Applying Genetic Algorithm for Line Balancing Problem in Garment Manufacture

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Abstract. The garment industry is one of the most intensely competitive in the world, and productivity is essential to sustaining that competitiveness. As one of the sectors that utilizes a large number of people and various activities at workstations, the garment industry is one that places a high priority on increasing productivity and reducing production costs. One of the biggest problems the garment sector has is line balance, which arises from the way the work is organized on the line and the coordination between workers, machines, and stages. Therefore, in an effort to increase productivity and reduce production costs, the line balancing problem is posed. In order to handle the nonlinear programming challenge, the GA heuristics technique was employed in this study. This study was tested with data from a clothing company to determine the efficacy of line balancing. Based on the results of line balancing, line managers can quickly balance lines to to minimize production cycle time and utilize workforce on the assembly line.

Keywords: Line balancing · genetic algorithms · efficiency

1 Introduction

After the 20th Century, the garment industry became a large-scale manufacturing industry. The whole industry has made breakthrough changes, from costumes that are sewn according to individual measurements at an expensive cost to the production for mass demand at low cost, from designs, models, materials, color, the time of use and the development of new products are also constantly being changed. Vietnam's textile and garment industry is also one of the key export industries and plays an important role in the growth of the economy, accounting for 12 - 16% of the country's total export turnover (Ministry of industry and trade of the socialist republic of Viet Nam). However, competition increased by globalization forcing companies to produce more efficiency. One of the most significant factors affecting the competitiveness of the Viet Nam garment industry is productivity. Line balancing is one of the techniques that can be used to enhance the productivity in production lines.

Line balancing means balancing the production line, or any assembly line. The main objective of line balancing is to distribute the task evenly over the workstation so that

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idle time of man of machine can be minimized. Line balancing aims at grouping the facilities or workers in an efficient balance of the capacities and flows of the production or assembly processes.

Assembly line balancing (ALB) is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods. Line balancing is a classic Operation Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the line balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must. Task allocation of each worker was achieved by assembly line balancing to increase an assembly efficiency and productivity.

This research focuses on problems confronted by garment factories due to labour and resource allocation practices they follow. Different kinds of line balancing algorithms have been applied for many years in apparel industry for job assignments and resource allocation. However, manual-operations oriented system of this sector makes it impossible to gain certain results with the algorithms currently used. A lot of factors cause variations on operational time of the same task such as the stochastic nature of operations, the experience of the operator, quality of the environment and performance of the machinery. Such variations on task time cause the line balancing problem in the clothing industry to become more complicated. Moreover, other major stochastic variables such as machine breakdown, re-working, absenteeism, the work of the supervisor, maintenance etc. significantly affect to imbalance a production line. Therefore, managers are up against unexpected bottlenecks, increasing idle time, decreasing level of efficiency, increasing operator fatigue and increasing the defect rate during the sewing process. As a result of that, production managers are unable to complete the orders at the scheduled time. One of the main reasons for above mentioned difficulties is unavailability of a line balancing procedure that could encompass the stochastic nature of the garment manufacturing process, which is manifested through the likes of variability of operating times, machine breakdowns, reworking, and operator breakings. Currently, the problem of line balancing at garment enterprises still mainly depends on the experience of the line balancer, thereby leading to inefficiencies in line balancing, the adaptability to changes in production is not high.

Therefore, the objective of this research is using genetic algorithm to balance the line automatically, increase accuracy and reduce dependence on humans.

2 Literature Review

2.1 Assembly Line Balancing Problem

Lean and agile manufacturing is a very vast field and line balancing in industries is also very important. Many times, in conferences this is main topic of discussion and many students and scholars also publish their works on this topic. Assembly line balancing is the problem of assigning various tasks to workstations, while optimizing one or more objectives without violating any restrictions imposed on the line. Assembly line balancing problem has been an active field of research over the past decades due to its relevancy to diversified industries such as garment, footwear and electronics.

Muhammad Babar Ramzan (2019) used time study approach to balance the line and improved the productivity with results a 36% increase the machine productivity, reduction of work in process and visibility of the processes also improved. Haile Sime & Prabir Jana (2018) used Arena simulation software to proves the use of simulation technique in designing and evaluating different alternative production systems from which the one with best performance can be selected for final implementation. This will help apparel industries to optimize utilization of their resources through effective line balancing. Markus Proster & Lothar Marz (2015) has shown a dynamic balancing is crucial for a high productivity in mixed – model assembly lines to handle the different assembly times of the variants. Common possibilities to treat the resulting capacity peaks are drifting and the allocation of jumpers. Simulation tool was shown which is able to simulate and visualize these methods and therefore reduces complexity and rises transparency in the planning of assembly lines.

Ghosh and Gagnon (1989) as well as Erel and Sarin (1998) provided detailed reviews on these topics. Configurations of assembly line for single and multiple products could be divided by three-line types, single – model, mixed – model and multi – model. Single – model assembles only one product, and mixed – model assembles multiple products, whereas a multi – model produces a sequence of batches with intermediate setup operations (Becker & Scholl, 2006). This paper solves single – model line balancing problem with real application. Boysen, Fliedner, and Scholl (2007,2008) classified ALBPs and pointed out that there were less than 5% articles explicitly solving line balancing of real-world assembly systems. As a result, for practical consideration, this paper focuses on the real case of an assembly line in garment manufacturing.

Assembly line balancing problem with different objectives could be classified into several types called ALBP – I to ALBP – V (Tasan and Tunali 2008, Kim et al. 1996), and among these ALBP – I, ALBP – II, and ALBP III are the most popular ones addressed in recent literature. ALBP – I and ALBP – II have a dual relationship. ALBP – I is formulated with the objective of minimizing the number of workstations used to meet a target cycle time. It can result in low labor costs and reduced space requirements. ALBP – II tries to minimize the cycle time for a given number of workstations and therefore can maximize the production rate. ALBP – III maximizes the workload smoothness, for a given number of workstations. Workload smoothness is accomplished by leveling the workload distribution as evenly as possible, and it can lead to the throughput increase of a line and the equity in task assignment among workers. ALBP – IV maximizes the work relatedness by arranging the tasks in a workstation that interrelated tasks are arranged into the same workstation as much as possible, so that work efficiency can be improved. ALBP – V is corresponding to the multiple objectives with ALBP – III and ALBP – IV considered simultaneously. ALBP – I problem will be the type of problem addressed in this research.

1. ALBP – I: minimizes the number of workstations, for a given cycle time.
2. ALBP – II: Minimized the cycle time, for a given number of workstations.

3. ALBP – III: Maximizes the workload smoothness, for a given number of workstations.
4. ALBL – IV: Maximizes the work relatedness by arranging the tasks in a workstation.
5. ALBP – V: Consider the multiple objectives with ALBP – III and ALBP – IV simultaneously.

2.2 Genetic Algorithm (GA)

Among the methods, GA (presented by John Holland in 1975) is the most popular one having been employed in solving ALBP, as compared with simulated annealing and tabu search (Holland, 1975). Based on evolutionary computation techniques, GA method has received much attention and has been applied successfully in many research fields. Within recent years, many studies have been made on the applications of GA to ALBP of different industries. GA is also one of the most popular heuristic algorithms in the deterministic approach adopted to solve ALBP (Brown & Sumichrast, 2005; Yong, Yeo & Yongkyun,1998). Recently, GA was applied to the production planning and scheduling problems (Balin, 2011; Chan, Au & Chan, 2006) and line balancing problems in textile manufacturing (Hsu, Hsiung, Chen & Wua, 2009). Wong, Mok and Leung (2006) also used GA to optimize the assignment of operators for ra garment assembly line.

A number of researchers have successfully applied GA to solve problems in garment manufacturing. Wong, Kwong, Mok and Chan (2005) described a GA approach to solve the job sequencing optimization problem, of the manual fabric – cutting process for garment manufacturing. Wong, Leung and Au (2005) focused on pre – sewing stage and proposed a real time GA – based rescheduling approach to handle the production planning and scheduling problem in dynamic garment manufacturing environment. Wong, Mok and Leung (2006) applied GA to optimize the operator assignment and minimize make span of garment assembly line. Song, Wong, Fan and Chan (2006) proposed an optimal operator allocation solution for solving ALBP with the consideration of the operator efficiency variance. These publications illustrate the potential of GA to address the garment industry assembly line balancing problems.

In summary, real case application for ALBPs are relatively few in literature. This paper will apply GA to solve real case ALBP II in garment manufacturing. The objective of this paper is eliminate the bottle necks in line production and improve the efficiency of line production based on the current resources: machines, manpowers.

3 Methodology

At first, for a certain garment order the number of operations, sequence of operations, seams length, types of fabric, number of workers, working hours, machine efficiency etc. were identified. The time needed for each operation by every worker was calculated. Tasks are then assigned to the operators based on their labor skill level.

Line balancing process is illustrated in the Fig. 1:

Today, there are many applications that can be applied to the garment sector to help us easily control production activities and increase productivity follow to the development of technology 4.0. One of the applications of 4.0 technology is the "Electronic ticket

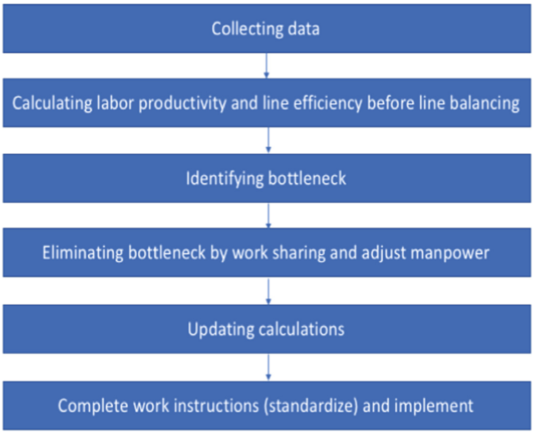

Fig. 1. Steps involved in line balancing

Fig. 2. ETS terminal

system" (ETS) production management system. During production process, ETS use RFID technology to track production information, moinitor production progress, keep track the worker performance, highlight the problem e.g. WIP, line balance, QC through real time report and analysis chart.

In general, ETS has 4 main parts: ETS terminal, ETS tag, Signal transceiver and N-port.

ETS terminal: The terminal use to receive information from ETS tag and transfer information to signal transceiver. In addition, user can type directly in data and set up by this terminal. ETS terminal is shown in the Fig. 2.

ETS tag: ETS tag is a Kanban card to store the data like style, PO, SO, quantity, color, data… ETS tag only store the card ID inside, it can help to faster in speed as all of MO basic information stored in system backend. ETS tag is shown in Fig. 3.

Fig. 3. ETS tag

The workers will scan ETS tag into terminal before producing and after finishing they scan again to complete the bundle. The working time to complete 1 bundle (20 pcs for bra and 40 pcs for panty) of workers, is the time between 2 scanning ETS tag. Data will be transferd to data center in a real time.

There are some terms related to line balancing process:

- SAM – standard allowance minutes: the allowance standard time for do one operation calculated by minute.
- On-standard SAM – this refers to the output multiplied to the SAM.
- SAH – Standard allowance hours
- On-standard time: This refers to the working time of the worker after removing the off time.
- Off time: this is the downtime like machine breakdown, quality problems and no supply.
- Efficiency: the ability to produce something without wasting materials, time and energy.

The time/ pcs, Takt time, labor productivity and line efficiency were calculated using following equations:

$$\text{Time/pcs} = \frac{\text{Time to finish 1 bundle}}{\text{number of pieces}} \tag{1}$$

$$\text{Efficiency capacity} = \frac{\sum \text{SAM of each operation}}{\sum \text{Time to complete 1 pcs of each operation(minute)}} \tag{2}$$

$$\text{Takt time} = \frac{\sum \text{Time/pcs}}{\sum \text{No of operators}} \tag{3}$$

$$\text{Labor productivity} = \frac{\text{Total number of output per day per line}}{\text{Total number of workers}} \tag{4}$$

After calculating these parameters, the important task is to figure out where the bottle necks are, how to allocate worker resources to optimize the total production time.

Genetic algorithms are typically used to search very large and possibly very high dimensional search space. They are adaptive heuristic search systems premised on the evolutionary ideas of natural selection and genetics. Hence, the basic concepts of genetic algorithm are designed to simulate processes in a natural system. It is efficient to:

- Find a solution when solution space is large, and when linear programming cannot find a in proper time.
- Deal with multi-constraints problems.
- Solve a problem when there is limited time or resources of the problem.
- Find approximate solution.

The following algorithm represents the implementation of the genetic algorithm in the line balancing problem:

Begin;

- Initialize generation number *G*, size of population *H*, crossover rate P_C , mutation rate;
- $t = 0$, t is index of generation *t*;
- Initialize the initial population *P(0)*;
- Calculate fitness of every individual in the *P(0)*;

Repeat:

- $t = t + 1$;
- Generate child population *O(t-1)* from *P(t-1)* by:

Repeat:

- Select two parents from the generation *P(t-1)* by Tournament selection to crossover;
- Crossover two parents with crossover rate P_C by a method which was inspired by Partially matched crossover (PMX);
- Mutation new offspring which was recently created with mutation rate P_M by Simple swap mutation operator;
- Two new offspring are added to child population *O(t-1)*;
- Until (size of population *O(t-1)* equals to size of *P(t-1)*);
- Generate new population *P(t)* by survivor selection in child population *O(t-1)* and old population *P(t-1)*;
- Save the best chromosome;
- Until (Iterator number is greater than generation number);

Table 1. Product style HMM21–00278-1101(XX)

Style name	Bra
Type of style	New style
Style No	HMM21–00278-1101(XX)
SO	8V2205302
MO	V220530228
Total order quantity	2760 pcs
Color	10–210 White Light Lace
Starting date production	26/04/2022
Completed sewing date	05/05/2022

Table 2. Time allowance of machine

Type of machine	Time allowance
1SLM, 2SLM, 1ZZ	18%
2OLM, 3OLM, 4OLM, CUCM, SPHM	15%
BT1M, 2CSM, 4CSM, UFSM	17%
MNHD, GIF	11%

4 Experiment

4.1 Current Capacity

This paper will focus on analyzing line balancing process for bra style: HMM21–00278-1101 (XX) in G09 in PU2, Crystal Martin Viet Nam company limited when this line change over style order. This style start in 26/04/2022 and finish in 05/05/2022 with total quantity order is 2760 pcs (from 30/4 to 3/5 is a National Day holiday in Vietnam).

After collect data in 27/04/2022, the next step is comparsion between the real time and the SAM for each operation. Because, the machine and manpower have time allowance, therefore it is need to calculate again time that operators do 1 piece by plus time allowance. The allowance are in the Table 2:

For example, in the Table 3, in the column Time/ pcs (minute), this is the operation 33, follow the Fig. 2.3, they use 3ZZM. Then the time allowance is set 18% and calculate the time/pcs is calculated by the below formulation:

$$\text{Time/pcs} = \frac{Time/3pcs}{180} * 1,18 = 0.577(\text{minutes}) \tag{5}$$

The Figure 4 will show the production layout of G09 when making style HMM21–00278-1101 (XX):

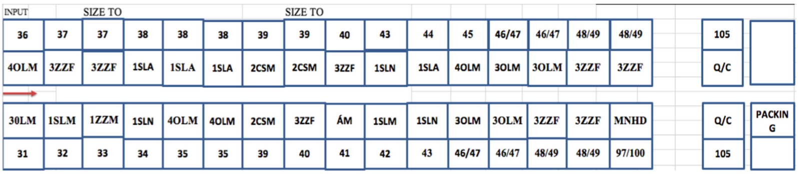

Fig. 4. Layout production

Table 3. Line capacity study

Operation No.	**SAM**	**Emp. No**	**Name**	**Time/pcs (second)**	**Time/pcs(minute)**	**Output capacity /hour (piece)**	**Efficiency Capacity**
31/32	0.316	202875	Pham Thi Dinh	39	0.760	79	42%
33	0.3342	233507	Doan Thi Bao	29	0.577	104	58%
34	0.5113	231882	Hoang Thi Tam	61	1.206	50	42%
35	0.9389	200328	Nguyen Thi Thuy	74	1.412	42	66%
36	0.4936	235402	Trieu Thi Ngan	34	0.652	92	76%
37	0.68	212908	Pham Van Doan	67	1.311	46	52%
38	1.3289	207980	Ninh Thi Hoi	175	3.442	17	39%
38	1.3289	208187	Duong Thi Thuong	127	2.504	24	53%
38	1.3289	235249	Ngo Thi Hong	61	1.200	50	111%
39	0.7207	211024	Nguyen Thi Hue	102	1.989	30	336%
39	0.7207	211924	Tran Thi Tram	98	1.918	31	38%
40	0.978	212652	Le Thi Hanh	62	1.219	49	80%
41	0.5494	231202	Nguyen Thi Tham	70	1.377	44	40%
42	0.2948	233756	Vo Thi Lam	33	0.656	92	45%

(*continued*)

Table 3. (*continued*)

Operation No.	SAM	Emp. No	Name	Time/pcs (second)	Time/pcs(minute)	Output capacity /hour (piece)	Efficiency Capacity
43	0.7001	235281	Nguyen Thi Loan	66	1.298	46	54%

From the Table 3, the actual efficiency of line production G09 could calculated by the formulation:

$$\text{Efficiency capacity} = \frac{\sum \text{SAM of each operation}}{\sum \text{Time to complete 1 pcs of each operation(minute)}} = 59\% \tag{6}$$

It is clearly that there are some bottle necks operation, for example operation 38, the workers must take 175 s to complete 1 piece, the efficiency of this operation is only 39% less than efficiency capacity of line G09 20%. Therefore, the objective of IE production is rearranged workers to match the capacity of the current sewing line.

Next step, IE production separate each operations to measure how many operators, how much time, time average to do this operation. As a result, they could calculate the time average that 1 operators do 1 piece in that lines by the formualation:

$$\text{Takt time} = \frac{\sum \text{Time/pcs}}{\sum \text{No of operators}} \tag{7}$$

After that, it is nessessary to draw a chart and see the performance, capacity of each operators. Then it is clearly that what operation has problem, who has problem to adjusted.

In the Fig. 5, there are some anomalies like operation 38, 39, 47, 48, 49 which are exceed the takt time. Therefore, the capacity of the line will be unbalanced, spots will appear some bottle neck. Moreover, some operations like 31, 32, 33, 42, 44 are less than the Takt time of line production value, so the operators will be waiting for other operations and machine is idle. It is necessary to arrange and arrange workers so that the operations are balanced in value of Takt time of line production.

4.2 Using GA to Balance Line G09

The target of line balancing by GA is set the operators and machines in order to time to do each operations is approximately takt time of production line. The data center will automatically calculate and balance the line with the current production capacity of the sewing line by GA algorithm.

In GA, the search for the appropriate hypothesis begins with a population, or an initial selective set of hypotheses. Individuals of the current population originate for the next generation population by random hybridization and mutation activities – sampled after biological evolutionary processes. At each step, hypotheses in existing populations are

Table 4. Time study for each operation

OPN	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	**SUM**
No of operators	0.5	0.5	1	1	1	1	1.5	3.5	2	1	1	1	2	1	1	2	2	1.5	1.5	26
Time/pcs	47	69	108	198	221	107	220	1120	570	218	210	114	425	109	220	420	560	370	455	
Time avg/ opn	94	138	108	198	221	107	146.7	320	285	218	210	114	212.5	109	220	210	280	246.7	303.3	
Takt time	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	222	

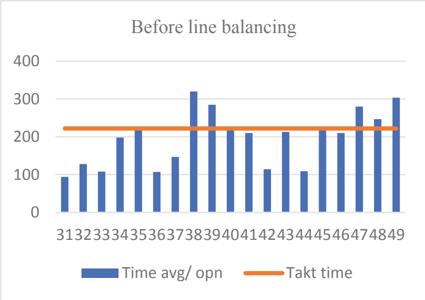

Fig. 5. Current line capacity chart

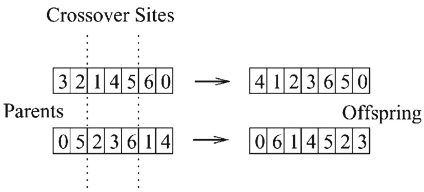

Fig. 6. Genetic algorithm method

estimated in relation to adaptive quantities, with the most suitable hypotheses selected by probability as seeds for the production of the next generation, called individuals. Individuals who are more developed, more adaptable to the environment will survive and vice versa will be eliminated. GA can detect the next generation with better adaptability.

After running genetic algorithm by Python programming language, it finds out the best adaptability and suggest balancing pass for decision-maker in desktop application. Decision maker can refer to how to automatically balance lines and adjust human resources to improve efficiency, reduce bottle necks and save costs for the company. The Table 5 will be an example of the line balancing suggestion that GA algorithm calculates based on actual production capacity.

From the Table 5, there are some parameters should take into account such as OPN (The operations), Head count with exactly the number of workers that line leader set up to do this operations, Time/pcs to measure exactly the time that IE production press in the line. And after line balance, parameter of Calculative operators should be under consideration which is the number of operators need to the operations in order to meet the takt time.

$$\text{Calculative operators} = \frac{\text{Time/pcs before}}{\text{Takt time}} \tag{8}$$

Further more, after line balance, the Head count (HC) after is also measured. The HC is the number of workers need to do the operations, worker can not odd therefore the number of workers is calculated by the following formulation:

$$\text{HC} = \text{MROUND}(\text{calculative},\ 0.5) \tag{9}$$

Table 5. Comparasion between before and after line balancing

BEFORE	OPN	31/32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	**SUM**
	Head count	1	1	1	1	1	1.5	3.5	2	1	1	1	2	1	1	2	2	1.5	1.5	26
	Time/pcs	111	108	198	221	107	220	1120	570	218	210	114	425	109	220	420	560	370	455	
Takt time		221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	221.6	
AFTER	OPN	31/32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	
	Calculative Operators	0.501	0.487	0.894	0.997	0.483	0.993	5.055	2.572	0.984	0.948	0.514 ara>	1.918	0.492	0.993	1.896	2.527	1.67	2.053	
	Head count	0.5	0.5	1	1	0.5	1	5	2.5	1	1	0.5	2	0.5	1	2	2.5	1.5	2	26
	Time/pcs	222	216	198	221	214	220	224	228	218	210	228	212.5	218	220	210	224	246.7	227.5	

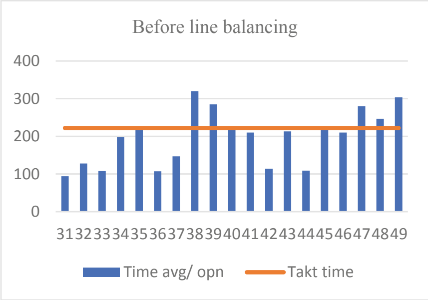

Fig. 7. Line capacity chart before line balancing

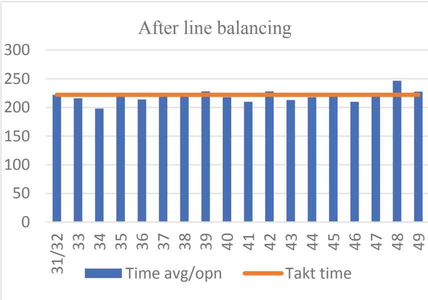

Fig. 8. Line capacity chart after line balancing by GA

Time/pcs after is the time to finish this operations after line balancing

$$\text{Time}/\text{pcsafter} = \frac{\text{Time}/\text{pcs before}}{\text{HC after}} \tag{10}$$

After calculation and analyze, the output report will suggest recommends to balance line production for leader production. For example, there are operation 31, 32 could be combined to reduce manpower. The line must increase the workers for operations 38, 39, 48, 49 to reduce bottle neck and improve the efficiency. More detail: Operation 38 need 5 operators; 1 operators do opn 36 could be supported for opn 39, therefore opn 39 has 2.5 workers; arrange 1 more workers to do both operations: 47,49.

The line capacity chart will help us easily visualize the change after automatic line balancing after running GA. From the Fig. 6 and Fig. 7, it is clearly that the line production is more stable, all operation is approximately the current takt time.

After running optimally with GA, we can see that the G09 pass is more balanced, the operations are below and approximately the same as the takt time. Thereby, it helps to reduce bottle necks and wastes on the production line such as motion waste and waiting waste.

Table 6. Current efficiency of line production G09

	26/4	**27/4**	**28/4**	**29/4**	**04/5**	**05/5**
On std SAH	10	95	130	126	131	136
On std time (h)	55	270	262	259	250	258
Efficiency	17%	35%	49%	49%	52%	53%

Table 7. Efficiency of G09 line if apply line balancing by GA

	26/4	27/4	28/4	29/4	04/5	05/5
Efficiency	17%	$\approx$ 59%	Min 59%	Min 59%	Min 59%	Min 59%

Table 8. Comparison the effectiveness of line balaincing

Criteria	**Before**	**After**
Manpower	26 workers	26 workers
Highest bottle neck	320 s	247 s
On std SAH	95 SAH	153.4 SAH
Lead time	6 days	5,03 days
Efficiency	35%	59%
Saving		7,566,000 VND

In addition, the efficiency of line G09 in 27/04/2022 could be achieve based on current production capacity is calculate by the formulation:

$$\text{Efficiency capacity} = \frac{\sum \text{SAM of each operation}}{\sum \text{Time to complete 1 pcs of each stage(minute)}} = 59\% \tag{11}$$

Therefore, if automatic line balancing by GA is applied, the performance of G09 line can be improved according to the Table 7. The Table 6 and Table 7 will show the efficiency of line G09 from 26/04 to 05/05/2022:

Excluding the first day of April 26, 2022, because in April 26, 2022 the line G09 start changeover, there are many problem about machine, technical requirement, worker skills and G09 must fullfill the old style order, the total production SAM would be:

$$\sum\nolimits_{27/04}^{05/05} On\ std\ SAH = 618(\text{SAH}-\text{Standard allowance hour}) \tag{12}$$

Table 9. Total saving cost if apply line balancing by GA

Month	Total on std SAHf new style (SAH)	Total saving cost 1 (VND)
April	50,945	613,734,415
May	39,712	478,410,464
June	34,656	417,500,832
July	44,941	541,404,227

The average working time in each day would be:the time/pcs is calculated by the below formulation:

$$\sum On\, std\, time = 260\,(\text{SAH}) \tag{13}$$

Based on production efficiency is 59% each day, On std SAH that line G09 could achieve in each day:

$$On\, std\, SAH_1 \sum On\, std\, time * 59\% \;=\; 260\; * 59\% \;=\; 153.4(\text{SAH}) \tag{14}$$

The total day to complete this order with new efficiency of 59% would be:

$$\text{Total day} \;=\; \frac{\sum_{27/04}^{05/05} On\, std\, SAH}{\text{On std SAH1}} == \; 4.03(\text{days}) \tag{15}$$

From total day, it is clearly that production line G09 could decrease about 0.97 day of production. Therefore, the factory could descrease the salary paid for employees in 0.97 day. The saving salary would be calculate by:

$$\text{The saving salary} \;=\; \text{Saving day} \;*\; \text{on std time} \;*\; \text{salary per hour} \;=\; 0.97 * 260 * 30\,000 \;=\; 7,566,000\,(\text{VND}) \tag{16}$$

(Average Salary Cost of Worker: 30,000 VND/hour)*

Saving coefficient when applying automatic line balancing by GA:

$$\alpha = \frac{The\ saving\ salary}{\sum_{26/04}^{05/05} On\, std\, SAH} == 12,047.77(\text{VND/SAH}) \tag{17}$$

There are many criterias to evaluate the effetiveness of line balancing process such as takt time, efficiency, lead time, manpower, output… The table below will show the comparison between before and after balancing the line G09, style HMM21–00278-1101(XX):

The Table 9 will depict the total SAH of ***new style order*** in production unit 2 (PU2) in April, May, June, July and the total saving cost if applying automactic line balancing by GA:

$$\sum Saving\ cost\ 1\ each\, month = \alpha * \;\text{Total on std SAH each month of new style} \tag{18}$$

After applying GA to solve the line balancing problem, one production unit can save an average of about 512,762,484 VND per month. The level of savings may increase if the line balancing process in the following production days can be improved. Moreover, the sewing line can cut production lead time, thereby helping to improve customer satisfaction.

5 Conclusion

The study has summarized the theortical basis of the line balancing problem and how to use genetic algorithms to solve that problem, the study has shown the effectiveness of the genetic algorithm in optimization problems, it helps us to sovle large – scale problems with better accuracy and time than another algorithm. The research has demonstrated the effectiveness of the genetic algorithm when solving the line balancing problem. It could save a large amount of production costs for sewing business, helping sewing business accelerate lead-time production and increase customer satisfaction. Applying GA to solve the problem of line balance quite effectively, it helps the company save costs and increase the efficiency. From the research, it is effectively solving the line balancing problem helps improve costs, increase production efficiency and competitive advantages for the company.

Although the article has positive contributions, there are still some limitations with time consuming for solving problem. The problem could be automatically solved with more advanced tool such as AI application. It could be developed furthermore to build line balancing faster running the GA algorithm and easy to use and manipulate for users. In addition, the time to solve the line balancing problem will depend on the complexity of the stages of each type of order.

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