Journal of Industrial and Systems Engineering
Vol. 12, No. 1, pp. 215-243
Winter (January) 2019

Reduction of production disturbances of a shoe making industry through discrete event simulation approach

Wogiye Wube[1*]

[1]*Mechanical and Industrial Engineering Faculty, Bahir Dar institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia*

Wogismart@gmail.com

Abstract

This study presents reduction of production disturbances of a shoe making industry through discrete event simulation approach. The study is conducted at Peacock Shoe factory found in Addis Ababa, Ethiopia. This factory faces line balancing problem that becomes production disturbance for its assembly lines. Detail time study is carried out for selected shoe model using stop watch. Assembly process chart is used to understand chronological sequence of assembly operations. Arena input analyzer is used to fit the input data, and K-S test is conducted to validate the goodness of fit. Hence, simulation model for existing stitching, and lasting and finishing assembly lines are developed after taking basic simulation assumptions. The model is verified by checking coding error of SIMAN language through try and error, and validated by comparing its output with real system. Production disturbance (bottleneck) assembly line and operations are identified based on parameters such as average waiting time, WIP, production rate, capacity utilization and total flow time. To alleviate line balancing problem, five scenarios are proposed, and the detail what if analysis is done using Arena simulation software. Scenario five is selected to reduce the level of production disturbances of stitching assembly line. This scenario reduces average waiting time and WIP from 2118.28 to 417.05 sec. and 252 to 85 respectively. Scenario one is selected to reduce the level of production disturbances of existing lasting and finishing assembly line. This scenario reduces average waiting time and WIP from 2026.91 to 641.26 sec. and 169 to 65 respectively.

Keywords: Production disturbance, modeling, line balancing, DES

1-Introduction

In the era of globalization, all manufacturing companies are aspiring to have more reliable and robust manufacturing systems to increase the productivity and overall efficiency of their production lines. However, the issue of disturbances (bottlenecks) in production line is a common industrial problem (Smet et al. 1997). According to Drucker (1990), Wu (1994) and Kuivanen (1996), only 50 to 60% of total production time is used for manufacturing while the rest gets wasted over variety of disturbances. Production disturbance affects product quality, work safety, and satisfaction of workers in addition to affecting overall efficiency of assembly industries. Thus, an intelligent management of disturbances in a manufacturing system is a way to increase efficiency.

*Corresponding author

ISSN: 1735-8272,

Footwear industry is one of manufacturing industry that is highly affected by presence of production disturbance (bottleneck) in its assembly lines (Eryilmaz et al. 2012). The study is conducted at Peacock Shoe factory found in Addis Ababa, Ethiopia. It is one of well known Footwear industries found in Ethiopia. It produces shoe with variety of model for both men and females. The production section of the factory consists of two main assembly lines named as stitching, and lasting and finishing. However, there is line balancing problem in these assembly lines which negatively affect labor productivity and efficiency of the production lines. Available resources (labor and machine) are not assigned in optimal way in the assembly lines, and it results to have bottleneck operations and assembly line that are disturbance for the overall productivity of the factory. Presence of bottleneck/ disturbance in the assembly line negatively affects the productivity of the factory. This problem is addressed by reducing the level of production disturbances, bottleneck operations and assembly lines, through the application of discrete event simulation modeling.

Ethiopia, one of the fastest economic growing countries in the horn of Africa, is striving to change its policy from agriculture lead economy to manufacture lead economy. Growth and Transformation Plan II (GTP II) was developed to realize this policy, and it has been executing since 2015. This plan focuses on opening and enlarging of labor intensive manufacturing industries. Footwear industry is one of labor intensive manufacturing industries found in Ethiopia. This paper focuses on Ethiopian footwear industries in general and Peacock Shoe factory in particular. This factory faces difficulty to identify assembly operations and assembly lines that are disturbance, bottleneck, manually due to nature and complexity of assembly operations. Thus, the paper plays vital role to address this challenge by developing simulation model for proposed scenario. Developed simulation model for proposed scenario has significant contribution in detecting bottleneck assembly operations and lines with short time, low resource cost, high reliability in detection, and without interruption of production process in the factory. Moreover, it contribute a lot in knowing the impact of various scenarios on the interaction of operators with assembly processes and machines over time without incurring any cost and interruption of production process of the factory. It also plays significant contribution in getting hard currency, one of the key problems of the country in recent period, by improving the productivity of the company through the application of proposed method. About $485,212.07 additional profit will be gained annually if the factory changes the study to reality.

2-Literature review

Reduction of production disturbances, bottlenecks, in assembly lines of the shoe making section is a means to increase efficiency of the factory. Bottleneck assembly line and operations should be identified properly to know which line and operations strongly affect the efficiency of the assembly line. However, it is difficult to identify bottleneck line and operations easily without detail investigation. Several authors (Quintero et al., 2011; Garza-Reyes et al., 2010; Ingemansson and Bolmsjo, 2004; Shang et al., 2004) argued that no specific production disturbance (bottleneck) can be singled out without subsequent investigation. Many scholars (Padhi and Mohapatra, 2010; Garza-Reyes et al., 2010; Hassan and Gruber , 2008; Ingemansson et al., 2005; Law and Kelton , 2000) have used a more systematic process simulation approach to identify and eliminate disturbances (bottlenecks) in a production lines to increase the overall productivity.

It is known that most operations in shoe making process are labor intensive by its nature. Thus, identification of bottleneck line and operations that are production disturbance for entire assembly process manually becomes challenging since many operations and workstations are involved in shoe making process. Hence, the study uses discrete event simulation technique to identify bottleneck lines and operations correctly by predicting, comparing, and optimizing the performance of processes without the cost and risk of disrupting existing operations or building a sequence of new processes. Literatures regarding with applications of discrete event simulation for the reduction of production disturbances through assembly line balancing are reviewed.

Many scholars (Mohamad et al., 2012; Temesgen and Nahom, 2014; James et al., 2014; Padih et al., 2013; Eryilmaz et al., 2012) have used discrete event simulation to identify production disturbances, bottleneck operations and assembly lines, investigate the impact of production disturbance (bottleneck) on production line efficiency, and to conduct what if analysis for proposed alternative scenarios. Moreover, Aggarwal et al. (2011), Daniel et al. (2010) and Corte et al. (2010) have used discrete event simulation approach to improve line balancing problem by eliminating bottleneck operations and assembly lines. The result of these studies provides production manager with a simulation based optimization tool that helps to gain assembly line information without disturbing the actual system, and indicate the key to improve system performance in particular and increased productivity of the company in general.

Few papers that deal about reduction of production disturbances in footwear industry are found. However, these papers have used limited number of parameters, average waiting time, output rate and Work in process inventory (WIP), to reduce the level of production disturbances of such industries. Thus, this study uses balance line efficiency, production efficiency and optimal number of resources as a parameter to proceed the study in addition to parameters used by previous papers. Moreover, the study improves the layout of the case company after conducting cost benefit analysis unlike to previous papers.

3-Methodology

The study is conducted at Peacock Shoe factory found in Addis Ababa, Ethiopia. Frequency of order, complexity of tasks to be done, and processing time are used as a parameter to select one model among the available one. Based on these parameters, safety shoe of model 2263 is selected since it has high demand (a lot of frequency of order), easily understandable tasks and longest processing time as compared to the remaining shoe models.

3-1-Data collection

Direct observation is used to observe the flow of operations and how they are done in workstations. It also used to understand the sequence and name of operations required assembling a finished shoe, and how input materials are moved from one work station to another. Furthermore, it used to record the processing time of all operations (tasks) that are done in three assembly lines of the factory. Stop watch is used to record processing time of all operations needed to assemble a shoe. Literatures related to this study are reviewed to have understanding about methodologies proposed by different scholars. Furthermore, factory’s monthly production report for stitching and lasting assembly lines is used to know the output of the real (existing production line of the factory) system.

3-2- Data analysis

The study used assembly process chart to depict chronological sequence of assembly operations done to obtain finished safety shoe of model 2263. Starting from stitching to finishing assembly lines, a total of 46 operations are involved in assembly operation to obtain finished shoe of this model. About 15 parts named as vamp, vamp toung, lastny, quarter, shera, lastny lining, quarter lining, sock pad (sponge), stiffner ,vamp sponge, lastny sponge, insole, outer sole, quarter reinforcement, and foot sole are assembled together to get finished shoe of this model. These parts are categorized in to three main components of the shoe named as vamp, quarter and lastny.

Detail time study is carried out to register processing time of all operations required to get finished safety shoe of selected model. However, time required for completing an operation affected by the nature of task, the operator, the properties of lather and sub materials, working environment, quality level of the product, the hour of the day, psychology of the operator etc. To absorb these factors, ten observations are taken for each operation using stop watch. Personal, fatigue and other allowances are considered during time study period. Variation of processing time through ten observations is fitted with one of probability distributions using Arena 14 input analyzer. Kolmogorov Smirnov test is used to test the goodness of fit. According to Law & Kelton (2000) and Brunk (1960), it is advisable to take the level of significance as 0.05 (95% confidence interval) for the Kolmogorov Smirnov test.

Six assumptions are made to develop simulation model for assembly lines of the factory. Replication Parameters is adjusted before the simulation model start to run. It refers to values that provide information

on the replication within the simulation software, found under Run Setup. Replication values include the number of replications, replication length, warm up period, replication start day, as well as time units.
Number of Replications: the study uses the formula developed by Toledo et al. (2003) to determine the number of replication. Here is the formula:

$$N = [(s(m)t_{m-1,1-\alpha/2})/(\bar{X}(m)\varepsilon)]^2 \quad (1)$$

Where,

N	:Number of replication,
S(m)	:The estimate of the real standard deviation *s* from *m* simulation runs,
$\bar{X}$	: The estimate of the real mean μ from m simulation runs (samples),
α	: The level of significance,
ε	: Allowable percentage error of the estimate, and
$t_{m-1,1-\alpha/2}$	: Critical value of the two-tailed t-distribution at a level of significance α given m-1 degrees of freedom.

The allowable percentage error of the estimate ε and sample mean μ is determined using the following formula:

$$\varepsilon = |\bar{X}(n) - \mu|/\mu \quad (2)$$

$$\mu = \bar{X}(n) \pm t_{n-1,1-\alpha/2}(s^2(n)/n)^{1/2} \quad (3)$$

Where,

$\bar{X}(n)$	:The estimate of μ from n simulation runs (samples),
$s^2(n)$	: The estimate of standard deviation from *n* simulation runs (samples),
n	: The number of initial simulation run,
$t_{n-1,1-\alpha/2}$	: Critical value of the t-test for *n*-1 degrees of freedom and significance α.

Replication Length: The study uses the duration survey (one and half month) as a replication length to see the result of the model for that specified period of time.

The existing assembly line simulation model is verified by checking coding error of SIMAN language through try and error, and validated by comparing its output with real system.
Measures of Line Balance Efficiency: Efficiency of both assembly lines is measured using equation developed by (Groover, 2000).

$$E_b = (TWC/wTS) \quad (4)$$

Where,

E_b	: balance efficiency, often expressed as a percentage
Ts	: the maximum available service time on the line, and
w	: number of workers

4-Result and discussion

As stated earlier safety shoes of model 2263 is selected to conduct the study. A total of 46 operations are identified in the assembly process of safety shoe. Assembly lines of the factory are shown in the following picture:

Fig. 1. Stitching assembly line of Ramsay shoe factory

Fig. 2. Lasting and finishing assembly line of Ramsay shoe factory

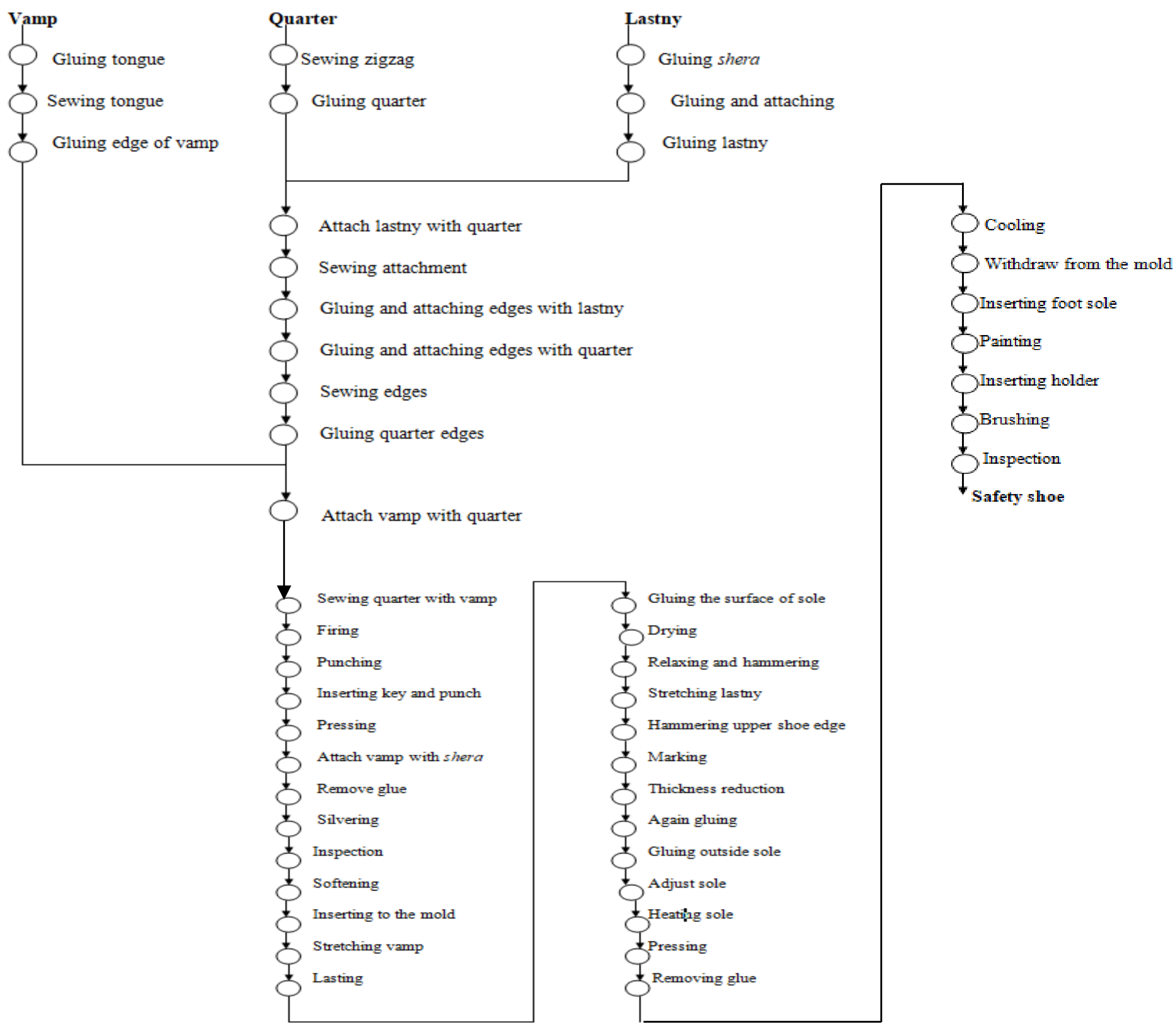


Fig. 3. Assembly process chart of safety shoe model 2263

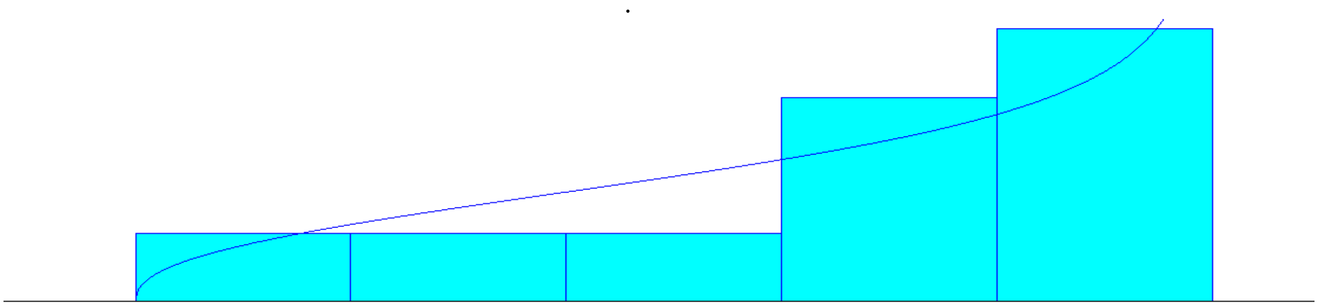
Figure 3 depicts chronological sequence of assembly operation done in stitching and lasting assembly lines. In addition, it shows how the three main components of safety shoe are assembled together to get finished shoe.

4-1-Distribution fit and goodness of fit

It is obvious that the processing time for certain operation in shoe making process varies through elapse of time due to operator's and raw material problems, machine failure and low strength of thread. Thus, identification of a probability distribution that fit the variation of processing time for every operation in all assembly lines of the factory is essential to develop simulation model for the real system. Ten observations are taken for time study. Appropriate type of test used to validate the goodness of distribution fit for ten observations is Kolmogorov Smirnov test.

One example is given below:

Sorting: it is attempted to fit its processing time with Beta, Erlang, Exponential, Gamma, Lognormal, Normal, Triangular, Uniform and Weibull probability distributions, and to select the one that best fit the input data.



```
        Distribution Summary

Distribution:   Beta
Expression:     14.2 + 6.79 * BETA(1.41, 0.772)
Square Error:   0.012931


Kolmogorov-Smirnov Test
  Test Statistic        = 0.16
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 10
Min Data Value          = 14.8
Max Data Value          = 20.5
Sample Mean             = 18.6
```

Fig.4. Density function graph for sorting operation

Figure 4 shows the result of input analyses. Kolmogorov Smirnov test depicts p value for Sorting operation is greater than 0.05. Thus, square error is used to compare the available probability distributions. The result of square error for each probability distribution is shown in the table given below from the best to the worst.

Table 1. Summary of square error for probability distributions

Function	Square error
Beta	0.0129
Uniform	0.08
Triangular	0.0235
Normal	0.075
Erlang	0.123
Weibull	0.0886
Gamma	0.121
Exponential	0.0801
Lognormal	0.149

Table 1 shows the result of square error committed by the above listed probability distributions that fit with the input data. Beta probability distribution function is selected as a best fit to the processing time of sorting operation since it has minimum square error as compared to the remaining probability distributions. The remaining operations are fitted to best probability distribution function using the same fashion as above. Expressions for the remaining operations in three assembly lines are summarized in the table shown below:

Table 1. Arena input analyzer result of distribution function for all operations in three assembly lines

Tasks	Distribution Type	Expression	Square Error
Stitching assembly line			
Sorting	Beta	14.21 + 6.79 *BETA(1.41, 0.772)	0.012931
Gluing tongue	Beta	38 + 3.47 * BETA(0.527, 0.671)	0.00735
Sewing tongue	Triangular	TRIA(23, 26, 33)	0.01052
Sewing zigzag	Lognormal	38 + LOGN(3.48, 4.96)	0.00893
Gluing shera	uniform	UNIF(22, 34)	0.02000
Gluing and attaching	Erlang	21.1 + ERLA(1.51, 2)	0.00471
Gluing and Attaching lastny with quarter	Triangular	TRIA(19, 30.5, 42)	0.0056
Sewing attachment	Normal	NORM(43.4, 3.06)	0.02769
Gluing and attaching edges with lastny	Exponential	16 + EXPO(3.84)	0.02021
Gluing and attaching edges with quarter	Gamma	22 + GAMM(6.34, 1.17)	0.030242
Sewing edges	Beta	79 + 15 * BETA(0.794, 1.01)	0.00496
Gluing quarter edges and attach with vamp	Uniform	UNIF(28, 45)	0.10000
Sewing quarter with vamp	Beta	52 + 31 * BETA(1.29, 0.994)	0.00838
Firing	Gamma	18 + GAMM(11, 1.08)	0.04199
Punching	Beta	12.4 + 3.23 * BETA(0.722, 1.09)	0.01875
Inserting button and punch	Beta	32 + 15 * BETA(0.504, 0.817)	0.02096
Pressing for compactness	Beta	13 + 10 * BETA(0.601, 1.18)	0.04856
Gluing the vamp and attach with *shera*	Weibull	49 + WEIB(6.76, 1.66)	0.00492
Removing glue	Beta	50 + 34 * BETA(0.852, 0.764)	0.01026
Silvering	Beta	12 + 12 * BETA(0.747, 0.892)	0.03304
Inspection	Beta	42 + 14 * BETA(0.89, 1.02)	0.01862
Arresting quarter (hand attach)	Normal	NORM(56.4, 7.91)	0.0280
Lasting assembly line			
Softening	Normal	NORM(24.49, 3.07)	0 .01045
Inserting to the mold	Erlang	1.49 + ERLA (0.406, 2)	0.004636
Stretching vamp	Normal	NORM(18.2, 5.01)	0.004625
Lasting the edge and attach with inner sole	Uniform	UNIF(14, 23)	0.020000
Gluing the surface of sole	Beta	10 + 6.6 * BETA(0.818, 1.28)	0.017070
Drying glue	Uniform	UNIF(13, 36)	0.020000
Relaxing and hammering	Beta	28 + 13 * BETA(0.703, 0.82)	0.111845
Stretching lastny	Beta	30 + 16 * BETA(0.836, 0.988)	0.032613
Hammering the foot edge of upper shoe	Erlang	13 + ERLA(2.36, 3)	0.058163
Marking	Normal	NORM(36.8, 5.15)	0.083364
Thickness reduction	Weibull	23 + WEIB(2.76, 1.11)	0.037782
Again gluing	Beta	24 + 5 * BETA(0.629, 0.745)	0.010652
Gluing outside sole	Beta	15 + 13 * BETA(0.834, 0.868)	0.037673
Adjust sole	Beta	48 + 12 * BETA(0.795, 0.896)	0.007847
Heating sole (softening)	Beta	52 + 14 * BETA(0.524, 0.695)	0.050493
Pressing	Normal	NORM(25.2, 4.89)	0.013242
Removing glue	Uniform	UNIF(27.52, 30.4)	0.000000
Cooling	Triangular	TRIA(55, 95.5, 100)	0.033827
Withdraw from the mold	Weibull	25 + WEIB(4.8, 1.86)	0.006294
Gluing foot sole and inserting to shoe	Beta	30 + 11 * BETA(0.937, 0.617)	0.015648
Painting	Beta	32 + 12 * BETA(0.702, 0.755)	0.055493
Inserting holder	Beta	42 + 11 * BETA(0.708, 0.905)	0.029750
Brushing	Lognormal	28 + LOGN(2.99, 2.69)	0.085649
Inspection	Beta	28 + 12 * BETA(0.291, 0.385)	0.085019
Packing	Gamma	7 + GAMM(6.11, 1.09)	0.009701

4-2-Simulation model development

Arena14 simulation software is used to develop simulation model for the assembly lines. There are conditions that occur in the real system but it is difficult to include them in the simulation model. Thus, difficulty to develop simulation model is avoided by assuming these conditions are not occur in the real system. The following assumptions are made to develop approximate simulation model for the assembly lines. These are:

- 480 minutes working time does not include breaks,
- There is no maintenance process performed during the working period,
- Transportation of WIP from one assembly line to another is performed by supervisors,
- All process times for three assembly lines include insignificant breakdowns ,
- The transfer time is assumed as negligible since it is too small as compared to the processing time of operations.
- Setup time is included in the processing time

By considering these assumptions the simulation models for both factories' assembly lines are developed as shown below:

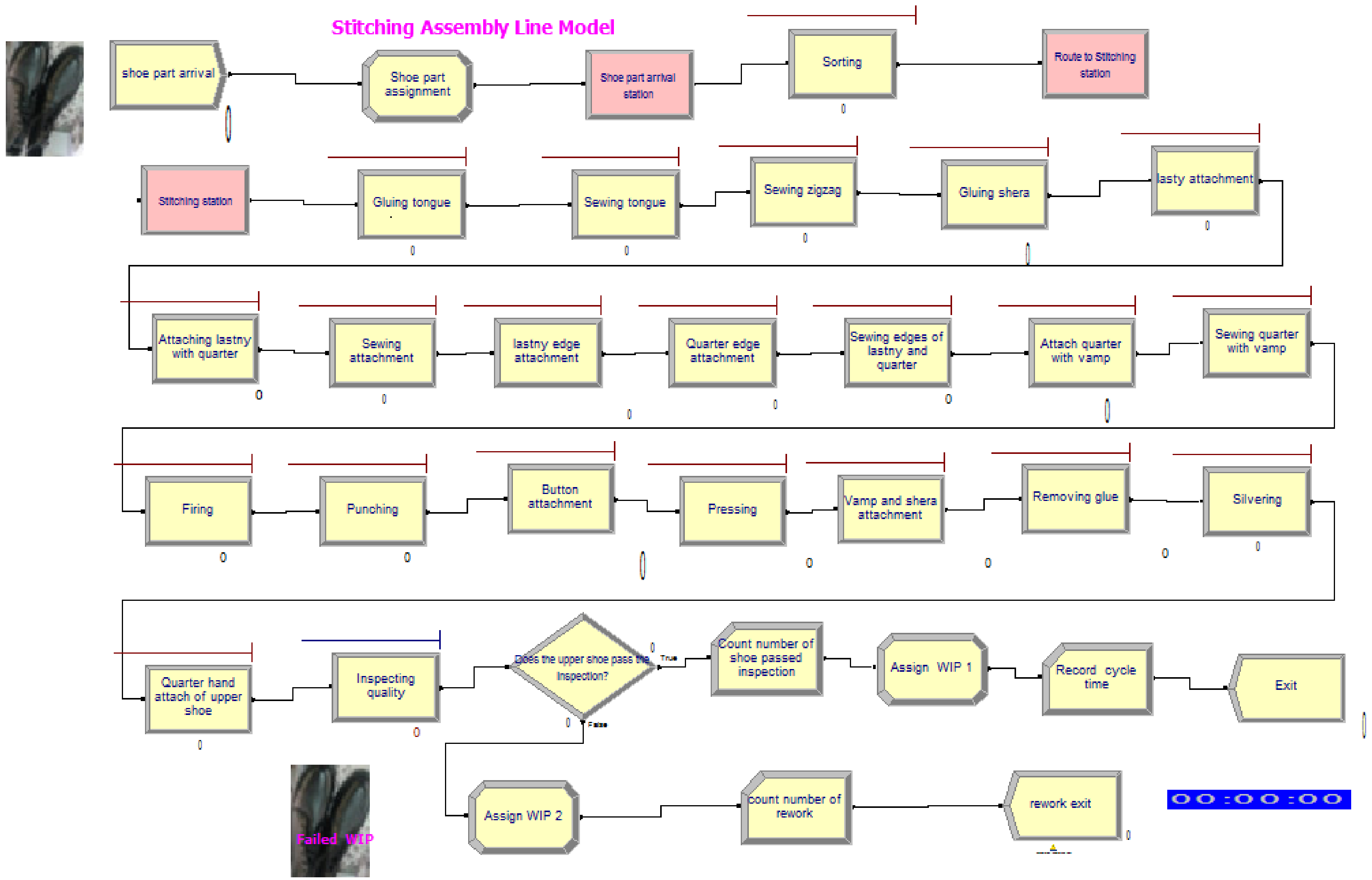


Fig.5. Arena simulation model for existing stitching assembly line

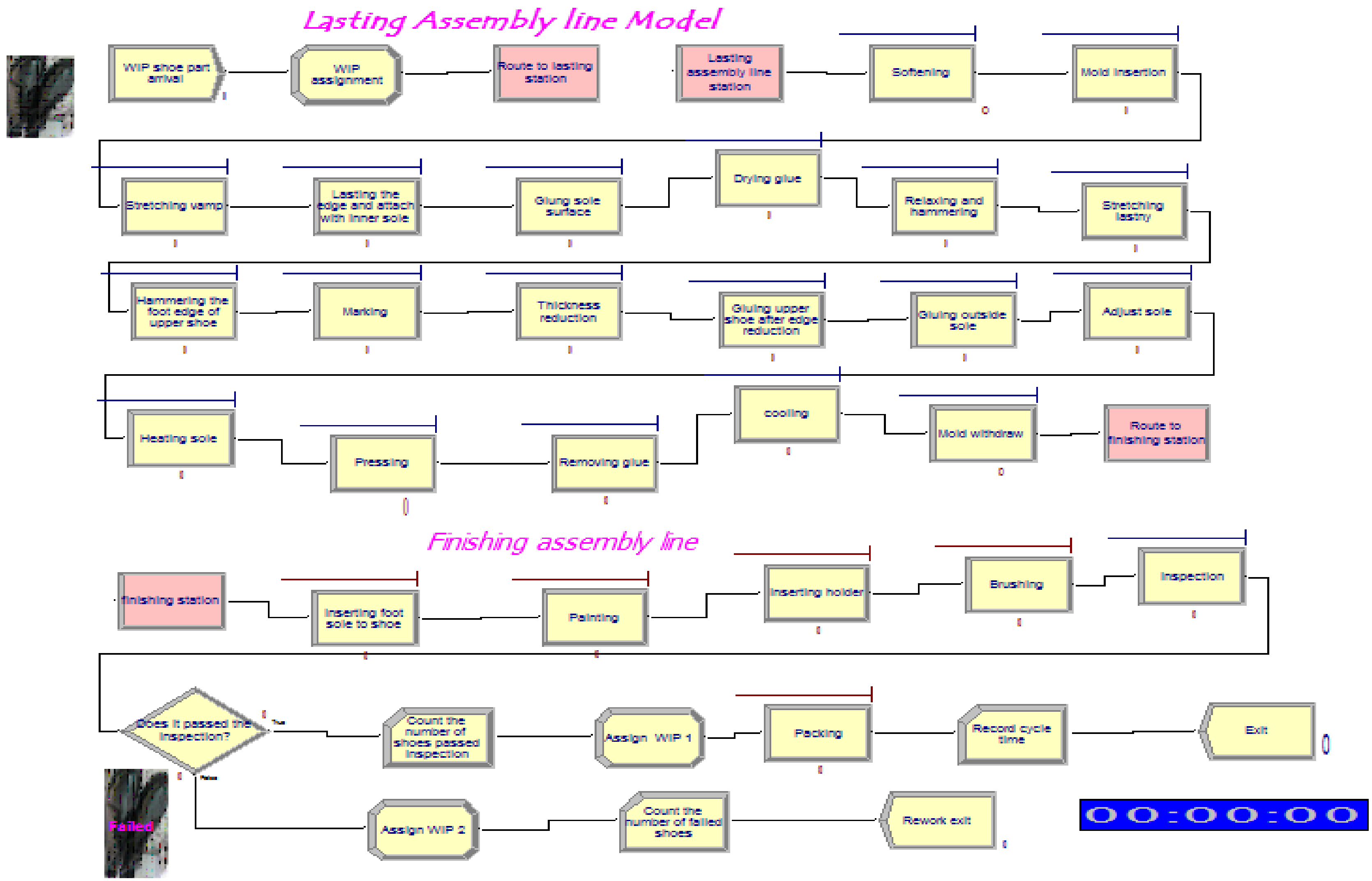


Fig.6. Simulation model for existing lasting and finishing assembly line

Determination of number of replication Arena simulation should run and the adequate warm up period, how long the simulation should run before it starts actual production simulation in order to avoid simulation bias, are crucial for the sake of increasing the degree of approximation of the simulation model to the real production output of the factory. The study considers the mean daily production outputs of both stitching, and lasting and finishing lines to check the significance of model output in terms of mean daily output of real system. The factory has one working shift starting from 8:00 AM to 5:30 PM. Workers have 15 minutes tea break both at the morning and afternoon, and one solid hour for lunch time. Hence, eight daily working hours are taken as replication length to run both stitching, and lasting and finishing assembly lines.

Depending on the type of simulation, steady state and terminated simulation, warm up period is another factor that should be computed to avoid bias during simulation process. A steady state simulation is a type of simulation where the simulation is assumed to run infinitely and there is simulation bias during start of the simulation run. Unlike to steady state simulation, terminated simulation is type of simulation where the simulation run terminates at certain period of time, at the end of replication length. As a result, the study takes start of simulation time, TNOW, as a warm up period.

The study takes 10 initial replications and 95% confidence interval to determine the standard deviation and mean of the initial outputs of the simulation run, sampling error and the required number of replication.

The result of ten initial replications for the simulation model of stitching and lasting assembly lines is shown in the table given below:

Table 2. Mean standard deviation and average daily production output for ten initial replications

Number of replication	Stitching line output	Lasting and finishing line output
1	1142 = 571 pairs	415.5 pairs
2	1140 = 570 pairs	410.5 pairs
3	1136 = 568 pairs	406 pairs
4	1137 = 568.5 pairs	407.5 pairs
5	1128 = 564 pairs	406 pairs
6	1127= 563.5 pairs	408 pairs
7	1120 = 560 pairs	410 pairs
8	1128 = 564 pairs	415.5 pairs
9	1130 = 565 pairs	409.5 pairs
10	1123 = 561.5 pairs	408 pairs
Mean	565.55	409.65
Standard deviation	5.66	3.43

Number of replication (N) for both stitching and lasting assembly lines is determined using Equ.3.1. This equation gives two Number of replication, N1 and N2, and the one that has greater number of replication is selected since the number of replication increases the accuracy of the model also increases. As a result, 33 and 35 number of replications is found for stitching and lasting assembly lines respectively.

Verification of simulation model is done by checking programming codes (SIMAN languages) step by step for both stitching, and lasting and finishing assembly lines. If there is debugging (code writing) problem exists in one of the flow process or data module, the Arena 14 simulation never run instead the SIMAN language show the error for correction. Until the correct coding is obtained, edition of error is continued.

Factory's monthly report shows that average daily production output of stitching assembly line is 582.3 pairs of upper shoes, and the average daily production output of lasting and finishing lines is 428.74 pairs of completed shoes. Thus, simulation model experiment for stitching assembly line results 563 pairs of shoes. The error committed by the model as compared to the real system is 3.31 % which implies that there is no significant difference between the output of the model and the real system. The same approach is used to check validity of lasting assembly line model, and error committed by this model as compared to the real system is 2.62 % which implies that there is no significant difference between the output of the model and the real system. To address the line balancing problem of the factory, it is crucial to identify production disturbance (bottleneck) assembly line and operations based on the output of the simulation experiment. Number of WIP, Average waiting time (sec.), resource utilization and flow time are used as a parameter to identity production disturbance (bottleneck) assembly line and operations. The result of simulation experiment for these parameters is given in the table shown below:

Table 4. Number of WIP, production rate, processing time and resource utilization

S.N	Stitching assembly line	Lasting and finishing Assembly line
WIP	252	169
Production rate	563 / 8 hours	417. 5/ 8 hours
Average waiting time (sec.)	2118.28	2026.91

Table 4 shows the result of the simulation experiment for stitching and lasting assembly lines in terms of the four parameters. The assembly line that has high WIP, average waiting time, and average total flow time as compared to the remaining assembly lines is considered as production disturbance (bottleneck) for the whole production process. Hence, stitching assembly line is identified as production disturbance (bottleneck) for the whole production section of Ramsay shoe factory.

Overall resource utilization for both stitching and lasting and finishing assembly lines is shown in the graph given below only for the purpose of comparison (different colours present different tasks and processes).

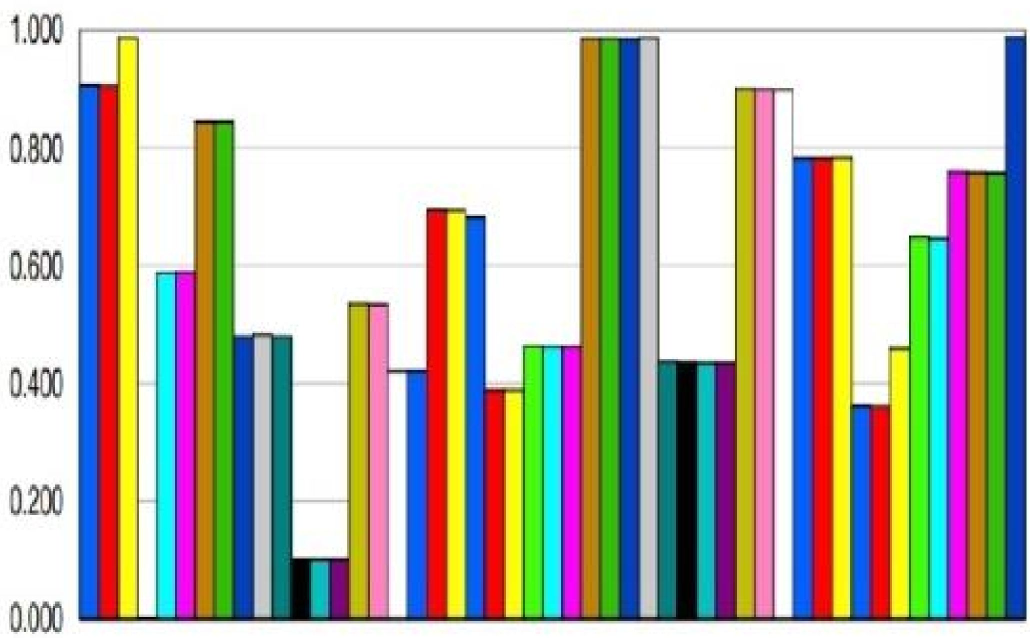


Fig. 7. Resource utilization of existing stitching assembly line

The above bar graph depicts that button attach worker 1 and 2 , glue remove works, gluing operators, inspectors ,pressing operators, punching operators, sewing edge operators, sewing operators , sorter, zigzag operators , and shera and vamp attaches have resource utilization of more than 85% as compared to the remaining resources. This implies that there is unbalanced resource utilization in this assembly line. The resource utilization bar graph for lasting and finishing assembly line is shown below

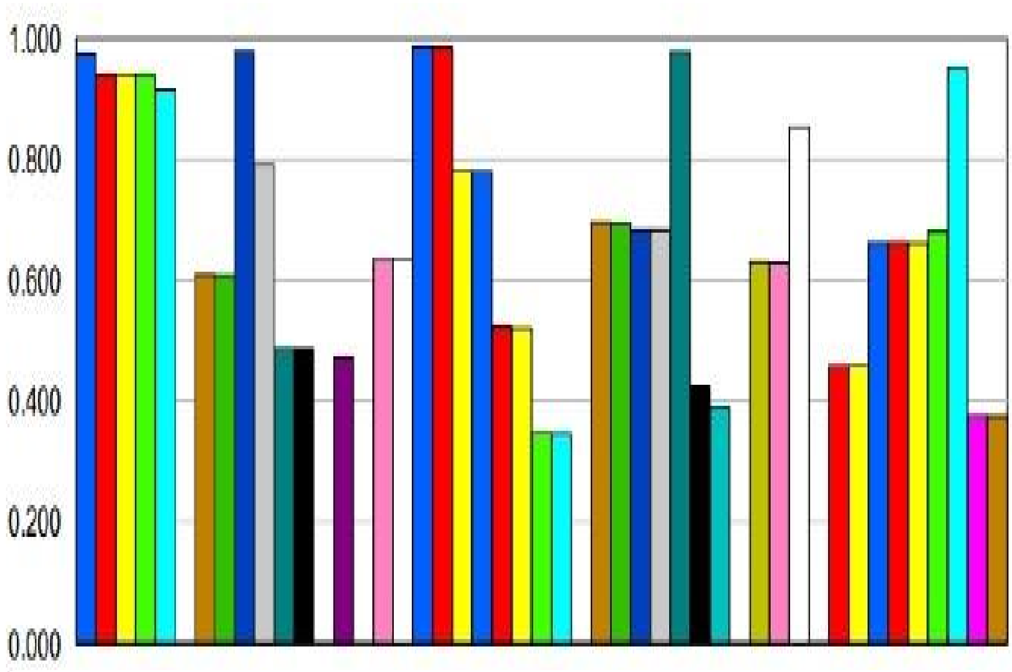


Fig.8. Resource utilization for existing lasting and finishing assembly line

The above bar graph shows that thickness reduction worker, heating sole worker 1 and 2, Glue remove workers, cooling and drying workers ,brushing operator, mold withdraw and pressing operators have resource utilization of more than 85% whereas most of the remaining resources have resource utilization less than 50 % . This implies that there is unbalanced resource utilization in this assembly line.

In addition to identifying the main production disturbance (bottleneck) assembly line based on those parameters described above, it is essential to identify operations (workstations) from both stitching, and lasting and finishing assembly lines for the sake of improving the overall productivity of the factory. Number of WIP , average waiting time in the queue and resource utilization are selected as a parameter to identified bottleneck operations from both assembly lines among those parameters described above since these parameters are direct indicators of whether or not certain operation is production disturbance for that assembly line as compared to the remaining one. The identified bottleneck operations from both assembly lines are depicted in the table shown below.

Table 3. Bottleneck operations in stitching, and lasting and finishing assembly lines

Name of operation	% Utilization	WIP	Average waiting time (sec.)
Stitching assembly line			
Button attachment	88.97	3	2.6878
Removing Glue	97.3	115	1110.52
Sewing zigzag	99.4	54	457.97
Gluing tongue	99.35	48	449.45
Firing		4	2.873
Vamp and shera attachment	94.02	4	8.903
Sewing edge of lastny and quarter	89.77	3	10.46
Inspection	88.16	1	15.7224
Punching	91.32	1	10.2533
Sewing tongue	94.38	4	10.698
Lasting and finishing assembly line			
Heating sole	98.58	83	1143.77
Brushing	97.4	46	731.22
Mold withdraw	97.75	13	116.04
Cooling	93.82	4	6.23
Stretching vamp		3	
Drying glue	91.5	2	23.05
Thickness reduction	95.15	2	21.9
Remove glue	97.9	3	27.35

The result of simulation experiment for stitching assembly lines shows that the total work content (Twc), total time elapsed to process all entities for specified replication length, is 3031.83 seconds. The maximum time an entity (shoe) stay in a work station is available service time (TS). From time study it is found, the maximum average time shoe stay in a workstation (work station for sewing edges of lastny and quarter provides maximum average processing time) is 85.465 seconds. 65 workers are available in stitching assembly lines. By using equation 2.4 the result of line balancing efficiency for stitching line is 54.57%. By applying similar method, the result of line balancing efficiency for lasting assembly line is 62.83%.

It is critical to determine the production efficiency of both stitching and lasting assembly line. Production efficiency (Ep) is the ratio of output to input. Thus, Ep for stitching and lasting assembly lines is 76.08% and 77.31% respectively.

The layout of existing assembly line of Ramsay shoe factory is given in the figure shown below. Workstations of the three assembly lines are place squencialy based on the chronological sequence of operations required to make the completed shoe.

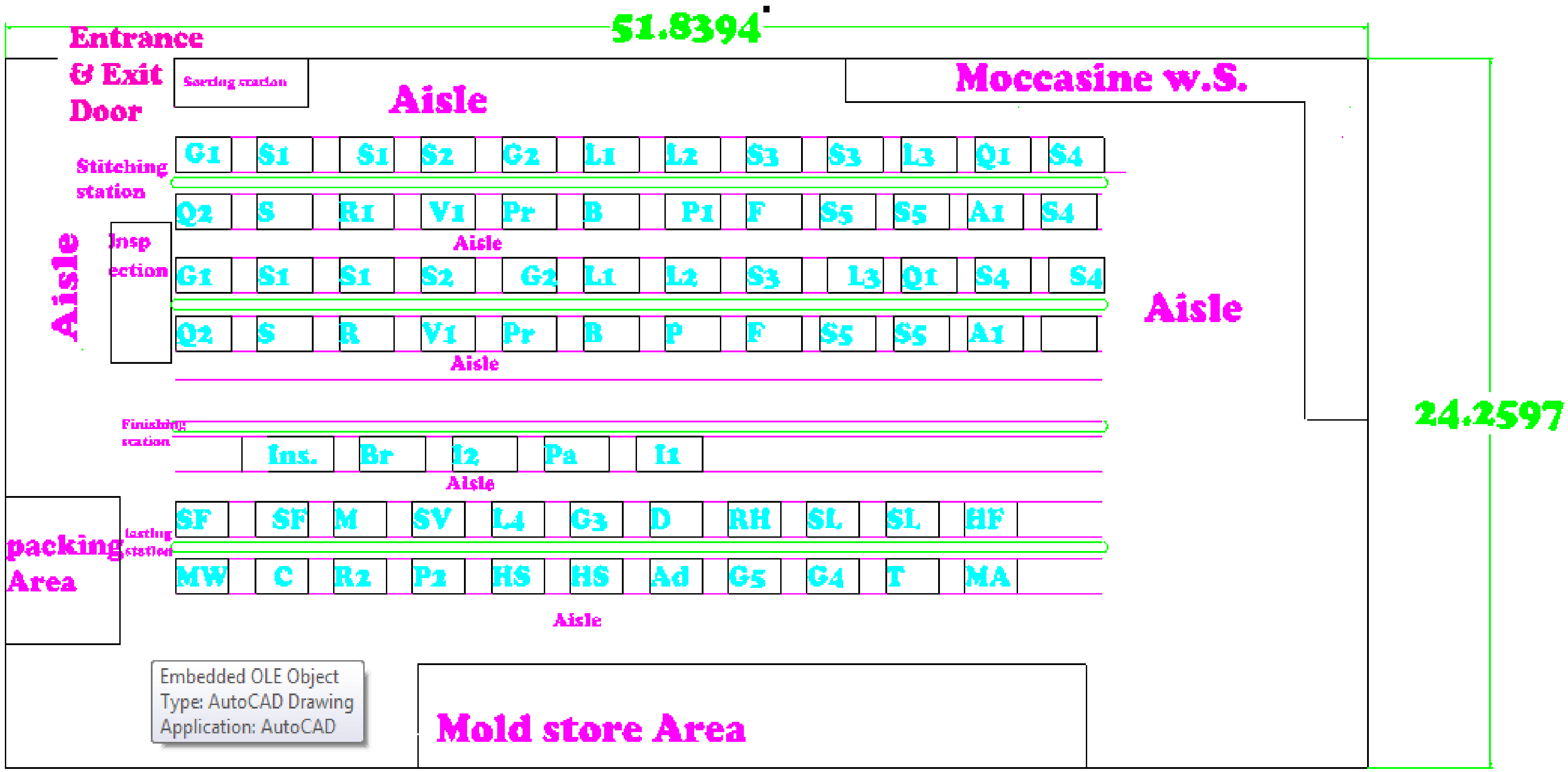


Fig. 9. Existing layout of the stitching, lasting and finishing assembly lines (dimensions are in meter)

4-3-What if analysis for proposed scenarios

This section deals about alternative solutions that provide various approaches to improve line efficiency of the existing system that will result in an increased productivity of the company.

Scenario one: Add one work centre (machine) and one operator at bottleneck operation:- Under this scenario one machine and one operator are added to bottleneck operations for both stitching, and lasting and finishing assembly lines in order to reduce the level of production disturbance, and increase efficiency of the assembly lines in the way that results improved productivity of the case company. Thus, the output of the simulation experiment after including this scenario in the existing simulation model for both assembly lines is given below.

Table 4. Simulation experiment result of scenario one for stitching assembly line

	Existing system	**Scenario one**
Bottleneck operations	Allocated resource	
Sewing zigzag	2	3
Sewing tongue	4	5
Removing glue	3	4
Gluing tongue	2	3
Sewing edges of quarter and lastny	4	5
Vamp and *shera* attachment	2	3
Sewing lastny with quarter	3	4
Summary	**As-Is**	**Scenario one**
Total worker	65	72
Total waiting time (sec.)	2118.28	350.84
WIP	252	68
Ep	76.08%	87.22%
Eb	54.57%	81.54 %
Output	563 pairs	645.5 pairs

Table 6 shows that scenario one consists of seven more resources (machines) as compared to As-Is system. In addition to this, it provides shorter waiting time, reduced WIP, increased production and line efficiency , and increased output as compared to As- Is system.

Table 5. Simulation experiment result of scenario one for lasting and finishing assembly line

	Existing system	**Scenario one**
Bottleneck operations	Allocated resource	
Heating sole	2	3
Brushing	1	2
Mold withdraw	1	2
Cooling	3	3
Drying	1	2
Thickness reduction	1	2
Removing glue	1	2
Summary	**As-Is**	**Scenario one**
Total worker	47	54
Total waiting time (sec.)	2026.91	641.26
WIP	169	65
Ep	77.31%	86.01%
Eb	62.83%	90.65%
Output	417.5 pai	464.5pairs

Table 7 shows that scenario one for lasting assembly line consists of seven more resources (machines) as compared to As-Is system. In addition to this, it provides shorter waiting time, reduced WIP, increased production and line efficiency , and output as compared to As- Is system.

Scenario Two: Add two work centers (machine) and two operators at bottleneck stations: - The result of the simulation experiment after including this scenario in the existing simulation model of stitching and lasting assembly lines is given in the table shown below:

Table 8 shows that scenario two consists of 12 more resources (operators) as compared to As-Is system. In addition to this, it provides shorter waiting time, reduced WIP and increased production and line efficiency , and output as compared to As- Is system.

Table 6. Simulation experiment result of scenario two for stitching assembly line

	Existing system	**Scenario two**
Bottleneck operations	Allocated resource	
Sewing zigzag	2	4
Sewing tongue	4	6
Removing glue	3	5
Gluing tongue	2	4
Sewing edges of quarter and lastny	4	6
Vamp and *shera* attachment	2	4
Sewing lastny with quarter	3	5
Summary	**As-Is**	**Scenario two**
Total worker	65	77
Total waiting time (sec.)	2118.28	671.97
WIP	252	102
Ep	76.08%	85.83%
Eb	54.57%	82.13%
Output	563 pairs	639.5 pairs

Table 7. Simulation experiment result of scenario two for lasting and finishing assembly line

	Existing system	**Scenario two**
Bottleneck operations	Allocated resource	
Heating sole	2	4
Brushing	1	3
Mold withdraw	1	3
Cooling	3	3
Drying	1	2
Thickness reduction	1	3
Removing glue	1	3
Summary	**As-Is**	**Scenario two**
Total worker	47	59
Total waiting time (sec.)	2026.91	648.24
WIP	169	84
Ep	77.31%	84.25%
Eb	62.83%	80.09%
		457.5 pairs
Output	417.5 pairs	457.5 pairs

Table 9 shows that scenario two consists of 12 more resources (machines) as compared to As-Is system. In addition to this, it provides shorter waiting time, reduced WIP, increased production and line efficiency , and output as compared to As- Is system.

Scenario Three: Shifting workers whose resource utilization is less than 50% to busy workstations:- The result of the simulation experiment for scenario three is given below in table form.

Table 8. Simulation experiment result of scenario three for stitching assembly line

Bottleneck operations (work stations)	Existing system	Scenario three
	Allocated resource	
Lastny edge attachment	3	1
Lastny attachment	4	2
Quarter edge attachment	3	2
Sewing zigzag	2	3
Sewing tongue	4	4
Removing glue	3	4
Sewing edges of quarter and lastny	4	5
Inspection	2	3
Summary	**As-Is**	**Scenario three**
Total worker	65	65
Total waiting time (sec.)	2118.28	525.25
WIP	252	139
Ep	76.08%	83.11%
Eb	54.57%	86.54%
Output	563 pairs	627.5 pairs

Table 10 shows that scenario three consists of the same number of resources (machines and labor) as As-Is system. But, it provides shorter waiting time, reduced WIP, increased production and line efficiency and output as compared to As- Is system.

Table 9. Simulation experiment result of scenario three for lasting and finishing assembly line

Bottleneck operations (work stations)	Existing system	Scenario three
	Allocated resource	
Lasting edge and attach with inner sole	2	1
Upper shoe hammering	2	1
Softening	2	1
Gluing smoothed upper shoe	2	1
Heating sole	2	3
Brushing	1	2
Mold withdraw	1	2
Cooling	3	3
Drying	1	1
Removing glue	1	2
Summary	**As-Is**	**Scenario three**
Total worker	47	47
Total waiting time (sec.)	2026.91	341.05
WIP	169	68
Ep	77.31%	83.18%
Eb	62.83%	74.3%
Output	417.5 pairs	441.5 pairs

Table 11 shows scenario three consists of the same number of resources (machines and labour) as compared to As-Is system. But, it provides shorter waiting time, reduced WIP, increased production and line efficiency , and output as compared to As- Is system.

Scenario Four: Mixing of two work stations having similar operation and low resource utilization together and load more entities:- The result of the simulation run for this scenario is depicted in the table shown below:

Table 10. Simulation experiment result of scenario four for stitching assembly line

Bottleneck operations (work stations)	Existing system	Scenario four
	Allocated resource	
Attaching lastny with quarter mixed with Lastny and shera attachment	3-4	7
Quarter edge attachment mixed with lastny edge attachment	3-3	6
Summary	**As-Is**	**Scenario Four**
Total worker	65	65
Total waiting time (sec.)	2118.28	661.60
Eb	76.08%	85.06%
Eb	54.57%	86.59%
WIP	252	109
Output	563 pairs	638 pairs

Table 12 shows scenario four consists of the same number of resources (machines and labor) as compared to As-Is system. However, it provides shorter waiting time, reduced WIP, increased production and line efficiency , and output as compared to As- Is system

Table 11. Simulation experiment result of scenario four for lasting and finishing assembly line

Bottleneck operations	Existing system	Scenario four
	Allocated resource	
Lasting edge and attach with inner sole mixes with gluing sole surface	2-1	3
Upper shoe hammering mixes with marking	2-2	4
Gluing smoothed upper shoe mixes with gluing outside sole	2 -1	3
Gluing smoothed upper shoe	2	1
Heating sole	2	2
Brushing	1	2
Mold withdraw	1	2
Cooling	3	3
Drying	1	1
Summary	**As-Is**	**Scenario Four**
Total worker	47	49
Total waiting time (sec.)	2026.91	320.44
WIP	169	44
Ep	77.31%	85.7%
Eb	62.83%	75.8%
Output	417.5 pairs	463 pairs

Table 13 shows scenario four consists of two more resources (labor) as compared to As-Is system. In addition to this, it provides shorter waiting time, reduced WIP, increased production and line efficiency , and output as compared to As- Is system.

Scenario Five: Apply scenario one and three at the same time:- This scenario combines scenario one and three for the sake of reducing the level of production disturbance (bottleneck) operations from both stitching, and lasting and finishing assembly lines that result in the overall productivity improvement of the case company. The result of the simulation experiment for this scenario is given in the table shown below:

Table 12. Simulation experiment result of scenario five for stitching assembly

Bottleneck operations	**Existing system**	**Scenario five**
	Allocated resource	
Lastny edge Attachment	3	1
Lastny attachment	4	1
Quarter edge attachment	3	2
Sewing zigzag	2	4
Sewing tongue	4	5
Removing glue	3	4
Gluing tongue	2	4
Sewing edges of quarter and lastny	4	6
Inspection	2	3
Summary		
	As-Is	**Scenario Five**
Total worker	65	71
Total waiting time (sec.)	2118.28	417.05
WIP	251	85
Ep	76.08%	86.43%
Eb	54.57%	87.34%
Output	563 pairs	652.5 pairs

Table 4.14 shows scenario five consists of six more resources (labor and machine) as compared to As-Is system but it provides more output, improved line and production efficiency, and reduced total waiting time. As a result, this scenario is better than the existing one.

Table 13. Simulation experiment result of scenario five for lasting and finishing assembly line

Bottleneck operations	**Existing system**	**Scenario five**
	Allocated resource	
Lasting edge and attach with inner sole	2	1
Upper shoe hammering	2	1
Softening	2	1
Gluing smoothed upper shoe	2	1
Drying	1	1
Thickness reduction	1	2
Removing glue	1	3
Heating sole	2	4
Brushing glue	1	3
Mold withdraw	1	3
Cooling	3	3
Summary	**As-Is**	**Scenario Four**
Total worker	47	56
Total waiting time (sec.)	2026.91	614.01
WIP	169	72
Ep	77.31%	83.79%
Eb	62.83%	83.03%
Output	417.5 pairs	455 pairs

Table 15 shows scenario five consists of nine more resources (labor and machine) for lasting and finishing assembly line as compared to As-Is system but it provides more output, improved line and production efficiency, and reduced total waiting time. As a result, this scenario is better than the existing one.

Detail what if analysis is done in the above section for five scenarios. Thus, scenario five is selected as a best approach to reduce level of production disturbances (bottleneck) by improving line efficiency and productivity of existing stitching assembly line. This scenario improves line and production efficiencies from 54.57% to 87.59% and 76.08% to 86.432% respectively, increase output from 563 pairs per eight hours to 652.5 pairs per eight hours, and reduce average waiting time and WIP from 2118.28 Sec. to 417.05 sec. and 252 to 85 respectively of existing stitching assembly line. On the other hand, Scenario one is selected as a best approach to reduce level of production disturbances (bottleneck) by improving line efficiency and productivity of existing lasting and finishing assembly line. This scenario improves line and production efficiencies from 62.83% to 90.65% and 77.31% to 86.01% respectively, , increase output from 417.5 pairs per eight hours to 464.5 pairs per eight hours, and reduce average waiting time and WIP from 2026.91 Sec. to 641.26 sec. and 169 to 65 respectively of existing lasting and finishing assembly line.

Figure 10 shows proposed simulation model for stitching assembly line. It is built by including resource allocation of scenario five in to the existing model.

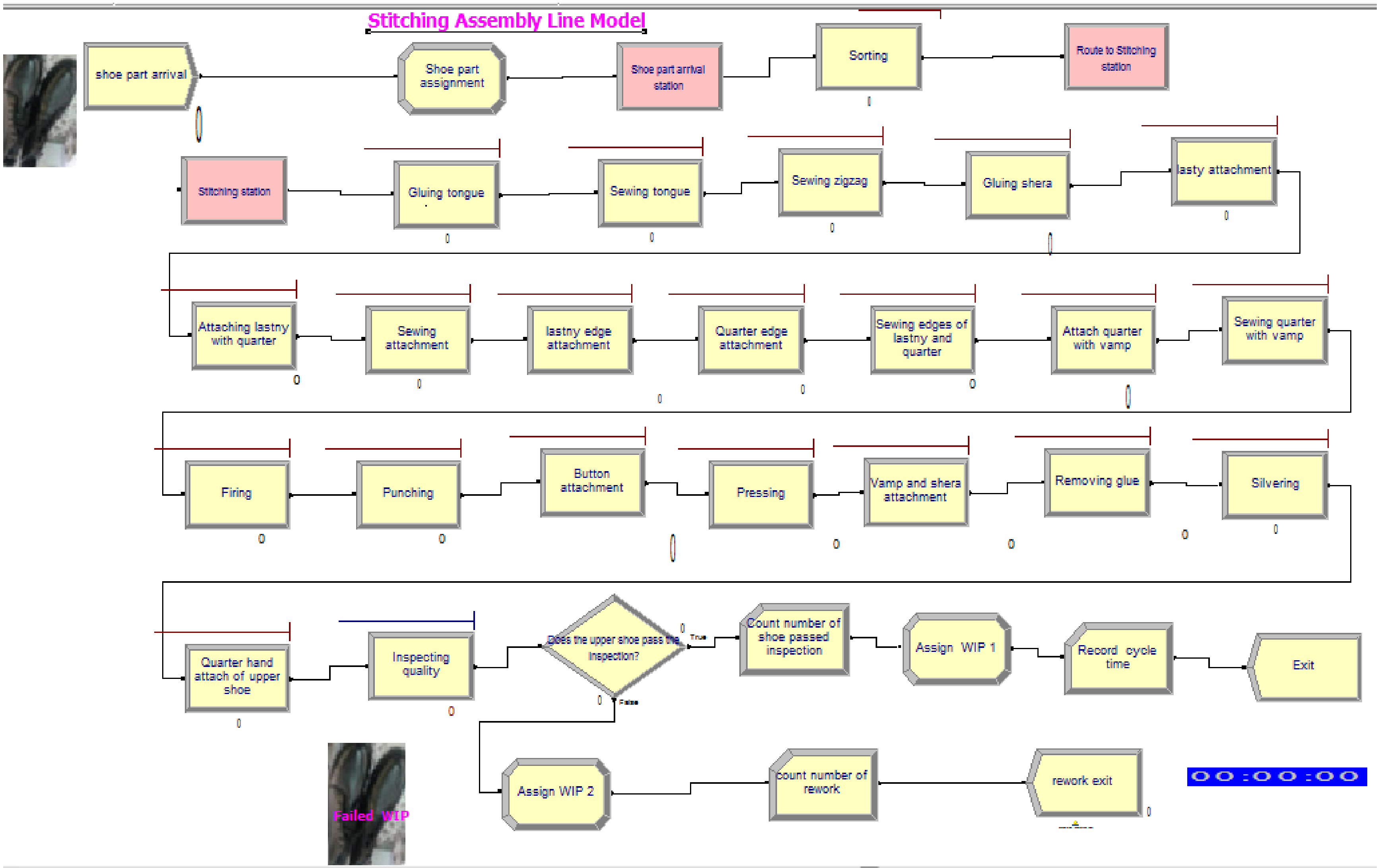


Fig.10. Proposed simulation model for stitching assembly line

Figure 11 shows proposed simulation model for lasting assembly line. It is built by including resource allocation of scenario one in to the existing model. Cost benefit analysis shows that if the company applies the proposed scenarios in its assembly lines, it will result additional profit of 13,610,200 birr per year. Layout of the proposed scenario is given below:

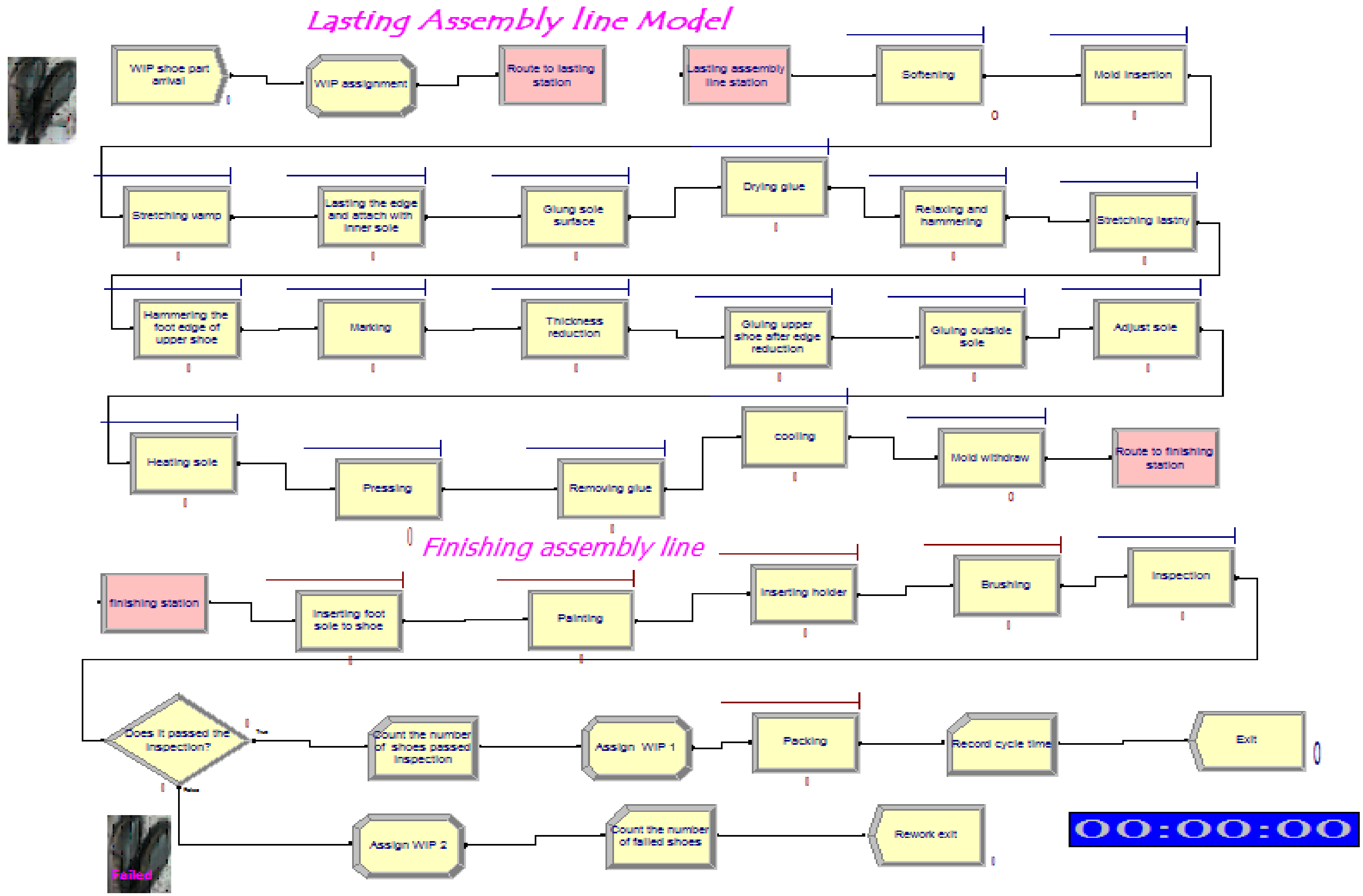


Fig.11. Proposed simulation model for lasting and finishing assembly line

Fig.12. Layout of proposed scenario for three assembly lines (dimensions are in meter)

The above figure shows how the proposed scenario is changed in to application (placement). The place (work station) for newly added machines is shown by red color along the three assembly lines.

4-4-Error and impact of choosing inappropriate distribution function

The processing time for assembly operations in shoe making industry varies through elapse of time due to operator's and raw material problems, machine failure and low strength of thread. Thus, identification of a probability distribution that accommodate (fit) the variation of processing time for every task in all assembly line is essential to develop simulation model for the real system. Assembly operations that are required to make a shoe are fitted to one of the twelve probability distributions using sum of square error, the goodness of fit is checked by Kolmogorov Smirnov test as stated at the beginning of this section heading. The type of probability distribution that has least sum of square error is fitted to an assembly operation. As the sum of square error for distribution function increases the variation between simulation model and real system also increase such that the simulation model reveals significance difference as compared to the output of the real system.

If the choice of probability distribution is inappropriate, it results wrong simulation model for the real system. It also results wrong conclusion about effect of parameters on various scenarios during conducting detail what- if analysis. Furthermore, choosing a probability distribution that has high square error as compared to others results serious consequences such as inability to complete assembly operations in time leading to substantial time and money loss for both labor and machines and proposing wrong design of facility layout of existing company

5-Conclusion

Nowadays, all manufacturing companies are aspiring to have more reliable and robust manufacturing systems to increase the productivity and overall efficiency of their production lines. However, presence of production disturbance (bottleneck) in the production section especially in the assembly lines is the key problem. The study aims to reduce the level of production disturbance (bottleneck) from both stitching, and lasting and finishing assembly lines of the case company by solving existing line balancing problem using discrete event simulation approach. Necessary data that used to precede the study is collected through direct observation, interview, review of factory's report and time study. Assembly process chart is used to map the sequence of operation and assembly process for selected shoe model. Thus, Arena input analyzer is used to fit variation of processing time in to one of the probability distribution, and K-S test is used to check goodness of fit.

Six assumptions are made to develop simulation model for both stitching and lasting assembly lines. The adequate number of replication for stitching and lasting assembly lines is found as 33 and 35 respectively having independent 28800 seconds run length. The output of simulation experiment for both assembly lines has no significant difference with existing system. Hence, stitching assembly line is identified as production disturbance (bottleneck) assembly line based on average waiting time, output, WIP, total flow time ,production rate and resource utilization. Furthermore, bottleneck operations are identified from both assembly lines using the same parameters.

Five scenarios that used to reduce production disturbance (bottleneck) by solving line balancing problem from both assembly lines are proposed. Thus, scenario five is selected as a best approach to reduce the level of production disturbances (bottleneck) by improving line and production efficiency of stitching assembly line. This scenario improves line and production efficiencies from 54.57% to 87.59% and 76.08% to 86.432% respectively, increase output from 563 pairs per eight hours to 652.5 pairs per eight hours, and reduce average waiting time and WIP from 2118.28 Sec. to 417.05 sec. and 252 to 85 respectively of existing stitching assembly line. On the other hand, scenario one is selected as a best approach to reduce the level of production disturbances (bottleneck) by improving line efficiency and productivity of existing lasting and finishing assembly line. This scenario improves line and production efficiencies from 62.83% to 90.65% and 77.31% to 86.01% respectively, increase output from 417.5 pairs per eight hours to 464.5 pairs per eight hours, and reduce average waiting time and WIP from 2026.91

Sec. to 641.26 sec. and 169 to 65 respectively of existing lasting and finishing assembly line. If the Peacock shoe factory applies the proposed scenarios in its assembly lines, it will gain additional profit of $485,212.07 annually.

Acknowledgement

I would like to thank Mr. Elias Badada, general manager of Peacock Shoe factory, for his unreserved support and encouragement while doing the study. I would also like to extend my gratitude to all staffs of Peacock Shoe factory particularly Ms.Tsion Alemayehu , Production manager of the company, for her willingness and cooperation in giving me the required information.

References

Aggarwal, V., Padhi, S. S., and Bhatnagar, V. (2011). Performance improvement in parallel manufacturing systems through scenario analysis and optimal design of parameters. International Journal of Production Research, 13(6), 85–107.

Brunk , H. D. (1960). An Introduction to Mathematical Statistics (vol.2). Michigan: Ginn.

Corte, P., Onieva, L. and Guadix, J. (2010). Optimizing and simulating the assembly line balancing problem in a motorcycle manufacturing company: a case study. International Journal of Production Research, 48(3), 3637–3656.

Daniel, K., Amare, M. and Solomon, T. (2010). Assembly line balancing using simulation technique in a garment manufacturing firm. Journal of EEA, 27(1), 69-80.

Drucker, P. F. (1990). The emerging theory of manufacturing. Harvard Business Review, 68 (3), 94-102.

Eryilmaz, M .S. , Kusakci, A. O. , Gavranovich, H. and Findik, F. (2012). Analysis of shoe manufacturing factory by simulation of production processes. Journal of Soft Computing, 1(3), 120- 127.

Garza-Reyes, J. A., Eldridge, S., Barber, K. D., Soriano –Meier, H. (2010). Overall equipment effectiveness (OEE) and process capability (PC) measures: A relationship analysis. International Journal of Quality & Reliability Management, 27 (1), 48 – 62.

Groover, P. (2000). Automation, Production Systems, and Computer-Integrated manufacturing 2nd Ed., Delhi, Pearson Education.

Hassan, M. M., Gruber, S. (2008). Application of discrete-event simulation to study the paving operation of asphalt concrete. Construction Innovation. Journal of Information, Process, Management, 8(1), (109-118).

Ingemansson, A., Bolmsjo, G. S. (2005). Improved efficiency with production disturbance reduction in manufacturing systems based on discrete-event simulation. Journal of manufacturing technology management, 15(3), (267 -274).

James, C., Putra, A. P. , Anggono, N. and Chen, J. (2014). Simulation modeling and analysis for stitching line of footwear industry. International Conference on Industrial Engineering and Operations Management. Bali, Indonesia.

Kuivanen, R. (1996). Disturbance control in flexible manufacturing. International journal of human factors in manufacturing, 6(1), (41-56).

Law, A. M. and Kelton, W. D. (2000). Simulation modeling and analysis 3rd ed. Boston, McGraw-Hill.

Mohamad, E., Salleh, M. R., Nordin, N. A. (2012). Simulation study towards productivity improvement for assembly line. Journal of Human Capital Development,5(1), 59-69.

Padhi, S.S., Wagner, S. M., Niranjan, T. T. and Aggarwal, V. (2013). A simulation-based methodology to analyse production line disruptions. International Journal of Production Research, 51(6), 1885–1897.

Padhi, S. S., Mohapatra, P. K. J. (2010). Process evaluation of award of work contracts in a government department, International journal of electronic governance, 2(3), 118 -130.

Quintero, L. A., Conway, P. P., Velandia, D. M. S., West, A. A. (2011). Root cause analysis support for quality improvement in electronics manufacturing, Assembly automation, 31(1), 38-46.

Shang, J. S., Li, S. and Tadikamalla, P. (2004). Operational design of a supply chain system using the taguchi method, response surface methodology, simulation and optimization. International Journal of Production Research, 42(18), 3823 – 3849.

Smet, R. D., Gelders, L. and Pintelon, L. (1997). Case studies on disturbances registration for contineos improvement. Journal of quality in maintenance engineering, 3(2), 91-108.

Toledo, T., Koutsopoulos, A. D., Ben-Akiva, M. E., Burghout, W., Andreasson, I ., Johansson ,T.and Lundin, C. (2003). Calibration and Validation of Microscopic Traffic Simulation Tools: Stockholm Case Study. Transportation Research Record (1831): 65-75.

Temesgen, G. and Nahom, M. (2014). Modeling and performance analysis of manufacturing systems in footwear industry. Science, Technology and Arts Research Journal, 3(1), 132-141.

Wu, B. (1989). Manufacturing systems design and analysis: Context and techniques 2nd Ed. London ,Chapman and Hall.