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ANALYSIS OF TIME FLUCTUATION ON SELECTED WORKPLACE IN TERMS OF AUTOMOTIVE INDUSTRY

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Abstract

This paper focuses on time analysis and optimization of selected process, which is subject to IATF 16949 standard for automotive industry. Each company has its own production system, according to which it tries to optimize production and thus meet the requirements of ISO 9000 series standards. The most important requirements are understanding and a description of the process. The aim of this work is to find and remove weaknesses of the process according to the principles of lean production. Furthermore, the study focuses on finding what can be improved in terms of time fluctuation of individual activities. A reason of time deviation is detected and evaluated based on a detailed movement and time study of selected activities. Some of corrective actions are suggested and several methods are mentioned and described in the conclusion, which will be used for continuous improvement of the whole process in the context of ISO 9001.

Keywords: IATF 16949; lean manufacturing; operation snapshot; time fluctuation

1. Introduction

Quality is one of the most important things in automotive industry. Although a product quality is satisfying for the customers, it doesn't have to signify a victory for a company which made the product. For company in automotive industry it is necessary keeping all requirements according the norm IATF 16949 which extends the norm ISO 9001.

A producer in automotive industry has to improve every day. It coheres with an use miscellaneous methods for identification and minimisation risks, optimization of material flow and handing with materials. There are also the principles of lean manufacturing for keeping process efficacy. [1]

In this article there is aimed at time managing of making product and its well-timed delivery. This requires sufficient machine output. The fact is influenced by lots of factors. The first objective is making primal movement and time study of work including a verification sufficient machine efficiency which will be a base for other studies of selected workplace.

1.1. Problem statement

The efficacy of machine is always influenced by machine setting but also its crew. On selected workplace there are two workers who manage whole operation, including machine work (a description in the chapter 2.1). That's why we analyse the work of both workmen for finding the weakest spots of process. After that we can improve and increase the machine efficacy step by step. Thanks to that a risk of threat fluently delivery to the customer can be declined or the chance can be completely removed.

Every action, which is practised by the worker, has a time for its compliance. It is according the work instruction. It is clear that human isn't a robot and he can't do one action in same time again and again during one shift. Therefore there is fixed a time interval and every workman is able to manage the operation without problems during this period.

The norm uses time fluctuation during some work cycles. In the company, where this analysis is made, there is given maximal value of time fluctuation for 10 %. Goal of this analysis is checking a compliance of this requirement.

1.2. Literature research

This paper is created in the company which goes by main principles of Toyota. There exist 14 bases and they are kept by Toyota from its establishment. Even that brings a success in the market. However it is obvious that the adjusted system can transfer into every company only in general and it is necessary transform it along an actual conditionals. It is a way of thinking how we can evolve and constantly improve the company and its culture. It consists of many methods for manufacturing optimization but also for set the objectives and choose right way. Of course that accounts for people motivation and prefers a teamwork. [2], [3]

This philosophy is called TPS – Toyota production system. It has some basics which is necessary keeping and after that it gradually builds others principles and techniques. It is shown in the Fig. 1. All rudiments and also pillars are important for the functioning of the system. Thanks to that, a collapse is impossible. Either the principle of lean manufacturing is often used for optimization all manufacturing or only little part of that.

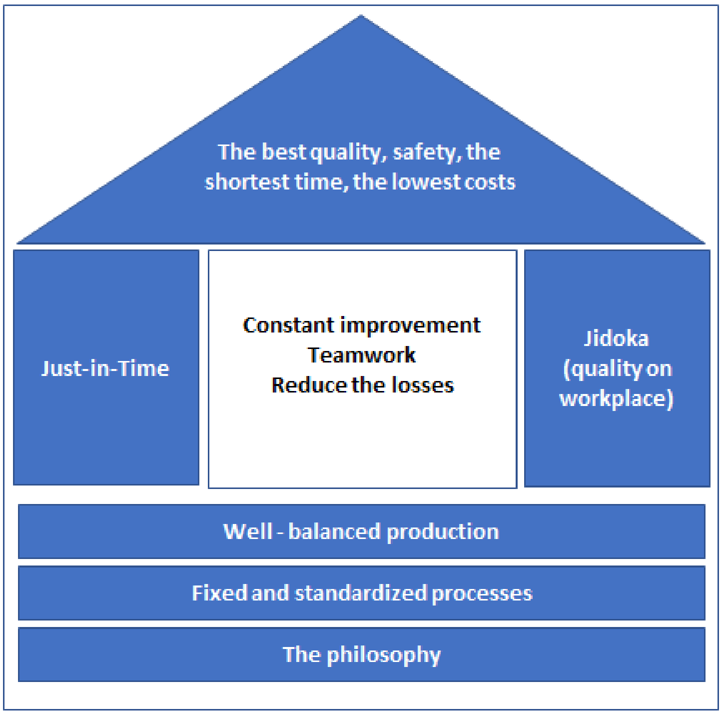

Fig. 1. The basics of TPS system [3]

1.3. Lean manufacturing

It aims at trying to eliminate activities which don't add any value and remove waste. Thereby it makes the processes more efficient, production time is shorter and machine productivity increases. There are lots of methods which we can apply for this change, for example cycle PDCA (plan, do, check and act), system Kanban, Kaizen, 5S or Six sigma. Automotive companies in Czech Republic use these ways of continuous improvement every day and they aim at rationalisation and streamlined work and processes with their help. Main point is utilization all sources and not only potentiality of machines, which we have, but also employees. [4]

All tools and principles of thinking have one thing in common. It‘s always needful to have a knowledge about selected operation for applying and making an analysis. By the way it is used movement and time study of work. This paper deals about understanding the work cycle and it utilizes a continuous time analysis of work processes. Thanks to that it continually observes the consumption of time. [5]

2. An experiment

The experiment is accomplished on the selected workplace with the help of the operation snapshot and ten cycles are researched for both workmen. During first spotting it is clear that one of those things, which will be researched more upon the problem solution, is the lasts in singles activities of workmen like grasp components and their storing into fixture. These acts are described in the work proceeding and the worker should do it along it. After that there shouldn't be bigger time divergence.

2.1 Description of the selected place

The selected workplace is situated in automotive company with serial production. It is a welding cell which is operated by two workmen. The cell has a turning table and on the each side there is one a fixture.

The fixture is mechanical equipment where be used for storing the components and holding their places during work machine cycle. It is marked the letters A and B and the workers store every single parts into it as per the given proceeding.

Along the both sides of workplace there are found boxes with the components and on the right side transport system is also here. In every beginning of work cycle finished product is hanging up on it and thanks to this it is transported into next workplace which is called Reweld. This stand serves for fix up finished part because a welding robot doesn't always weld perfect. Then the corrections are necessary and an opted weld has to complete by welder. That's why there are two welders on the Reweld and after correction of product they put it into prepared containers.

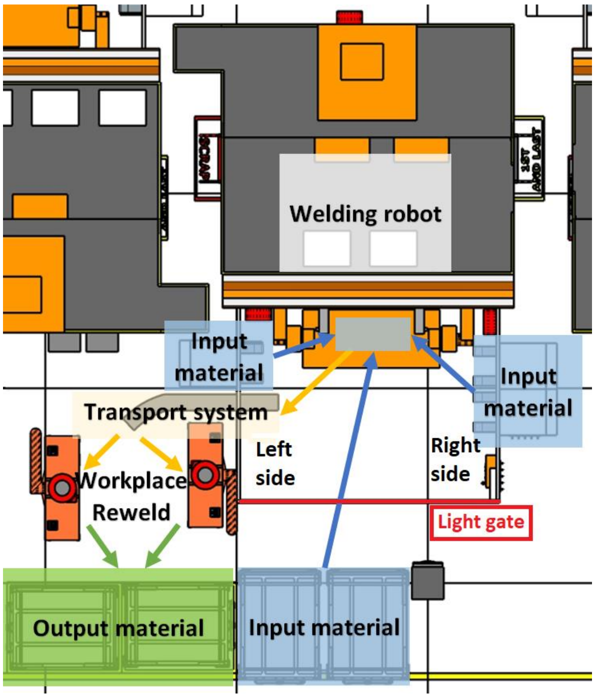

Fig. 2. Selected workplace on company layout with description of material flow

For storing all components into the fixture both workers have to walk away from the rotating table beyond a red line which is drawn on the Fig. 2. There is light gate that controls whether workers stand in a safety distance. If the light gate would be missing and man would stand somewhere in the cell, there would be an accident during the table rotation with the fixture and take a man inside the machine. A distance is 2,2 metres from the fixture to red safety line. On average two hundred and eight pieces are made every shift. It means that through one shift they walk almost one kilometre during go towards the fixture and back on the given place for waiting. Plus, between every two activities it follows walking approximately 2,2 seconds. Because of this safety rules workmen walk several kilometres every day at the work and it increases their physical effort.

2.2 Description of the experiment

Every worker does variously activities during one work cycle and it is very short stage. That's why whole cycle is taken a video. Then it is gradually evaluated. For bigger candour of measurement there are ten cycles. The most important

part of spotting for acquirement of data is setup right start points so that it doesn't make any distortion. Start point should be some good visibly act for example turn body or push a button.
First item is an observation of whole operation and makes the notes about every act. Then we assess things which are important for analysis like walking or manual proceeding. After we make a table for a time record of every activity and write down it into the table. The last step is processing and evaluation of acquired data.

Time Measurement Sheet															
Date:	23.7. 2019	Workplace:	Weld004 - human 1				Author:		Štěpánka Šambergerová				Shift:	1 st	
#	Work element	Start Point	1	2	3	4	5	6	7	8	9	10	Max - min	Min. Time	Modified Time
1	walk	turn on the light	2.6	2.2	2.8	2.9	2.5	2.2	2.2	2.8	2.5	3.0	0.8	2.2	2.3
2	removal the finished part	rising hands	1.0	1.2	1.2	1.3	1.5	1.7	1.3	1.3	1.2	1.2	0.7	1.0	1.1
3	walk	turn of body	1.7	1.1	1.3	1.3	1.3	1.2	1.4	1.2	1.3	1.3	0.6	1.1	1.2
4	hanging the finished part	turn the part	1.8	6.2	1.8	5.2	2.3	5.4	1.8	1.8	1.9	7.6	5.8	1.8	3.7
5	removal the crush can	turn of body	5.0	6.9	5.7	4.6	6.9	4.4	4.4	4.2	6.2	5.2	2.7	4.2	4.9
6	deposit a component	rising hand	5.5	4.3	3.1	6.5	3.1	7.1	3.4	2.8	2.9	4.8	4.3	2.8	3.5
7	deposit body of the crush can	a press	4.9	5.2	5.3	5.1	6.4	5.9	4.9	4.3	4.4	5.0	2.1	4.3	5.3
8	grasp a component	deposit a part	3.0	2.1	3.8	3.6	1.5	3.2	2.2	2.5	3.4	2.3	2.3	1.5	1.8
9	deposit a component	a grasp	15.7	4.4	8.3	4.3	8.5	7.0	7.8	9.6	8.7	4.3	11.4	4.3	8.1
10	grasp a component	rising hand	2.0	2.0	3.6	1.7	2.4	2.1	1.8	2.3	1.6	2.6	2.0	1.6	2.1
11	walk	turn of body	5.2	2.3	2.3	1.6	2.3	1.5	3.9	1.9	2.1	1.7	3.7	1.5	2.5
12	grasp a component	rising hand	1.3	1.0	0.9	0.9	1.2	1.8	1.5	0.8	1.4	1.5	1.0	0.8	1.0
13	walk	a grasp	1.9	2.0	1.8	2.8	2.0	1.9	2.0	2.2	2.4	1.9	1.0	1.8	2.1
14	deposit body of the crush can	turn of body	6.0	6.2	5.2	5.8	8.3	6.8	6.2	9.0	7.1	7.5	3.8	5.2	5.8
15	walk	turn of body	3.1	1.9	1.8	2.2	1.5	1.6	1.4	2.0	2.2	2.4	1.7	1.4	1.7
16	grasp a component	rising hand	3.3	3.0	3.1	2.7	2.6	3.0	3.6	3.1	2.7	2.7	1.0	2.6	2.9
17	insertion into the mark. station	put down a compon.	1.8	3.2	2.6	2.9	1.2	1.9	2.1	1.2	1.1	2.3	2.1	1.1	1.6
18	walk	a straightened back	2.7	6.1	4.0	2.8	1.4	2.6	3.6	1.3	1.8	3.1	4.8	1.3	2.7
19	wait	stop walking	13.4	35.8	28.0	23.1	23.0	36.3	20.1	22.8	26.3	21.1			
Total Element Cycle Time:			68.5	61.3	58.6	58.2	56.9	61.3	55.5	54.3	54.9	60.4	-	40.5	54.3
													Min - Modified Time:		13.8
Lowest Cycle Time:		54.3													
Average Cycle Time:		59.0													
Highest Cycle Time:		68.5													

Fig. 3. Time measurement sheet for workman on the left side

The man on the left side does 19 activities during one work cycle, the worker on the right side does 17 actions. The last activity of both workers is waiting for the machine. This time isn't important for an earning power of machine because the man is waiting for the engine and not reversely. That's why it isn‘t counted to the total cycle time and in the Fig. 3 and 4 it is signified by grey colour. There is founded one minimum time in every activity (a column Min in the Fig. 3 and 4) and a difference maximal and minimal time are calculated. It is situated in a column which is called Max – Min and these values are time fluctuation.

Time Measurement Sheet															
Date:	23.7. 2019	Workplace:	Weld004 - human 2				Author:		Štěpánka Šambergerová				Shift:	1 st	
#	Work element	Start Point	1	2	3	4	5	6	7	8	9	10	Max - min	Min. Time	Modified Time
1	walk	turn on the light	5.9	6.6	7.7	5.7	5.9	5.8	7.1	5.5	7.7	5.8	2.2	5.5	5.9
2	removal one component	put down a comp.	2.6	2.5	2.0	2.2	2.0	2.3	2.9	2.3	3.3	2.4	1.3	2.0	2.3
3	removal the crush can	put down a comp.	4.3	4.1	3.2	4.5	3.8	4.0	5.0	4.3	4.3	3.8	1.8	3.2	3.6
4	reach for two components	put down the cc	1.3	1.1	3.2	1.2	1.1	1.1	1.1	1.0	1.3	2.0	2.2	1.0	1.4
5	deposit two components	a grasp	7.4	7.1	11.8	5.5	6.8	5.1	5.2	4.8	5.3	5.1	7.0	4.8	6.7
6	deposit body of the crush can	a press	6.2	4.3	4.1	4.5	5.0	5.3	4.2	4.7	4.2	4.6	2.1	4.1	4.5
7	walk	deposit a part	1.2	1.1	1.4	1.1	1.2	1.2	1.0	1.0	0.9	1.2	0.5	0.9	1.0
8	grasp two compon. for the cc	reach	2.4	2.0	1.8	2.1	2.0	2.4	2.3	2.0	2.0	2.0	0.6	1.8	1.9
9	walk	a grasp	2.0	1.6	1.7	1.3	1.5	2.6	1.7	1.6	1.8	1.5	1.3	1.3	1.6
10	deposit body of the crush can	turn of body	2.6	5.9	3.0	6.2	6.8	2.6	7.2	3.6	2.6	9.5	6.9	2.6	4.5
11	walk	turn of body	1.2	1.8	1.9	1.5	1.6	2.1	1.7	2.4	1.7	2.0	1.2	1.2	1.4
12	grasp a component	reach	0.9	1.1	1.0	1.1	1.0	1.0	1.2	0.8	1.4	0.9	0.6	0.8	0.9
13	grasp a component	a dip	1.3	1.9	1.1	1.5	1.2	1.3	3.2	1.5	1.5	1.4	2.1	1.1	1.5
14	walk	a straightened back	1.4	1.5	1.2	1.8	1.3	2.7	3.3	1.5	1.2	1.0	2.3	1.0	1.4
15	deposit two components	turn of body	4.7	4.2	6.6	3.7	11.1	4.2	7.6	5.2	8.9	7.8	7.4	3.7	5.6
16	walk	a straightened back	4.2	4.3	4.3	4.4	3.1	4.2	3.7	5.5	3.7	3.8	2.4	3.1	3.5
17	wait	stop walking	27.6	32.5	42.2	32.7	25.4	50.8	38.6	29.9	30.6	25.6			
Total Element Cycle Time:			49.6	51.1	56.0	48.3	55.4	47.9	58.4	47.7	51.8	54.8	-	38.1	47.7
													Min - Modified time:		9.6
Lowest Cycle Time:		47.7													
Average Cycle Time:		52.1													
Highest Cycle Time:		58.4													

Fig. 4. Time measurement sheet for workman on the right side

Afterwards all measurements of every activity the total cycle time are counted up for each of ten cycles. Then we pick out the time which takes the shortest time and it is pointed by blue colour (Fig. 3 and 4). It is written down into last column which is called Modified time. Next we summarize the column of minimal time and afterward we need a difference between this value and minimum total cycle time. The first workman has 13,8 seconds (Fig. 3) and a difference for the second worker is 9,6 seconds (Fig. 4). We multiply these numbers by ten (13,8 and 9,6 seconds) and we get the merits how many tenths we give it out among the time for every activity. It is called a modified time. It means that it needs to touch up the times of the first worker about 138 tenths and 96 tenths for activities of the second workman. This severance is subjective and for resolution there is used the fluctuation. The values are divided into the several groups and the tenths are added along how many there is the time divergence. The bigger fluctuation of the first man is 11,4 seconds for storing component (work element number nine in the Fig. 3) and minimal time is 4,3 seconds. Therefore we decide that this degree gets the bigger score of tenths. The time is modified on 8,1 seconds (we adds 38 tenths). And like this we resume for every time of activity. Till the end we give out 138 tenths and total modified time equals minimum total cycle time.

3. Experimental results

Thanks to the creation primal analysis, the merits of time divergence are found out for both employees. In table number 1 we can see the results of time fluctuation – for the first workman (on the left side) the value of fluctuation equals 20,7 % and for the second workman (on the right side) it is 18,3 %. In the beginning of the article we wrote about maximal value of time fluctuation which is 10 %. How you can see in the Table 1, this number is overstepped in both cases.

Date:	**23. 7. 2019**	**Author:**	**Štěpánka Šambergerová**	
Workplace:		**Weld004 – human 1**	**Shift:**	**1 st**
Maximal value of time fluctuation			10 %	
Highest cycle time			68.5 s	
Lowest cycle time			54.3 s	
Highest – Lowest cycle time			14.2 s	
Actual value of time fluctuation			**20.7 %**	
Workplace:		**Weld004 – human 2**	**Shift:**	**1 st**
Maximal value of time fluctuation			10 %	
Highest cycle time			58.4 s	
Lowest cycle time			47.7 s	
Highest – Lowest cycle time			10.7 s	
Actual value of time fluctuation			**18.3 %**	

Table 1. The values of time fluctuation for both workmen

The time divergence was made by conversation during observation which causes slowdown or stopping their acts, or also by infringing right work proceeding. Other case is wrongly storing components into the fixture, a control sensor find out it and it stops the machine or there are the machine defects. Sometimes it happens that the welding robot doesn't work, it only remains and it doesn't react for command. Majority of described things is able to solve for instance pay attention to keep the work morals and the work instructions.

There is also situated waiting which doesn't count into total cycle times. The reason, why we do it, is a waiting for the machine by worker. This situation is always better for every company. It is caused that one machine hour costs more than one worker's hour. So we want the welding robot to make the products which are paid by the customer.

Now we can ask ourselves – why was the time fluctuation solved? When after that the employee has to wait for machine cycle. But there is one important thing. We should appreciate a fact that the experiment was observed during 10 cycles in one shift. Through the interval we couldn't see everything. It exists periodic work which means for example clearing a machine several times per shift. It takes approximately 5 minutes but sometime it lasts longer time. They clear a machine and only then the robot starts to work. For prevention it would be good when worker cleans some small part of fixture through the waiting time. Thanks to a change, machine productivity would increase because losing time of cleaning would be removed. Other advantage is that workers would make easy their effort as they wouldn't have to clean the whole table in one moment. For improving the situation, it needs changing work instruction.

4. Discussion results

There are lots of solutions for increase the machine productivity and decrease the time fluctuation. Difficulty of this paper is the fact that the operation snapshot was made from ten work cycles. That's why it is possible that there wasn't noticed bigger time loss which can cause to make fewer products. For greater objectivity it should be necessary to observe worker's activities for at least two shifts.

Whereas the company keeps the automotive standard IATF 16949, it is adjusted several tools for continuous controlling and measuring activities. The operation snapshot is just the first part of this observing and after that there are next steps for find weak points and their elimination. Therefore the research would be enriched by other methods which the company uses. For instance there are a diagram Yamazumi and a calculation of actual machine capacity along the work cycle and its time fluctuation. Both ways count with periodic work. It means change empty boxes on selected workplace or necessary and regular maintenance of machine (cleaning and so on).

The Yamazumi is graphical visualization of every time data for all activities. An output is stacked column chart and every part is marked by different colour for better lucidity. For a teaser there is Yamazumi board in the Fig. 5 where time sections are marked. An important specification is value of tact time which borders the whole chart and shows the difference between target and current tact time. Thanks to this we can find out what would happen if the non-value-added activity times were removed. Main target is a reduction of current tact time to a target tact time. [6], [7]

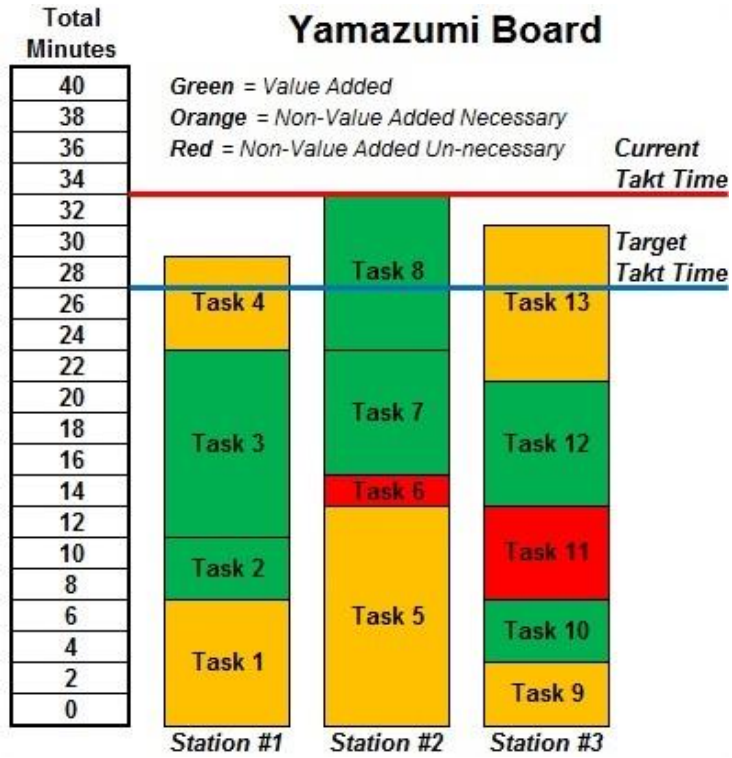

Fig. 5: The teaser of Yamazumi board [8]

Except the adjusted system in the company there exists more tools for process analysis. Through them we can control and appreciate the production. In any case it is necessary to choose useful indicators. These things are important for ensuring the requirement of reliability and capability of the production process. It can be applied a Histogram, a Process capability or a Control chart. Of course there are other statistic methods, whose the use is required by standards in the automotive industry. [9], [10]

The improvement would be also done in an ergonomic part, whereas, how it was written at the beginning of the article, the workers walk the distance a few kilometres and they stay during one whole shift. But it would be needed to change a disposition of workplace and make other safety rule than the light gate in the edge of welding cell.

5. Conclusion

The aim of this paper was the time analysis and optimization of the selected process which is managed according the requirements of standard IATF 16949 for automotive industry. At first we focussed to find and remove the weak points of the selected process along the principles of lean manufacturing.

Based on detailed the movement and time study of researched activities there were detected the time deviations. In particular they bear on time fluctuation of individual activities. That’s why there is designed some remedial proceeding like economics of movements, changes in description of work procedures or safety measures.

Because main objective in future is complex ranking of all activities in the company, we can point the study described above like primal proposition of rating methodology.

How it follows from the discussion results, it will be requisite to fill used movement and time study by more parameters or add another tool of process evaluation. Thereby we get a complex methodology for the assessment and subsequent optimization of selected workplace. We will be able to apply it for all activities in the company and optimise the production. Thanks to this we will carry out the requirements of ISO 9000 and primarily it will lead to improve the working conditionals and reduce the time losses.

6. Acknowledgement

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