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Improving the Apparel Production Process by Using Simulation Modelling with a Waves Algorithm

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Abstract
In this study, a simulation study was carried out in order to increase the production efficiency of a company that produces hoodies. The simulation technique has been included in many studies for line balancing in the apparel industry. However, in this study, unlike others, an algorithm that can be easily applied is proposed for the software practitioner to use in the alternative model development process in order to increase the efficiency of an existing production line. Based on real production line data, a waves algorithm was applied in the simulation model, whose verification and validity processes were completed. In the results obtained with the help of the waves algorithm (acting according to two different assignment scenarios), it was determined that the average production values per person had increased.

Key words: *apparel industry, line balancing, simulation, productivity, waves algorithm.*

Introduction

Most real-world systems are too complex to allow realistic models to be evaluated analytically, thus these models must be studied by simulation. In simulation a computer is used to evaluate a model numerically, and data are gathered in order to estimate the desired true characteristics of the model. Simulation represents one of the tools most frequently used to observe the behaviour of a production system in order to highlight its efficiency levels and evaluate new management solutions in a relatively short time [1].

A system is defined as a collection of entities e.g., people or machines, that act and interact together toward the accomplishment of some logical end. Systems are categorised as two types: discrete and continuous. A discrete system is where the state variables change instantaneously at separate points in time. A continuous system is where the state variables change continuously with time. Discrete-event simulation concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time [2]. Discrete-event simulation has played a significant role in evaluating the design and operational performance of manufacturing systems [3-5]. Successful applications of simulation in many practical real-world problems have proved its effectiveness in approaching various problems in the manufacturing sector [6].

All simulation studies are basically carried out in 6 steps [7]:

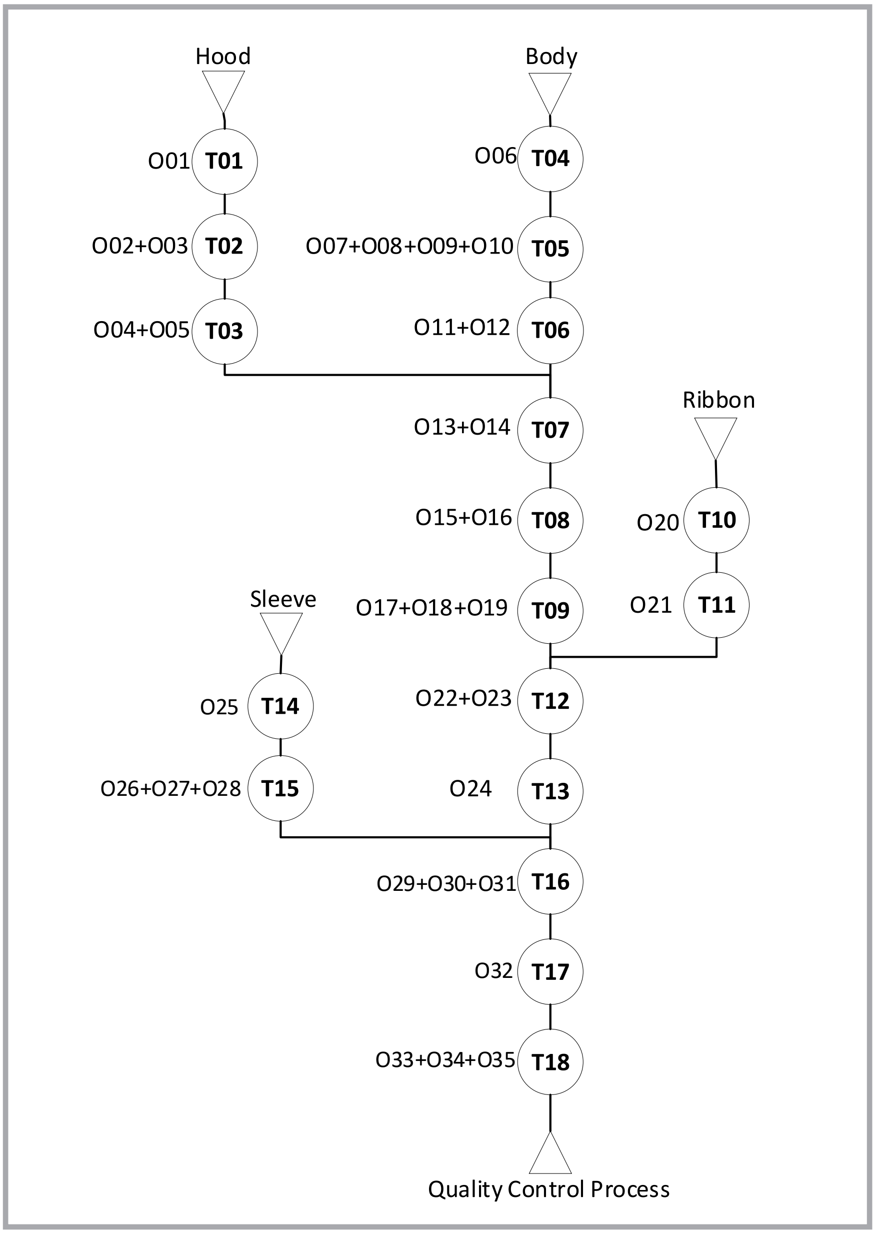

Figure 1. Work flow of hoodies.

1 – Problem analysis and information collection
2 – Data collection for estimating model input parameters
3 – Model construction by using a software
4 – Model verification and model validation
5 – Designing and conducting simulation experiments
6 – Output analysis and final recommendations

Since 1989, many simulation studies have been carried out in the field of textile and apparel production. The biggest advantage of simulation studies is that they handle the stochastic structure of production systems correctly. The most common study topics are as follows: line balancing in the apparel industry, production analysis in the variable demand condition in the finishing area, determining production bottlenecks in the knitting and weaving area, and problems related to the worker-machine relationship in yarn production [8]. Studies especially in the field of apparel focus on the following subjects: exploring various production scenarios in a trouser plant [9], understanding the operational characteristics of modular manufacturing [10], analysing the modular manufacturing system [11], applying labour flexibility on the production line [12], analysing different production scenarios [13], reducing the cycle time [14], assessing the effects of different production configurations on flow time and production capacity [1], analysing cellular manufacturing [15], and line balancing [16-23].

Line balancing optimisation is generally performed in simulation studies in the process of developing alternative models after the validity phase. In line balancing optimisation in a previous studies, researchers dealt with assembly line balancing using simulation and optimisation methods, but independently [3]. In this study, unlike others, a new process called a waves algorithm that can be easily used by software practitioners has been developed in order to create a more efficient production line. After using real data obtained from a company that produces hoodies in the model construction process, the average hourly production per operator was used as a performance indicator in an alternative model development process. The results obtained for two different scenarios with the help of a waves algorithm were examined.

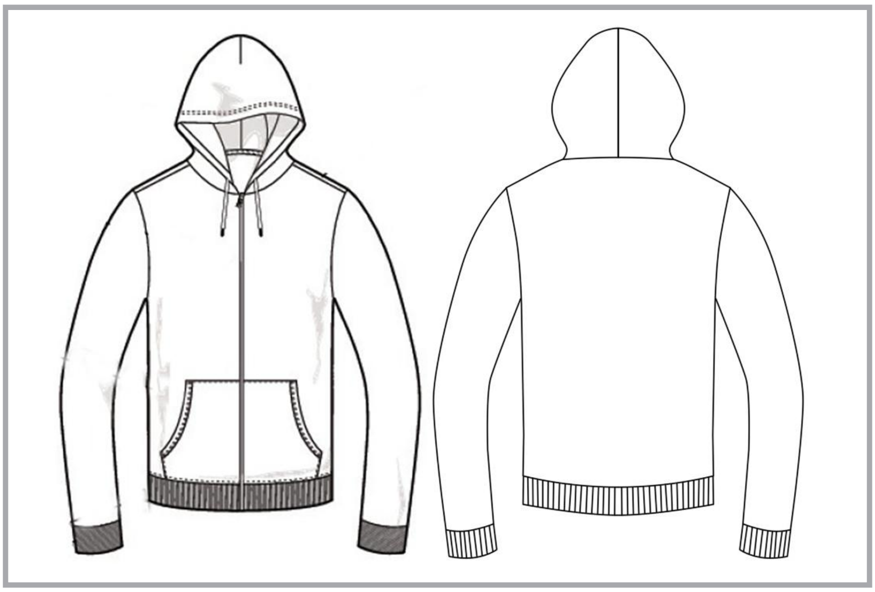

Figure 2. Technical drawing of hoodies.

Material & method

In this study, a most repeated pattern of hoodies produced on a straight production line was examined. According to factory data, this model has Standard Allowed Minute (SAM) of 22.63 s. The reason for choosing a frequently repeated model is that the possibility of oversight in the verification and validation phases is higher when the simulation model is constructed. The work flow and technical drawing of the model are given in ***Figure 1*** and ***Figure 2***. In ***Figure 1***, the task numbers and operator numbers are shown with the "T" and "O" initials, respectively.

In order to determine the statistical distribution of each operation, a time study was carried out. 30 measurements were taken for each operation. Among these measurements, daily activities such as yarn change and yarn breakage were also included. A total of 18 different operation values were collected for the simulation model. Statistical distributions were then

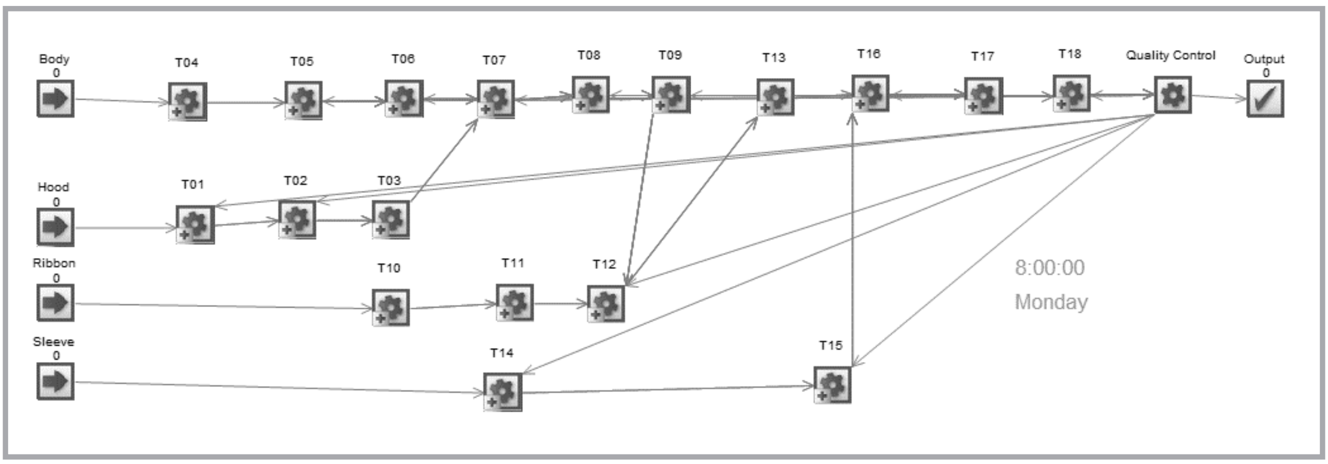

Figure 3. SIMUL8 model of hoodie production.

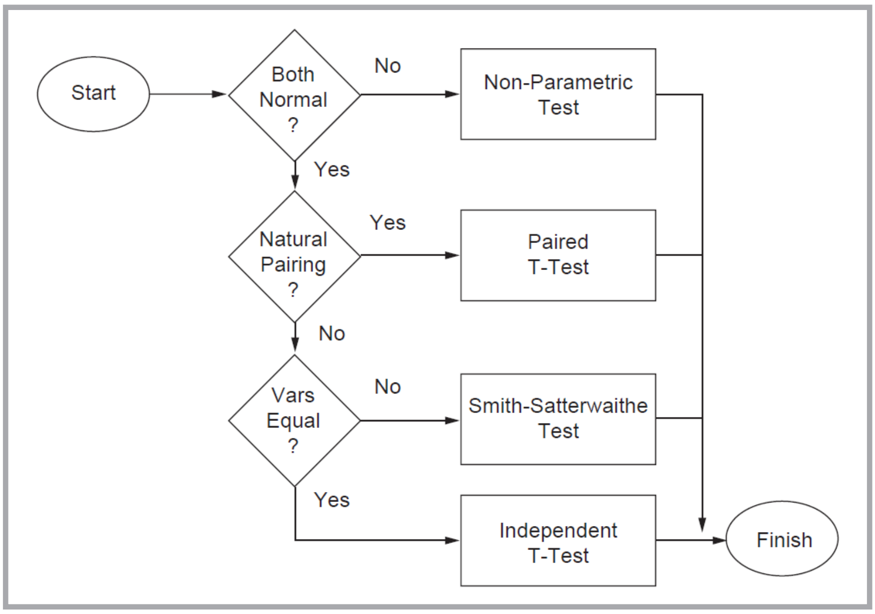

Figure 4. *Validation process [25].*

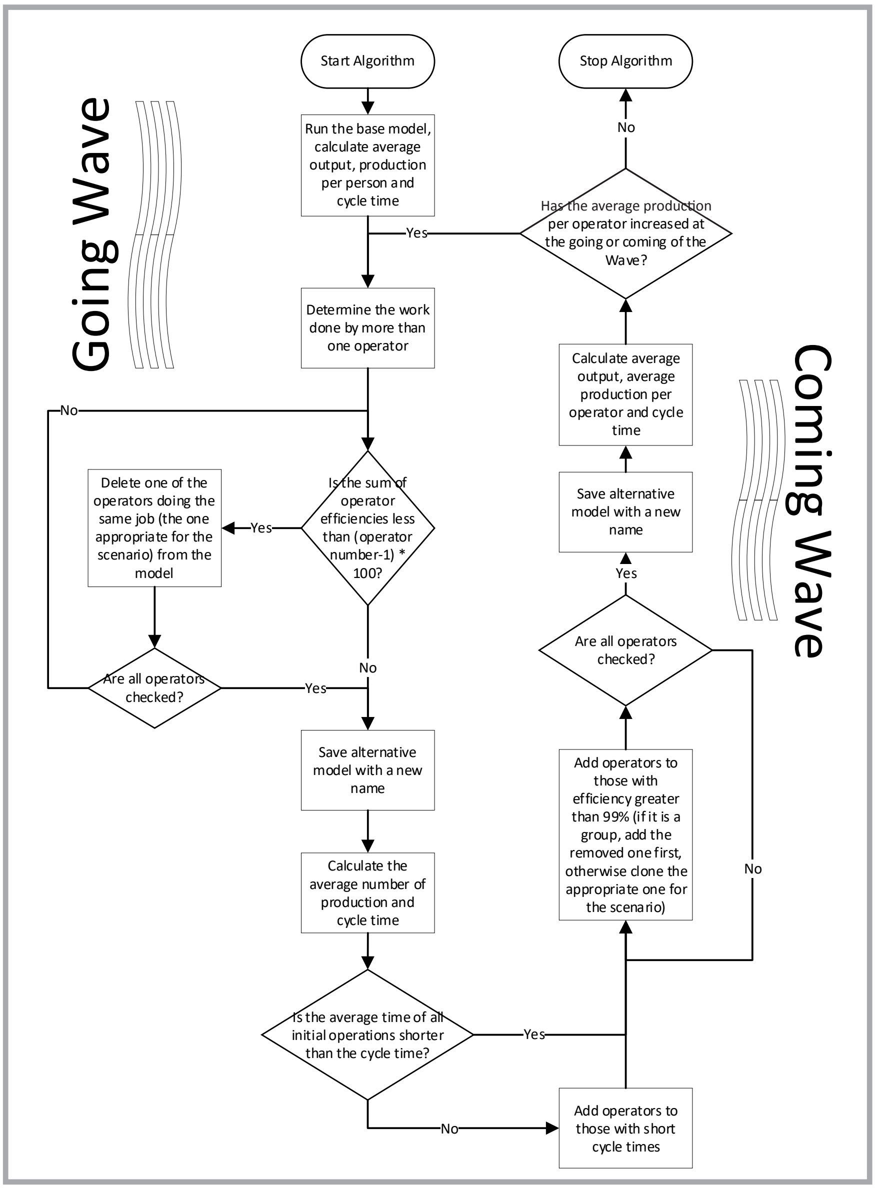

Figure 5. *Waves algorithm.*

obtained by evaluating all these values with the Stat-Fit module of SIMUL8 software. The Stat-Fit module automatically calculates the most appropriate distribution type for the current values.

All the applications of the study were realised in SIMUL8 software, which is a computer package for discrete event simulation from the SIMUL8 Corporation. Its intuitive graphic interface enables the user to create a visual model of the system being investigated by drawing simulation objects directly on the screen. There are four main building blocks (start point, queue, activity, end point) and also two important elements (work items -also known as entities-, resources) [24].

A simulation model of the production line was developed under the following assumptions:

- The queuing discipline, First-In-First-Out (FIFO) is employed in all queues.
- Setup times are ignored.
- The assembly line is never starved.
- All operation times for sewing operations include ‘insignificant breakdowns’, like thread breakage.
- Based on analysis of past data, the defective rates of all operations are included in the simulation model (***Figure 3***).

The verification process of the main model is done by examining the model output for reasonableness under a variety of settings of the input parameters and verifying that what is seen in the animation imitates the actual system. Validation of the main model is performed using the different types of hypothesis tests in ***Figure 4***.

Algorithm developed

The main purpose of the algorithm prepared for the study is to create alternative models by the program user to increase the efficiency of the current production system. The basic criterion of system efficiency is the average hourly production per operator. Each model is run 30 times, therefore the average hourly output is given by the SIMUL8 program. Depending on the number of operators used in each alternative model, the average hourly production per operator is calculated with the help of ***Equation (1)*** below.

$$\text{Average hourly production per operator } = \\ = \frac{\textit{Average hourly production (30 model runs)}}{\textit{number of operators in model}} \qquad (1)$$

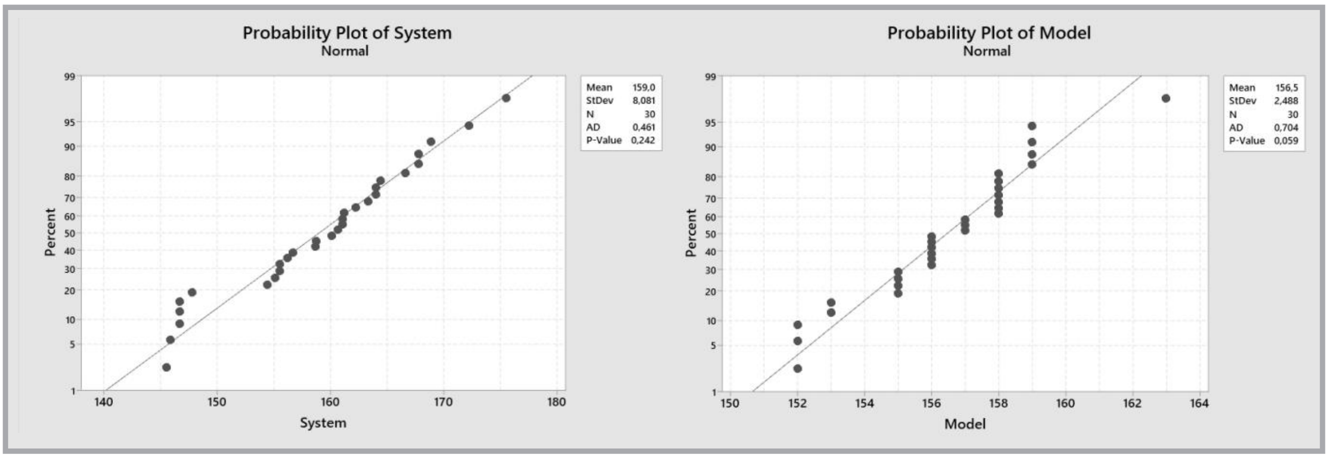

Figure 6. *Normality test results for system and base model.*

Another important point in the application of the model is the cycle time. Each alternative model has a unique cycle time depending on the number it produces ***Equation (2)***.

$$Cycle\ time = \frac{Production\ time\ (3600\ seconds)}{Total\ number\ of\ production} \quad (2)$$

The importance of the cycle time for the algorithm is as follows: Since all the parts to be produced in the waves algorithm are fed excessively by the start point operations of the model, the start point operators are constantly working with 100% efficiency. Whether the operators in question really create a bottleneck is determined by comparing the average operation time with the cycle time.

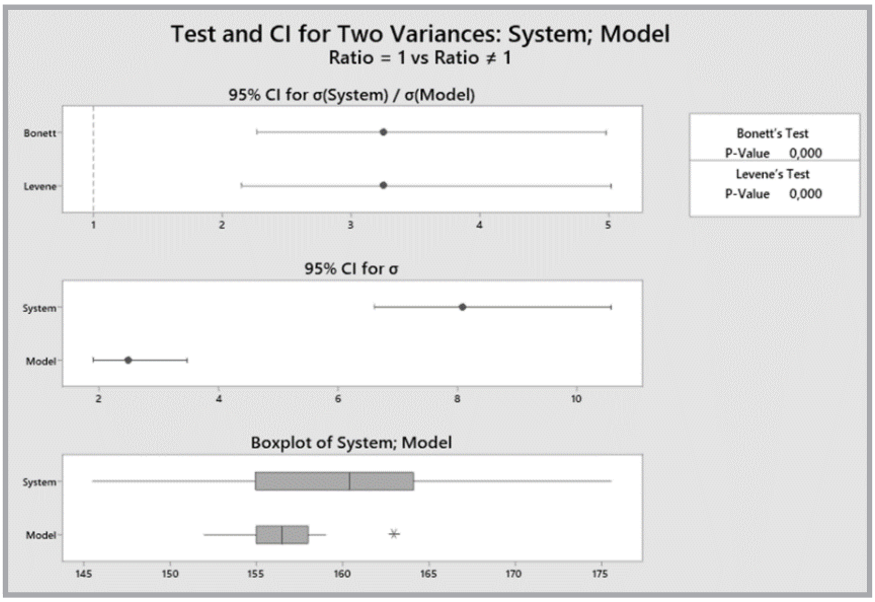

Figure 7. *Variance test results for system and base model.*

The waves algorithm is called as such as it creates alternative models and recalls the movement of waves. After the base model is run for the first time, the efficiency values of all operators are recorded. While it is aimed to remove an operator from the operation group which performs the same operations in the going wave in a way that will not create a bottleneck, the goal is to add an operator to the operations that work with a performance above 99% in the coming waves (except the start point operations of the model). After both going and coming waves, the model is saved with a new alternative name. If there is no change in the average hourly production per operator as a result of the movement of the waves, the algorithm is stopped, and the alternative that gives the best result is selected.

Two scenarios were run for adding and removing operators from the appropriate operations. The optimistic scenario had been named "good waves". Accordingly, to add a new operator to the model, the distribution of the fastest operator was used from the operation group in which the operator was located, while a slow operator was selected when removing the operator. In the pessimistic scenario "bad waves", on the other hand, the opposite of the process mentioned was performed. However, for both scenarios, if a previously removed operator was added with the coming wave, the relevant operator was added to the model with its own distribution. The waves algorithm is given in ***Figure 5***.

Results

First, the durations of all operations were calculated with the time study performed in this research. In ***Table 1***, time values for the "T01- Hood Topstitch" operation are given as an example. Then, by using Statfit software, different distributions of different operators were calculated for the same operations, since different operators performed differently (***Table 2***).

Validation of the base model is performed using the different types of hypothesis tests in ***Figure 4***. First, both base model and production line outputs

Table 1. *Time values for "Hood Topstitch" operation.*

Hood topstitch values, second					
19	17	15	17	14	14
14	15	14	15	15	17
14	14	14	15	14	14
14	15	14	15	15	17
14	14	14	15	17	19

are tested for normality using 'Minitab 17' software in order to compare the hourly production rate. If the "p-value" of these tests is less than the chosen α-level, the null hypothesis can be rejected and we can conclude that the population is nonnormal. As is seen in ***Figure 6***, for both base model ($p_{model} = 0.059$) and system ($p_{system} = 0.242$), the p-value is greater than the α-level (0.05). Thus, all data did not deviate significantly from the normal. After this step, Levene's and Bonett's tests were performed for comparing model and system variances, and it was determined that the variances were different (***Figure 7***). And finally, a t-test was performed and the following conclusion reached; on average the hourly production rate of system (M = 159.05, SE = 1.5) was more than base model (M = 156.47, SE = 2.49). This, the difference was not significant $t(34) = 1.67$, $p = 0.104 > 0.05$. Base model validity was provided.

Once the simulation model of the actual system had been properly validated, what-if scenarios were investigated considering the waves algorithm. Operator efficiencies of the waves algorithm created for this study are given in ***Table 3***. Models G3*, B3*, B5* and B6* were created in accordance with the algorithm steps, even though there was no change in the operator assignment. Since O01, O06, O20 and O25 were initial operators, they continuously worked with 100% efficiency. However, since the cycle times of alternative models were greater than the operation time of the start point operators, a new operator had not been assigned to the relevant operations.

In ***Table 4***, the best alternative models were selected by considering the average hourly production per operator. As a result of the application of good and bad waves algorithms, alternatives G2 and B4 give the best output. The algorithm stopped at the point where the mean production rate per operator did not increase.

Conclusions

The use of simulation modeling and analysis techniques enabled the examination of the hoodie production line of an apparel factory. This process consisted of data collection, data fitting, model building, verification, validation, experimental design, and statistical analysis. Because simulation is the only effective analytic technique that can be used to examine the operation of a production system without disruption or compromising efficiency requirements, it can be used in any production optimisation study. However, it is not clear how practitioners will make the current system more efficient during the use of simulation. In this study, a waves algorithm

Table 2. *Statistical distribution of operations.*

Operation	Task	Operator	Distributions
Hood topstitch	T01	O01	Binomial, 19., 79.6
Hood overlock	T02	O02	A discrete probability profile distribution from 20. to 24. with equal probabilities
Hood overlock	T02	O03	Binomial, 32., 85.1
Hood strap attachment	T03	O04	A discrete probability profile distribution from 28. to 31. with equal probabilities
Hood strap attachment	T03	O05	A combination distribution with a fixed offset of 13.1, then add Log Normal, 3.72, 2.76
Pocket binding	T04	O06	A discrete probability profile distribution with 12 (35%) and 10 (65%)
Pocket stitch	T05	O07	A discrete probability profile distribution with 53 (40%), 54 (40%) and 57 (20%)
Pocket stitch	T05	O08	A combination distribution with a fixed offset of 57.3, then add Pearson5, 1.81, 2.85
Pocket stitch	T05	O09	A discrete probability profile distribution with 60 (37%), 65 (27%), 66 (%30) and 77 (6%)
Pocket stitch	T05	O10	Binomial, 62., 90.6
Shoulder stitch	T06	O11	A combination distribution with a fixed offset of 19.9, then add Pearson5, 2.8, 6.15
Shoulder stitch	T06	O12	A combination distribution with a fixed offset of 4.81, then add Log Normal, 15., 1.7
Hood attachment	T07	O13	Binomial, 17., 88.
Hood attachment	T07	O14	A combination distribution with a fixed offset of -76.3, then add Gamma, 2.72e+003, 3.44e-002
Sleeve attachment	T08	O15	Binomial, 31., 74.2
Sleeve attachment	T08	O16	Binomial, 31., 95.4
Side stitch	T09	O17	A discrete probability profile distribution from 38. to 41. with equal probabilities
Side stitch	T09	O18	Binomial, 44., 84.9
Side stitch	T09	O19	A discrete probability profile distribution with 40 (7%), 43 (33%), 46 (%23) and 47 (37%)
Hemline stitch	T10	O20	A discrete probability profile distribution with 14 (80%), 15 (13%), and 18 (7%)
Hem overlock	T11	O21	Binomial, 20., 97.2
Hem rib stitch	T12	O22	A discrete probability profile distribution from 24. to 25. with equal probabilities
Hem rib stitch	T12	O23	A combination distribution with a fixed offset of -721, then add Log Normal, 760, 4.03
Front body attachment	T13	O24	A discrete probability profile distribution with 12 (40%), 13 (37%) and 14 (23%)
Sleeve rib preparation	T14	O25	A discrete probability profile distribution from 14. to 16. with equal probabilities
Sleeve rip stitch	T15	O26	A combination distribution with a fixed offset of 34.5, then add Pearson5, 1.05, 1.44
Sleeve rip stitch	T15	O27	A combination distribution with a fixed offset of -64.7. then add Gamma, 854, 0.139
Sleeve rip stitch	T15	O28	A discrete probability profile distribution with 38 (13%), 39 (27%), 43 (%20), 44 (%17) and 45 (23%)
Sleeve rib attachment	T16	O29	Binomial, 45., 91.3
Sleeve rib attachment	T16	O30	Binomial, 45., 83.2
Sleeve rib attachment	T16	O31	A combination distribution with a fixed offset of 17.8, then add Pearson5, 206, 4.41e+003
Label stitch	T17	O32	create a combination distribution with a fixed offset of 10.3, then add Pearson5, 6.7, 20.3
Safety stitch	T18	O33	Binomial, 35., 95.4
Safety stitch	T18	O34	Binomial, 31., 94.4
Safety stitch	T18	O35	Binomial, 50., 85.5

was developed to close this gap. Basically, it was possible to produce alternative models with this algorithm, which operates two different scenarios (good waves & bad waves) in the assignment to and removal of new operators from the existing system. When the results obtained on a real hoodie production line are examined, it is determined that both scenarios provide higher efficiency. According to the results, it was determined that the average hourly production per operator had increased by approximately 15-17%.

It should be noted that the waves algorithm proposed can be used in all types of garment production. However, implementing this approach in another garment type production would require customising existing simulation models in order to reflect the changes in respective

Table 3. *Operator efficiency results for good and bad waves.*

Task	Operator	Base model	Good waves				Bad waves					
			G1	G2	G3*	G4	B1	B2	B3*	B4	B5*	B6*
T01	O01*	100	100	100	100	100	100	100	100	100	100	100
T02	O02	76.11	76.11	76.1	76.1	76.09	76.1	76.1	76.1	76.07	76.07	76.07
T02	O03	88.59	88.59	88.61	88.61	88.63	88.62	88.62	88.62	88.64	88.64	88.64
T03	O04	88.14	88.14	88.1	88.1	88.12	88.06	88.06	88.06	88.13	88.13	88.13
T03	O05	66.71	66.71	66.77	66.77	66.72	66.78	66.78	66.78	66.71	66.71	66.71
T04	O06*	100	100	100	100	100	100	100	100	100	100	100
T05	O07	100	100	99.85	99.85	83.68	100	100	100	85.05	85.05	85.05
T05	O08	100	100	99.93	99.93	88.75	100	100	100	90.3	90.3	90.3
T05	O09	100	100	99.93	99.93	90.4	100	100	100	91.89	91.89	91.89
T05	O10	100	100	99.9	99.9	85.67	100	100	100	87.28	87.28	87.28
T05	O36	X	X	99.88	99.88	83.02	X	100	100	91.9	91.9	91.9
T05	O39	X	X	X	X	83.32	X	X	X	92.02	92.02	92.02
T06	O11	80.58	80.58	94.85	94.85	96.18	80.58	92.51	92.51	96.35	96.35	96.35
T06	O12	75.34	75.33	94.38	94.38	94.47	75.33	91.82	91.82	94.49	94.49	94.49
T07	O13	58.2	58.2	58.13	58.13	58.13	58.21	58.09	58.09	58.12	58.12	58.12
T07	O14	62.32	62.32	62.26	62.26	62.33	62.31	62.3	62.3	62.16	62.16	62.16
T08	O15	84.58	84.6	84.83	84.83	84.89	84.6	84.76	84.76	84.89	84.89	84.89
T08	O16	91.55	91.55	91.35	91.35	91.43	91.58	91.43	91.43	91.36	91.36	91.36
T09	O17	88.94	89	89.11	89.11	89.04	88.9	89.03	89.03	89.01	89.01	89.01
T09	O18	87.89	87.86	87.67	87.67	87.74	88	87.83	87.83	88.03	88.03	88.03
T09	O19	92.36	92.41	92.62	92.62	92.64	92.23	92.26	92.26	92.47	92.47	92.47
T10	O20*	100	100	100	100	100	100	100	100	100	100	100
T11	O21	100	100	73.21	73.21	73.21	100	73.12	73.12	73.12	73.12	73.12
T11	O37	X	X	72.94	72.94	72.94	X	73.11	73.11	73.11	73.11	73.11
T12	O22	72.19	72.19	99	99	62.77	72.19	98.95	98.95	99.03	99.03	99.03
T12	O23	93.27	93.27	99.63	99.63	81.33	93.26	99.51	99.51	99.57	99.57	99.57
T12	O40	X	X	X	X	62.75	X	X	X	X	X	X
T13	O24	69.78	69.78	85.67	85.67	85.95	69.76	85.58	85.58	85.62	85.62	85.62
T14	O25*	100	100	100	100	100	100	100	100	100	100	100
T15	O26	99.96	99.96	78.87	78.87	78.91	99.96	79.9	79.9	79.89	79.89	79.89
T15	O27	99.96	99.96	87.85	87.85	87.85	99.96	89.44	89.44	89.47	89.47	89.47
T15	O28	99.97	99.97	81.47	81.47	81.45	99.97	82.17	82.17	82.16	82.16	82.16
T15	O38	X	X	78.81	78.81	78.76	X	89.37	89.37	89.45	89.45	89.45
T16	O29	75.25	75.25	92.04	92.04	91.97	75.14	92.2	92.2	92.29	92.29	92.29
T16	O30	69.96	69.97	86.16	86.16	86.5	70	86.11	86.11	86.32	86.32	86.32
T16	O31	72.57	72.6	89.11	89.11	89.26	72.55	89.21	89.21	89.39	89.39	89.39
T17	O32	75.73	75.73	93.17	93.17	93.6	75.77	93.34	93.34	93.34	93.34	93.34
T18	O33	64.32	87.59	100	100	79.95	97.71	100	100	79.82	79.82	79.82
T18	O34	59.45	80.36	100	100	74.02	X	X	X	74.06	74.06	74.06
T18	O35	75.03	X	X	X	88.92	98.98	100	100	88.24	88.24	88.24

Table 4. *Results of good and bad waves.*

	Base model	Good waves				Bad waves					
		G1	G2	G3	G4	B1	B2	B3	B4	B5	B6
Average hourly production	156.2	156.24	193.52	193.52	204	157.64	161.04	161.04	201.36	201.36	201.36
Average hourly production per operator	4.46	4.59	5.23	5.23	5,1	4.63	4.35	4.35	5.16	5.16	5.16
Cycle time, s	23.04	23.04	18.6	18.6	17.64	22.8	22.3	22.3	17.8	17.8	17.8

workflows. However, it is estimated that the more complex the model to which the algorithm will be applied, the better the result will be. In line balancing processes of apparel production, SAM values of operations are generally taken into account. In garment types with more operations, such as jackets, line balancing is more difficult to achieve in dependence on the number of operations. However, due to its stochastic nature, the simulation technique analyses the bottlenecks between operations more accurately than SAM [3-5].

For future studies, it is proposed that more detailed scenarios (such as considering the classification of operators' skills, cost analysis etc.) can be used in the simulation model. Also, an algorithm should be developed so that resource assignments are made according to machine types.

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References

1. Bevilacqua M, Ciarapica F, Crosta A, Mazzuto G, Paciarotti C. Designing an Efficient Production System: A Case Study of a Clothing Company. *International Journal of Engineering Business Management* 2013; 5, Special Issue on Innovations in Fashion Industry: 1-8.
2. Law AM. *Simulation Modeling and Analysis*, Fifth ed., New York: McGraw -Hill Education, 2015.
3. Bongomin O, Mwasiagi JI, Nganyi ve EO. Nibikora I. A complex garment assembly line balancing using simulation -based optimization. *Engineering Reports* 2020; cilt 2, 11: 1-23.
4. Bongomin O, Mwasiagi JI, Nganyi ve EO, Nibikora I. Simulation metamodeling approach to complex design of garment assembly lines. *Polos One* 2020; cilt 15, 9: 1-22.
5. Sime H, Jana ve P, Panghal D. Feasibility of Using Simulation Technique for Line Balancing In Apparel Industry. *Procedia Manufacturing* 2019; cilt 30: 300-307.
6. Negahban A, Smith JS. Simulation for manufacturing system design and operation: Literature review and analysis. *Journal of Manufacturing Systems* 2014; 33, 2: 241-261.
7. Altıok T, Melamed B. *Simulation Modeling and Analysis with Arena*, Burlington: Academic Press, 2007.
8. Ünal C. Production Simulation Applications in Textile and Apparel Industry. *International Congress of Innovative Textiles ICONTEX*, Tekirdağ, 2019.
9. Sommerfeld JT, Tincher WC, Rosser PS. Discrete-event Simulation Applied to Apparel Manufacturing. *Final Report for Defense Logistic Agency*, Atlanta, Georgia, 1990.
10. Wang J, Schroer BJ, Ziemke MC. Understanding Modular Manufacturing in the Apparel Industry Using Simulation. *Winter Simulation Conference Proceedings*, Phoenix, 1991.
11. Kalaoğlu F, Sarıçam C. Analysis of Modular Manufacturing system in Clothing Industry by Using Simulation. *FIBRES & TEXTILES in Eastern Europe* 2007; 15, 3(62): 93-96.
12. Nassirnia P, Tap MM. Strategies to Achieve Labor Flexibility in the Garment Industry. *International Journal of Computer Science Issues* 2010; 7, 6: 41-48.
13. Zülch G, Koruca Hİ, Börkircher M. Simulation-supported change process for product customization – A case study in a garment company. *Computers in Industry* 2011; 62, 6: 568-577.
14. Atan SA, Ramlan R, Foong TG. Cycle Time Reduction of a Garment Manufacturing Company Using Simulation Technique. *Proceedings International Conference of Technology Management, Business and Entrepreneurship* 2012 (ICTMBE2012), Melaka, Malaysia, 2012.
15. Pan G. A Quantitative Analysis of Cellular Manufacturing in Apparel Industry by Using Simulation. *Journal of Industrial Engineering and Management* 2014; 7, 5: 1385-1396.
16. Güner MG, Ünal C. Line Balancing in The Apparel Industry Using Simulation Techniques. *FIBRES and TEXTILES in Eastern Europe* 2008; 16, 2(67): 75-78.
17. Kurşun S, Kalaoğlu F. Simulation of Production Line Balancing in Apparel Manufacturing. *FIBRES and TEXTILES in Eastern Europe* 2009; 17, 4(75): 68-71.
18. Ünal C, Tunalı S, Güner M G. Evaluation of Alternative Line Configurations in Apparel Industry using Simulation. *Textile Research Journal* 2009; 79, 10: 908-916.
19. Kurşun S, Kalaoğlu F. Dikim Bandında Simulasyonla Bant Dengeleme. *Tekstil ve Konfeksiyon* 2010; 20, 3: 257-261.
20. Kurşun Bahadır S. Assembly Line Balancing in Garment Production by Simulation. *Assembly Line Theory and Practice*, IntechOpen, 2011; pp. 67-82.
21. Eryürük SH. Clothing Assembly Line Design Using Simulation and Heuristic Line Balancing Techniques. *Tekstil ve Konfeksiyon* 2012; 23, 2: 143-151.
22. Kayar M, Akalin M. Comparing Heuristic and Simulation Methods Applied to the Apparel Assembly Line Balancing Problem. *FIBRES & TEXTILES in Eastern Europe* 2016; 24, 2(116): 131-137. DOI: 10.5604/12303666.1191438.
23. Ünal C, Demirbaş ZA. Creating an Alternative Production Line by Using a Simulation Technique in Duvet Cover Production. *FIBRES & TEXTILES in Eastern Europe* 2018; 26, 4(130): 8-12. DOI: 10.5604/01.3001.0012.1306.
24. Shalliker J. An Introduction to Simulation in the Service Industry using, 31 May 2019. [Online]. Available: https://www.simul8.com. [Accessed 9 November 2020].
25. Chung CA. *Simulation modeling handbook: a practical approach*, Lonon: CRC Press, 2004.

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