Songklanakarin J. Sci. Technol.
40(1), 219-230, Jan. - Feb. 2018

http://www.sjst.psu.ac.th

Original Article

Productivity improvement for heating ventilation and air conditioning unit assembly

Vichai Rungreunganun* and Teansin Sriwasut

Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok,Bang Sue, Bangkok, 10800 Thailand

Received: 30 May 2016; Revised: 28 October 2016; Accepted: 2 December 2016

Abstract

The objective of this research was to improve the productivity for the air conditioner unit of for car manufacturers. The target production volume of the air conditioner unit was greater than 46 pieces per hour. The current capacity was insufficient, so the researchers studied the problems using a study of the assembly standard time. The study found the assembly line bottleneck standard time was 1.64 minutes per piece, representing a yield of 36 pieces per hour. The labor productivity was 1.84 pieces per person per hour. The operation two-hand chart and operation area check sheet analysis was applied to find the operations that should be improved because the standard time was over the takt time. After that the Eliminate, Combine, Rearrange, Simplify (ECRS) technique was used to propose a method for process improvement. After improvement, the bottleneck was 1.28 minutes per piece which represented a yield of 46.9 pieces per hour. The labor production rate was equivalent to 2.35 pieces per hour or an increase of 27.1%.

Keywords:productivity improvement, standard time, motion economy, ECRS

1. Introduction

Thailand's uncertain political situation during the first quarter of 2014 directly affected the automobile industry. For example, some automobile manufacturers postponed production plans of new car models. Nevertheless, after the new government came to power, Thailand's political situation improved. Automobile manufacturers started introducing new car models to the market leading to the anticipated higher sales volumes. The company under study is a manufacturer of parts for the car air conditioning units for car manufacturers such as Isuzu, Nissan, and Suzuki. A car manufacturer opened a new assembly line in a new factory and launched a new car model in the market leading to a higher demand outlook. This caused the production volume to likely increase for the parts of the air conditioning unit for the company under study, which is considered one of the foremost suppliers. Upon comparing the demand from its customers and the company's output, it was found that in January the required production capacity per hour would need to increase to 46 cars per hour or a 27% increase in production capacity to accommodate the demand. On worker capacity basis, it was found that the current capacity of one worker was 1.55 pieces per hour, whereas the target of the engineering department was 2.25 pieces per labor hour. This showed that the actual labor hour capacity fell short of the target by 31% which would impact the production cost and the company's profitability. It thus became necessary to improve the assembly process of the automobile air conditioning unit to increase output in line with demand and improve productivity to achieve the company's target.

*Corresponding author
Email address: r_vichai@yahoo.com

2. Materials and Methods

2.1 Selection of the company's production line

The company under study produces parts for the automobile parts manufacturing industry. It has 6 business units comprised of electronics, air conditioning, heat exchange systems, compressors, exhaust system parts, and parts found in the car interior (Figure 1).

From the initial study, the air conditioning unit business is the group's second largest in terms of sales that represents 19% of the company's entire business and employs up to 38% of its workers. Moreover, within the air conditioning unit business, it was found that the production volume of the H60A part was likely to increase significantly. As a result, the researchers decided to choose the H60A production line to conduct the study.

The researchers studied monthly production volume and found that the volume had a tendency to increase and actually increased from June 2014 to March 2015 (Table 1). The average production in 2014 between October and December was 6,513 units per month. The production volume started to increase in January 2015 at 7,535 units per month and continued to increase to 7,808 units in March 2015 or a 15% surge. From January 2015 onwards, production was recorded at 46.1 pieces per hour with a takt time of 1.3 minutes per piece.

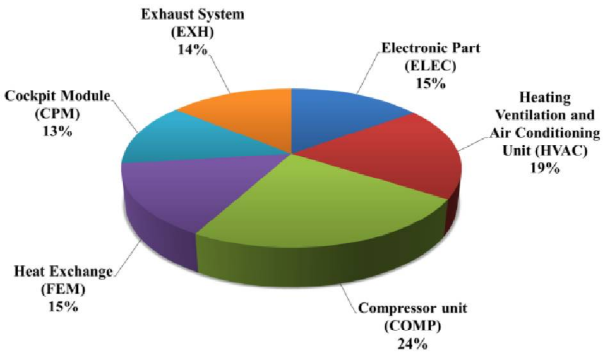


Figure 1. Company's business unit and sales amounts in %.

2.2 Process analysis

2.2.1 Assembly process flow chart

The researchers used the process flow chart analysis method (Sornsuvith, 2003) for a preliminary understanding of the complete production process of the product under study by dividing the process into 3 separate parts, i.e. sub-line, main line and final assembly line (Figure 2).

2.2.2 Standard time

To determine the current productivity, the researchers used the standard time analysis method. The tasks of each workstation were divided into work elements based on the Standard Operation Sheet of each workstation. Then a decimal type stop watch was used to measure the work element. Maytag's method (Kanjanapanyakom, 2008) was applied to compute the time study identified by 95% confidence level and an acceptable ±5% error and then configured for the selected time. The rate of workingwas evaluated by Westinghouse's rating system (Kanjanapanyakom, 2008) to adjust the selected time to represent the normal time. The last step was the evaluation allowance factor required for the performance of each employee and adjusted to standard time of each work station. The 8 steps in the standard time analysis are shown in Figure 3. Values of the time study can be computed by application of Maytag's method which has 2 ways to compute N.

If the cycle time was more than 2 min, the initial time study was (n) = 5.

$$N = \left[\frac{\frac{\bar{R}}{\bar{X}}}{0.025 \times 2.326}\right]^2$$

If cycle time was less than 2 min, the initial time study was (n) = 10.

$$N = \left[\frac{\frac{\bar{R}}{\bar{X}}}{0.025 \times 3.078}\right]^2$$

But normally, sometimes the operator can change or rearrange the workstation. So we applied the Westinghouse rating system (Kanjanapanyakom, 2008) to evaluate the working ratio of each operator (Table 1).

2.2.3 Line balancing analysis

After the standard times were studied, the next step was to compare the standard times of each work station and with the customer requirements or the takt time (Komanasin, 2006). Table 2 shows the minimum takt time in January as 1.3 min per piece and we used the line balancing chart (Hafizuddin*et al.,* 2012) (Figure 4). It can be seen that there were huge differences between the standard time for each work station. Upon studying the balance of the production line it was found that the line balance value (Komanasin, 2006) stood at 65.4% and the total standard time from 20 stations was 21.3 minutes. Therefore, we could determine the minimum number of operators as 16 operators according to this equation: minimum number of operators = total standard time/minimum takt time.

The bottleneck process consisted of 4 stations, i.e. station numbers 7, 8, 11, and 18, that had standard times of 1.66, 1.57, 1.58, 1.53 minutes per piece by sequence, which were higher than the takt time or equivalent to 36.8 pieces per hour. We found 9 work stations with standard times that were under the takt time too often. Therefore, it was deemed that such a rate of production would not meet the customer requirements. In the meantime, the direct productivity rate from the 20 workers yielded a capacity of 1.84 pieces per worker per hour.

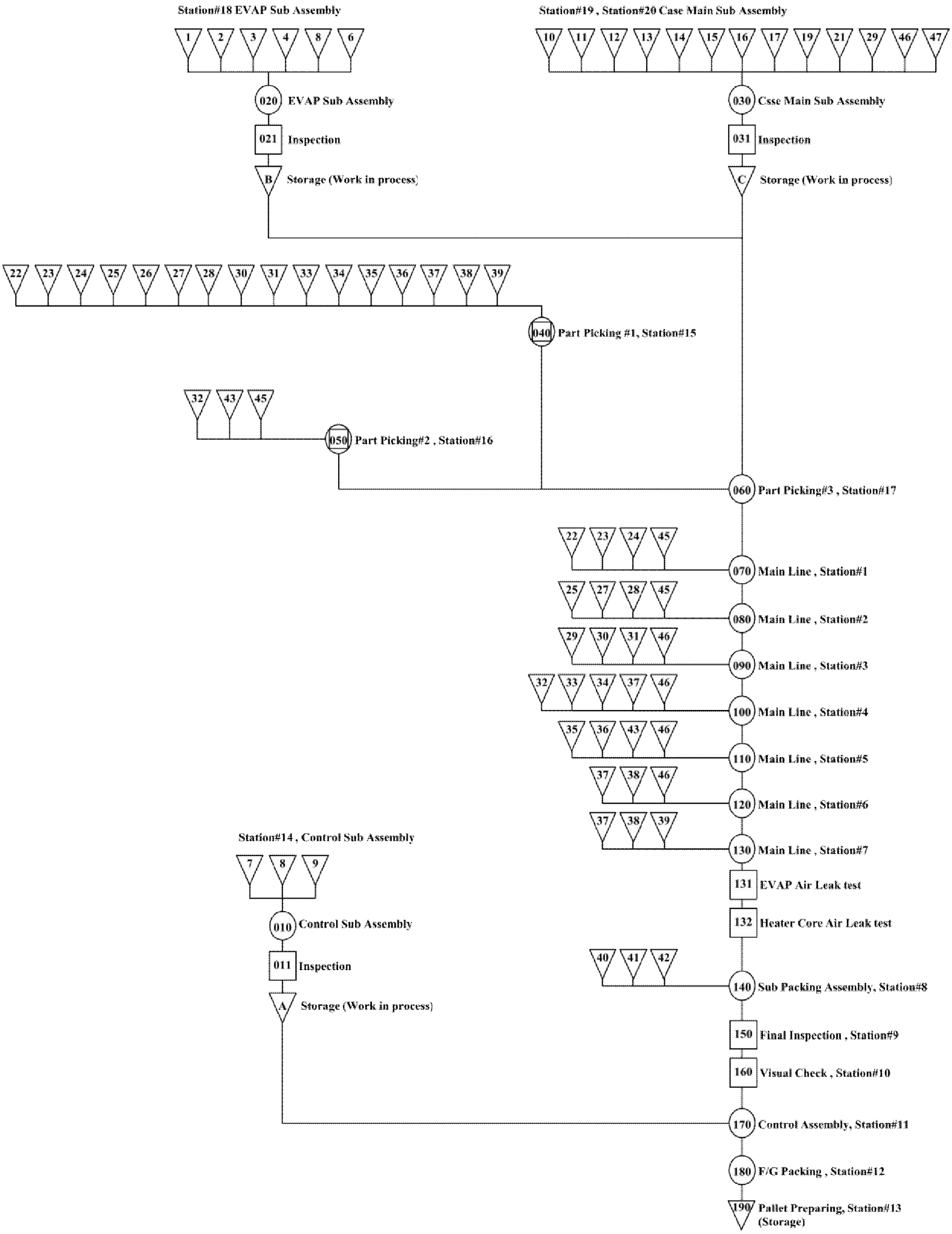


Figure 2. Assembly process flow chart.

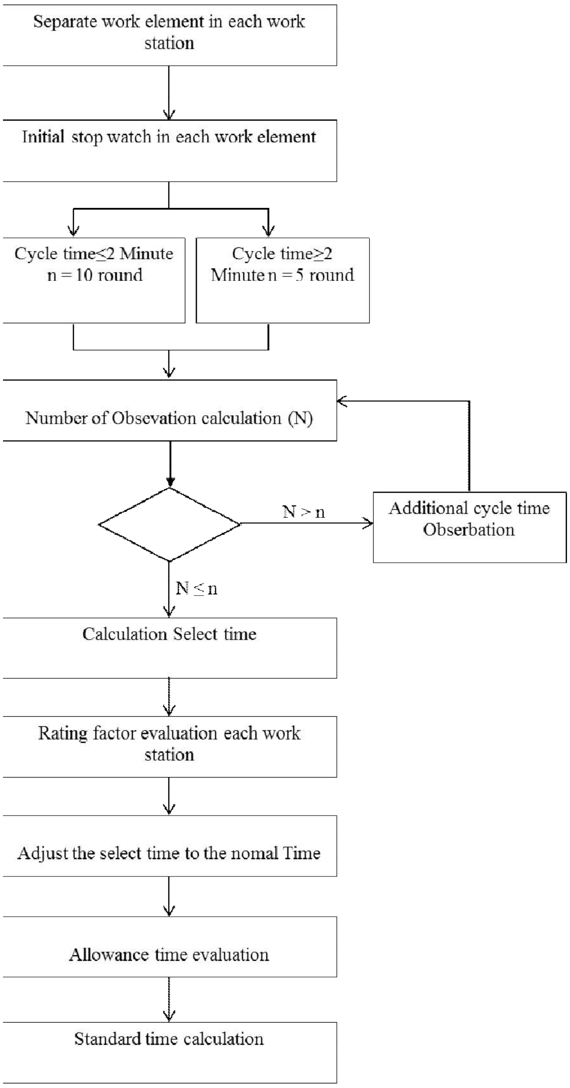


Figure 3. Standard time procedure.

Table 1. Westinghouse's rating system (Kanjanapanyakom, 2008).

Skill			Effort		
+0.15	A1	Superskill	+0.13	A1	Excessive
+0.13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0.08	B2		+0.08	B2	
+0.06	C1	Good	+0.05	C1	Good
+0.03	C2		+0.02	C2	
+0.00	D	Average	0.00	D	Average
-0.05	E1	Fair	-0.04	E1	Fair
-0.10	E2		-0.08	E2	
-0.16	F1	Poor	-0.12	F1	Poor
-0.22	F2		-0.17	F2	
Condition			Consistency		
+0.06	A	Ideal	+0.04	A	Perfect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0.00	D	Average	0.00	D	Average
-0.03	E	Fair	-0.02	E	Fair
-0.07	F	Poor	-0.04	F	Poor

Table 2. Production in each month.

Details/Month	Formula	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Order Per Month	A	1709	2166	3462	6042	5437	6513	6184	7535	7134	7808
Working Hour Per Shift	B	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17
Number of Working Day	C	21	23	20	23	22	22	21	20	19	21
Number of Shift	D	1	1	1	1	1	1	1	1	1	1
Output Unit Per Hour	E=A/B/C	10.0	11.5	21.2	32.2	30.2	36.2	36.0	46.1	46.0	45.5
Takt Time Per Unit (Minute)	F=60/E	6.02	5.21	2.83	1.87	1.98	1.66	1.66	1.30	1.31	1.32

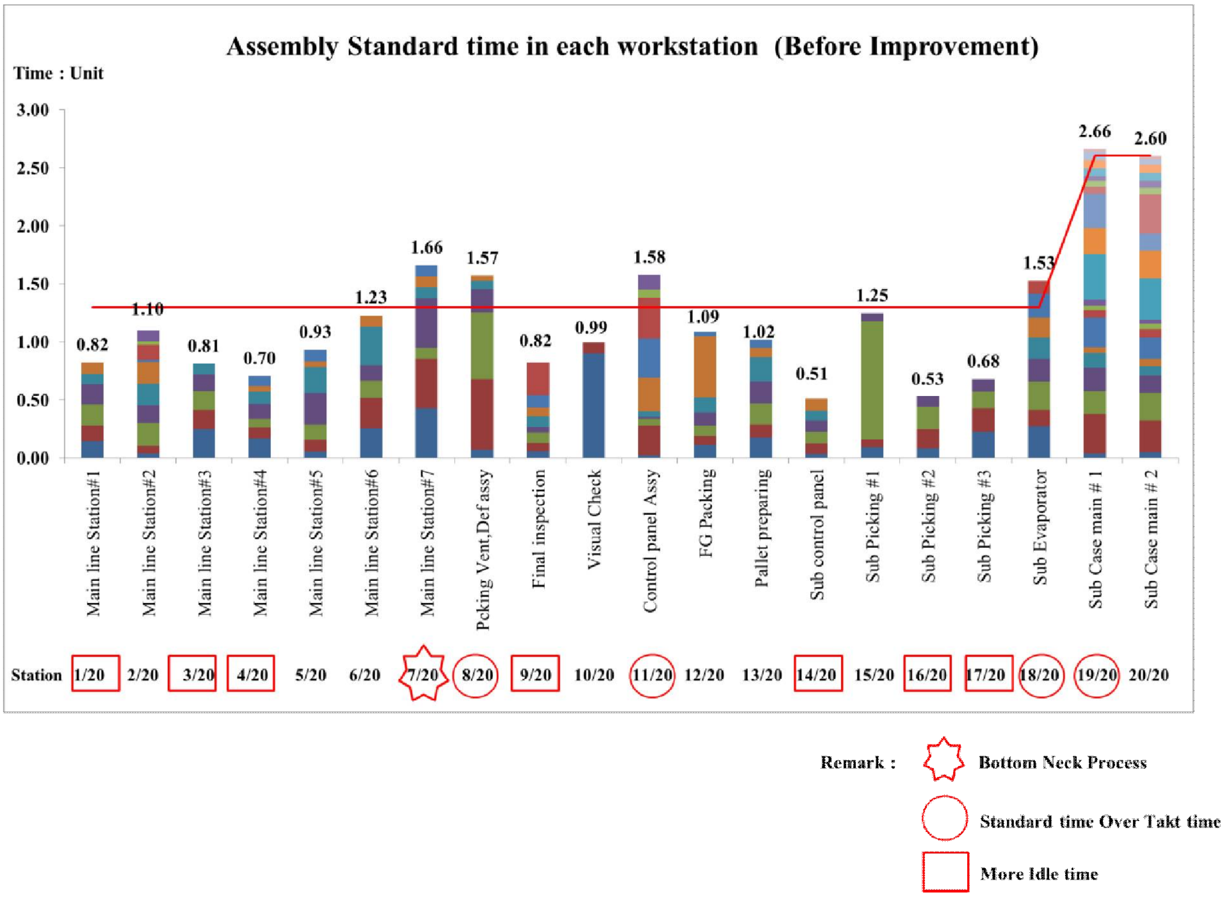


Figure 4. Standard time in each work station (before improvements)

2.2.4 Operation analysis

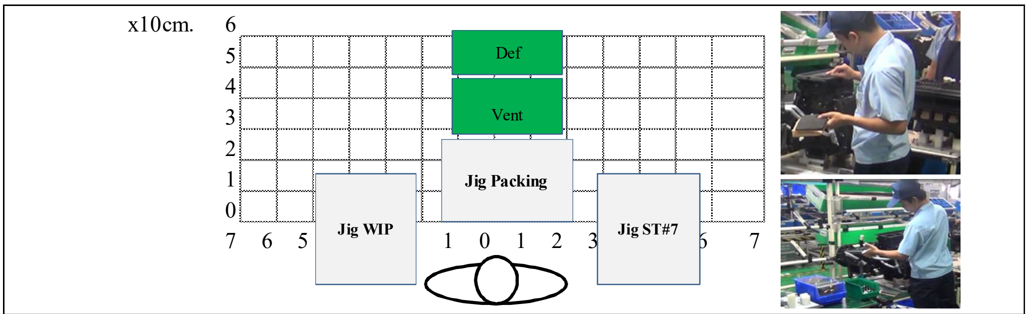
After learning the production issues, the team performed an analysis to improve the process by selecting the workstation that had the standard time higher than the takt time for further refinement using the operation two-hand chart (Figure 5). The outcome of the analysis revealed that the production capacity of the station that exceeded the takt time was indeed low. The results of the operation two-hand chart are shown in Table 3. The percentages of the operations were not very high. At station 8 the percentages were 39%, 21%, 10%, and 8% for operation, transportation, holding, and idle, respectively.

Next the study team applied the economic motion concept (Rijiravanich, 2002) to identify the operation area that required improvement by analyzing the working area (Figure 6). The outcome of the analysis revealed that the stations that consumed more time than the takt time were located outside the Over Point in several places which should be relocated to reduce the assembly time. The results of the operation area check sheet (Table 4) found that station 18 and station 19 had more over limit points. Therefore, we needed to redesign the layout of the working area or reduce the working area space.

Operation Two Hand Chart

Process	QUANTITY LH	RH	RATIO LH	RH
OPERATIONS	4	11	21%	58%
TRANSPORTS	2	6	11%	32%
HOLD	10	2	53%	11%
DELAYS	3	0	16%	0%
TOTAL	19	19		
DISTANCE (cm)	184	385		

CHARTED BY / DATE	12/11/2557
OPERATION NAME	Station # 8 Packing Vent,Def
OPERATOR NAME	
REMARKS	Before Improvement



	LEFT HAND	DISTNACE	OPERATION	TRANSPORT	HOLD	DELAY	OPERATION	TRANSPORT	HOLD	DELAY	DISTANCE		RIGHT HAND
1	Move the HVAC from ST#7 to jig packing.	84		●				●			30	1	Move the HVAC from ST#7 to jig packing.
2	Idle					●		●			60	2	Picked the Packing Def from the shelves to table
3	Remove the masking tape off half		●				●					3	Pulled Packing Def from the masking tape
4	Hold the Packing Def				●		●					4	sticked the Packing Def on part
5	Removed remain masking tape		●						●			5	Hold
6	Hold				●		●					6	sticked remain the Packing Def on part
7	Idle					●		●			65	7	Picked the PackingVent#1 from the shelves to table
8	Remove the masking tape off half		●				●					8	Pulled the PackingVent#1 from the masking tape
9	Hold the Packing Def				●		●					9	sticked the PackingVent#1 on the main part
10	Remove the masking tape remain		●						●			10	Hold
11	Idle					●		●			65	11	Picked the PackingVent#2 from the shelves to table
12	Hold				●		●					12	Pulled the PackingVent#2 from the tape
13	Hold				●		●					13	Sticked the PackingVent#2 into main part
14	Hold				●		●					14	Pulled the PackingVent#2 from the masking tape
15	Hold				●		●					15	Sticked the PackingVent#2 into main part
16	Hold				●		●					16	Pulled the PackingVent#2 from the masking tape
17	Hold				●		●					17	Sticked the PackingVent#2 into main part
18	Idle				●			●			65	18	Return the Packing Vent#2 to the shelves
19	Move the HVAC to next station	100		●				●			100	19	Move the HVAC to next station
		184	4	2	10	3	11	6	2	0	385		

Figure 5. Application of an operation two-hand chart

Table 3. Operation two-hand analysis results

Element	Symbol	Station 8			Station 11			Station18			Station19		
		RH	LH	%	RH	LH	%	RH	LH	%	RH	LH	%
Operation	○	4	11	39	9	10	53	11	15	59	14	13	44
Transport	⇨	2	6	21	3	3	17	9	2	25	13	3	26
Hold	▽	10	2	32	4	3	19	0	3	7	1	5	10
Idle	D	3	0	8	2	2	11	2	2	9	3	10	20
Total		19	19		18	18		22	22		31	31	

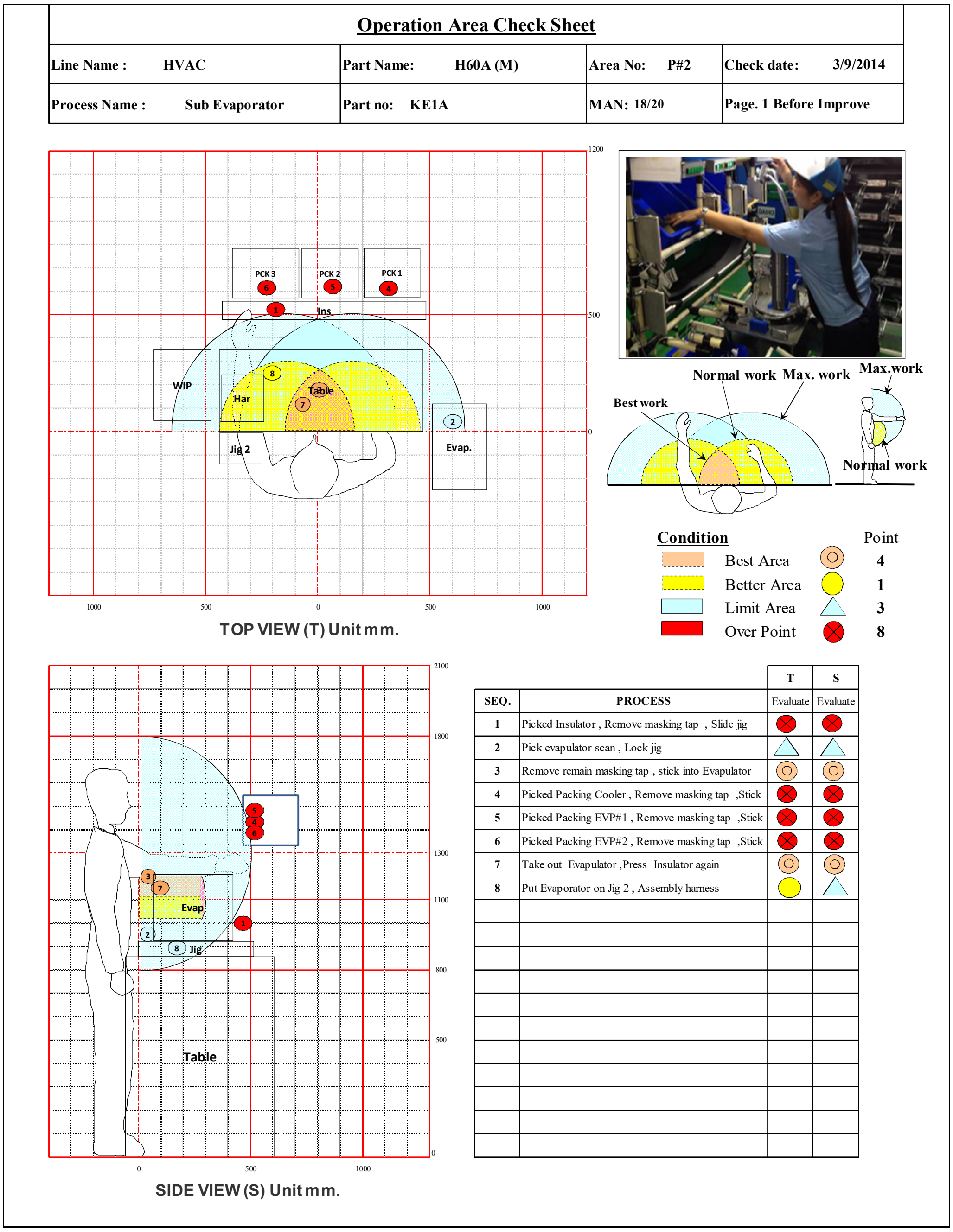


Figure 6. Application of the operation area check sheet.

Table 4. Operation area check sheet analysis results.

Working Area	Symbol	Station8	Station11	Station18	Station19
Best Area		18	7	4	4
Better Area		0	4	1	8
Limit Area	△	6	7	3	14
Over Point	⊗	0	0	8	12

2.2.5 Problem solving

The research team had a brainstorming session to come up with recommended guidelines to improve the process which was summarized in bullet point format (Table 5). From the line balancing chart and considering the process flow chart (Figure 2), we could separate the ideas to rearrange the work elements into 4 groups (Figure 7). Group 1 was to rearrange the job from station 20 to station 1. Group 2 was to rearrange and change the job sequence between the main line stations 4, 5, 6, and 7. Group 3 was to change the job sequence from station 8 to station 9. The final group change is the job sequence from station 11 to station 14. In order to increase the operation ratio of stations 8 and 18, the researcher applied a simple jig to the packing vent holding. Therefore, we could eliminate some work elements that had no value. Figure 8 shows the simple jig concept design. For stations 18 and 19 that had over limit areas we could redesign the layout and adjust the position of the working table to reduce the reach distance. Figure 9 shows the improvement of over limit point reduction.

3. Results and Discussion

After implementation of the improvement points, we performed an analysis using the operation two-hand chart and the operations were checked again. We found that for stations 8 and 19 we could eliminate 2 steps of work elements for both hands or equal to the movement for 135-mm and 151-mm reductions. For station 18 we could eliminate 6 steps of work elements by both hands or equal to a movement reduction of 431 mm (Table 6).

From an operation area check, we found the over limit points were reduced. Station 18 had no over limit point, station 19 was reduced by 6 points but still had 6 points (Table 7). The study team also took note of the new standard times (Figure 10).

The line balancing results of the 4 groups are shown in Figure 10. All stations that rearranged the jobs and changed the operation sequences of the standard times were under the takt time and the line balance after the adjustments improved to 79.1%. The bottleneck stations with the new longest processing times were stations 6 and 11 that had a new standard time of 1.28 min per round which yielded a production capacity of 46.9 pieces per hour, or equivalent to the capacity of 20 workers at 2.35 pieces per hour per worker (Table 8).

4. Conclusions

From studying the problems associated with the production process, the team found that purchase orders which had soared to 45 pieces per hour required the assembly lines to operate for 21.3 minutes to complete the job with station 7 recording a processing time of 1.64 minutes per piece or 36 pieces per hour. Its efficiency value stood at 1.84 pieces per person per hour thus failing to meet the client's requirements. The production line balance value was recorded at 64.5% causing waiting time or idle time in some cases.

After implementing the suggested guidelines, the standard time, taking into account all assembly processes, was reduced to 20.24 minutes with station 6 recording the longest processing time of 1.28 minutes that equated to an assembly capacity of 46.9 pieces per hour and still using the same 20 workers. The productivity improved to 2.35 pieces per person per hour and the balance value in the production lines increased to 79.1%. Comparisons of the operational efficiency and effectiveness of this project are illustrated in Table 9.

Fine-tuning of the work process can further be implemented for the preparation of part function or sub picking at stations 15, 16, and 17. More jobs could be eliminated and the factory under study should conduct a further analysis in order to identify spots that require improvements. This would support productivity enhancement to meet the prescribed targets

Table 5. Guidelines to resolve the problems.

Problem	Station	Improvement Theme	Countermeasure / Action
1. More idle time & Unbalance line	1 - 7	Rearrange	1.Consider job sequence, Rearrange job base on Assembly flow chart
2. OperationRate (O) too low	8	Eliminate	2.1Eliminate the job not addition values
	11		
	18	Simplify	2.2 Addition Jig and fixture to support part holding
	19		
3. Over limit working area	18	Motion Economy	3.Relayoutworking area
	19		

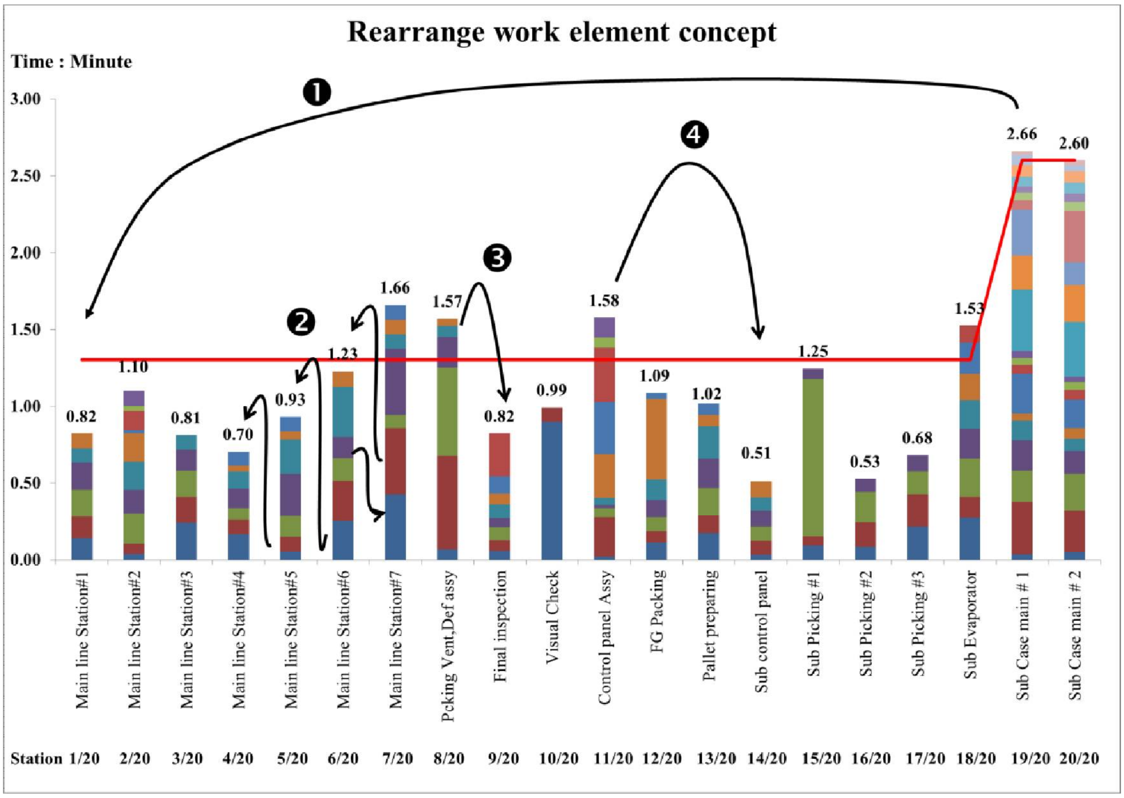
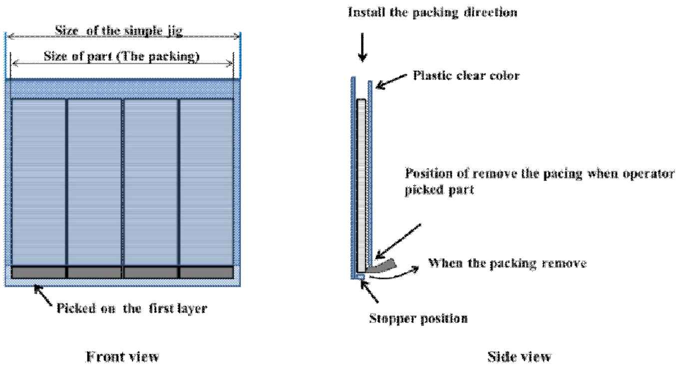
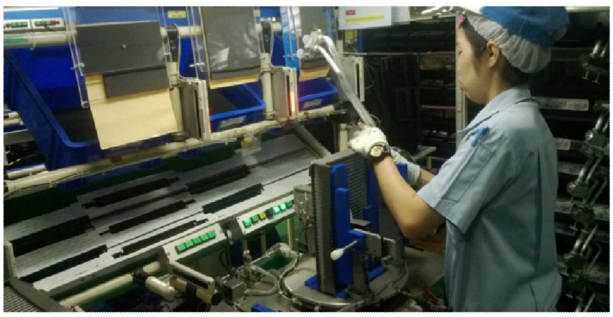


Figure 7. Concept for rearranging the work elements.

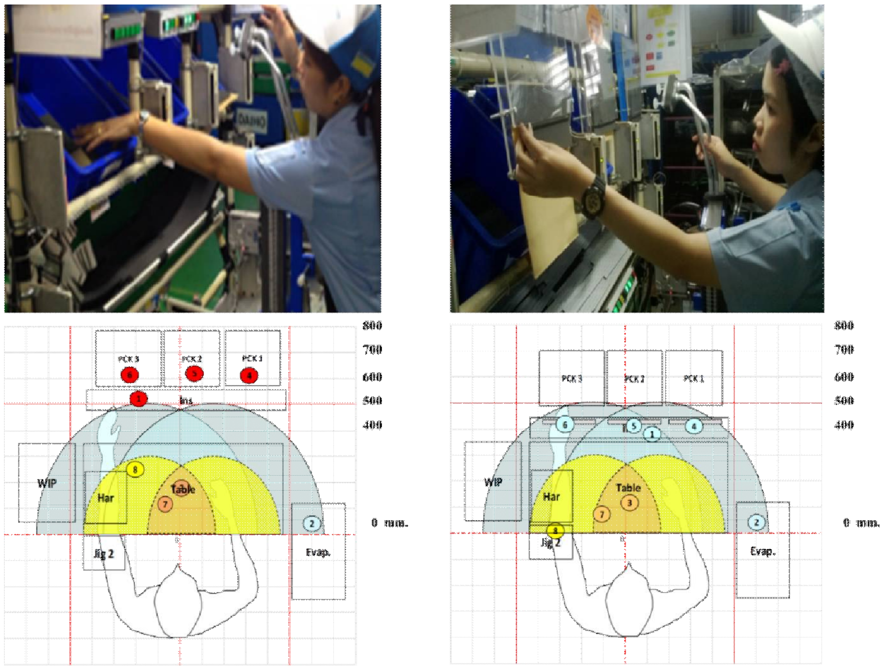


Figture A: Designed Concept for The Simple Jig



Figture B : The Simple Jig install for 3 size of part (The packing)

Figure 8. Simple jig concept designed and installed.



A : Operation area (Before improve)

B : Operation area (After improve)

Figure 9. Reduced over limit points in the operation area.

Table 6. Operation ratio improvement results.

Station	Station No.8						Station No.11					
	Before		After		Diff.		Before		After		Diff.	
Process	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH
OPERATIONS	4	11	4	11	0	0	9	10	9	10	0	0
TRANSPORTS	2	6	2	4	0	-2	3	3	3	3	0	0
HOLD	10	2	3	2	-7	0	4	3	4	3	0	0
DELAYS	3	0	8	0	5	0	2	2	2	2	0	0
TOTAL	19	19	17	17	-2	-2	18	18	18	18	0	0
DISTANCE (cm)	184	385	184	250	0	-135	155	220	155	220	0	0
Difference					-135						0	
Station	Station No.18						Station No.19					
	Before		After		Diff.		Before		After		Diff.	
Process	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH
OPERATIONS	12	17	14	15	2	-2	14	14	13	13	-1	-1
TRANSPORTS	9	2	3	2	-6	0	13	3	13	3	0	0
HOLD	4	3	1	0	-3	-3	1	4	0	3	-1	-1
DELAYS	2	5	3	4	1	-1	3	10	3	10	0	0
TOTAL	27	27	21	21	-6	-6	31	31	29	29	-2	-2
DISTANCE (cm)	479	123	131	40	-348	-83	805	248	682	220	-123	-28
Difference					-431						-151	

Table 7. Operation area improvement results.

Improvement result		Station No.8			Station No.11			Station No.18			Station No.19		
Area	Symbol	Before	After	Diff.	Before	After	Diff.	Before	After	Diff.	Before	After	Diff.
Best Area		18	10	-8	7	7	0	4	3	-1	4	2	-2
Better Area		0	0	0	4	4	0	1	1	0	8	5	-3
Limit Area		6	10	4	7	7	0	3	12	9	14	23	9
Over Point		0	0	0	0	0	0	8	0	-8	12	6	-6

Table 8. Comparison of the outcomes.

Item	Measurement unit	Before	After
Bottom neck station no.	Station	7	6
Standard time	Minute	1.64	1.28
Total assembly time	minute	21.30	20.24
Manpower	Person	20	20
% line balancing	%	65.4%	79.1%
Output	Unit per Hour	36	46.9
Productivity Rate	Unit per man hour	1.84	2.35

Table 9. Comparisons of operational efficiency and effectiveness.

Item	Before	After	Efficiency	Target	Effectiveness
Bottom neck standard time	1.64	1.28	Reduce21.9%	1.30	Achieve rate 1.53%
TotalAssembly time	21.3	20.24	Reduce4.9%	-	-
Line balance(%)	65.4%	79.1%	Increase20.9%	80%	Not achieve rate 1.12%
Output rate	36	46.9	Increase30.2%	46	Achieve rate 1.9%
Productivity Rate	1.84	2.35	Increase27.1%	2.25	Achieve rate 4.4%

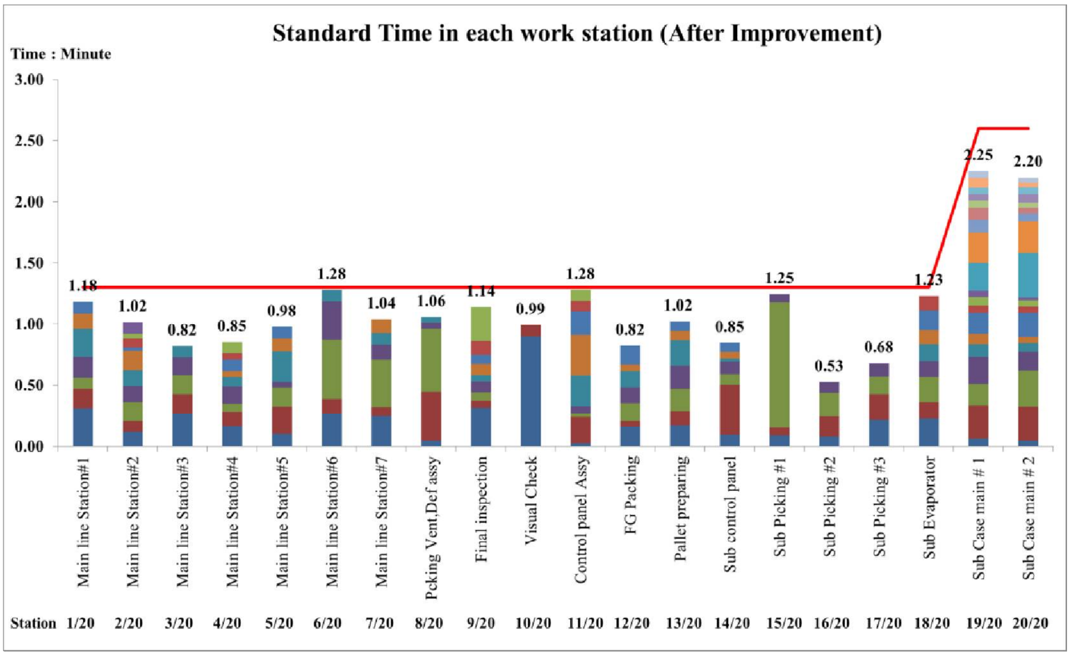


Figure 10. Standard time in each work station (after improvement)

Acknowledgements

We wish to thank Assistant Professor Dr. Vichai Rungreunganun, the advisor who provided advice, assistance, helpful knowledge and ideas for this study to become a success.

References

Hafizuddin, M. M., Ahmad Nazif, N. K., Needza, Y. M., &Nadiah, D. A. (2012).A Study on line balancing in assembly line at automotive component manufacturer. *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management,* Istanbul, Turkey, July 3–6, 2012, 1633-1638.

Kanjanapanyakom, R. (2008). *Industrial work study.* Bangkok, Thailand: Top Publishing.

Khalid, S. A. (2010). Productivity improvement of a motor vehicle inspection station using motion and time study techniques.*Journal of King Saud University,23*(1), 33-41.

Komanasin, K. (2006). *LEAN : The Ways of creating value to the organization is excellent.* Bangkok, Thailand: Thailand Productivity Institute.

Rijiravanich, V. (2002).*Work study: Principles and case study.* Bangkok, Thailand: Chulalongkorn University Printing House.

Sandip, K. K., Niranjan, M. R., & Sanjay, T. S. (2014). Assembly line Production Improvement by Optimizeation of Cycle Time.*Proceeding of 10th IRF International Conference 2014*, 124-128.

Saranpracha, S. (2013).Improving production capacity of car seats in car seat production line using Toyota production technique.*Journal of Engineering,* 2013.

Sornsuvith, N. (2003). *Method engineering.* Bangkok, Thailand: Technology Promotion Association (Thailand-Japan).