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Streamlining logistics flows with lean tools using TX Plant Simulation software support

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Abstract: A critical factor in the manufacturing industry is waste and losses in individual operations and processes. The expansion of elements of lean production, such as the pull system with the interconnection of key technologies, brings new elements of production planning and control. Thanks to new technologies, many more possibilities exist to uncover potential bottlenecks. Simulations and modelling bring new possibilities for experimentation in the virtual environment of prepared systems or devices without directly disturbing the functioning system. The presented article deals with the issue of applying lean approaches in finding optimal solutions within logistics flows. The aim of the article is to define and test the potential for streamlining logistics flows with TX Plant Simulation software support. The research and empirical part of the study was solved based on a rigorous analysis of the initial situation in a specific company for the selected product group, as the Value Stream Mapping method was used for the analysis. A simulation model of a real line was created in the TX Plant Simulation software with the help of the Value Stream Mapping library for value creation, which is part of the software. The goal was to find out possible waste within the logistics flow, and its causes and propose the necessary steps to eliminate the waste.

1 Introduction

The current trends in the manufacturing industry include the acceleration of product development, the earliest possible start of production, the growth of flexibility, quality, and variability of production in conjunction with low costs. Changing demands from customers, changing products, and developing technologies all affect the structure of business processes, and affect work procedures, input materials, and production equipment. From this also follows the need to achieve adaptability of enterprise processors, which, however, must pass through all hierarchical levels. It is possible to reflect on this challenge through the evolutionary concept of Industry 4.0. The basic pillars of Industry 4.0 are digitization (of products, processes, equipment, and services) and the application of exponential technologies. However, the transformation of the enterprise into a smart factory will require expertise and know-how in all functional areas of the enterprise. This concept is already known from ten years ago when it was presented at the Hannover Mess. However, it is a question of how it penetrated industrial reality [1-3].

From the point of view of designing and developing production and logistics systems, it is necessary to look at the difference between flexible and adaptable systems. Flexibility means the ability to respond to changes within a predetermined range of requirements efficiently, timewise, and cost-effectively. In terms of manufacturing logistics, flexibility involves adapting structures and processes to changes at the tactical level by referring to the joint interaction of employees, machines, production systems, and the network to create value. Adaptability exceeds flexibility because it represents the system's potential to respond to changes beyond predetermined corridors of activity and to proactively respond to changes. In logistics, adaptability means the ability of a material flow system to adapt to new circumstances by being variable. Processes and systems can be changed and modified. Achieving these goals is conditional on the implementation of new technologies capable of handling such demands. Product functionality verification in a virtual environment will be an essential standard soon. With increasing global competition and increasing customer demands, the importance of improving business processes is growing. In recent years, the term lean management has become more and more frequently associated with this connection. The origin of this approach to management is associated with the Japanese company Toyota, and thanks to the ability to respond more quickly and flexibly to customer requirements, it has penetrated the entire world, and gradually increasing case studies testify to ever-new areas of its use [4-10].

The concept of lean thinking describes the work philosophy and practices of the Toyota Production System. In TPS, the use of a resource that does not add any value according to the customer is excluded [5]. The processes work on the principles of using less material, requiring less investment, using less inventory, needing less space, and using fewer people [11-13].

Achieving a value stream in lean manufacturing consists of four key strategies [11]:

- Synchronization of external deliveries to customers.
- Internal production synchronization.
- Flow formation.
- Creation of a traction system.

The main goal of these strategies is the elimination of losses [11]:

- Transportation.
- Waiting.
- Overproduction.
- Defects and repairs.
- Storage.
- Movement.
- Redundant processing

When trying to improve processes, many companies encounter the problem that there is no person who has the necessary knowledge about the entire flow of material and information, or about all the processes associated with the product. A common method that enables this deficit to be overcome and at the same time to identify areas where improvement efforts should be directed and solutions suitable for the entire company should be proposed is value flow mapping. The interface between process innovation and process improvement is not well defined. Innovations constitute a more radical leapfrog transformation in the process. Under the word improvement, we imagine the activities of people involved in processes who try to increase their performance daily (elimination of waste, expenses, downtime, increasing performance and quality). Improving the overall process chain as a complete system of activities involves value stream mapping which is also the focus of the case study below [14-16].

2 Methodology

2.1 Input data for creating a simulation model

The company under investigation looks at each request for a new bar line individually, uses experience from several realized projects, listens to customers and considers their ideas about the product, and uses its test center either to develop and design new ideas or to verify customer recipes on a test bar line.

The bar line is a technological device suitable mainly to produce bars, prepared from several materials and various ingredients, such as classic cereal, nut, oat, coconut, marzipan or caramel, popular protein beetroot and fruit raw, or other mixed recipes. I can also mention various specialties such as French nougat, dried bananas, and apricots in chocolate or multi-layer bars. In Tab. 1 we can see processes related to the production of the bar.

Table 1 Processes related to the production of the bar

Description of the bar manufacturing process	
Area	**Information**
Customer	• the required number of sticks is 100,000 pieces in 2 weeks • one type of bar - nut, caramel, or fruit covered in chocolate • the average number of working days in a month is 20 (net shift time fund is 480 min.) • packaging of finished bars - 50 pieces in a box
Supplier	• supplies the necessary raw materials (nuts, caramel, fruit mixture, chocolate, packaging) • raw materials are stored in the warehouse
Planning	• all communication with the customer and supplier is electronic • planning accepts weekly or daily refinements • information on the daily production plan is based on the physical inventory of the warehouse)
Expedition	• it will be shipped from the warehouse in 2 weeks
Production	• input caramel, nuts and chocolate • melting caramel, grinding nuts and chocolate • mixing caramel and nuts and mixing with fruit mixture • solidification of the mixture and melting of the chocolate • cutting the mixture into bars of the appropriate size • coating the bar with chocolate and its solidification and control • printing and cutting the package and wrapping the bar • storage in boxes and waiting in the warehouse for dispatch

2.2 Simulation model of the production of the selected product

In the TX Plant Simulation VSM library, we simulated the production of a chocolate bar filled with nuts, caramel, and a fruit mixture. The customer requests to produce

100,000 pieces of this type of bar within 2 weeks. Chocolate, nuts, and caramel enter the simulation from separate inputs. The chocolate is ground and then melted. The nuts are also ground and mixed with the melted caramel into one mixture. After that, a fruit mixture is mixed with the mixture of nuts and caramel, which comes from another separate entrance and is subsequently cooled to a solid state cut into smaller pieces, and travels to the intermediate warehouse. From it, the solidified cut mixture is coated with chocolate and the process of chocolate solidification follows. After solidification, the worker checks the formed sticks, and they go further to the intermediate storage 2.

During these operations, the bar wrapper is printed from a separate input and then cut to the required size. The last station is the packaging of the bar, where one worker is also present to check possible defective pieces. The others are packed in boxes and that's the end of the process. The course of the simulation can be seen in Figure 1.

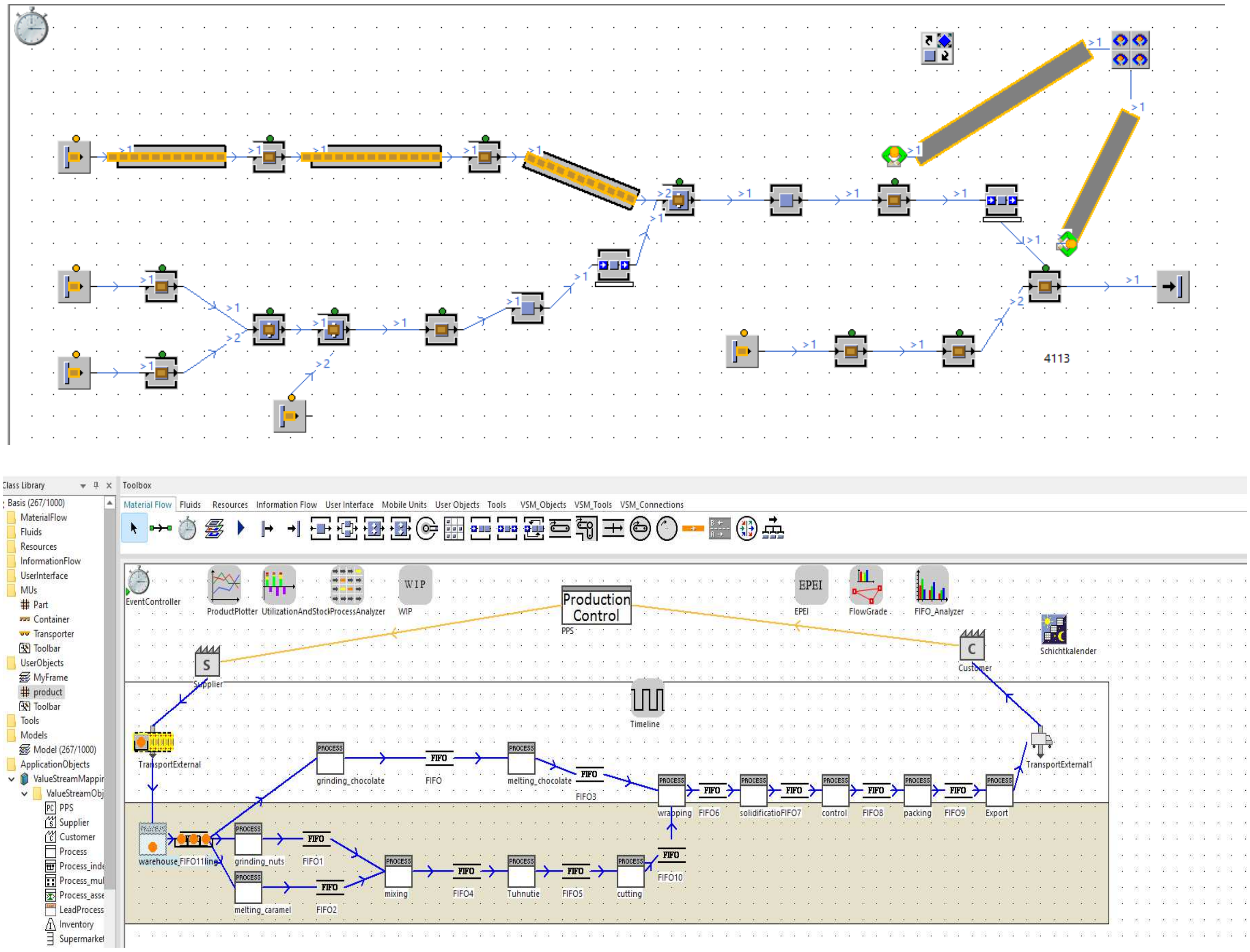

Figure 1 Simulation of the current state – process diagram and WSM diagram

After the end of the simulation, we will see the final table of produced pieces, see Table 2

Table 2 Result information after simulation – current state

.Models.Model

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
output_product	Part	40.3741	4112	514	95.27%	0.00%	4.73%	59.39%	

Cumulated statistics of the parts which the drain deleted.

From this table, we find that 4,112 bars are produced in 8 hours, the productivity of the simulation is 95.27%, the storage is 4.73%, and the added value of the entire simulation is 59.39%.

Table 3 Resulting indicators of the current state

Total number of operations	14
Number of value-adding operations	8
The ratio of adding operations / total operations	**57.14%**
Time of value-adding operations (min)	3840
Time of non-value-adding operations (min)	2880
Total production time (days)	5.68
VA index	**11.16**

From the process diagram, we gradually drew a map of the value stream in the TX Plant Simulation library, see Figure 2.

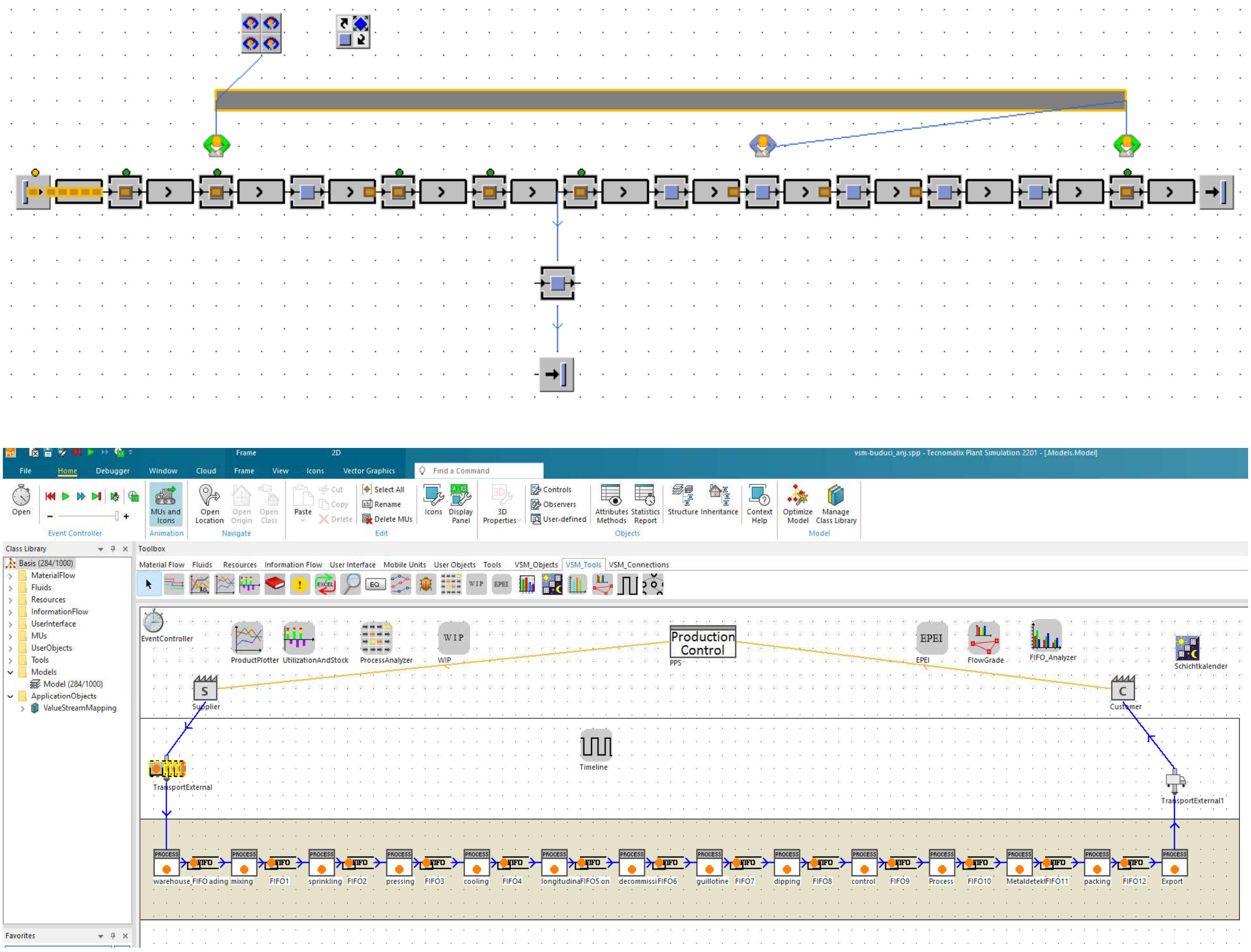

Figure 2 Simulation of the proposal state – process diagram and WSM diagram

After the end of the simulation, we will see the final table of produced pieces, see Table 4.

Table 4 Result information after simulation – proposal state

.Models.Model

Simulation time:8:00:00.0000

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
output_product	Part	1:26.0045	5692	712	55.82%	44.18%	0.00%	50.00%	
output_snippets	Part	56.7500	58	7	47.58%	52.42%	0.00%	38.77%	

Cumulated statistics of the parts which the drain deleted.

3 Result and discussion

After simulating the current situation, we found that 4,112 sticks are produced in eight hours of one shift, that is, 8,224 sticks are produced in a day with a two-shift operation. If the customer requests 100,000 pcs in two weeks, which is 10 working days, only 82,240 pcs will be produced, so we will reach the goal of 100,000 pcs in only 13 working days.

After simulating the future state, we found that in eight hours of one shift, 5,692 pcs of sticks are produced, which is 1,580 pcs more than in the current state, while another 58 pcs are scraps. During the two-shift operation, 11,384 pieces are produced per day and 116 pieces of offcuts are created. If the customer still requires 100,000 pcs in two weeks, which is 10 working days, 113,840 pcs will be produced, which means we will reach this goal. More positive is the fact that we will exceed it one day earlier, that is, in nine days.

For a better understanding of these results, we can also display them graphically in Figure 3.

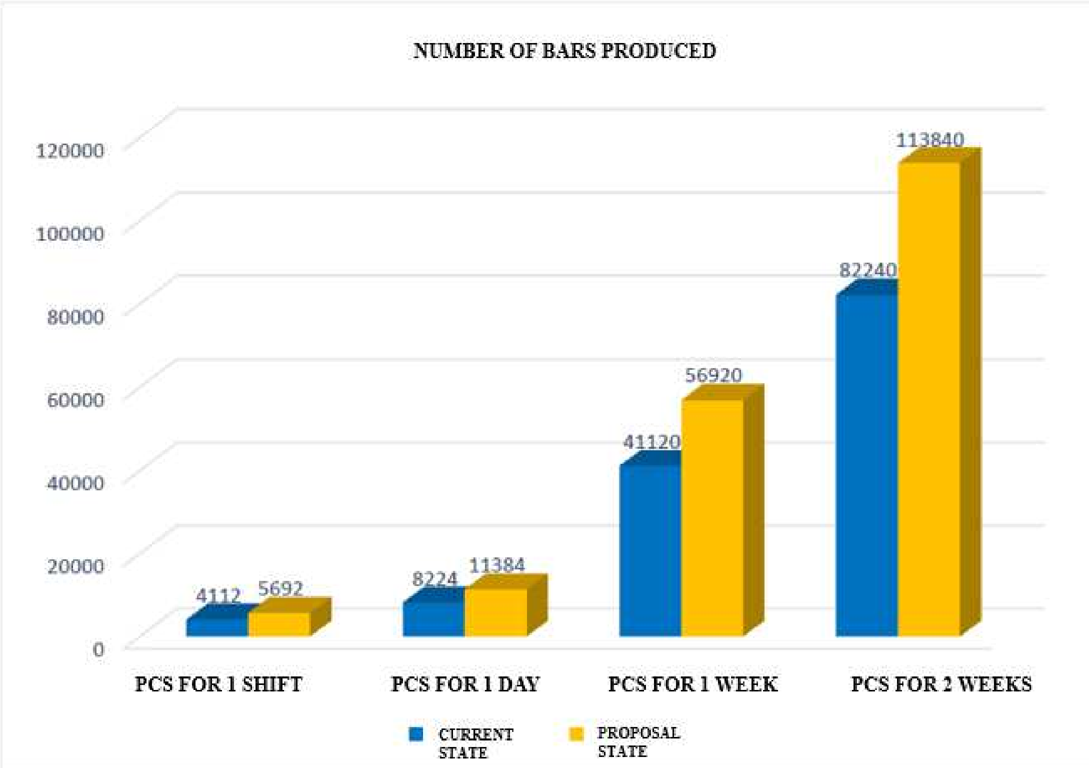

Figure 3 Graphical representation of produced pieces of bars

The added value of the entire current simulation is 59.39%. The added value of the entire future simulation is 51.68%, which is 7.71% less than the current one, but a larger number of bars will be produced and in a shorter time. The productivity of the current simulation is 95.27% and the productivity of the future simulation is 57.30%. The ratio of value-added activities to the total number of activities is 57.14% in the current state and 53.85% in the future state. The last compared indicator is the VA index, where in the current simulation it has a value of 11.16% and in the future simulation it has a value of 35%.

These indicators can also be seen in Figure 4.

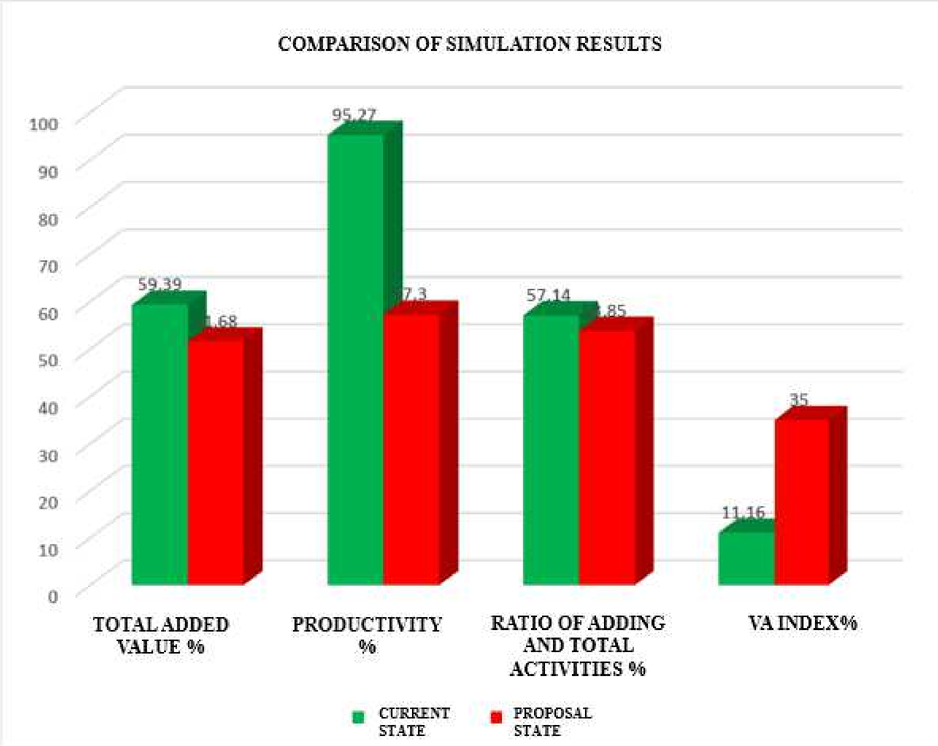

Figure 4 Graphical display of percentage comparison of simulations

Although some indicators show the current state as better, we must also look at the customer's requirements. Since it was requested to complete the order in two weeks, a future simulation where more pieces of sticks are produced in a shorter time is more acceptable. Here, too, the rule that less is sometimes more is confirmed.

Value stream mapping is one of the most important methods that a company can use to increase its productivity. By mapping, we get an overview of the activities taking place in the company, in specific places at the current time. By mapping, we can deduce how much time, space, and effort a certain activity will take, and thus we are able to eliminate waste. The map is much more complex, it contains time intervals, so it is better to create it by handwriting directly at the workplace, rather than complicated and inconvenient on the computer.

When using the VSM - Value Stream Mapping method as a tool for redesigning production flows, the key output is the VAI - Value Added Index. However, the production flow in operation is not smooth, there are frequent downtimes of material (or production in progress), due to the accumulation of stocks before technological operations - this is an activity that does not add value to the product and therefore neither to the customer nor to the production company. The company subsequently tries to minimize the times that do not add value as part of continuous improvement.

This work dealt with the mapping of the value flow in the production of bars in a specific company. It was necessary to focus on a specific type of product and production because the company is not focused on mass production, but on custom production, where different machines or devices are always produced, as well as different confectionery. Therefore, it is difficult to calculate various indexes and downtimes because each order is original. By using simulation software, the company can save costs in the event of unsuccessful prototypes or introduced changes directly into production. On the simulation model, as was pointed out in the thesis, it is possible to try the introduction of new operating systems, without directly interfering with the real company.

4 Conclusions

Value stream mapping is one of the most important methods that a company can use to increase its productivity. By mapping, we get an overview of the activities taking place in the company, in specific places at the current time. By mapping, we can deduce how much time, space and effort a certain activity will take, and thus we are able to eliminate waste. The map is much more complex, it contains time intervals, so it is better to create it by handwriting directly at the workplace, rather than complicated and inconvenient on the computer.

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