Enhancement of Brake Pads Production Planning with Time Management and Process Condition Using VBA on Microsoft Excel

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Abstract. *This research aims to increase the efficiency of work management in the production planning process. This research uses an industrial engineering method based on a time and motion study to record operational data and create a standard planning process in the production process. It also uses the VBA on Microsoft Excel to analyze data and facilitate the work of the operators. The results of time data recording can be used to calculate the standard time as part of setting work sequence standards. The trials for two sessions (session 1 is a daytime production and session 2 is a nighttime production) with different production process results showed that the program could be used to plan the two sessions' production with no difference. The usability test revealed that programmed planning results were greater in percentage mean accuracy compared to actual production than existing planning. There was a 72.17% increase in efficiency in session 1 and a 73.48% increase in efficiency in session 2. This was a statistically significant increase in efficiency. Therefore, it can be concluded that using the above principles and methods can improve the production planning process to be able to plan production more accurately.*

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1. Introduction

Thailand's automotive sector is essential to the country's economy since it has a huge production base, which is the primary source of employment and growth in other industries such as the automobile components business [1]. Currently, the Thai auto parts sector is under competition from many large competitors, especially those from countries with lower cost advantages and competing for market share. Customers now have more purchase options. Companies must improve their competitiveness. Therefore, it is vital to set operating standards in the production process that can reduce expenses, waste, and loss of opportunity. This will allow businesses to survive and meet the demands of their clients more efficiently. This research aims to improve the efficiency of production planning and management within the production process. The authors study relevant research to determine tools and principles that identify weaknesses and develop new models suitable for the automotive parts industry. The authors explore several studies that have the same goals but apply to different sectors. Typically, operators are prioritized in improving task activities, workflows, and planning. Production expenses are lowered, and systems perform better. The first relevant research is the development of efficient production processes to manage the human, machine, and time resources flexibly based on the scenario, employing ILO-guided principles, and studying hours spent. This technique has the potential to increase production efficiency by 35% [2]. An in-depth examination of time principles has applied this principle to the development and administration of production processes, such as Toyota's research on boosting productivity, decreasing cycle times, and minimizing non-value-added tasks. It is verified in conjunction with the Kaizen Research

Principles and the Kaizen Blitz. Reduced cycle times have been demonstrated in research. This improves operator efficiency and productivity. As a result, this strategy or philosophy can help to expand knowledge [3]. Another intriguing application is for a global energy glass manufacturer to improve job efficiency through time and motion research. The goal is to improve firms' ability to use their resources more efficiently by implementing management and production time concepts. The study discovered that waiting times for unnecessary tasks were minimized. In addition, the efficiency was 53% higher than before, and the simulated capacity was increased [4]. Work principles and production time management can be combined with long-term growth criteria in the research of how to make the manufacturing process more efficient. Previously, the review investigated the standardization of organic lens manufacturing. Based on the premise of monitoring time and movement by establishing work standards, one study discovered that productivity increases as assessed by job quality, employee weariness, and the balance of production time [5]. Another method for developing process planning is to observe how others do things and consider the challenge and its consequences. Process analysis and ergonomic analysis are based on schematics, while functional models are based on what is possible in practice. According to this study, production cycle times are reduced, and human resources, equipment, and workloads are enhanced [6, 7].

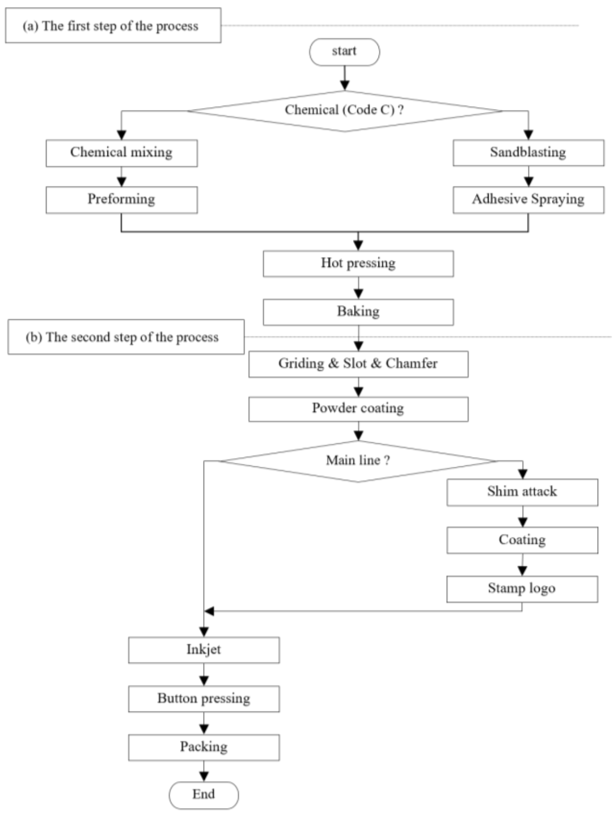

Fig. 1 Schematic of the manufacturing process of automobile brake pads

This research is a study of automotive brake pad spare parts companies according to the company's current situation to meet the needs of customers. There is a wide variety of products. Production planning is more challenging to manage. The manufacturing process is divided into two major steps: the brake pad preforming and the brake pad adding accessories to your equipment to improve its appearance and attract customers. The details of all sub-processes are shown in Figure 1. The study found that the actual production work in the second step of the production process did not meet the production plan due to the diversity of the process, which caused difficulty in planning the production at the time of production. The author decided to start working with the task management system in the second step of the production process before starting the first step. It was found that the problem was caused by inconsistent communication between the planning and production departments and problems with the production process. Another problem is that companies do not record information about production times and conditions to standardize the performance of each subprocess. What is needed to make planning easier and more accurate is to set standards based on the length of time it takes to produce each product as well as the production conditions. Therefore, the goal of this research is to create a brake pad production planning system that is more in line with time and process restrictions to standardize task management in the process and reduce errors.

2. Methodology

2.1 Observation and Data Collection in the Disc Brake Production Process

The authors consider the problems of the process and monitor the movement patterns in the production process. Production lines are separate for each product and record processing times using a tool called "The Study of Time and Motion." Such a tool is a strategy to look at actions or tasks in detail to identify rewarding activities and eliminate those that are worthless or wasteful [5]. The research process is as follows [8]:

1. Process mapping (Process chart) and scoping of study and development.
2. Study the structure and movement in the manufacturing process to determine the parts to be developed.
3. Calculate the number of observations required to increase the reliability of the data. When considering the time spent on each sub-activity The number of observations was 5 times if the time spent on the sub-activity was greater than 2 minutes (120 seconds), but 10 times if the time spent on the sub-activity was less than 2 minutes. Calculate the obtained number of observation times (N) using Equation (1) and compare the values with a table called "Maytag" to determine the number of times suitable for the next calculation is shown in Table 1. After getting the number of times of the timer and all the time data, verify and confirm the normal distribution data in the principle of "Work-Time Distributions and Motion-

Time Patterns" [9] with the Minitab program. This proves that the data that was recorded can be used to represent the time data for other calculations.

$$N = \frac{R}{\bar{x}} \tag{1}$$

where $\bar{x}$ = Average time value of the element for sample, R = Range of time for sample (data max- data min), and N = Required number of observations from Maytag table.

N	Data from Sample of		N	Data from Sample of		N	Data from Sample of	
	5	10		5	10		5	10
0.1	3	2	0.42	52	30	0.74	162	93
0.12	4	2	0.44	57	33	0.76	171	98
0.14	6	3	0.46	63	36	0.78	180	103
0.16	8	4	0.48	68	39	0.8	190	108
0.18	10	6	0.5	74	42	0.82	199	113
0.2	12	7	0.52	80	46	0.84	209	119
0.22	14	8	0.54	86	49	0.86	218	125
0.24	17	10	0.56	93	53	0.88	229	131
0.26	20	11	0.58	100	57	0.9	239	138
0.28	23	13	0.6	107	61	0.92	250	143
0.3	27	15	0.62	114	65	0.94	261	149
0.32	30	17	0.64	121	69	0.96	273	156
0.34	34	20	0.66	129	71	0.98	284	162
0.36	38	22	0.68	137	78	1	296	169
0.38	43	24	0.7	145	83			
0.4	47	27	0.72	153	88			

Table 1 Maytag table [10].

2.2 Process and Time Data Analysis (Normal Times and Standard Times)

The analysis of process and time data can be further analyzed from the time recording. It is explained that the recorded time is reliable, and the average time, normal time, and standard time are calculated in that process [11]. The normal time was determined as Equation (2), which is calculated by multiplying the average observed time by a rating factor score. The observer determines the rating factor scoring factor. The time and motion study analyst multiplies real time by a figure known as the "Rating Factor" to establish the normal time that a regular worker would take. This is expressed as a percentage of the representative operator's efficiency, illustrating how effective an operator is concerning some of his peers. It was set at 80% for this study because it was an acceptable value for the factory practical.

$$NT = T_{avg} \times R_{fac} \tag{2}$$

where R_{fac} = Rating factor (Set at 80 %), T_{avg} = Average observed time and NT = Normal time.

The next step calculated the standard time using Equation (3), which is the normal time multiplied by the time allowed for each step. An allowance is a monetary value related to the availability of accommodation for personal needs such as fatigue, waiting time, and rest time, which applies to 7%, which is acceptable by factory practical.

$$ST = NT \times \frac{100}{100-A} \tag{3}$$

where A = Allowance in percent (Set at 7%), NT= Normal time and ST = Standard time.

After that, remove non-value-added activities or tasks that do not create or modify products by using observable data analysis and record keeping to develop a more efficient production plan. This meant that a standard operating system based on the ideas of Lean Manufacturing had to be made [12]. Establish work standards by simulating the sequence of plans that result in an efficient and verifiable production process. As the standard changes, the new standard serves as the foundation for future improvements. In most cases, a typical job consists of three cases [13]. The first case is a production time tracking, which refers to the rate at which a product must be processed to meet consumer demand. The second case is accurate work orders with on-time completion of tasks by operators. The last case is standard inventory, which includes the unit of the machine. It's important to keep the process running smoothly. In the last step, scheduling is a decision-making process that involves allocating limited resources to the optimum, such as human resources, job processing, and task sequence.

2.3 Processing and Displaying the Work Order Sequence in a Production Process using VBA on Microsoft Excel

VBA is a program for building sub-modules with a structured user interface in Microsoft Excel that makes it easy to use [14]. Researchers came up with algorithms for how to work and used VBA on Microsoft Excel to process and make an interface for the operator to use. The workflow is as follows:

1. Create a production workflow structure from the conditions and constraints studied are shown in Figure 2.
2. Create a work order sequencing processing system for production planning [15].
3. Write a program to show the sequence of work, work status, and total time in production using VBA on Microsoft Excel.

2.4 Trial and Evaluation

The trial and evaluation are divided into two main parts.

The first part is the testing of time recording data for use in calculating the time to standardize the work order sequence in the production process according to the industrial engineering principles of "Work Time Distribution and Animation Timing Format" [9]. There is a normality test of the recorded time to perform a reliability analysis with a p-value by the Minitab program, as the shown in Table 2. If the p-value exceeds 0.05, he recorded time is normally distributed. Once it was verified that the recorded time was normally distributed, it was used to calculate the average time, as shown in Table 2. Then take the average time to calculate the normal time and standard time, as shown in Table 3 to standardize the work order sequence in the process and create a processing planning simulation program for the user.

The second part is the testing of planning in the production process with a simulated program. There are two sections to the trial. The first section is examining the implementation of the program by comparing two different sessions with different production stages. It consists of sessions 1 during the day (8:00 a.m.–17:00 p.m.) and sessions 2 at night (17:00 p.m.–2:00 a.m.) using t-test statistical analysis to examine the differences in program usage. The t-test of the experimental data for both sessions was performed using the data analysis function on the Microsoft Excel program. The second section is to test the accuracy and efficiency of the simulated production planning program against existing production planning. The evaluation compares the effectiveness of existing planned production with the simulated planned production using a t-test by the data analysis function on the Microsoft Excel program.

3. Result

3.1. Timekeeping, Normal Times, and Standard Times for All the Inspections of the Process

A survey of the current state of the problem using the work-study principle was conducted. 10 preliminary timings were performed in each process, and the obtained values were computed for statistical reliability with the Minitab program. An analysis of the six processes' timing and movement indicated that some had distinct process patterns, which are represented by the numbers under the processes in Tables 2 and Table 3. The time sequences for each pattern were split and altered by the researchers. It indicates that the investigators used a hypothetical p-value to test and validate their reliability. The investigator measured and validated by starting with 10 times, calculating the N value using Equation (1), and using the resultant N value to obtain the best number of timings using the Maytag table in Table 1. Based on the time recording verification principle in Section 2.4, the researcher used the Minitab program to examine the distribution of all data values tested at the 0.05 significance level. The results showed that the p-value was exceed 0.05 for all processes. This indicates that the data have a normal distribution and can be used to calculate normal time and standard time. Data for recording times and values P of each process is shown in Table 2. Table 3 shows examples of the results of the calculation of the normalized time according to Equation (2) and the standard time according to Equation (3) that will be used in the further standardization process.

Process Pattern / Number of preliminary timings	Powder coating (s)			Shim (s)		Stamp logo (s)	Coating (s)	Button pressing (s)			Packing (s)		
	1	2	3	1	2			1	2	3	1	2	3
1	16.65	14.49	16.68	0.76	4.36	3.46	2.04	1.24	1.48	1.30	1.39	0.62	1.26
2	16.68	14.52	16.63	0.78	4.30	3.82	2.06	1.28	1.49	1.21	1.48	0.64	1.25
3	16.63	14.52	16.74	0.75	4.75	3.07	1.61	1.27	1.57	1.24	1.48	0.68	1.24
4	16.87	14.42	16.65	0.73	4.69	3.06	1.89	1.26	1.32	1.33	1.21	0.68	1.38
5	16.71	14.19	16.76	0.74	4.81	3.12	1.64	1.36	1.51	1.25	1.41	0.64	1.41
6	16.71	14.36	16.67	0.69	4.58	3.48	1.97	1.34	1.52	1.43	1.42	0.55	1.38
7	16.75	14.25	16.76	0.74	5.15	3.30	1.91	1.29	1.27	1.29	1.46	0.68	1.26
8	16.67	14.21	16.74	0.68	5.11	3.41	2.04	1.15	1.38	1.47	1.35	0.65	1.28
9	16.65	14.36	16.54	0.68	5.06	3.22	1.77	1.31	1.54	1.27	1.49	0.67	1.11
10	16.62	14.27	16.83	0.84	4.25	3.05	1.87	1.18	1.53	1.22	1.43	0.69	1.26
Average time ($\bar{X}$)	**16.69**	**14.36**	**16.70**	**0.74**	**4.71**	**3.30**	**1.88**	**1.27**	**1.46**	**1.30**	**1.41**	**0.65**	**1.28**
Range (R)	0.25	0.33	0.29	0.16	0.90	0.77	0.45	0.21	0.30	0.26	0.28	0.15	0.30
N	0.01	0.02	0.02	0.22	0.19	0.23	0.24	0.17	0.21	0.20	0.20	0.22	0.23
Number of Observation from Maytag value	2	2	2	8	7	10	10	6	8	7	7	8	8
P-value from Minitab program	0.09	0.42	0.65	0.43	0.53	0.27	0.29	0.59	0.05	0.16	0.07	0.06	0.08

Table 2 Processing timekeeping and averaging the time of each process.

Process Pattern	Powder coating (S)			Shim (S)		Stamp logo (S)	Coating (S)	Botton pressing (S)			Packing (S)		
	1	2	3	1	2			1	2	3	1	2	3
Average time (T_{avg})	16.69	14.36	16.70	0.74	4.71	3.30	1.88	1.27	1.46	1.30	1.41	0.65	1.28
Rating Factor (80 %)	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Normal time (NT)	13.36	11.49	13.36	0.59	3.77	2.64	1.50	1.01	1.17	1.04	1.13	0.52	1.03
Allowance (7 %)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Standard time (ST)	14.29	12.29	14.30	0.63	4.03	2.82	1.61	1.09	1.25	1.11	1.21	0.56	1.10

Table 3 The average time, normal time, and standard time of each process.

Work session 1		
Observation	Test dates	Accuracy of the production sequence from the programmed plan vs. the actual production sequence in the production process (%)
1	18/10/2021	82.14
2	19/10/2021	78.94
3	20/10/2021	84.61
4	21/10/2021	84.61
5	26/10/2021	84.84
6	27/10/2021	81.48
7	28/10/2021	84.61
8	29/10/2021	85.29
9	1/11/2021	83.33
10	2/11/2021	84.38

Table 4 Accuracy of the production sequence from the programmed plan compared with an actual sequence in production for work session 1 (8:00 a.m.-5:00 p.m.).

Work session 2		
Observation	Test dates	Accuracy of the production sequence from the programmed plan vs. the actual production sequence in the production process (%)
1	18/10/2021	83.84
2	19/10/2021	88.24
3	20/10/2021	86.66
4	21/10/2021	90.90
5	26/10/2021	83.87
6	27/10/2021	86.11
7	28/10/2021	91.30
8	29/10/2021	75.00
9	1/11/2021	84.00
10	2/11/2021	78.13

Table 5 Accuracy of the production sequence from the programmed plan compared with an actual sequence in production for work session 2 (5:00 p.m.–02:00 a.m.).

3.2 Establishing Production Ordering Standards

The elimination of unnecessary activities, waste generation activities, and activities that result in time exceeding the standard time were all accomplished. Then, create new work standards and utilize them to create action plans or task orders in the production process. The researcher used Microsoft Excel's Visual Basic Application (VBA) to analyze and monitor data for this study. This is because Microsoft Excel is the primary planning tool now. The researcher simulated a preliminary program to test apps to analyze differences in use in two sessions with different production patterns, session 1 and session 2. The results of ten days of production are documented to compare the accuracy of program implementation with the actual production of the number of jobs to be created that day. If the program's work order sequence results match the actual production sequence, the results are recorded as 1. If it does not match, the results are recorded as 0. The findings, compiled as a percentage of mean accuracy for that day, are shown in Table 4 and Table 5. Two sessions of programming variability were tested by t-test at a 0.05 significant level. A p-value greater being than 0.05 indicates that there was no difference in the simulation program used in both sessions. The results show that the standard can be applied to the emulator for both sessions.

3.3 Comparative Evaluation of the Accuracy Performance of Programmed Planning Versus Existing Lanning

From the test that the program can be used in both sessions, the evaluation will compare the efficiency of the planned production with the simulated program created with the existing planning. Assessment of production planning performance using a simulated program compared to existing production planning can be determined by the t-test at a 0.05 significant level. As a result of test session 1, the existing production sequence planning compared to the actual production sequence planning had a mean planning accuracy percentage of 11.25 percent, a standard deviation was 7.53, a variance was 56.69, and a coefficient of variation could reach 66.9 percent. This means it has a low level of reliability compared to actual production. The mean percentage accuracy of the simulation program in this study in terms of sequence planning was 83.42 percent, the standard deviation was 2, the variance was 4.2, and the coefficient of variation was 2.4 percent reliable compared to actual production. This means it has a higher level of reliability than the existing planning compared to the actual production. The investigators confirmed the increase in efficiency by t-testing the production planning efficiency using a simulated program. The results showed that the p-value was less than 0.05. The results could explain the simulated program production planning was more efficient than the existing production planning. After statistical testing and confirmation by the t-test, it can be concluded that the mean percentage of production planning accuracy with the simulated program is greater than the existing mean percentage of production planning accuracy. Figure 3 depicts a mean percentage accuracy of 11.25 percent to 83.42 percent, an increase of 72.17 percent. As a result, in session 2, existing sequence planning compared to actual sequence planning had a mean planning accuracy percentage of 11.33 percent, the standard deviation was 9.48, the variance was 89.84, and the coefficient of variance was as high as 83.69 percent. This means it has a low level of reliability compared to actual production. The mean percentage accuracy of the simulation program in this study in terms of sequence planning was 84.81 percent. The standard deviation was 5.16, the variance was 26.60, and the coefficient of variation was 6.08, which was reliable compared to actual production. This means there was a higher level of reliability in the existing planning compared to the actual production. The investigators confirmed the increase in efficiency by testing the efficiency of production planning using the t-test. The p-value was less than 0.05. The results could explain the simulated program production planning was more efficient than the existing production planning. After statistical testing and confirmation by the t-test, it can be concluded that the mean percentage of production planning accuracy with the simulated program is greater than the existing mean percentage of production planning accuracy. Figure 4 depicts a mean percentage accuracy of 11.33 percent to 84.81 percent, an increase of 73.48 percent.

4. Conclusion

This research is a case study of the brake pad industry, which applies industrial engineering principles and methods to develop production processes. The study of time and motion in the production process involves eliminating unnecessary processes that result in wasted time and process waste. The creation of working standards in the production process is combined with scientific technology using VBA on Microsoft Excel. The planning management system in the production process according to working standards is developed because of this, it can be done in a systematic way to manage the allocation of resources in the process of making something. The simulation implemented in 2 sessions with different production modes shows an increase in the efficiency of sequence planning compared to pre-development planning. In session 1, average accuracy increased by 72.17 percent, while in session 2, average accuracy increased by 73.48 percent. It was concluded that the study for the development of sequence planning by using industrial engineering tools combined with scientific programming technology could increase the efficiency of production sequence planning in the brake lining industry.

Further guidance is needed for the industry model because this research is a timed edition during the COVID-19 situation, when production is not under normal conditions. Therefore, if the situation returns to normal, the practitioner should update the information to be more current. For advice for those who continue to study this research, because this research is a simulation of solving problems in the automotive brake lining industry management, where the principles or methods for solving problems are applied only to some parts of the tool in industrial engineering as appropriate. Therefore, if there is a change in the industry for problem-solving studies, more tools should be studied for more precise problem-solving. Another part is choosing a program that is used to facilitate the practitioner. This research is based on the basic program used by the sample industry, Microsoft Excel, using the function VBA processing for operators. It is convenient to use, although the form of use is still semi-automatic. Further development may lead to an automatic program that is more stable and easier to use.

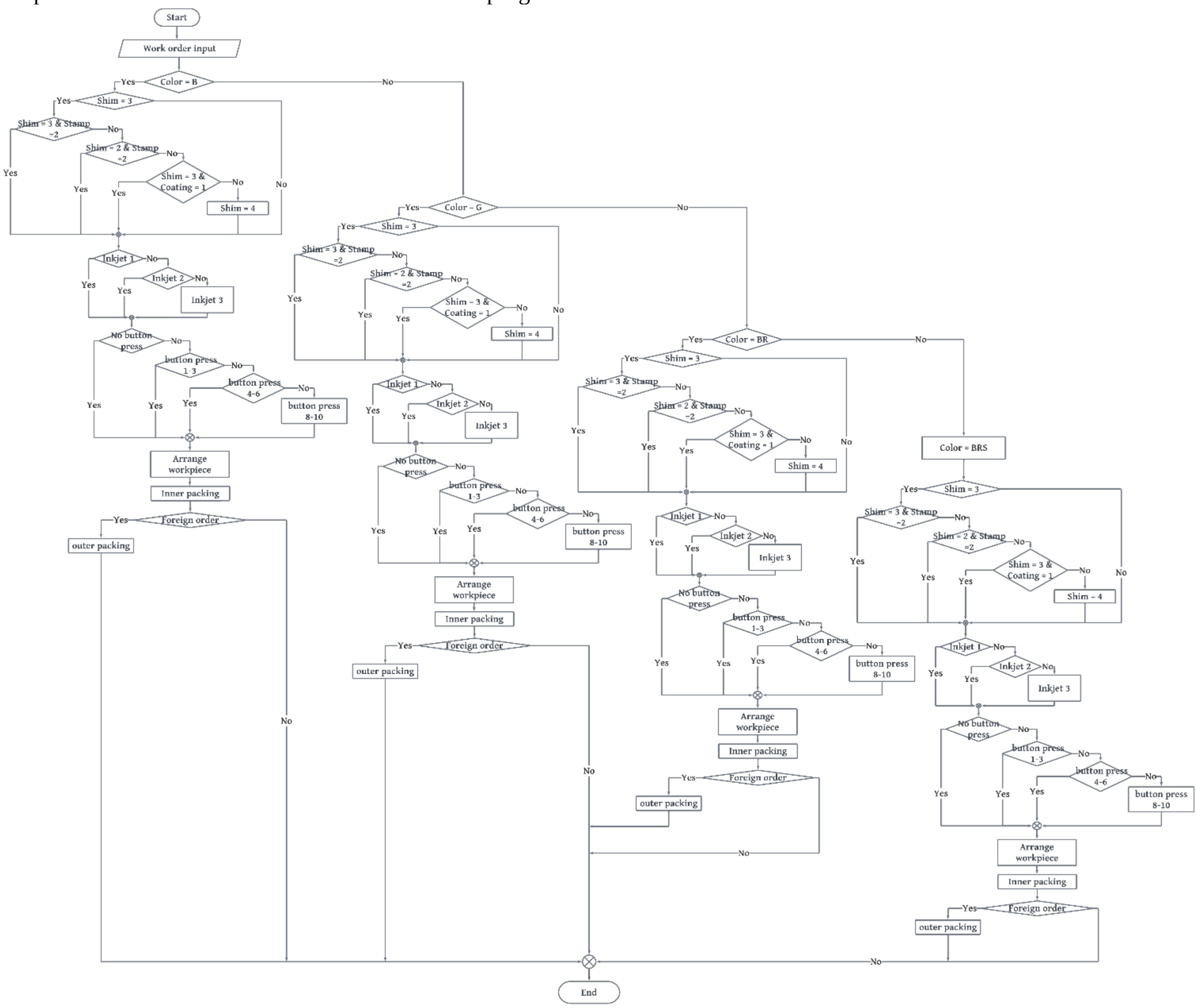

Fig. 2 Flowchart displaying VBA processing conditions

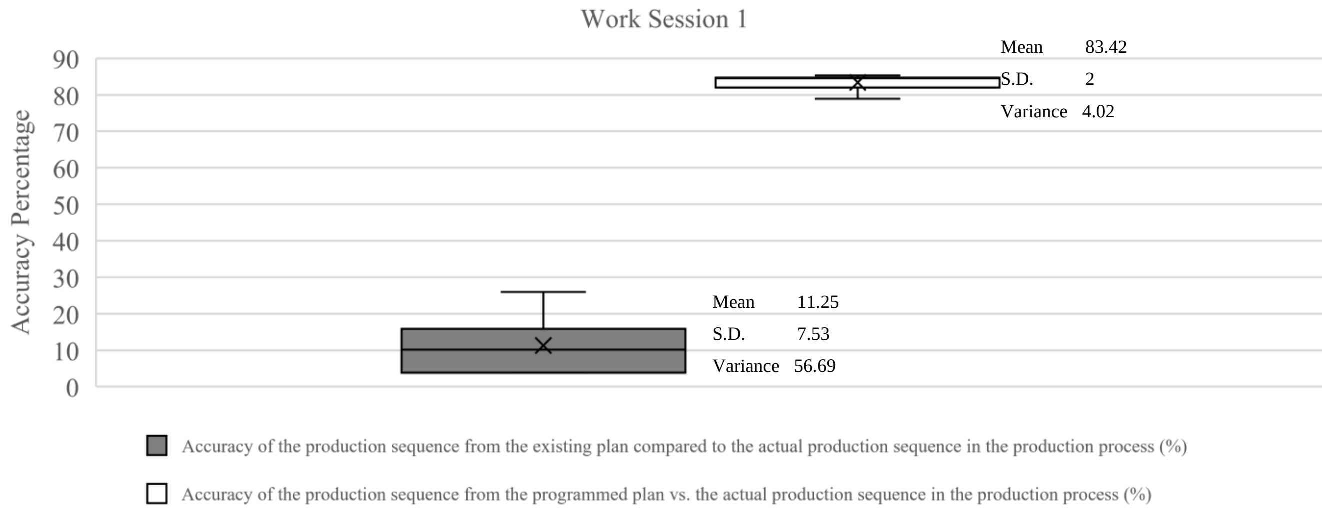

Fig. 3 Planning efficiency after using the built-in planning program in session 1

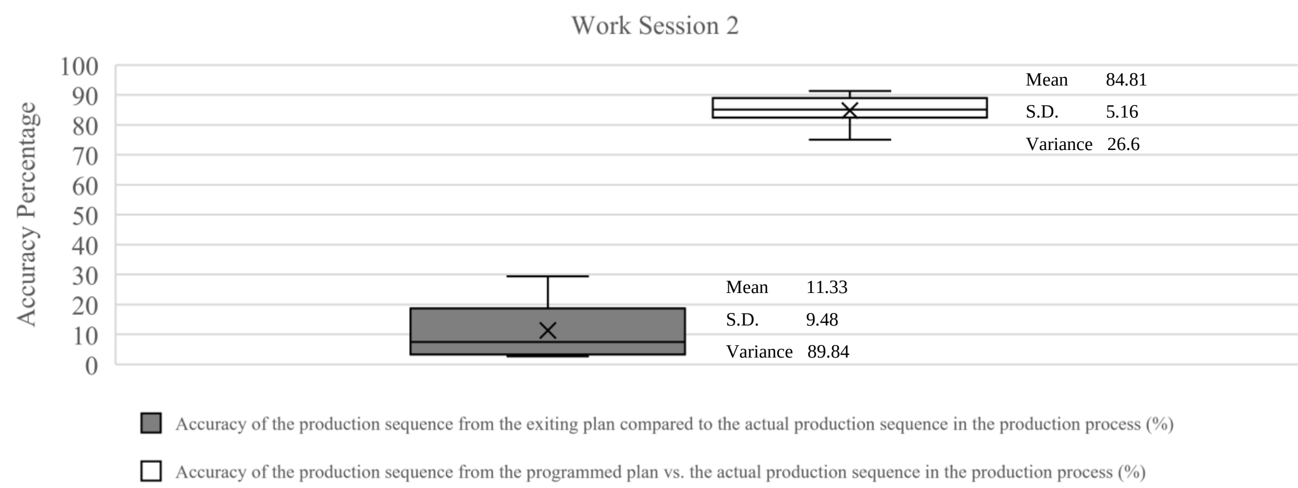

Fig. 4 Planning efficiency after using the built-in planning program in session 2

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