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TIME MEASUREMENT, LEFT AND RIGHT HAND OF THE ELECTRIC PLUG ASSEMBLY PROCESS.

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Abstact. A work map is a good tool used to analyze a job in order to facilitate work improvement planning for increased efficiency and productivity. A local work map is a work map to analyze work done at 1 work station. Right-hand and left-hand maps are part of a local work map. Local work maps are useful for assembly or production activities. Industries that produce products consisting of several components whose assembly process still uses operator power always carry out assembly activities at the local work station. The movements of the left and right hands when working are depicted on the left and right-hand maps. The layout of the components on the work table and the use of the right work map will provide better assembly cycle times. Furthermore, it will guarantee higher productivity and efficiency. The study focused on manual electrical plug assembly activities carried out by respondents at the research site. The layout of the plug components is placed on the assembly table arranged in such a way. Likewise with the division of tasks for the left and right hands when assembling the plug. The measurement produced 30 work elements in the assembly process and the cycle time for all work elements was 32.5 seconds. By adding adjustment factors and allowance factors, the normal time was obtained as 28.83 seconds. After calculating the allowance, the standard time is 32.15 seconds.

Keywords: work elements, cycle time, adjustment, allowance, standard time, work map.

1. Background

Ergonomics comes from Greek, consisting of two words: “ergon,” which means work, and “nomos,” which means rules or laws [1]. Ergonomics is a systematic branch of science that utilizes information about the nature, abilities, and limitations of humans in designing an effective work system to achieve desired goals through effective, efficient, safe, and comfortable work [2]. Ergonomics is the science, art, and application of technology to harmonize all facilities used in activities and rest based on human physical and mental capabilities and limitations, thereby improving overall quality of life [3]. Through the application of ergonomics, it is beneficial for increasing work productivity [4]. Ergonomics is a science that, in its application, strives to harmonize work and the environment for individuals to the highest degree by optimally utilizing human factors, which includes the reciprocal harmonization of work with labor for efficiency and comfort [5].

Generally, to achieve the best work results, humans must be placed in the best system (work environment, work tools, and work methods) [6]. It is known that a work map is a good tool for analyzing a job to facilitate the planning of work system improvements. Improving work methods by enhancing the work map can increase worker productivity [7]. The left-hand and right-hand maps are work maps that depict activities in the industry for producing products through the assembly process at local workstations. The left-hand/right-hand map is a tool from motion study used to analyze the movements performed by the left and right hands during tasks, which are typically assembly processes [5]. This map illustrates all movements during work as well as idle time of both hands. It also shows the comparison between tasks assigned to the left and right hands. The map provides a comprehensive depiction of operations, making it very practical for improving manual tasks, especially when each cycle of work occurs quickly and repeatedly. This tool is excellent for analyzing a work system to achieve better equipment layout, improved worker movement patterns, and effective task sequencing. By using this map, inefficient movement patterns and unnecessary actions can be clearly identified. To ensure that work remains within the normal working area, it is not sufficient to only optimize the layout; anatomical considerations must also be taken into account [8].

A description of the left and right hand maps and standard time is carried out through an electric plug assembly experiment. An electric plug is an electronic product produced through an assembly process. To determine the standard time for the assembly process and how the left hand and right hand cooperate in the assembly process, this research is necessary. Assembly is performed manually using standard screwdriver tools. The layout of the components to be assembled is positioned on the assembly table in such a way as to provide comfortable assembling movements. Likewise, the division of tasks between the left and right hands is aimed to be balanced to minimize idle hands. The stages of assembly and alternatives are created, and the best alternative assembly stages are selected. For ease of measurement, the assembly of the electric plug is divided into several work elements. Time measurements are conducted for each work element. The total time required to assemble one unit of the plug is the sum of the times for each of these work elements. The respondents are industrial engineering students from Untar. This study aims to obtain standard time. Standard time is the time required by a worker with an average skill level to complete a job. It includes allowances for time based on the situation and conditions of the work that needs to be completed. Standard time refers to the duration needed by an operator with an average skill level to finish a task. This standard time takes into account allowances for time based on the situational conditions of the work that must be accomplished. Previous research has found that work method improvements can be made by analyzing movements and times displayed on the left-hand and right-hand maps [9].

2. Methods

2.1 Samples

In this study, the respondents were 50 industrial engineering students.

2.2 Measurement

All research activities follow the research flowchart as presented in Figure 4. The research equipment and materials are shown in Figures 1, 2, and 3.

Figure 1. HandPhone

Figure 2. Electric plug

Figure 3. Standard screwdriver

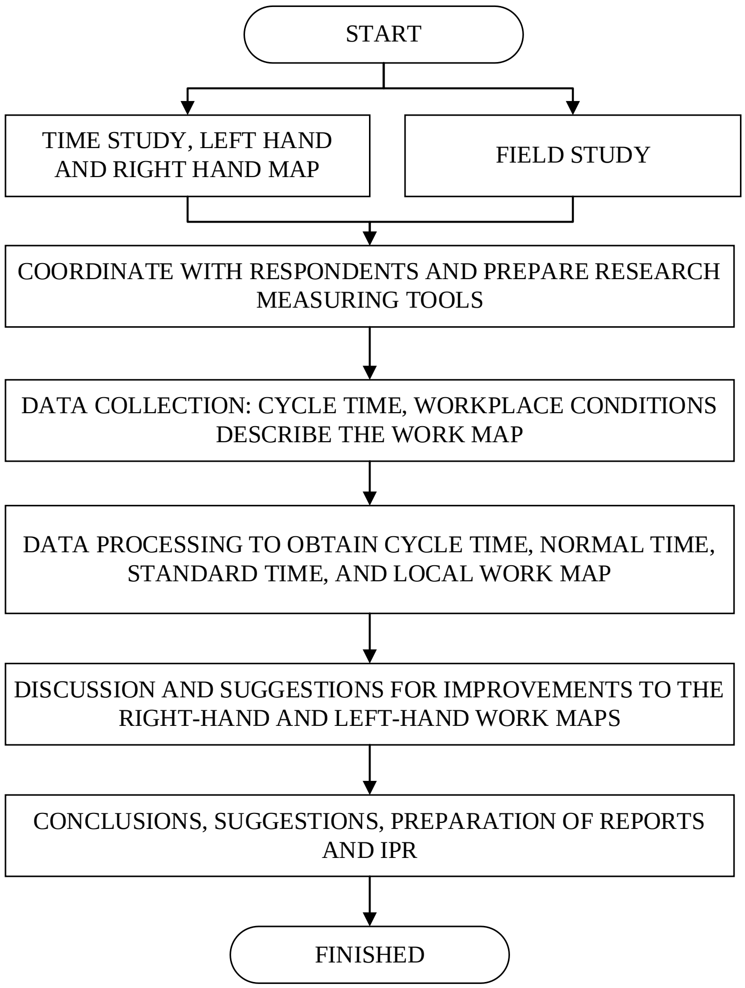


Figure 4. Research Flowchart

2.3 Data collection and analysis.

The research was conducted in the Ergonomics and Work System Design Laboratory using electric plugs as the research material. Below are displayed several images of the elements of the electric plug that will be assembled and the assembly process.

Figure 5. Electric Plug Body

Figure 6. Plug Cover Part 1

Figure 7. Screw

Figure 8. Cable Clamp

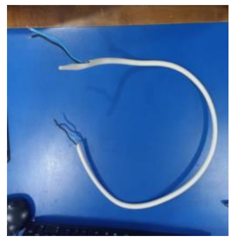


Figure 9. Cable

Figure 10. Assembly Process

In this study, 30 work elements were identified. Tables 1, 2, and 3 present a summary of the cycle time calculations for the work elements in the assembly process of the electric plug. The uniformity of the data was also tested, and the results are shown in the following figures.

Table 1. Mean, Median, Mode, and Standard Deviation of Work Elements 1-10 in the Assembly of Electric Plugs.

Statistics	WORK ELEMENTS (Time in Seconds)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mean	1,44	0,31	0,26	0,33	2,14	0,82	0,49	1,31	2,56	0,93
Median	1,43	0,32	0,26	0,33	2,13	0,81	0,50	1,32	2,58	0,92
Mode	1,37	0,3	0,28	0,33	2,22	0,81	0,5	1,32	2,5	0,88
Varians	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00
Standard	0,10	0,02	0,02	0,02	0,07	0,06	0,04	0,08	0,06	0,06

Table 2. Mean, Median, Mode, and Standard Deviation of Work Elements 11-20 in the Assembly of Electric Plugs.

Statistics	WORK ELEMENTS (Time in Seconds)									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Mean	0,47	1,09	10,19	0,77	0,21	0,56	1,43	1,25	0,91	0,47
Median	0,47	1,08	10,22	0,77	0,21	0,57	1,43	1,26	0,91	0,47
Mode	0,48	1,13	10,22	0,75	0,21	0,59	1,48	1,25	0,88	0,48
Varians	0,00	0,01	0,01	0,00	0,00	0,00	0,00	0,01	0,00	0,00
Standard	0,03	0,08	0,12	0,04	0,02	0,04	0,05	0,08	0,05	0,03

Table 3. Median, Mode, and Standard Deviation of Work Elements 21-30 in the Assembly of Electric Plugs.

Statistics	WORK ELEMENTS (Time in Seconds)									
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Mean	4,06	1,63	1,01	2,43	14,91	0,47	0,30	0,79	2,40	2,89
Median	4,05	1,64	1,02	2,46	14,90	0,47	0,30	0,80	2,42	2,91
Mode	4,1	1,66	1,03	2,2	14,9	0,5	0,3	0,86	2,42	2,98
Varians	0,01	0,00	0,01	0,02	0,00	0,00	0,00	0,00	0,01	0,02
Standard	0,09	0,04	0,08	0,14	0,06	0,04	0,02	0,06	0,10	0,14

Meanwhile, the uniformity test of several data for the assembly work elements is presented in the following series of control charts.

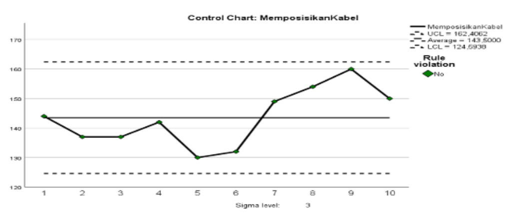


Figure 11. Control Chart for Positioning the Cable

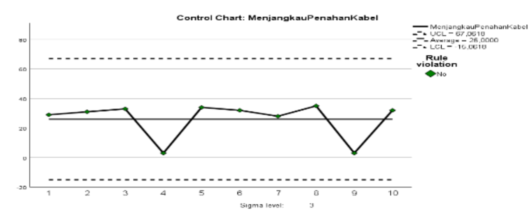


Figure 12. Control Chart for Reaching for the Screwdriver

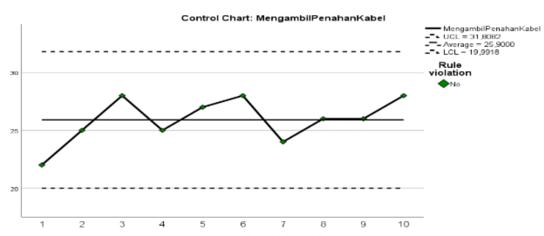


Figure 13. Control Chart for Taking the Cable Holder

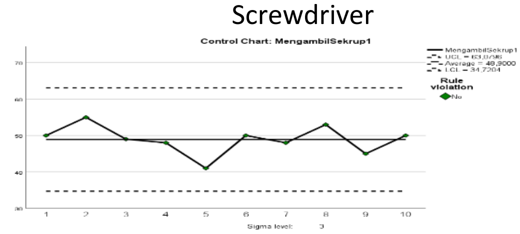


Figure 14. Control Chart for Taking the Screwdriver

3. Results and Discussion

In the assembly process of the electric plug, the placement of the plug components follows Figure 15. The components are arranged in such a way that the assembly process can be carried out quickly and comfortably. The left-hand and right-hand work maps obtained from this study are presented in Figure 15. As is known, the left-hand/right-hand map is a tool from motion study used to determine the various movements performed during specific activities, particularly in the assembly process of products. By illustrating this map, it becomes easier to identify efficient movements and inefficient ones. Efficient movements are those that are necessary for performing a task. In the assembly of the plug, the action of screwing is considered efficient, while the action of holding components can be categorized as less efficient.

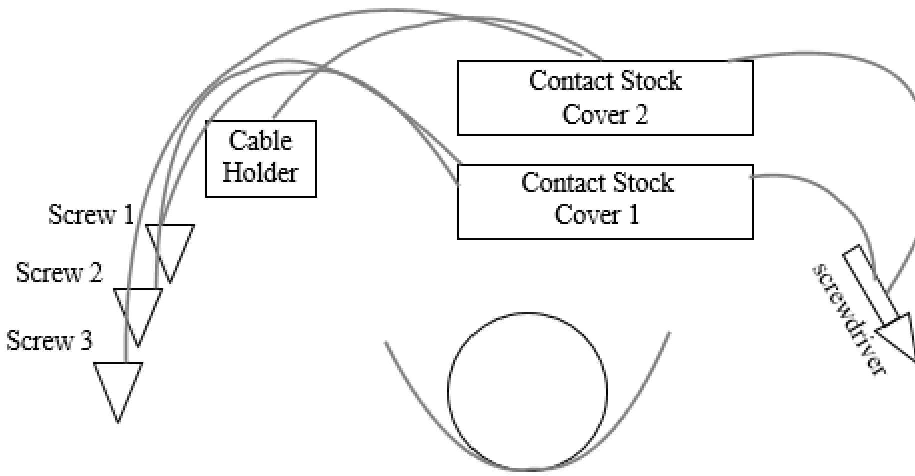


Figure 15. Operator Layout and Placement of Electric Plug Elements.

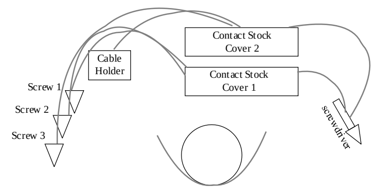
This map illustrates all movements during work and the idle time of both the left and right hands, and it also shows the comparison between tasks assigned to the left and right hands when performing an assembly job. Thus, through this left-hand and right-hand work map, improvements to the work station can be made. Based on the above, the left-hand and right-hand map for the assembly process of the electric plug is presented in Figure 16.

Next, a plug assembly workstation was designed. The work station is a place where an operator performs their job of making products or providing services. At the work station, there are various elements, including work tools or facilities, work tables, personnel, and it is situated in a specific work environment. To design an effective work system, a technique for organizing the components of the work system is necessary to achieve the desired work efficiency [5]. In the study of the electric plug assembly work station, the aspect considered is ergonomics, particularly the dimensions of the human body in determining the dimensions of the work table and the placement distance of the assembled product elements.

As is known, anthropometry is the field that studies the physical dimensions of the human body, which is useful for designing products, tools, and workspaces [1]. Dynamic anthropometry is more related to measuring physical characteristics of humans in dynamic situations, where the dimensions measured occur in various body positions during movement, making it more complex and challenging. In the assembly of the electric plug, the operator's body performs various movements, especially with the left and right hands. An illustration of dynamic anthropometry is presented in Figure 17. Based on the illustration, the placement of the assembled product components should be within a reach zone accessible to the operator in a static seated position, with a range of 394 mm to 597 mm. If there are few product components, they should be placed as close to the body as possible to reduce reaching time and other time losses. However, if a wider area is required, component placement can extend to the maximum reach achievable while seated. Products that are most frequently handled should be positioned closest, and vice versa. The following is a design for a box to hold the plug components and the layout for placing the box at the electric plug assembly work station. The base of the box is designed to be slanted so that the components always remain at the forefront of the box; this is because the components will slide forward due to the slanted base.

Left Hand and Right Hand Work Map

Job : Plug Assembly
Map Number : 01
Mapped by : I Wayan Sukania, Michael, Rymartin Jonsmith Djaha
DATE SET : July 23, 2024



Left hand	Distance (cm)	Time (seconds)	Label		Time (seconds)	Distance (cm)	Right hand
Positioning Cables	-	3	RE	RE	3	-	Positioning Cables
Reach the Cable Holder	5	1	G	G	1	5	Reach the Cable Holder
Take out the Cable Holder	-	0,5	M	M	0,5	-	Take out the Cable Holder
Positioning the Cable Holder	-	3	P	P	3	-	Positioning the Cable Holder
Reaching Screw 1	3	2	A	A	2	2	Reaching for a Screwdriver
Taking Screw 1	-	0,5	RE	RE	0,5	-	Take a Screwdriver
Holding Screw 1	-	0,5	G	G	0,5	-	Holding a Screwdriver
Installing Screws 1	-	1	M	M	1	-	Holding a Screwdriver
Reaching Contact Stock Cover 1	5	2	H	H	2	5	Reaching Contact Stock Cover 1
Using a Screwdriver To Tightening Screws 1	-	3,5	A	A	3,5	-	Using a Screwdriver To Tightening Screws 1
Retrieving Cover Stock Contact 1	-	0,5	M	M	0,5	-	Retrieving Cover Stock Contact 1
Holding Contact Stock Cover 1	-	0,5	H	H	0,5	-	Holding Contact Stock Cover 1
Reaching Screw 2	3	2	RE	RE	2	2	Reaching for a Screwdriver
Taking Screw 2	-	0,5	G	G	0,5	-	Take a Screwdriver
Holding Screw 2	-	0,5	M	M	0,5	-	Holding a Screwdriver
Reaching Contact Stock Cover 2	5	3	H	H	3	5	Reaching Contact Stock Cover 2
Taking Stock Contact Cover 2	-	0,5	A	A	0,5	-	Taking Stock Contact Cover 2
Holding Contact Stock Cover 2	-	0,5	RE	RE	0,5	-	Holding Contact Stock Cover 2
Installing Contact Stock Cover 2	-	2,5	G	G	2,5	-	Installing Contact Stock Cover 2
Take, Install and Tightening Screws 3	5	5	M	M	5	5	Picking up, installing and Tightening Screws 3
Total	26	32,5			32,5	22	
Ringkasan	-						
Number of Products Each Cycle	**1**						
Time to Make One Product	**32,5**						

Figure 16. Left-Hand and Right-Hand Work Map.

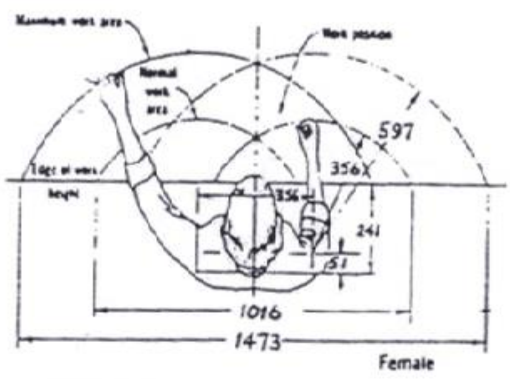


Figure 17. Dynamic Anthropometry [4].

Figure 18. Layout of the Box Placement at the Electric Plug Assembly Work Station.

Most products consist of several to thousands of components. The smallest arrangement that forms a product is called an element. Several elements form sub-elements, which together with other sub-elements combine to create sub-products. A product can be composed of functional elements that are either modular or integral [12]. For complex products, the final assembly occurs at the sub-product level. The electric plug consists of several elements, and in this study, the electric plug product comprises at least 11 components. The switch is actually a sub-component because it consists of several joined elements that function to connect or disconnect the electrical current. In this study, the switch is considered as a single element. For the ease of data collection, the assembly activities focus on the installation of several screws and the assembly of the electric plug body.

Based on observations and the left-hand and right-hand maps, it appears that the right hand is more actively engaged. However, in other tasks, such as sewing, the left hand is more active [15]. This research involved industrial engineering students from the 2021 cohort. To facilitate the study, the students were divided into 10 groups. Each group member conducted experiments assembling plugs and created left-hand and right-hand maps. Before data collection, each participant was given the opportunity to practice assembling until they felt their assembly skills were sufficient for the data collection process. The activities took place in the work system design and ergonomics laboratory. Human activities are influenced by several factors [5]. These factors can originate from the individual (internal) or as a result of external influences (external). One external factor is the work environment during the activity. The state of the environment is shaped by various elements, including air temperature and humidity, air circulation, lighting, noise, mechanical vibrations, odors, speed, acceleration, height, depth, and others. Based on the laboratory conditions, it can be stated that the work environment supports the assembly activities.

The time measurement for assembling the electric plug is a direct measurement, which is conducted on-site using a stopwatch technique. Assembly is performed on a table, and all activities are carried out using the left and right hands. Therefore, the analysis is conducted using the left-hand and right-hand maps. All activities consist of 30 work elements. After conducting data adequacy tests, uniformity tests, and normality tests, it was found that the amount of data collected was sufficient. Based on the distribution of measurement data in the control chart, it is evident that all activities show uniform data. Therefore, data analysis proceeded to the calculation of the average and standard deviation of the cycle times for each work element in the assembly of the plug. Based on the calculation results, the average and standard deviation of the cycle times for various work elements in the assembly process are presented in Tables 3.5 to 3.9. Thus, the cycle times for the work elements have been successfully obtained.

However, the measurements were conducted under non-ideal conditions; therefore, the results require adjustment factors and allowances. Adjustment factors are used when the observer notices the operator working at an unusual speed, necessitating adjustments to obtain a reasonable average cycle time. Allowances are given for personal needs, alleviating fatigue, and unavoidable hindrances. In this practical work, adjustment factors were applied using the Westinghouse method with an adjustment table tailored for Indonesians. The factors of skill, effort, work conditions, and consistency were taken based on the laboratory conditions. For the skill factor, an average level was chosen with a score of 0.00, and the effort was valued at -0.04, which is a new adjustment by Sutalaksana & Gustomo. For the work conditions, a score of -0.05 was taken, and consistency was valued at -0.04 [5]. Based on these adjustment factors, the normal times for the work elements in the plug assembly can be calculated.

Next, to obtain standard time, allowance factors need to be determined. The allowance factors include the energy expended, work attitude, work movements, eye fatigue, workplace temperature, atmospheric conditions, and overall environmental quality. Allowance factors are expressed as a percentage of the cycle time. Based on the workload exerted, the assembly of the plug components is considered very light (unloaded), so an allowance value of 0-6 is chosen, with a score of 5. Regarding work attitude, since assembly is performed in a seated position, a score is taken from 0-1, with a score of 1 being assigned. For the movement factor, the assembly movements are categorized as normal with a score of 0. For eye fatigue, a value of 0-6 is taken, with a score of 5 assigned, given that the components being assembled are small and require careful visual attention. The temperature of the workspace is categorized as normal, thus a score of 0 is assigned. The atmospheric conditions are good, with adequate air circulation and a clean and healthy environment, which also results in a score of 0. Personal needs receive an allowance of 2.5.

The following is a summary of the adjustment and allowance factor values in the standard time calculations for the left-hand and right-hand assembly processes presented in Table 4.

Table 4. Adjustment Factors and Allowance Factors in the Electric Plug Assembly Process.

Number	Adjustment Factors.	Value %.	Allowance Factors.	Value %.
1.	Effort.	-0,04	Work Attitude.	1
2.	Working Condition	-0,03	Work Movements.	0
3.	Consistency.	-0,04	Eye Fatigue.	5
4.			Temperature.	0
5.			Atmospheric Conditions.	0
6.			Personal Needs.	2,5
Total		**-0,11**	**Total**	**13,5**

Cycle Time of Electric Plug Assembly. = 32,5 Seconds
Normal Time for Electric Plug Assembly. = Wn =Ws x P = 32,5 Seconds x (1 - 0,11)
= 28,83 Seconds

Standard Time for Electric Plug Assembly. = WB = WN + (Wn × Alowance)
= 28,33 + (28,33 x 13,5%)
= 28,33 + 3,82
= 32,15 Seconds

In the manual assembly process of the electric plug using a screwdriver, it is known that the left and right hands have been assigned balanced tasks. However, in this case, there is an ineffective work element, which is the element of holding components.

4. Conclusion

The analysis of work methods in the assembly of electric plugs using the left and right hand maps yields several conclusions and recommendations:

a. The assembly process of electric plugs using the left and right hands consists of 30 work elements.
b. Through time measurements, the addition of adjustment factors and allowance factors results in a standard time of 32.15 seconds for the assembly of 1 unit of electric plug.
c. The layout of the plug components located on the left side and the top of the workbench results in a cycle time of 32.5 seconds for the assembly.

Recommendations.

Several recommendations for improving the results of this research include:

a. Various alternative layouts for the components to be assembled are needed to achieve minimal assembly time.
b. A more detailed investigation is required regarding the assignment of the left and right hands to ensure a more balanced approach, allowing for faster assembly times.
c. It is necessary to measure the time when a holding aid is provided to determine whether it leads to faster assembly times or not.
d. Assembly trials conducted by two or more individuals should be performed to obtain the fastest assembly time.

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