Analysing changeability and time parameters due to levels of Automation in an assembly system

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Abstract

Products of today are becoming increasingly customized. Smaller batches in the assembly and decreasing time limits for set-ups between products are some of the resulting demands on the assembly systems, due to the increasing number of variants in the assembly flow. Consequently, assembly systems have to become more flexible and efficient. When companies adopt automated solutions, there is a need to determine the correct amount of automation. It is also necessary to identify the optimal parts of the value-flow to be automated. In automation decisions it is necessary to consider human resources, as well as mechanical technology and information flow. The paper will discuss the importance of measuring different time parameters in an assembly system. Furthermore an analysis of the ability to change level of automation in an assembly system will be discussed based on theory and a case study example

1. Introduction

Products of today become more and more customised and the demand on decreasing the lead-time to the customer. This sets high demands on the company and the assembly system. Consequently, assembly systems have to be able to getting the right things, to the right place, at the right time, in the right quantity to achieve perfect work flow while minimizing waste and being flexible and able to change [1]. Companies rapidly try to adopt the philosophy and tools of lean production. Lean tools have a clear positive influence on the material flow in terms of, e.g., lead-time, work in progress and visibility [2]. This paper brings up some of the lean tools related to time parameters to be able to reduce the throughput time in the assembly system.

Companies also adopt automated solutions, when doing this there is a need to determine the correct amount of automation. By definition, automation is a technology by which a process or procedure is accomplished without human assistance [3]. Unfortunately, automation not always fully fulfilling expectations, the need for human intervention in cases of disturbances and system failures is still high. Smart automation is defined by [4] as the human aspect of 'autonomation' whereby automation is achieved with a human touch. The implementation of the lean philosophies based on time parameters and choosing optimal automation level could result in competitive benefits for the companies such as;

- ***Flexibility*** - the ability to adapt to the changes, i.e. volume, routing, capacity and mix/product- flexibility [9-13].
- ***Proactivity*** - the ability to transform unplanned changes to planned without losses in effectiveness and profitability [14, 15].
- ***Efficiency*** - could assembly right products in the right way at the right time [1, 4].

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2. BACKGROUND

This paper will bring up three important parameters or factors that make companies more flexible, have the ability to act proactive and become more efficient;

- To analyse and change levels of automation in real time and over time
- Time parameters – measurable values in an assembly system.
- Lean tools connected to time parameters

2.1. LEVELS OF AUTOMATION

The concept Levels of automation was developed in the DYNAMO project (2004-2007) [6] in association with five companies. The aim with this project was to develop a methodology for measuring and get an accurate picture of today's information flow and automation level in production systems. Furthermore to develop a reference scale for different Levels of Automation (LoA) that could be used in the manufacturing area [7], this is shown in table 1.

Table I Levels of Automation

Levels	Mechanical	Information
1	Totally manual	Totally manual
2	Static Hand tool	Decision giving
3	Flexible hand tool	Teaching
4	Automatic hand tool	Questioning
5	Static work station	Supervising
6	Flexible workstation	Interventional
7	Totally automatic	Totally automatic

Due to [8] the conclusion is that most tasks in manufacturing often involves a mix of both mechanised and computerised tasks and the companies has to consider both areas when automating their system. The methodology is an eight step mapping of today's automation level [16]. In order to analyse and optimise the future assembly system a development of the analysis step was done. The result were a matrix called LoA_{total} [8]. This matrix is based on a seven grade reference scale [7], seen in table 1.

The matrix was developed to be able to visualise and analyse not only the levels of automation but also measurable parameters. This paper focus on the relation between LoA and the time parameters. The matrix in figure 1 illustrates the dimensions LoA and time.

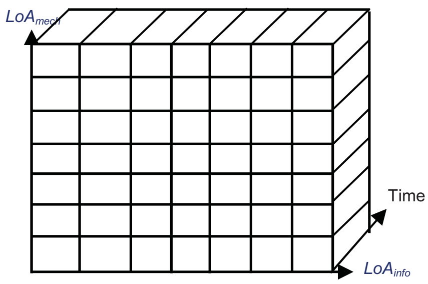


Figure 1 The Loa and Time matrix

Each square in the matrix represent one possible solution, the time parameters changes depending on the choice of mechanical and cognitive tools for the operator, assumptions about this is discussed in section 3.1.

2.2. *LEAN VERSUS TIME*

There are a lot of different time parameters that could be measured in a system. Due to [2] there are JIT tools that could be connected to different time parameters in a system, seen in figure 2. This is the second set of tools to be implemented. The order of implementation is read from top to bottom.

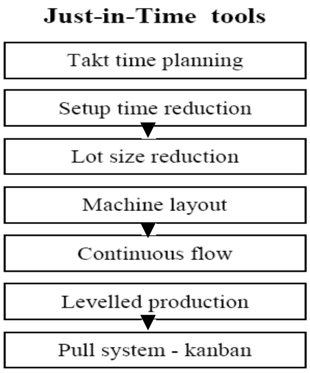


Figure 2 JIT tools and principles

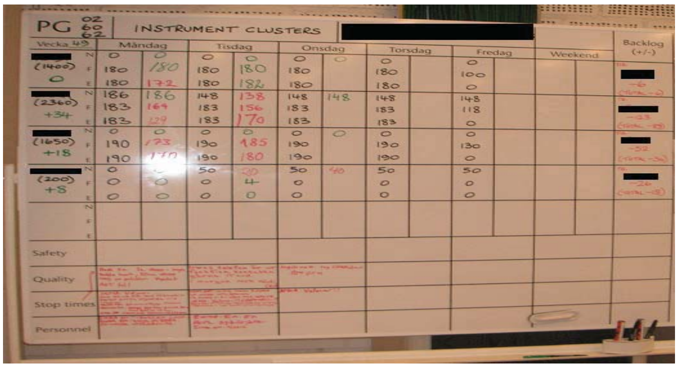


Figure 3 Visualisation of the production

Tact time planning – The takt time is the desired heartbeat of a process, which connects the demand from the customer with the production. Expressed as "seconds per piece", takt time is indicating that customers are buying a product once every so many seconds. To be able to achieve this it is importance to know, e.g., cycle time (C/T) for the different operations or tasks and sale-prognoses.

If you work faster this will lead to over production. If you work slower it could create bottlenecks [1].

Set-up time reduction – Set-up time is especially important to reduce in bottleneck resources, an overall throughput is gained. A method called SMED (Single Minute Exchange to Die) was formalised by Shigo in 1981[17]. An importance aspect of SMED is to convert internal to external Set-up time, or eliminate the need for resetting. The external resetting could be done without any loss in the machine operation time; the internal exchange could not be done while the machine is running.

An other important tool is visualise the production [1] – An example of this is to have tables as shown in figure 3 to show the production needed to be assembled in one day, the tact time. On this board the stop times is also noticed (the availability (A) could be counted from this data).

Table 2 shows the different time parameters that will be discussed in the next section. The two first columns are used if the production is a one-piece-flow and the third is used for batch assembling.

Table 2 Time parameters

Measure values	**Definition [18] – Tact line**	**Definition [19] – Tact line, one-piece flow**	**Explanation – Assembly system, batch assembly**
Cycle time **(C/T)**	The time it takes to get a product finished in a process and the time it takes for the operator to finish all of his/hers working moments	The cycle time could be described as $t_0= t_m+t_h +t_{vb}+t_{no}$ ***Where*** t_0 – Cycle time; t_{no} – waste t_m – Machine time or time to perform a task t_h – Handling time; changing pallets, products t_{vb} – Changing tools inside the machine	Cycle time $t_{C/T}=(t_m+t_{no})*n$ ***Where*** t_m – Machine time, or time to perform a task t_{no} – waste n – batch-size
Set-up time **(S/T)**	The time it takes to change the equipment between different product variants		$t_{S/T}=(t_h +t_{vb}+t_{no})/n$ ***Where*** t_{vb} – Internal exchange; t_h -External exchange n – batch-size
Internal **Lead time** **(L/T)**	The time it takes to get a product through a process or the whole value flow.	Internal lead-time for one product in a tact line, tLT; LT= (tt+0max) ***Where*** ttt -The transport time between stations t0max - The production time for the station with the longest cycle time ; n – Number of stations	$t_{Throughput-time} = \sum_{t=1}^{N} t_{C/T} + \sum_{t=1}^{N} t_{S/T} + \sum_{t=1}^{Nn-1} t_t$ ***Where*** N – Number of stations; t_t= Transport time $t_{C/T}$= Cycle time ; $t_{S/T}$= Set-up time
Availability		$A := \frac{MTBF}{MWT + MTTR + MTBF}$ ***Where*** MTBF= Mean time between failure MTTR – Mean Time To Repair MWT = Mean waiting time	$A := \frac{MTBF}{MWT + MTTR + MTBF}$

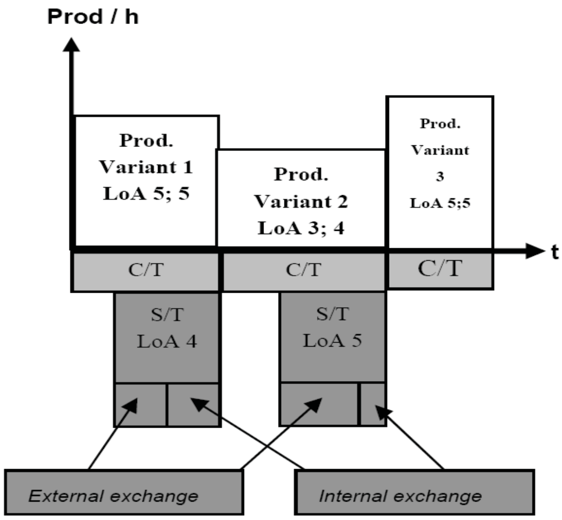
3. Discussion

This section will illustrate two examples; one theoretical and one case study example to show the relations between time parameters and levels of automation. The theoretical example will bring up two different scenarios. These scenarios will show the relation between the different time parameters and changeability of levels of automation.

Scenario 1

This is an example of minimising the internal activities in the set-up time between two products within the same operation, illustrated in figure 4a.

If the C/T for product variant 1 > S/T for product variant 2, the operator could do the set up while the first machine is assembling. This saves time and the productivity increases. The planning for these three variants is very important. If the operator chooses to load variant 3 first or assemble it directly after variant 1 the time saving is = 0.



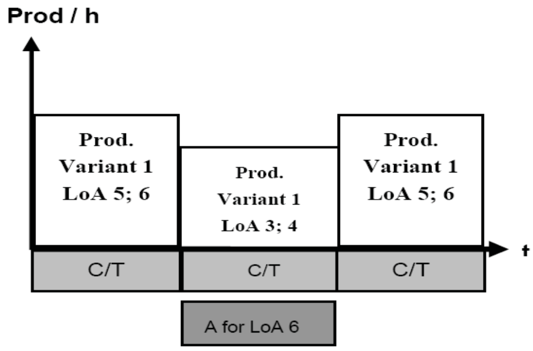


Figure 4a Scenario 1; Changeability in LoA and products vs. Set-up time, 4b, Scenario 2; Changeability in LoA vs. Availability (A)

Scenario 2

Scenarios 2 illustrate routing and process flexibility i.e. is able to change the technical LoA if the main resource does not work. One product, ability to use to two different machines (varying LoA), see figure 4b. If the robot cell (Loa 6) breaks down the ability to reroute the assembling to a static work station (LoA 4) increase the loos of products do to the breakdown. The two scenarios have shown that there are a relation between different time parameters and changing levels of automation. Furthermore there are relations between the different automation solutions chosen for the operations or tasks.

A result of the two scenarios is 4 assumptions about Levels of automation versus time parameters;

Assumption 1: The set-up time increases when increasing LoA.

Internal activities →0 when LoA→ 1 (Machine dependent)

Assumption 2: The cycle time changes when changing Levels of automation. The cycle time decrease when increasing LoA.

Assumption 3: The Availability (A) time increases when increasing LoA.

A →0 when LoA→ 1 (Machine dependent)

Assumption 4: The changeable of levels of automation is affecting four time parameters;

$$\mathbf{LoA} = f\,(\mathbf{T_{C/T}}, \mathbf{A}, \mathbf{T_{S/T}}, \mathbf{T_{L/T}})$$

The case study example is a practical illustration of scenario 2.

A case study was performed at company A. The steps 1-9 in the DYNAMO methodology were used to evaluate what Square of Possible Improvements (SoPI) the company thought that they could move within in future assembly systems, but also to see what kind of assembly system they had today.

The example is taken from the station that assembly pointer in instrument clusters. The operation description is shown in table 3. There are four different tasks that are performed and could be done either at a static work station or in a robot cell.

Table 3 Operation and task description for Op. 1.6

Task	Description	LoA Manual	LoA Robot cell	$\mathbf{SoPI_{task}}$
1.6	Pointer insertion			
1.6.1	Place in fixture/on pallet	(3;3)	(3;3)	(1-6;1-6)
1.6.2	Place pointers on engines	(3;3)	(5;6)	(1-6;3-7)
1.6.3	Press pointers	(3;5)	(5;6)	(1-6;3-7)
1.6.4	Analyse the press result	(3;3)	(5;6)	(1-6;3-7)
	$\mathbf{SoPI_{operation}}$			**(1-6:3-6)**

After the measurements were done the workshop was carried out. The result of this work shop was the $SoPI_{task}$, which is shown in column 5, table 2. The result of analysing possible $SoPI_{operation}$ is shown in table 2. The results was also visualised as seen in figure 3.

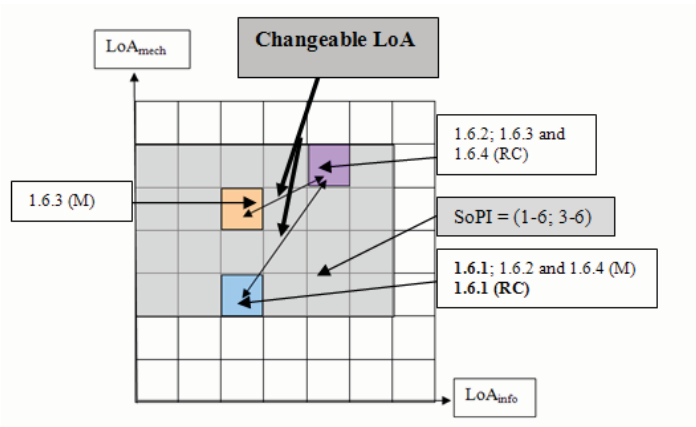


Figure 5 SoPI analysis for Op. 1.6 Pointer insertion

Figure 6 illustrate the possibility to change LoA in operations 1.6.1-1.6.4, in real time

But why does the company want to change LoA?

The reason is to increase the flexibility in the system. By flexibility the company means reroute the products if the robot cell is down, increase the capacity and volume in the system, if needed.

Due to assumptions from [13], to be able to achieve these types of flexibilities the system should have variable LoA within the boundaries; $SoPI_{Process/Product}$ = (3-6; 2-6), $SoPI_{Routing}$ = (3-6; 2-6), $SoPI_{Capacity/recourse}$ = (3-6; 2-6), see Figure 6.

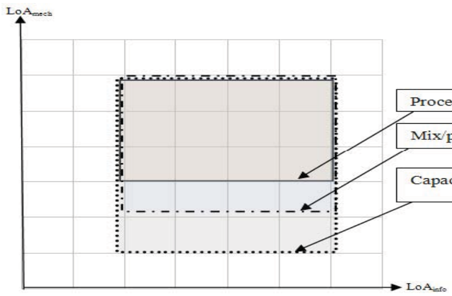


Figure 6 SoPi for different types of flexibilities

In operation 1.6 the ability to change between a robot cell and the static work station lays within the squares of flexibility in all the operations, see table 2. Due to this analyse of the case study example, we assume that this is a flexible system when it comes to routing, capacity and volume. One example to demonstrate the routing flexibility is illustrated in figure 7.

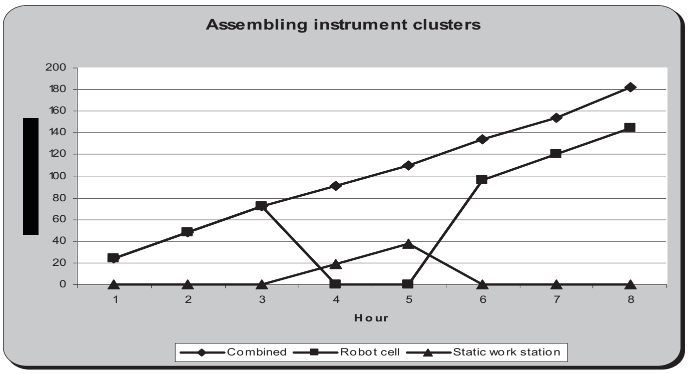


Figure 7 Number of products assembled

The robot cell is used as the main machine in the system. The productivity for one normal day is 24 products/hour→ 192 products/per shift. Assume that a breakdown for two hours is happened on the robot cell, without the routing flexibility the loss will be 24 parts/hour = 48 products. With the routing flexibility the company is able to use the static work station under the reparation producing 18 products/hour → a loss of 5 products/hour = 10 products.

4. CONCLUSIONS

This paper has shown the importance of lean awareness for the companies in terms of implementation the philosophies and its tools connected to time parameters (JIT tools). Furthermore it has been made known that companies could have competitive benefits if adopting the right level of automation due to flexibility and time parameters. Levels of automation are affecting four time parameters, this could be written as;

$$\boxed{\mathbf{LoA} = f\,(\mathbf{T_{C/T}}, \mathbf{A}, \mathbf{T_{S/T}}, \mathbf{T_{L/T}})}$$

The future research will be to validate the assumptions with help of more case studies. Deeper knowledge will be used to improve modelling and simulation tools for different levels of automation; this is a part of the research project SIMTER. Future research aims at simulating and visualising assembly systems with varying LoA in the system's stations and tasks. Improvement of flexibility and the flow- and time parameters will be measured; this will be done to be able to develop a proactive assembly system in the project ProAct.

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