BUILDING DATABASE IN BALANCING KNITTED GARMENT LINES SOFTWARE IN INDUSTRY

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ABSTRACT

The garment industry is one of the key industries contributing to the economic growth of Vietnam. Industry 4.0 has significantly altered the operational procedures of conventional enterprises. The implementation of technological, digital, and artificial intelligence applications has increased the global efficacy of corporate governance. To successfully assimilate into the regional and global economies, Vietnamese businesses must enhance their management capabilities and maximize both the quantity and quality of their products. In order to achieve this objective, the authors have conducted research to develop a database of sewing line balancing implemented in Assembly Line Balancing software for two common knitted products, namely Polo-Shirts, and T-Shirts. School of Textile-Leather and Fashion, Hanoi University of Science and Technology (HUST) methods compared and evaluated this result of sewing line balancing of 2 Polo-Shirt and T-Shirt products according to the manual, software, and actual calculation method at 3 enterprises: Star Fashion Company Ltd., Regent Garment Factory Ltd., and Hanoi General Textile Garment Joint Stock Company (Hanosimex). Since then, we have completed the sewing line balancing database for Polo-Shirt and T-Shirt products to row sewing lines for cases in which the path of semi-finished products is both straight and zigzag. The findings of this study can be applied to group conjugation lines and suspended lines transporting semi-finished goods. The database has been constructed meticulously and standardized to ensure the diversity, richness, and universality of all product technology structure options applicable to garment companies. The database is utilized in the Assembly Line Balancing software developed by the research team; this is an application-oriented research product that will transfer technology to garment enterprises producing knitwear, assisting them in overcoming current challenges. Reasonable production line layout contributes to optimizing existing production conditions, increasing labor productivity and the efficiency of production organization, and laying the groundwork for the application of digital technology.

KEYWORDS

Sewing line; Assembly line balancing; Polo-Shirt; T-Shirt; Assembly line balancing software; Assembly line balancing methods.

INTRODUCTION

Line balancing is a technique to arrange the ratio between several workers and machinery equipment at each stage in which output is equal and achieves the highest based on the actual conditions of the line, optimizing the actual situation on the line in the line balancing time. Line balancing is one of the most important issues for garment companies. It determines the capacity and output of the sewing line and simultaneously helps reduce workers' wasted time, optimize the number of machines, determine the shortest path of semi-finished products, and follow the turmeric work journey. It shows that line balancing significantly affects the profit and reputation of enterprises. Hence, businesses always want to find the most reasonable method of balancing line with the company and their garment products. In Vietnamese garment enterprises, line balancing is mainly done by traditional manual methods, is time-consuming, and the balancing performance is not high, not solving the problem of maximum efficiency in the production line and affecting the productivity of sewing line and the whole enterprise. Contributing to solving these bad problems, the authors have built a database of the sewing line balancing applied in the line balancing software by production practices.

Currently, there have been several research works on this issue. Santosh et al. applied the Rank Position Weight method (RPW) with a given number of workers to optimize cycle time [1]. Author Vrittika applies three methods including: Rank Position Weight (RPW); larger candidate rule and kill bridge and wester methods to optimize the cycle time when given several workers. The author points out that the

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results are the same [2]. Jayakumar et al. use RPW to enhance line efficiency [3]. The authors Dinh Mai Huong, Truong Van Long, Do Phan Thuan, Phan Thanh Thao, Nguyen Duc Nghia apply an exhaustive search for optimization assembly line balancing in garment industry [4]. Phan Thanh Thao and Dinh Mai Huong research various line-balancing methods for Polo-shirt products in Vietnam [5].

In this paper, the authors compare, evaluate the design results, and balance the sewing line of T-Shirt and Polo-Shirt products based on the Hanoi University of Science and Technology method by hand calculation and using BSL-HUST software with the results of actual production. Since then, we have proceeded to complete the design and balance database of the T-Shirt and Polo-Shirt products sewing line for the layout in which the path of the semi-finished products is straight and zigzag applied in industrial production. Compare and evaluate the design results and balance the sewing line of the T-Shirt and Polo-Shirt products based on the Hanoi University of Science and Technology method by hand calculation and using BSL-HUST software with the results of actual production. Complete the design and balance database of the T-Shirt and Polo-Shirt products sewing line for the layout in which the path of the semi-finished products is straight and zigzag applied in industrial production.

EXPERIMENTAL

Research subjects

T-Shirt products have a collar (neck) rib or collar facing, or neck tape (neckline), short-sleeved, slits or not. In the study, we chose a typical structure manufactured by three companies with the styles shown in Table 1. The product has a straight shape, rib roll collar, neckline from collar to shoulder, no split, bottom and sleeve-hem sewing dividing seams with two parallel lines. The product has a picture, as shown in Figure 1 (a).

Polo-shirt products have bottom down collar, neckline or not. Collar is by main fabric or rib. The shirt is made from single layer knit fabric. It is slip over dress, with collar and neck band placket (collar panel),short- or long-sleeve, slit or not, sleeve cuff or sleeve-hem sewing diving seams with two parallel lines.

Table 1. T-Shirt product codes, with each styled by three companies.

No.	Code	Style	Company
1	T01	DM21-008	Hanosimex
2	T02	PE19-025	Hanosimex
3	T03	PCN21-003	Hanosimex
4	T04	PE20-015	Hanosimex
5	T05	5V2202128	Star Fashion Co., Ltd
6	T06	SV22-009	Hanosimex
7	T07	142N212	Tinh Loi Garment Co., Ltd
8	T08	242N276	Tinh Loi Garment Co., Ltd

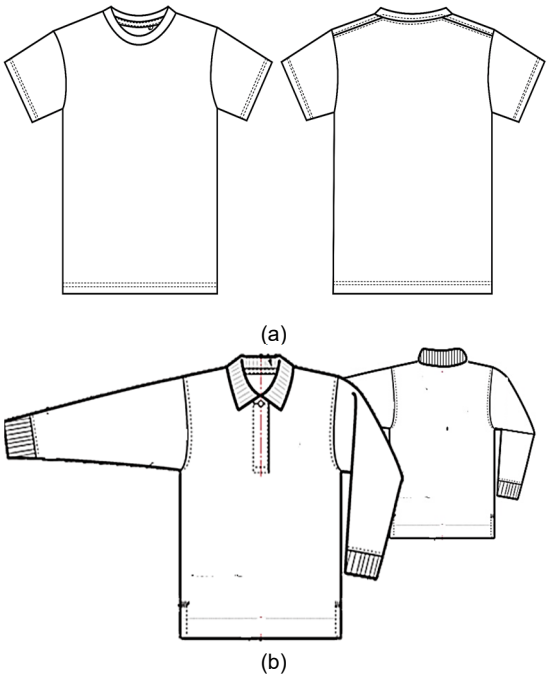


Figure 1. Representative images of (a) T-Shirt product - straight shape, rib roll collar, neckline from collar to shoulder, no split, bottom, and sleeve-hem sewing dividing seams with two parallel lines and (b) Polo-Shirt product - Bottom down collar by rib, not neckline; collar panel deviates; long sleeves by rib-knit cuff; split, bottom sewing one diving seam.

Table 2. Polo-Shirt product codes, with each style by two companies.

No.	Code	Style	Company
1	PL01	SNJ20-017	Hanosimex
2	PL02	PE18-019	Hanosimex
3	PL03	PE19-026	Hanosimex
4	PL04	342F107	Tinh Loi Garment Co., Ltd
5	PL05	06DHA22- 019	Hanosimex
6	PL06	DC1963	Tinh Loi Garment Co., Ltd

In the study, we choose a typical structure with the image described in Figure 1 (b), manufactured at two companies with the styles shown in Table 2. The product has bottom down collar by rib, not neckline; collar panel deviates; long sleeves by rib-knit cuff; split, bottom sewing one diving seam.

Research methods

Methods of database construction

To build a database on line balancing, the first step is to analyze and classify detailed clusters of knitted products, make a technological process for each product, and after that, design and balance the line and arrange the line layout for two inputs: the capacity of line P (the number of products produced in a shift) and the number of workers on line N (People).

Methods of building sewing technology process

Based on the theory of the method of building a sewing technology process, the authors build a diagram to analyze the technological process of sewing T-Shirt and Polo-Shirt products.

Methods of designing and balancing the sewing line

Designing and balancing the sewing lines in two ways: manually and using BSL-HUST software built by the design project, based on the Hanoi University of Science and Technology method.

a, The order of designing and balancing the sewing line according to Hanoi University of Science and Technology method.

- Preliminary determination of the parameters of the line
- Build a production technology diagram and balance the line
- Precisely define the parameters of the line
- Layout of the workplace and sewing line
- Calculate the economic-technical indicators of the line

b, Principles of organizing and coordinating tasks.

- The workstations must be made up of successive tasks on the technological journey or from tasks of different processing groups that do not affect product processing.
- The sequence of the combined operations must be consistent with the sequence of the product processing technology.
- The workstation time must be equal to or an integer times the cycle.
- The level of workers must be equal or differ by one unit.
- The tasks of the workstation must be performed on the same type of equipment; the processing mode, method, and type of processing material must be relatively uniform; the complexity of the work must be relatively uniform.
- In addition, it is necessary to coordinate the tasks so that the workstation can only be performed on the same object.

Check the optimal condition of capacity by the graph method. Draw the load graph of the line, in which the horizontal axis is the workstations, and the vertical axis is the individual cycle of workstations. On the graph, simultaneously show the values: the cycle (R), and the allowable tolerance limit of cycle ΔR ($R_{max} \div R_{min}$). Determine the ratio of the number of workstations with separate cycles within the allowable tolerance limit of the cycle to the total number of workstations in line *K* [%]. If K% ≥ 60%, the line balances in terms of load and calculated capacity to reach the optimal value.

c, Line designing and balancing process using BSL-HUST software

Implementation steps:

- Step 1: Start the program and double-click the software interface as shown below.
- Step 2: After the software interface appears, select "Create new code".
- Step 3: Input the information, including "Code details", "Technological process", "Process binding".
- Step 4: After inputting all the information, click "Optimize".
- Step 5: Enter the input data for the problem and continue to click "Optimize", you will get the results, including the workstation table, load chart, and line layout diagram.

Methods of collecting actual data

The research team collected documents on production orders of T-shirt products at three companies: Hanosimex, Star Fashion Co., Ltd and Tinh Loi Garment Co., Ltd; for Polo-Shirt products from two companies: Hanosimex and Tinh Loi Garment Co., Ltd.

Methods of analysis, evaluation and comparison

After obtaining the calculation results, analyze and compare to evaluate the efficiency of the production line's balance by the manual method, using BSL-HUST software and compare the actual production.

The codes T01, T02, T03, T04, T05, T06, PL01, PL02, PL03, and PL05 will compare the results of sewing line balancing design between the manual calculation method of HUST and BSL-HUST software. The criteria for comparison and evaluation include line balancing coefficient K%, balancing efficiency H%, capacity P, number of workers N, and cycle time R.

The codes T07, T08, PL04, and PL06 will compare the results of the sewing line balance design with the results of the actual production line at Tinh Loi Company, the manual calculation method of HUST, and BSL-HUST software. The criteria for comparison and evaluation include line balancing coefficient K%, balancing efficiency *H* %, capacity *P*, number of workers *N*, and cycle time *R*.

RESULTS AND DISSCUTION

Results of technical process analysis of sewing knitted products

During the research process, we calculated, compared, analyzed, and completed the sewing line balanced and design database, including eight T-Shirt codes and six Polo-Shirt codes. In the scope of this article, we represent a T-Shirt and a Polo-Shirt code.

We have developed a process analysis diagram for T-Shirt and Polo-Shirt sewing technology, and the results are presented in Figure 2 .

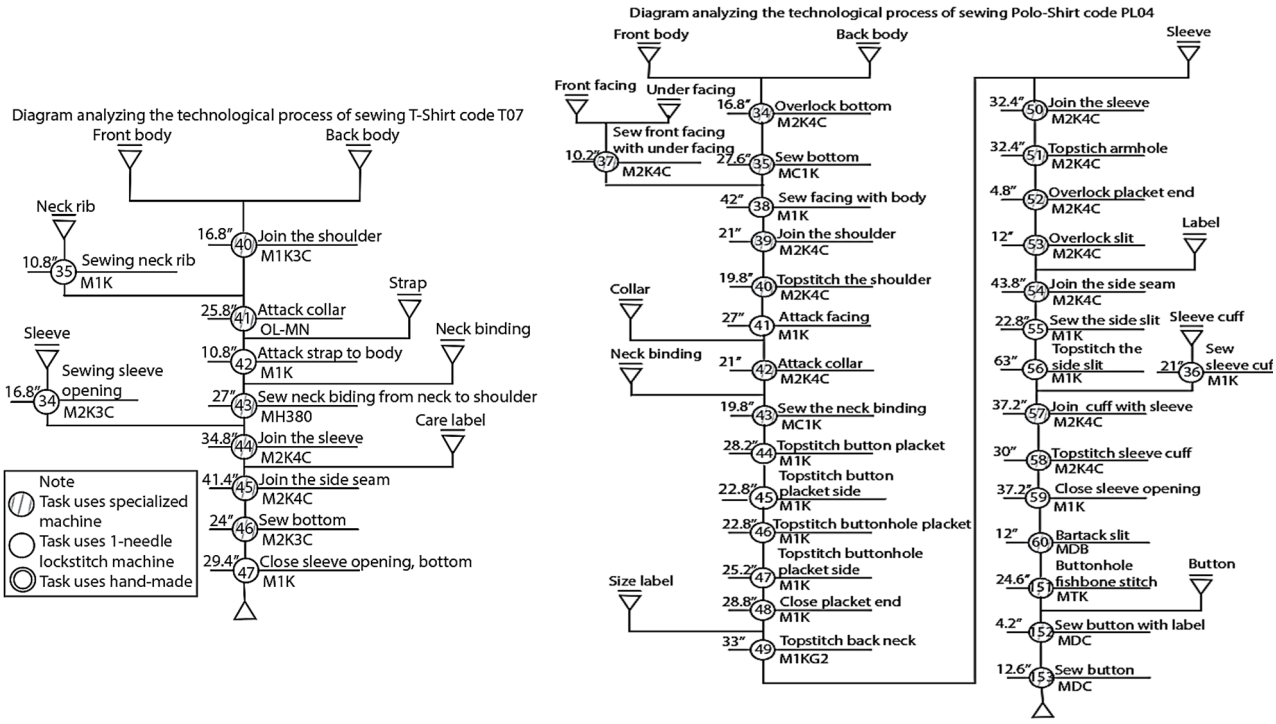


Figure 2. T-Shirt sewing technology analysis chart: (a) code T07, code PL04.

Table 3. Table of organization and coordination of tasks into workstations result, T-shirt coded T07 with the given capacity *P*.

Workstation	Task	Machine	Type	T_i [s]	Line balancing by hand		Line balancing by BSL-HUST software		Line balancing by Tinh Loi Garment Co., Ltd plan	
					T_j [s]	N_j [people]	T_j [s]	N_j [people]	T_j [s]	N_j [people]
1	34	M2K3C	4	16.8	8.4	2	8.4	2	16.8	1
2	35	M1K	3	10.8	10.8	1	10.8	1	10.8	1
3	40	M1K3C	3	16.8	16.8	1	8.4	2	16.8	1
4	41	OL-MN	4	25.8	12.9	2	12.9	2	8.6	3
5	42	M1K	3	10.8	10.8	1	10.8	1	10.8	1
6	43	MH380	4	27	13.5	2	13.5	2	13.5	2
7	44	M2K4C	4	34.8	11.6	3	11.6	3	11.6	3
8	45	M2K4C	4	41.4	13.8	3	13.8	3	10.35	4
9	46	M2K3C	4	24	12	2	12	2	12	2
10	47	M1K	3	29.4	9.8	3	9.8	3	14.7	2
Sum				237.6		20		21		20

Table 4. Comparison of full line load chart for product T-shirt coded T07 with the given capacity *P*.

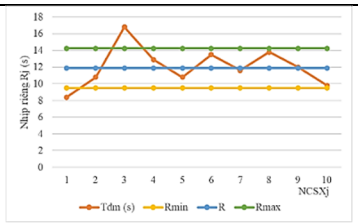
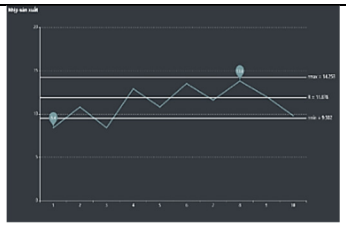
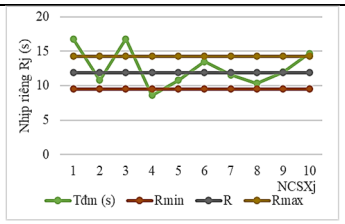
	Line balancing by hand of HUST method	Line balancing by BSL-HUST software	Line balancing by Tinh Loi Garment Co., Ltd plan
Image			
Comment	One workstation is overloaded, one workstation is underloaded.	Two workstations are underloaded	Three workstations are overloaded, one workstation is underloaded

Table 5. Comparison of the sewing line layout diagram for T-shirt coded T07 product with the given capacity *P*.

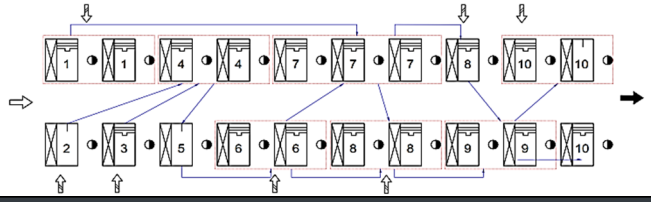
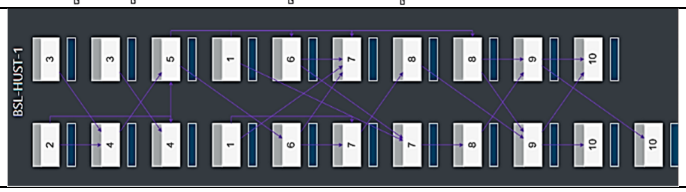
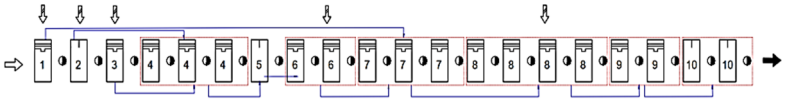
	The sewing line layout diagram for T-shirt product coded T07	Layout
By hand method of HUST		Class-form, semi-finished products are shipped by zigzag, with boxes
By BSL-HUST software		Class-form, semi-finished products are shipped by zigzag, with boxes
By design plan of Tinh Loi Garment Co., Ltd		Class-form, semi-finished products are shipped by zigzag, with semi-automatic hanging line

Table 6. Table comparing line parameters - line balancing coefficient *K*%, balancing efficiency *H*%, capacity *P*, number of workers *N*, and cycle time *R* of T-shirt coded T07 with the given capacity *P*.

***P*=2652 products/day**	***K* [%]**	***H* [%]**	***N* [people]**	***R* [s]**
By Tinh Loi Garment Co., Ltd	60	100	20	11.88
By hand method of HUST	80	100	20	11.88
By BSL-HUST software	80	95.26	21	11.88

Comparing and evaluating the design and balance results T-Shirt sewing line according to HUST method by hand calculation, using BSL-HUST software and the actual results at IE room of Tinh Loi Garment Co., Ltd

Comparing and evaluating the design and balance result sewing line when given the capacity of line P (products/shift)

- The cycle time: R
- Cycle time limit: ΔR=20%
- Line capacity: P = 2652 products/shift
- Working time: T_w = 8.75 (h)
- The time of task number i: T_i (s)
- The average production time at each working station number j: T_j (s)
- The number of workers for each task i: N_i (people)

Comparison of the organization and coordination of tasks results is shown in Table 3. Comparison of the full-line load charts is shown in Table 4. Comparison of the sewing line layout diagrams is shown in Table 5. Comparison of the exact results of line parameters is shown in Table 6.

Two ways of line balancing according to the method of HUST (manual calculation and BSL-HUST software) gave K = 80% > 60%, and line capacity P = 2652 products/day, which is optimal and higher than the results of Tinh Loi Garment Co., Ltd.

The number of workers N in the line calculated by BSL-HUST software is more significant than one worker, and the load factor H is smaller than the other two ways of balancing.

The results of the sewing line layout with the given capacity P from BSL-HUST software have an area larger than the remaining two methods due to the increase in the number of employees to 1 worker. However, the software gives more optimal passing results on the path of the semi-finished product.

It is class - form, semi-finished products shipped straight and zigzag, but Tinh Loi Garment Co., Ltd. will combine the two lines running the same T-Shirt product code, using hanging lines to replace boxes, help save area, and improve labour productivity. Therefore, the research team realized that it was necessary to improve the software to diversify layout options.

Cause: It can be seen in the load chart of the whole line from the software that there are no overloaded locations but mainly under-loaded operations, thus leading to an increase in the number of workers, and H% lower than the other two methods. But this is a perfectly reasonable result for avoiding overloading and congestion on the line.

Table 7. Table of organization and coordination of tasks into workstations result, T-shirt product coded T07 with given the number of workers *N*.

Workstation	Task	Machine	Type	T_i [s]	Line balancing by hand		Line balancing by BSL-HUST software		Line balancing by Tinh Loi Garment Co., Ltd plan	
					T_j [s]	N_j [people]	T_j [s]	N_j [people]	T_j [s]	N_j [people]
1	34	M2K3C	4	16.8	8.4	2	8.4	2	16.8	1
2	35	M1K	3	10.8	10.8	1	10.8	1	10.8	1
3	40	M1K3C	3	16.8	16.8	1	8.4	2	16.8	1
4	41	OL-MN	4	25.8	12.9	2	12.9	2	8.6	3
5	42	M1K	3	10.8	10.8	1	10.8	1	10.8	1
6	43	MH380	4	27	13.5	2	13.5	2	13.5	2
7	44	M2K4C	4	34.8	11.6	3	11.6	3	11.6	3
8	45	M2K4C	4	41.4	13.8	3	13.8	3	10.35	4
9	46	M2K3C	4	24	12	2	12	2	12	2
10	47	M1K	3	29.4	9.8	3	14.7	2	14.7	2
Sum				237.6		20		20		20

Table 8. Comparison of the full line load chart for T-shirt product coded T07 with given the number of workers *N*.

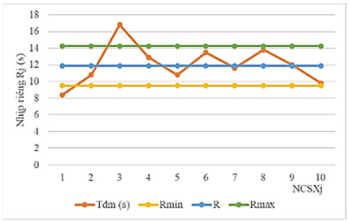
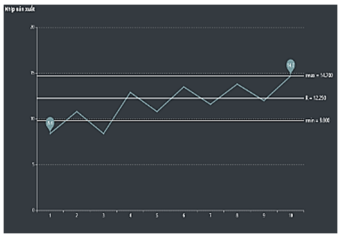
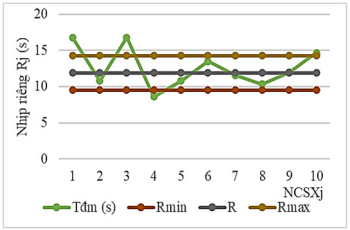
	Line balancing by hand of HUST method	Line balancing by BSL-HUST software	Line balancing by Tinh Loi Garment Co., Ltd plan
Image			
Comment	One workstation is overloaded, one workstation is underloaded	Two workstations are underloaded	Three workstations are overloaded, one workstation is underloaded

Table 9. Comparison of the sewing line layout diagram for T-shirt product coded T07 when given the number of workers *N*.

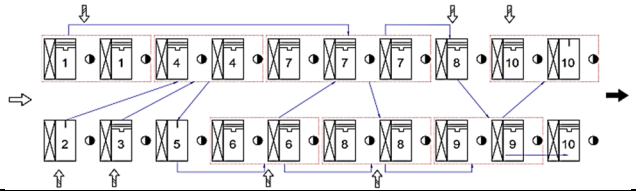
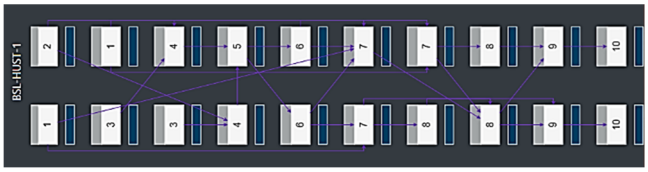
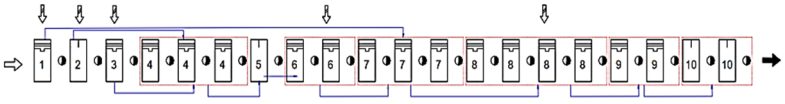
	The sewing line layout diagram for T-shirt product coded T07	Layout
By hand method of HUST		Class-form, semi-finished products are shipped by zigzag, with boxes
By BSL-HUST software		Class-form, semi-finished products are shipped by zigzag, with boxes
By design plan of Tinh Loi Garment Co., Ltd		Class-form, semi-finished products are shipped by straight, with semi-automatic hanging line

Table 10. Table of comparing line parameters - line balancing coefficient *K*%, balancing efficiency *H*%, capacity *P*, number of workers *N* and cycle time *R* of code T07 when given *N*.

***N* = 20 people**	***K* [%]**	***H* [%]**	***N* [people]**	***R* [s]**
By Tinh Loi Garment	60	100	20	11.88
By hand method of HUST	80	100	20	11.88
By BSL-HUST software	80	96.98	20	12.25

Table 11. Table of organization and coordination of tasks into workstations result of Polo-shirt coded PL04 when given the capacity *P*.

Line balancing by hand of HUST method					**Line balancing by BSL-HUST software**					**Line balancing by Tinh Loi Garment Co., Ltd plan**				
Workstation	**Task**	T_i	N_i	T_j	**Workstation**	**Task**	T_i	N_i	T_j	**Workstation**	**Task**	T_i	N_i	T_j
1	34	16.8	1	16.8	1	34	16.8	1	16.8	1	34	16.8	1	16.8
2	35	27.6	2	13.8	2	35	27.6	2	13.8	2	35	27.6	2	13.8
3	36	21	1	21	3	36	21	3	16	3	36	21	1	21
4	37	10.2	1	10.2		41	27			4	37	10.2	1	10.2
5	38	39	2	19.5	4	37	10.2	1	10.2	5	38	39	2	19.5
6	39	21	1	21	5	38	39	2	19.5	6	39	21	1	21
7	40	19.8	1	19.8	6	39	21	1	21	7	40	19.8	1	19.8
8	41	27	2	13.5	7	40	19.8	1	19.8	8	41	27	2	13.5
9	42	21	1	21	8	42	21	1	21	9	42	21	1	21
10	43	19.8	1	19.8	9	43	19.8	1	19.8	10	43	19.8	1	19.8
11	44	27	2	13.5	10	44	27	2	13.5	11	44	27	1	27
12	45	21	1	21	11	45	21	1	21	12	45	21	3	22
13	46	21	1	21	12	46	21	1	21		46	21		
14	47	24	3	16.8	13	47	24	3	16.8		47	24		
	48	26.4				48	26.4			13	48	26.4	2	13.2
15	49	33	2	16.5	14	49	33	2	16.5	14	49	33	1	33
16	50	32.4	2	16.2	15	50	32.4	2	16.2	15	50	32.4	2	16.2
17	51	32.4	2	16.2	16	51	32.4	2	16.2	16	51	32.4	2	16.2
18	52	4.8	1	16.8	17	52	4.8	1	16.8	17	52	4.8	1	4.8
	53	12				53	12			18	53	12	3	18.6
19	54	43.8	2	21.9	18	54	43.8	2	21.9		54	43.8		
20	55	22.8	1	22.8	19	55	22.8	2	11.4	19	55	22.8	1	22.8
21	56	60	3	20	20	56	60	3	20	20	56	60	3	20
22	57	36	2	18	21	57	36	2	18	21	57	36	1	36
23	58	24	2	12	22	58	24	2	12	22	58	24	1	24
24	59	37.2	2	18.6	23	59	37.2	2	18.6	23	59	37.2	2	18.6
25	60	12	1	12	24	60	12	1	12	24	60	12	1	12
26	151	24.6	1	24.6	25	151	24.6	2	12.3	25	151	24.6	1.5	16.4
27	152	4.2	1	16.8	26	152	4.2	1	16.8	26	152	4.2	1	16.8
	153	12.6				153	12.6			27	153	12.6		

Comparing and evaluate the design and balance result sewing line when given the number of workers N (people)

- Cycle time limit: ΔR = 20%
- Number of workers: N = 20 people
- Working time: T_w = 8.75 (h)
- The time of task number i: T_i (s)
- The average production time at each working station number j: T_j (s)
- The number of workers for each task i: N_i (people)

Comparison of the organization and coordination of tasks results is shown in Table 7. Comparison of the full-line load charts is shown in Table 8. Comparison of the sewing line layout diagrams is shown in Table 9. Comparison of the exact results of line parameters is shown in Table 10.

Two ways of line balancing according to the method of HUST gave K = 80% > 60%, which was higher than the company's result. The R value calculated from software is significantly larger than the other two methods, resulting in a smaller P value.

The results of sewing line layouts are similar: Class-form, semi-finished products shipped zigzag; but Tinh Loi Garment Co., Ltd. will combine the two lines running the same T-Shirt product code, using hanging lines to replace boxes, help save area, and improve labour productivity. Therefore, the research team realized that it was necessary to improve the software to diversify layout options. Cause: To ensure that the number of workers on the line is 20 people, the software has increased the cycle time to ensure efficiency, thereby affecting the load factor of the whole line.

Comparing and evaluating the design and balance results Polo-Shirt sewing line according to HUST method by hand calculation, using BSL-HUST software and the actual results at IE room of Tinh Loi Garment Co., Ltd

Comparing and evaluating the design and balance result sewing line when given the capacity of line *P* (products/shift)

- Cycle time limit: ΔR = 20%
- Line capacity: P = 1667 products/shift
- Working time: T_w=8.75 (h)
- The time of task number i: T_i (s)
- The average production time at each working station number j: T_j (s)
- The number of workers for each task i: N_i (people)

Comparison of the organization and coordination of tasks results is shown in Table 11. Comparison the full-line load charts is shown in Table 12. Comparison the sewing line layout diagrams is shown in Table 13. Comparison the exact results of line parameters is shown in Table 14.

With the given P, BSL-HUST software gave K% > 60%, much higher than the manual calculation of the HUST or IE department of Tinh Loi Garment Co., Ltd. However, the number of workers and the load factor have not been optimized.

The results of sewing line layouts are similar: Class-form, semi-finished products shipped zigzag; but Tinh Loi Garment Co., Ltd. will combine the two lines running the same T-Shirt product code, using hanging lines to replace boxes, help save area, and improve labour productivity. Therefore, the research team realized that it was necessary to improve the software to diversify layout options. Cause: It can be seen that the software gave no overloaded positions but mainly underloaded workstations, thus leading to an increase in the number of workers and the load factor is not optimal. But this is a perfectly reasonable result that can be applied to high performance.

Table 12. Table of comparison of full line load chart for product Polo-shirt coded PL04 when given the capacity *P*.

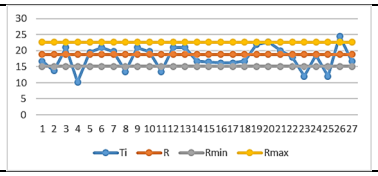
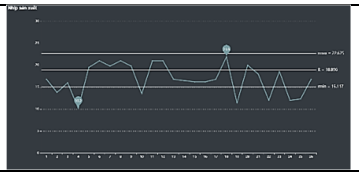
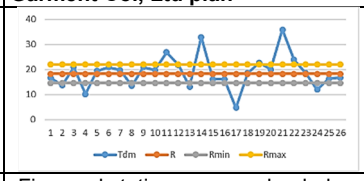
	Line balancing by hand of HUST method	**Line balancing by BSL-HUST software**	**Line balancing by Tinh Loi Garment Co., Ltd plan**
Image			
Comment	One workstation is overloaded, six workstations are underloaded	Seven workstations are underloaded	Five workstations are overloaded, six workstations are underloaded

Table 13. Table of comparison of sewing line layout diagram for PL04 product when given the capacity *P* of Polo-shirt coded PL04.

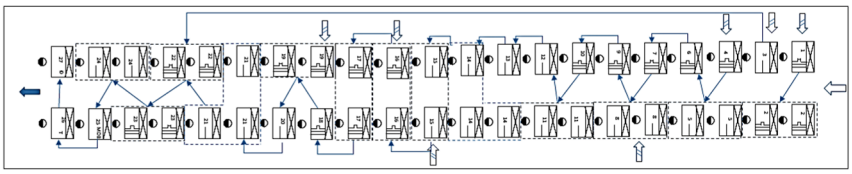
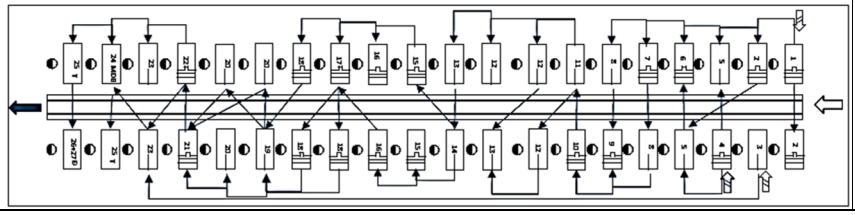
	The sewing line layout diagram for Polo-shirt product coded PL04	**Layout**
By hand method of HUST		Class-form, semi-finished products are shipped by zigzag, with boxes
By BSL-HUST software		Class-form, semi-finished products are shipped by zigzag, with boxes
By design plan of Tinh Loi Garment Co., Ltd		Class-form, semi-finished products are shipped by zigzag, with semi-automatic hanging line

Table 14. Table of comparing line parameters of Polo-shirt coded PL04 when given the capacity *P*.

***P*=1667 products/day**	***K* [%]**	***H* [%]**	***N* [people]**	***R* [s]**
By Tinh Loi Garment Co., Ltd	59	100	40	18.36
By hand method of HUST	70.4	93	42	18.9
By BSL-HUST software	73.1	88.3	44	18.9

Comparing and evaluating the design and balance result sewing line when given N (people)

- Cycle time limit: ΔR = 20%
- Number of workers: N = 40 people
- Working time: T_w = 8.75 (h)
- The time of task number i: T_i (s)
- The average production time at each working station number j: T_j (s)
- The number of workers for each task i: N_i (people)

Comparison the organization and coordination of tasks results is shown in Table 15. Comparison the full-line load charts is shown in Table 16. Comparison the sewing line layout diagrams is shown in Table 17. Comparison of the exact results of line parameters is shown in Table 18.

With the given the number of workers N, the BSL-HUST software gave an efficiency result of K% > 60%, much higher than the manual calculation method of the HUST or IE department of Tinh Loi Garment Co., Ltd. The power according to the balance software is lower, but the difference is not much. The load factor is not optimized by manual calculation of HUST or IE room; however, the software results only for five under-loaded workstations, with no overload.

The results of sewing line layouts are similar: Class-form, semi-finished products shipped zigzag; but Tinh Loi Garment Co., Ltd. will combine the two lines running the same T-Shirt product code, using hanging lines to replace boxes, help save area, and improve labour productivity. Therefore, the research team realized that it was necessary to improve the software to diversify layout options. Cause: With the number of 40 workers, the software has increased the cycle time to ensure efficiency, thereby affecting the load factor and capacity results.

Table 15. Table of organization and coordination of tasks into workstations result of Polo-shirt coded PL04 when given the number of workers N.

Line balancing by hand of HUST method					Line balancing by BSL-HUST software					Line balancing by Tinh Loi Garment Co., Ltd plan				
Workstation	**Task**	T_i	N_i	T_j	**Workstation**	***Task***	T_i	N_i	T_j	**Workstation**	***Task***	T_i	N_i	T_j
1	34	16.8	1	16.8	1	34	16.8	1	16.8	1	34	16.8	1	16.8
2	35	27.6	2	13.8	2	35	27.6	2	13.8	2	35	27.6	2	13.8
3	36	21	1	21	3	36	21	2	24	3	36	21	1	21
4	37	10.2	1	10.2		41	27			4	37	10.2	1	10.2
5	38	39	2	19.5	4	37	10.2	1	10.2	5	38	39	2	19.5
6	39	21	1	21	5	38	39	2	19.5	6	39	21	1	21
7	40	19.8	1	19.8	6	39	21	1	21	7	40	19.8	1	19.8
8	41	27	1	27	7	40	19.8	1	19.8	8	41	27	2	13.5
9	42	21	1	21	8	42	21	1	21	9	42	21	1	21
10	43	19.8	1	19.8	9	43	19.8	1	19.8	10	43	19.8	1	19.8
11	44	27	1	27	10	44	27	2	13.5	11	44	27	1	27
12	45	21	1	21	11	45	21	1	21	12	45	21	3	22
13	46	21	1	21	12	46	21	3	23.8		46	21		
14	47	24	3	16.8		47	24				47	24		
	48	26.4				48	26.4			13	48	26.4	2	13.2
15	49	33	2	16.5	13	49	33	2	16.5	14	49	33	1	33
16	50	32.4	2	16.2	14	50	32.4	2	16.2	15	50	32.4	2	16.2
17	51	32.4	2	16.2	15	51	32.4	2	16.2	16	51	32.4	2	16.2
18	52	4.8	1	16.8	16	52	4.8	1	16.8	17	52	4.8	1	4.8
	53	12				53	12			18	53	12	3	18.6
19	54	43.8	2	21.9	17	54	43.8	2	21.9		54	43.8		
20	55	22.8	1	22.8	18	55	22.8	1	22.8	19	55	22.8	1	22.8
21	56	60	3	20	19	56	60	3	20	20	56	60	3	20
22	57	36	2	18	20	57	36	2	18	21	57	36	1	36
23	58	24	2	24	21	58	24	1	24	22	58	24	1	24
24	59	37.2	2	18.6	22	59	37.2	2	18.6	23	59	37.2	2	18.6
25	60	12	1	12	23	60	12	1	12	24	60	12	1	12
26	151	24.6	1	24.6	24	151	24.6	2	12.3	25	151	24.6	1.5	16.4
27	152	4.2	1	16.8	25	152	4.2	1	16.8	26	152	4.2	1	16.8
	153	12.6				153	12.6			27	153	12.6		

Table 16. Comparison of full line load chart for Polo-shirt product coded PL04 when given the number of workers N.

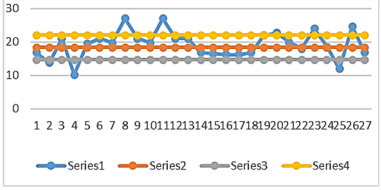
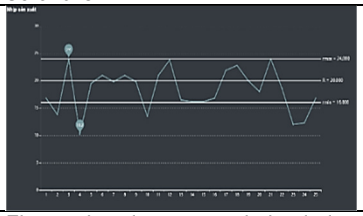
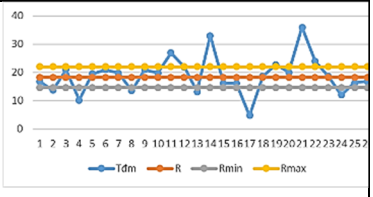
	Line balancing by hand of HUST method	**Line balancing by BSL-HUST software**	**Line balancing by Tinh Loi Garment Co., Ltd plan**
Image			
Comment	Five workstations are overloaded, three workstations are underloaded	Five workstations are underloaded	Five workstations are overloaded, six workstations are underloaded

Table 17. Comparison of sewing line layout diagram for Polo-shirt coded PL04 product when given the number of workers *N*.

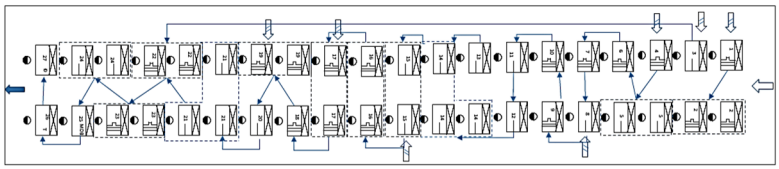
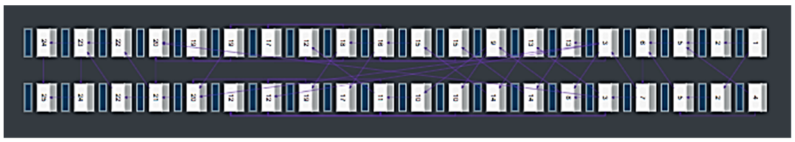
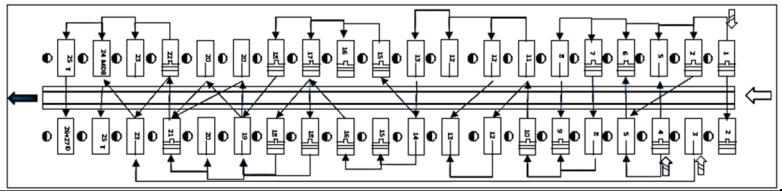
	The sewing line layout diagram for Polo- shirt product coded PL04	Layout
By hand method of HUST		Class-form, semi-finished products are shipped by zigzag, with boxes
By BSL-HUST software		Class-form, semi-finished products are shipped by zigzag, with boxes
By design plan of Tinh Loi Garment Co., Ltd		Class-form, semi-finished products are shipped by zigzag with a semi-automatic hanging line.

Table 18. Table comparing line parameters - line balancing coefficient *K*%, balancing efficiency *H*%, capacity *P*, number of workers *N* and cycle time *R* of Polo-shirt coded PL04 when given the number of workers *N*.

***N* = 40 people**	***K* [%]**	***H* [%]**	***P* [products/day]**	***R* [s]**
By Tinh Loi Garment Co., Ltd	59	100	1667	18.36
By hand method of HUST	70.4	100	1667	18.9
By BSL-HUST software	80	91.8	1575	20.0

Completing the design and balance database the sewing line two products T-Shirt and Polo-Shirt

Completing the design and balance database of T-Shirt product

a. Given the capacity *P*

The authors found that the design and line balancing results according to the method of Hanoi University of Science and Technology are the most optimal, so this result will be used as the standard database without the need to correct the algorithm and software design techniques (Table 19).

b. Given the number of workers *N*

The authors found that the design and line balancing results according to BSL-HUST software are the most optimal, so this result will be used as the standard database without the need to correct the algorithm and software design techniques (Table 20).

Completing the design and balance database of Polo-Shirt product

a. Given the capacity *P*

The authors found that the design and line balancing results according to BSL-HUST software are quite optimal because *K*% > 60%. However, the number of workers and the load factor are not optimal. Because the software accepts increasing the number of workers so that the transmission is always smooth and not overloaded, the result is acceptable (Table 21).

b. Given the number of workers *N*

The authors found that the design and line balancing results according to BSL-HUST software are the most optimal, so this result will be used as the standard database without the need to correct the algorithm and software design techniques (Table 22).

CONCLUSION

After conducting the research, the authors have completed the database on the design and line balancing of two typical products made from knitted fabrics, namely Polo-Shirt and T-Shirt. The authors compared and evaluated the design and balance results T-shirt sewing line according to HUST method by hand calculation, using BSL-HUST software and the actual results at IE room of Tinh Loi Garment Co., Ltd. With the given the capacity of line P (products/shift) and the given the number of workers *N* (people), the team compared and evaluated the design and balanced result sewing line by comparing the organization and coordination of tasks results, the full-line load charts, the sewing line layout diagrams and the exact results of line paraments. Then the authors compared and evaluated the

Table 19. Table of organization and coordination of tasks into workstations result according to the manual calculation method of HUST, T-shirt coded T07 when given the capacity *P*.

Workstation	Task	Machine	T_i [s]	T_j [s]	N_i [people]
1	34	M2K3C	16.8	8.4	2
2	35	M1K	10.8	10.8	1
3	40	M1K3C	16.8	16.8	1
4	41	OL-MN	25.8	12.9	2
5	42	M1K	10.8	10.8	1
6	43	MH380	27	13.5	2
7	44	M2K4C	34.8	11.6	3
8	45	M2K4C	41.4	13.8	3
9	46	M2K3C	24	12	2
10	47	M1K	29.4	9.8	3
Sum			237.6		20

Table 20. Table of organization and coordination of tasks into workstations result according to BSL-HUST software, T-shirt coded T07 when given the number of workers *N*.

Workstation	Task	Machine	T_i [s]	T_j [s]	N_i [people]
1	34	M2K3C	16.8	8.4	2
2	35	M1K	10.8	10.8	1
3	40	M1K3C	16.8	8.4	2
4	41	OL-MN	25.8	12.9	2
5	42	M1K	10.8	10.8	1
6	43	MH380	27	13.5	2
7	44	M2K4C	34.8	11.6	3
8	45	M2K4C	41.4	13.8	3
9	46	M2K3C	24	12	2
10	47	M1K	29.4	14.7	2
Sum			237.6		20

Table 21. Table of organization and coordination of tasks into workstations result according to BSL-HUST software. Polo-shirt coded PL04 when given the capacity *P*.

Workstation	Task	Machine	T_j [s]	Type	N_i [people]	T_j [s]
1	34	M2K4C	16.8	3	1	16.8
2	35	MC1K	27.6	4	2	13.8
3	36	M1K	21	3	3	16
	41	M1K	27			
4	37	M2K4CG1	10.2	3	1	10.2
5	38	M1KG1	39	4	2	19.5
6	39	M2K4C	21	3	1	21
7	40	MC1KG1	19.8	3	1	19.8
8	42	M2K4C	21	4	1	21
9	43	MC1KV	19.8	4	1	19.8
10	44	M1KG2	27	3	2	13.5
11	45	M1K	21	3	1	21
12	46	M1K	21	3	1	21
13	47	M1K	24	3	3	16.8
	48	M1K	26.4			
14	49	M1KG3	33	4	2	16.5
15	50	M2K4C	32.4	4	2	16.2
16	51	MC1KG1	32.4	4	2	16.2
17	52	M2K4C	4.8	3	1	16.8
	53	M2K4C	12			
18	54	M2K4C	43.8	4	2	21.9
19	55	M1KG4	22.8	3	2	11.4
20	56	M1KG3	60	4	3	20
21	57	M2K4C	36	4	2	18
22	58	MC1K	24	4	2	12
23	59	M1K	37.2	3	2	18.6
24	60	MDB	12	3	1	12
25	151	MTK	24.6	3	2	12.3
26	152	MDC	4.2	3	1	16.8
	153	MDC	12.6			

Table 22. Table of organization and coordination of tasks into workstations result according to BSL-HUST software, Polo-shirt coded PL04 code when given the number of workers *N*.

Workstation	Task	Machine	T_i [s]	Type	N_i [people]	T_i [s]
1	34	M2K4C	16.8	3	1	16.8
2	35	MC1K	27.6	4	2	13.8
3	36	M1K	21	3	2	24
	41	M1K	27			
4	37	M2K4CG1	10.2	3	1	10.2
5	38	M1KG1	39	4	2	19.5
6	39	M2K4C	21	3	1	21
7	40	MC1KG1	19.8	3	1	19.8
8	42	M2K4C	21	4	1	21
9	43	MC1KV	19.8	4	1	19.8
10	44	M1KG2	27	3	2	13.5
11	45	M1K	21	3	1	21
12	46	M1K	21	3	3	23.8
	47	M1K	24			
	48	M1K	26.4			
13	49	M1KG3	33	4	2	16.5
14	50	M2K4C	32.4	4	2	16.2
15	51	MC1KG1	32.4	4	2	16.2
16	52	M2K4C	4.8	3	1	16.8
	53	M2K4C	12			
17	54	M2K4C	43.8	4	2	21.9
18	55	M1KG4	22.8	3	1	22.8
19	56	M1KG3	60	4	3	20
20	57	M2K4C	36	4	2	18
21	58	MC1K	24	4	1	24
22	59	M1K	37.2	3	2	18.6
23	60	MDB	12	3	1	12
24	151	MTK	24.6	3	2	12.3
25	152	MDC	4.2	3	1	16.8
	153	MDC	12.6			

design and balanced results Polo-Shirt sewing line according to HUST method by hand calculation, using BSL-HUST software and the actual results at IE room of Tinh Loi Garment Co., Ltd. Similar to the process of T-shirt product, the author compared the organizaion and coordination of tasks results, the full-line load chart, the sewing line layout diagrams, the exact results of line parameters with given the capacity *P* (products/shift) and the number of workers *N* (people). Finnally the researcher completed the design and balanced database sewing line two products T-shirt and Polo-shirt with given the capacity *P* and the number of workers *N*. The design and line balance results according to BSL – HUST software are the most optimal compared to line balancing by hand of HUST method and Line balancing by Tinh Loi Garment Co., Ltd plan. The authors found that the result will be used as the standard database without the need to correct the algorithm and software design techniques. In the future, the author team will continue to research and expand with other items to diversify the database of designs and balance sewing lines.

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