator time while the machine is running
- Red: Operator time while the machine is waiting
- Blue: Machine time in an additional process step (bead mill)

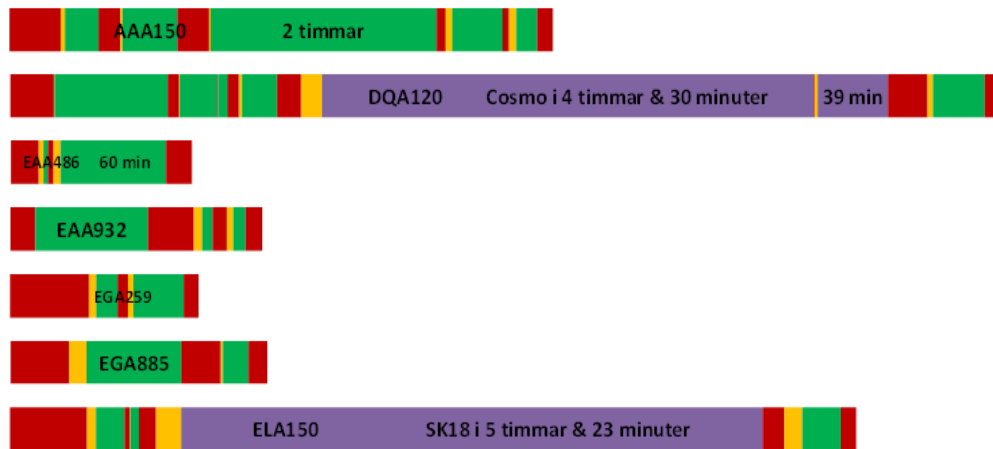


Fig. 3. Scheduling bars for a sample of products.

The new scheduling system is a variety of the classical load chart schedule or man-machine balance chart (Zandin, 2001). The times from Avix were imported via Microsoft Excel to Microsoft Visio. Visio facilitated arrangement of the bars on a weekly schedule graphically by splitting and moving the building blocks that build up the bars. A set of scheduling rules were created to constrain the arrangement of tasks. The rules are for example that preparation work (yellow) shall be made directly after finish of work while the machine has stood still. Rules for breaks were also included, paid breaks were only to be taken while the machine is running but within a specific time interval of the day. Buffer times and general preparation times were also included.

6. RESULTS

It was decided to run a live test in running production during week 7 2014. The weekly schedule was established in cooperation with the concerned production personnel and the result can be seen in Figure 4. The charging schedule is distributed over two days with two shifts at each day and one operator charging at each shift at two machines (D55 and D54 in figure 4). About two hours at the end of each day was left as buffer in case of any unforeseen disturbances.



Fig. 4. New schedule for two days in two machines manned by one operator.

The live test conducted during week seven indicates several positive things and supports the reliability of the calculated lead times. Looking at Table 3 it is clear that most of the calculated lead times are close to the measured values collected during the test. The deviations from the calculated lead times can be linked to the overall measured disturbance during the test period. The disturbances were measured through continuous observation and separate clocking during the live test. In the end of the first test day the charging plan was delayed with 57 minutes, which is close to the measured disturbance time of 54 minutes and 7 seconds. The difference between the actual delay and the measured one could be explained by the difficulty of capturing all small disturbances. Two of the measured lead times ended up being shorter than the calculated lead times and these are noted with a negative difference in Table 3. The reason for them being shorter is probably due to decreased amount of set-up time when charging

three EGA885 after each other (only the first batch requires set-up) in combination with the fact that there were only minor disturbances during that time.

Table 3. Outcome of the test.

Day	Product	Measured lead time [min]	Calculated lead time [min]	Difference [min]
Monday	SYA120	325	322	3
	EGA885	140	136	4
	EGA885	154	136	18
	EGA885	133	136	-3
	SZB000	307	299	8
Tuesday	HAB000	233	215	18
	HAJ019	Not finished	233	Not measured
	HAJ019	Not started	233	Not measured
	EGA885	142	136	6
	EGA885	130	136	-6
	EGA885	223	136	87

The trial was a success and a full week's production could in fact be run on only two days. This represents a productivity increase of over 160%. Calculations and schedules were made for two more weeks that were considered to represent "normal" production weeks for the factory: Week 46 and week 9. The calculated lead times for these are presented in Table 4 together with a predicted capacity increase. The average capacity increase for these three weeks was 123.33%.

Table 4. Capacity increase calculation for three weeks.

Week	Number of products	Needed time present state [min]	Needed time future state [min]	Capacity increase [%]
46	10	2325	1295	80
7	11	4650	1750	166
9	6	3487.5	1555	124
Average	9	3487.5	1533.33	123.33

The largest contributing factor of this amazing productivity increase is certainly the method improvements and the standardization that has led to a much higher utilization of the machines. Table 5 summarizes the effects achieved on the different P and U factors.

Table 5. Productivity factors improvements.

	Variable	Effect
P	Personal performance rate (P_P)	Increased awareness of the expectation of what was expected from them during a day's work was achieved. The operator probably worked around 100% MTM speed before the changes, but the new standards stresses the need of keeping an even pace when work is scheduled.
	Skill based performance rate (P_S)	The workers were experienced and skilled and the new work procedures introduced in the project did not require new skills, so this factor did probably not change.
U	Need based utilization rate (U_N)	The new schedules made it clear when there were suitable times to take breaks and also that it was ok to take break.
	System design utilization rate (U_S)	Since the system more or less lacked a design previously, it was impossible to determine the U_S . With the new system the U_S is determined for both the operators and the machines when the products are scheduled.
	Disturbance affected utilization rate (U_D)	The disturbances have decreased a lot, how much can't be determined since there were no measurements before.

7. CONCLUSIONS

Conclusions from this case can be drawn on three levels: For the company, for the validation of the productivity model, and for the manufacturing industry in general.

1. For the company has the project meant a totally new way of working and the prospect of becoming much more profitable. The company was already profitable, but had trouble to deliver the requested capacity. The selected department is a quite small part of the whole factory, but it was a bottle-neck for the particular product family. A capacity increase of over 160% one week and an average estimate of over 120% over a longer period with no investments in any new production equipment or resources is a tremendous result.
2. A theory about real world phenomena can never be proven, but empirical evidence can be presented to strengthen it or discard it. This case has provided very strong empirical facts to support the productivity model and the capacity model suggested by Sundkvist (2014). It has further shown that it is possible to increase productivity drastically without investments. The experience from the PPA studies tell that this particular company is not a special case, these large potentials are found in a very large portion of the studied companies.
3. The study has shown that it is possible to standardize long-cyclic manual work where the product variation is large. This is achieved by the realization that all the work carried out can be broken down in to smaller generic activities that can be combined to activity sequences for specific products that very well can be unique. This insight has potentially a tremendous impact, since standardization of manual work tasks for medium to long-cycle work is virtually non-existing in industry and a large portion of the assembly work carried out in the Swedish manufacturing industry is of this kind.

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