Optimizing Production Efficiency in Pakistani Shoe Manufacturing: A Simulation-Based Analysis

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Abstract

This research utilized discrete-event simulation to improve workforce productivity at a leading shoe manufacturing firm in Pakistan. The study targeted the lasting department, encompassing nineteen vital processes required to achieve the final shoe shape. A comprehensive analysis of all the operations was conducted, and reliable data on cycle times were gathered. Statistical analysis was performed to determine the suggested distribution of all the processes. A network model of the current system was formulated, revealing low workforce productivity and process flow inconsistencies. Three plans were proposed based on the simulation to address these issues, which proved more productive and efficient than the existing system, with no significant investment required. The T-test illustrated substantial differences between the productivity of the current and proposed plans. After careful evaluation, the most promising plan was selected and is now poised for implementation.

Keywords: discrete event simulation, footwear industry, production analysis, AweSim

1. Introduction

These days, organizations tend to be extra competitive with every passing day. The intensity of competitiveness dictates their capacity to sell their goods or services in a specific market. It is, thereby, essential to develop inspection protocols, observe the organizational procedures, and learn from its mistakes to improve quality and address the client's needs and desires. In addition, for the organization to be economical in the national and global markets, business competitiveness requires efficient and effective asset management, including financial assets, workforce management, and other resources [1].

The shoe manufacturing industry is not peculiar to this pattern. The shoe fabricating industry is one of Pakistan's oldest and most significant enterprises, producing excellent quality footwear, and has an incredible potential for further development. The Islamic Republic News Agency revealed that Pakistan trades footwear to 60 nations on five continents worldwide. Pakistan's footwear exports have shown a high pace of development recently. Nonetheless, with yearly exports of $110 million, Pakistan's share in worldwide footwear exports is just 0.001 percent. Footwear exports from other nations in the continent are considerably high. In Pakistan, numerous industrial facilities have 2,500 pairs per day production capacity, and some bigger units produce as many as 10,000 pairs per day. The footwear business benefits from the availability of the best quality leather in the region. Pakistan has excellent leather and benefits from its products industry. Pakistan's shoemaking industry is primarily located in and around the city of Lahore, with about 80 percent of the reported division of the nation. Other shoemaking areas include Karachi, Faisalabad, and Multan [2]. The current study used computer simulation to increase the workforce productivity of one of Pakistan's well-known shoe manufacturing firms. There were four shoe manufacturing departments: cutting, closing, lasting, and packing. One department, i.e., lasting, was selected for process improvement. The entire nineteen processes were involved in this department to bring the shoe into the final shape. All operations were studied thoroughly, and reliable data (cycle time) was collected. Statistical analysis was performed to find the proposed distribution of all the processes. A network model of a current system was formulated. The model revealed the low productivity of the workforce and irregularities in the process flow. Three plans to resolve these problems are proposed based on a simulation that outweighs the current system's productivity and flows without significant investment. The T-test showed substantial differences between the productivity of existing and proposed plans. Finally, the best method among these plans is selected and is ready to be implemented.

1.1 Literature Review

Observation and analysis of the existing systems for optimization are fundamental [3].

Optimal utilization of resources is vital for every firm because under-utilized resources lead to high costs. Furthermore, ensuring the proper utilization of all the resources leads to increased production [4]. Therefore, the maximum utilization of resources improves efficiency. Similarly, the smooth workflow in the production line is also significant. Due to irregular workflow, workers must perform excessive movements to complete their specific tasks. The production capacity can, thereby, be increased by removing the irregularities in production and maximizing the utilization of resources. Simulation is a flexible practice that is used to analyze the behavior of current and proposed activities [5]. In this study, simulation is performed to analyze an operation in the manufacturing process of shoes. Results achieved from the simulation helped to understand the current system of that department. The potential areas for improvement were identified based on these results, and the proposed plans were developed. Simulation utilized to examine and explore different strategies regarding different techniques makes it an essential part of the decision-making process [6]. Computer simulation is the methodology of designing a mathematical-logical model of a real system and experimenting with this model on a computer [7]. The simulation includes a model-building process and the design and implementation of appropriate experiments, including that model. These experiments, or simulations, license implications to be drawn about systems; (1) without building a model if they are only proposed systems; (2) without disturbing the system if they are operating systems that are costly or unsafe to experiment with; and (3) without destroying the system [8].

A system is a collection of items from a circumscribed reality sector that is the object of study or interest [9]. The scope of a simulation model is determined by the particular problems the model is designed to solve. To consider a system's scope, one must consider its limitations and contents. The boundary of a system may be physical; however, it is better to think of boundaries in terms of cause and effect [10]. External factors like sales, financial, union, and raw material supply may affect the system [8]. A simulation model represents a system of interest used to pick up experiences about existing systems and investigate systems under new operating conditions [6]. Models are usually developed based on theoretical laws and principles. The scale of the model is based on physical objects, mathematical equations, and relations, or graphical representations. The usefulness of the models has been demonstrated in describing, designing, and analyzing systems [11].

Utilization is the percentage of available working time that a worker works or a machine run [12]. Utilization is a performance measure that should be handled with great care. Specifically, it should be emphasized that the objective of most businesses is to maximize the profits of firms, not to maximize the utilization of the workforce [13]. Flow production is a continuous process of parts and sub-assemblies passing on from one stage to another until the completion of work [14], [15]. The flow of units should be smooth; units are worked upon in each operation and then passed to the next workstation without waiting [16]. The production line can work smoothly in every operation and must be of standard length. The smooth flow of production was achieved through pre-production planning, raw materials planning before purchases, and delivery (just in time) [17]. The computer simulation allows us to authenticate or visualize the outcome(s) of the process without a significant investment of resources, i.e., man, material, time and/or energy, on a real system. The latest tools, like a computer simulations, replace traditional testing methods and analyze the process. It becomes easier to identify the bottlenecks within the process(es), and it helps to obtain a different solution, which improves the decision-making process. These tools are convenient for selecting an optimal solution, making the process cost-effective [18]–[21].

Further research and studies have been conducted to apply process simulation to improve production in the shoe making industry, which aims to define and integrate the different strategies for analyzing the system and make necessary changes for improvement using the heuristic approach(es) [22]. Some other studies focused on exploring the effect of decision variable(s), which are related to the time performance of the system [23]. This study considered the total length of the planning period, material availability, and the link between the production orders and customer orders regarding color mix as diverse factors. These factors are analyzed through computer simulation, evidence that the production-planning process is one of the most critical areas of improvement in the manufacturing process. The modification of this process will affect the weighted average delivery time significantly.

1.2 Problem Statement

Shoe manufacturing is still highly labor-intensive in Pakistan, with minimal automation. Workers are, therefore, the essential resource in this business. Hence, the effective use of this resource can bring many benefits to the firm. In a meeting

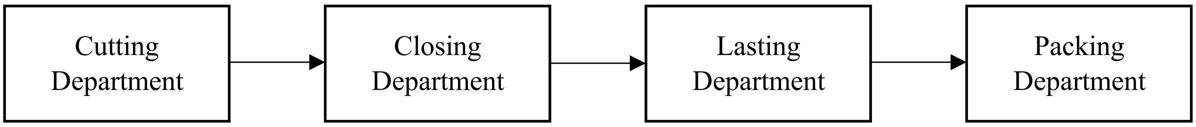

Fig. 1: Shoe manufacturing process flow chart

with the firm's production department, it was observed that they were facing problems regarding the optimal utilization of its workforce. There were four departments for shoe manufacturing, i.e., cutting, closing, lasting, and packing. The flow process of shoe manufacturing is shown in Fig. 1. Among these four departments, the lasting department was selected for the current study as lasting is an important process for the final shape of the shoe and faced several problems. The workforce and equipment were underutilized and the workload was not equally divided among all the workers, with most of the workers waiting to perform their tasks. As a result, the flow of products through operations was not smooth, and servers remained idle, leading to low resource utilization. In addition, the cycle time of all workstations was not the same, due to which workers had to stop the conveyer or bring back the shoe from the conveyer to complete their process.

2. Methods

The successful development of a simulation model consists of beginning with a simple model elaborated evolutionarily to meet the problem-solving requirements. The steps of the simulation of the current process are shown in Fig. 2. Total of nineteen operations was performed in the lasting department. For the evaluation of the whole lasting department, the data of each process was accurately and precisely collected through "time study." First, a plan for data collection was made. In this study, forty observations of each process were collected, and the extreme values were neglected. All data were entered into "Minitab" software to select the processes' proposed probability distribution [24], [25]. Parameters of the proposed distribution were found after finding the proposed probability distribution. All the data were entered into the Simulation software to generate sample data. Awesim [8] software was then used to simulate the current system. The result of the current system is shown in the summary report in Table 2. The details of the simulation and its results are discussed in the following section.

3. Analysis and Discussion

The forty (40) values of each process cycle time were collected, and the distribution was found for each process with the help of the "goodness of fit" test applied in Minitab 15. Appendix - A (Table I) provides the details of each process. The data shows that the arrival rate of the lasting department was 38.57 seconds, and its distribution was exponential. The network model of the current system was made in AweSim. The network modeling of the current system is shown in Appendix - B (Figure I). All data entered in the model was in seconds. The results of the current system are shown in Table 1.

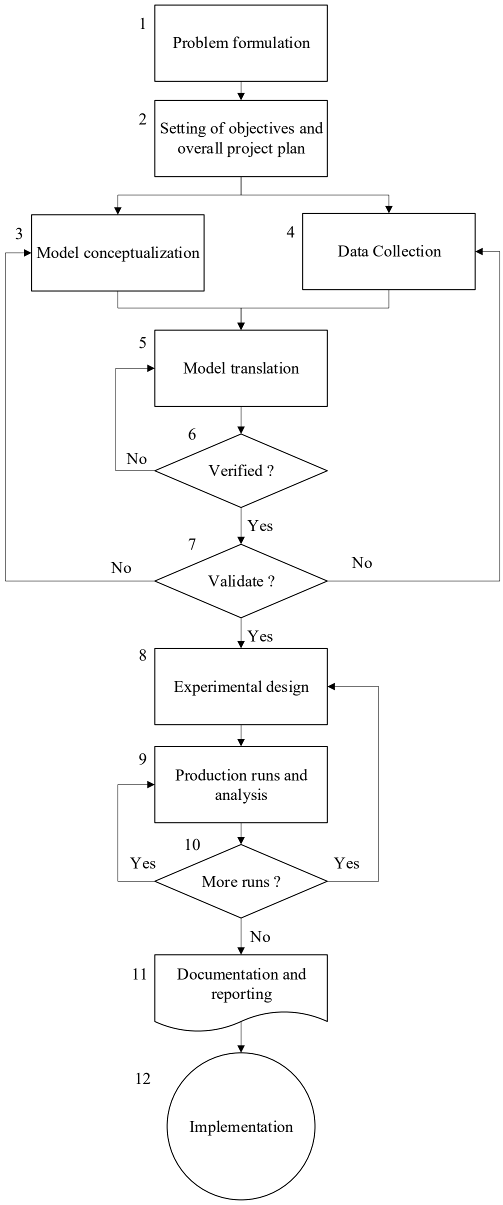

Fig. 2: Simulation process steps [6], [26]

In the Create node, the entities (shoe pieces) were created from the closing department. Then, in the Activity node, the process/service was actually performed. Then, in the Queue node, the shoe pieces wait for their process/service. Finally, there is a Terminate node, which terminates the shoe pieces from the lasting department to be further processed in the packing department.

Terminate node, which terminates the shoe pieces from the lasting department to be further processed in the packing department.

Table 1: Results of current system simulation

**** OBSERVED STATISTICS REPORT ****

Label	Mean Value	S.D	No. of Observations	Minimum Value	Maximum Value
Lasting Department	382.671	85.031	699	261.248	659.109

**** FILE STATISTICS REPORT ****

File Number	Label or Input Location	Average Length	Standard Deviation	Maximum Length	Current Length	Average Wait Time
1 QUEUE	Line 3	0.574	1.040	6	2	21.776
2 QUEUE	Line 5	0.001	0.029	1	0	0.032
3 QUEUE	Line 7	0.000	0.022	1	0	0.019
4 QUEUE	Line 9	0.015	0.122	2	0	0.566
5 QUEUE	Line 11	0.000	0.000	1	0	0.000
6 QUEUE	Line 13	0.132	0.365	3	0	5.047
7 QUEUE	Line 15	0.017	0.131	2	0	0.652
8 QUEUE	Line 17	1.497	2.095	10	1	57.250
9 QUEUE	Line 19	0.000	0.000	1	0	0.000
10 QUEUE	Line 21	0.000	0.019	1	0	0.014
11 QUEUE	Line 23	0.006	0.078	1	0	0.235
12 QUEUE	Line 25	0.000	0.000	1	0	0.000
13 QUEUE	Line 27	0.006	0.074	1	0	0.214
14 QUEUE	Line 29	0.000	0.022	1	0	0.019
15 QUEUE	Line 31	0.000	0.021	1	0	0.018
16 QUEUE	Line 33	0.002	0.044	1	0	0.074
17 QUEUE	Line 35	0.005	0.067	1	0	0.176
18 QUEUE	Line 37	0.000	0.007	1	0	0.002
19 QUEUE	Line 39	0.030	0.170	1	0	1.147

**** SERVICE ACTIVITY STATISTICS REPORT ****

Activity Number	Label or Input Location	Server Capacity	Productivity	Standard Deviation	Maximum Idle Time or Servers	Maximum Busy Time or Servers
1	Pro # 01	1	0.646	0.478	189.427	577.833
2	Pro # 02	1	0.369	0.483	202.669	66.051
3	Pro # 03	1	0.192	0.394	222.062	18.968
4	Pro # 04	1	0.403	0.490	221.475	90.940
5	Pro # 05	1	0.147	0.354	227.899	7.422
6	Pro # 06	1	0.583	0.493	193.071	323.627
7	Pro # 07	1	0.381	0.486	196.732	68.647
8	Pro # 08	1	0.844	0.363	159.700	4530.149
9	Pro # 09	1	0.362	0.481	178.263	20.162
10	Pro # 10	1	0.459	0.498	178.749	50.394
11	Pro # 11	1	0.479	0.500	181.322	112.337
12	Pro # 12	1	0.100	0.300	195.670	5.938
13	Pro # 13	1	0.452	0.498	199.681	72.074
14	Pro # 14	1	0.342	0.474	214.856	30.608
15	Pro # 15	1	0.341	0.474	229.848	30.298
16	Pro # 16	1	0.389	0.488	244.019	32.018
17	Pro # 17	1	0.408	0.491	259.700	54.502
18	Pro # 18	1	0.248	0.432	279.218	20.216
19	Pro # 19	1	0.561	0.496	288.152	92.609

The current simulation time was 27,000 seconds, a total working time of one day in the lasting department. In this study, a period of one working day was taken. The total number of products produced for the current simulated system are 699 units/day, which are the same as the current system produced / day, i.e., 700 units. The average time for one unit in a system is 382.671, which includes the average waiting time of one unit in all operations. The standard deviation is 85.031 units, and the minimum and maximum time for the unit to remain in the system was 261.248 and 659.109 seconds, respectively.

The queue data of the first station is labeled as "1 QUEUE", in Table 1, under the file number column, which has all the information about the unit's waiting at the first station. The average number of units waiting at station 1 is 0.574, with a standard deviation of 1.040 units, as shown in Table 1. The maximum number of units waiting at the first station is six, and the number of units in station 1 at the end of the simulation is 2. Therefore, the average waiting time for the product in the first station is 21.776 seconds. Similarly, it shows all the information for each station. The average number of units waiting at station 8 is 1.497, the maximum number of average waiting units for the whole process. The maximum number of units waiting at station 8 is ten, and the number of units in station 8 at the end of the simulation is 1. The average waiting time for the units at station 8 is 57.250 seconds. Hence, Station 8 is the bottleneck process. These are the results of the current system of the lasting department. At all stations, there is one server that performs the specific operation. Process number 8 has the worker's maximum productivity, 84.4%, and worker at workstation number 12 has minimum productivity, which is 10%. The values in the maximum idle time and maximum busy time refer to the maximum length of the server's idle period and busy period. The detail of the current system costing is shown in Table 2.

Two plans were proposed to improve the current system. In proposed plan I and II, those workstations were combined whose sum of cycle time is less than or equal to the bottleneck of the workstation [27]. A combination of all these workstations was possible without affecting precedence requirements. This way, the total workstations are reduced from 19 to 14 in proposed plan I and 12 in proposed plan II. Proposed plans I and II have no effect on the process's physical orientation. The sequence of each process will remain the same for the implementation of proposed plans I and II. Table 3 shows the combined workstations and their effects on the physical orientation of the processes.

Table 2: Current system costing

Piece Rate = 0.575 PKR; Lines = 5; Workers = 19 per line; Production = 700 pcs per line			
Cost (PKR)	**Per line**	**Per day**	**Per year**
	7648	38238	13765500

Table 3: Proposed plan I and II workstations and their effects on the physical orientation of the processes

Proposed Plan I					**Proposed Plan II**					**Pro Plan I & II**
CW	**Pro**	**CT**	**S.D**	**Dist.**	**CW**	**Pro**	**CT**	**S.D**	**Dist.**	**Effect**
1	1	24.48	2.72	N	1	1	24.48	2.72	N	No
2	2	14.29	5.25	N	2, 3	2	21.71	5.42	N	No
3, 4, 5	3	28.55	5.45	N	4, 5	3	21.13	5.28	N	No
6	4	22.12	8.29	N	6	4	22.12	8.29	N	No
7	5	14.59	2.82	LN	7	5	14.59	2.82	LN	No
8	6	32.39	1.21	LN	8	6	32.39	1.21	LN	No
9, 10	7	31.21	4.57	LN	9, 10	7	31.21	4.50	LN	No
11	8	18.45	5.53	LN	11, 12	8	22.29	5.56	LN	No
12, 13	9	21.13	3.79	N	13, 14	9	30.55	4.33	N	No
14, 15	10	26.44	2.58	N	15, 16	10	28.14	1.74	N	No
16	11	14.98	0.78	LN	17	11	15.67	3.93	LN	No
17	12	15.67	3.93	LN	18, 19	12	31.40	2.79	N	No
18	13	9.60	1.14	N			-			No
19	14	21.82	2.78	N			-			No

Key: CW – combined workstation number, Pro – process number, CT – cycle time, S.D – standard deviation, Dist. – distribution, N – Normal, LN – Log-Normal

Table 4: Results of proposed plan I

** OBSERVED STATISTICS REPORT **

Label	Mean Value	Standard Deviation	No. of Observations	Minimum Value	Maximum Value
Lasting Department	385.523	81.315	701	265.887	635.402

** FILE STATISTICS REPORT **

File Number	Label or Input Location	Average Length	Standard Deviation	Maximum Length	Current Length	Average Wait Time
1 QUEUE	Line 3	0.590	1.053	7	0	22.424
2 QUEUE	Line 5	0.002	0.040	1	0	0.062
3 QUEUE	Line 7	0.627	1.085	7	0	23.847
4 QUEUE	Line 9	0.054	0.231	2	0	2.056
5 QUEUE	Line 11	0.009	0.093	1	0	0.331
6 QUEUE	Line 13	0.924	1.192	6	1	35.249
7 QUEUE	Line 15	0.095	0.298	2	0	3.643
8 QUEUE	Line 17	0.002	0.043	1	0	0.071
9 QUEUE	Line 19	0.009	0.096	1	0	0.353
10 QUEUE	Line 21	0.043	0.204	1	0	1.661
11 QUEUE	Line 23	0.000	0.000	1	0	0.000
12 QUEUE	Line 25	0.001	0.027	1	0	0.029
13 QUEUE	Line 27	0.000	0.000	1	0	0.000
14 QUEUE	Line 29	0.009	0.096	1	0	0.359

** SERVICE ACTIVITY STATISTICS REPORT **

Activity Number	Label or Input Location	Server Capacity	Productivity	Standard Deviation	Maximum Idle Time or Servers	Maximum Busy Time or Servers
1	Pro # 01	1	0.638	0.480	273.298	654.495
2	Pro # 02	1	0.361	0.480	279.673	53.200
3	Pro # 03	1	0.742	0.438	254.754	1474.676
4	Pro # 04	1	0.584	0.493	253.310	251.560
5	Pro # 05	1	0.384	0.486	249.791	52.525
6	Pro # 06	1	0.848	0.359	191.178	1567.911
7	Pro # 07	1	0.815	0.388	193.983	587.995
8	Pro # 08	1	0.488	0.500	203.388	58.606
9	Pro # 09	1	0.547	0.498	208.383	76.218
10	Pro # 10	1	0.689	0.463	217.047	201.035
11	Pro # 11	1	0.390	0.488	245.402	17.895
12	Pro # 12	1	0.411	0.492	261.811	50.312
13	Pro # 13	1	0.250	0.433	273.581	13.441
14	Pro # 14	1	0.564	0.496	284.217	90.426

The network modeling of the proposed plan I and II is shown in Appendix - B (Figures II & III), respectively, and the results of proposed plans I and II are shown in Tables 4 and 5.

In the proposed plans I and II, the simulation time is the same as the current system, i.e., 27,000 seconds. The total number of units that were produced in I day in the simulated model is 701 units in proposed plan I and 716 units in proposed plan II. The current system and proposed plan I produced almost the same output, i.e., 700 and 701, respectively. Proposed plan I, however, had the same production, with less input than the current system. The current system produced 700 pieces per line using 19 workers, whereas the proposed plan I produced the same output, i.e., 701 parts per line with the usage of 14 workers. The average time for I unit in a system is 385.523 seconds. In proposed plan II, the number of units produced would be 716 pieces per line, 16 more per line than those produced by the current system. Proposed plan II had more output with less input than the current system. The current system produced 700 pieces per line using 19 workers, whereas the proposed plan II produced more output, i.e., 716 pieces per line with 12 workers. The average time for one unit in a system is 426.819 seconds. The detail of proposed plans I and II and the costing is shown in Table 6.

Table 5: Results of proposed plan II

** OBSERVED STATISTICS REPORT **					
Label	**Mean Value**	**Standard Deviation**	**No. of Observations**	**Minimum Value**	**Maximum Value**
Lasting Department	426.819	126.781	716	262.770	833.694

** FILE STATISTICS REPORT **						
File Number	**Label or Input Location**	**Average Length**	**Standard Deviation**	**Maximum Length**	**Current Length**	**Average Wait Time**
1 QUEUE	Line 3	0.701	1.378	10	0	25.745
2 QUEUE	Line 5	0.043	0.213	2	0	1.584
3 QUEUE	Line 7	0.057	0.236	2	0	2.107
4 QUEUE	Line 9	0.116	0.339	2	0	4.264
5 QUEUE	Line 11	0.018	0.136	2	0	0.677
6 QUEUE	Line 13	2.225	3.034	14	9	82.074
7 QUEUE	Line 15	0.100	0.300	2	1	3.727
8 QUEUE	Line 17	0.011	0.105	1	0	0.421
9 QUEUE	Line 19	0.187	0.359	2	0	7.015
10 QUEUE	Line 21	0.017	0.131	1	0	0.651
11 QUEUE	Line 23	0.000	0.003	1	0	0.000
12 QUEUE	Line 25	0.152	0.359	2	1	5.704

** SERVICE ACTIVITY STATISTICS REPORT **						
Activity Number	**Label or Input Location**	**Server Capacity**	**Productivity**	**Standard Deviation**	**Maximum Idle Time or Servers**	**Maximum Busy Time or Servers**
1	Pro # 01	1	0.666	0.472	160.409	968.625
2	Pro # 02	1	0.583	0.493	158.670	296.196
3	Pro # 03	1	0.571	0.495	145.312	313.474
4	Pro # 04	1	0.592	0.491	164.433	504.717
5	Pro # 05	1	0.399	0.490	168.798	125.434
6	Pro # 06	1	0.866	0.341	141.648	3625.131
7	Pro # 07	1	0.834	0.372	149.885	1162.290
8	Pro # 08	1	0.597	0.490	182.273	104.060
9	Pro # 09	1	0.821	0.383	203.342	992.347
10	Pro # 10	1	0.748	0.434	235.741	170.138
11	Pro # 11	1	0.413	0.492	264.502	47.223
12	Pro # 12	1	0.832	0.374	283.523	919.746

Table 6: Proposed plan I and II costing

Proposed Plan I		**Proposed Plan II**	
Piece Rate	0.575 PKR	Piece Rate	0.575 PKR
Workers	14 per line	Workers	12 per line
Production	701 pcs per line	Production	716 pcs per line
Lines	5	Lines	5
Cost (PKR)		**Cost (PKR)**	
Per line	5463	Per line	4940
Per day	28215	Per day	24702
Per year	10157490	Per year	8892720
Current system (per year)	13765500	Current system (per year)	13765500
Saving per year	**3608010**	**Saving per year**	**4872780**

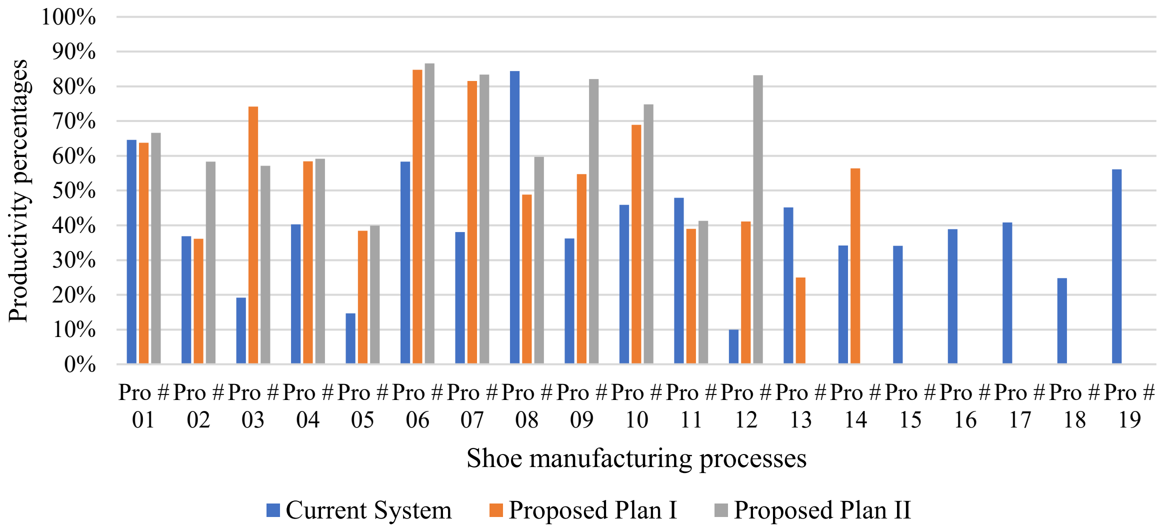

Fig. 3: Bar chart of productivity of the current system and proposed plans

Table 7 (a): Two-sample T-test for current system vs. proposed plan I

	N	Mean	StDev	SE Mean
Current system	19	40.5	17.6	4.0
Proposed plan I	14	55.1	18.1	4.8

Difference = mu (Current System) - mu (Proposed Plan I)

Estimate for difference: -14.61

95% CI for difference: (-27.54, -1.67)

T-Test of difference = 0 (vs not =): T-Value = -2.32 P-Value = 0.028 DF = 27

Table 7 (b): Two-sample T test for current system vs proposed plan II

	N	Mean	StDev	SE Mean
Current system	19	40.5	17.6	4.0
Proposed plan II	12	66.0	16.2	4.7

Difference = mu (Current System) - mu (Proposed Plan II)

Estimate for difference: -25.54

95% CI for difference: (-38.25, -12.83)

T-Test of difference = 0 (vs not =): T-Value = -4.14 P-Value = 0.000 DF = 25

The values in the maximum idle time and maximum busy time refer to the maximum length of the server's idle period and busy period. The bar chart of the productivity of the current system and the proposed plans I and II is shown in Fig. 3. Two-Sample T-Test was performed to compare current system productivity to the proposed plans I and II. The results are shown in Table 7 (a) & (b).

Comparing the current system to the proposed plan I, the P-Value was 0.028 (2.8 %), i.e., less than 5%, which shows that there is a significant difference between the current system productivity and the productivity of proposed plan I. Finally, comparing the current system and the proposed plan II, the P-Value was 0.000 (0 %), i.e., less than 5%, which shows that there is a significant difference between the current system productivity and the productivity of proposed plan II. The boxplot of productivity for current system and proposed plans I and II are shown in Fig. 4a and 4b. After successful implementation of either proposed plan I or proposed plan II, proposed plan III (scenario I or II) can be implemented for further improvements in the lasting department.

In the current system, there are five lines in the lasting department producing 700 pieces per

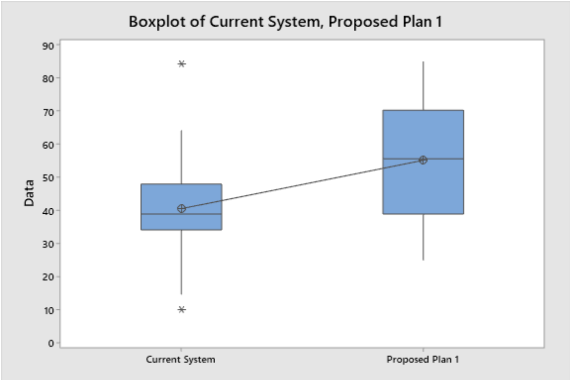

Fig 4(a): Boxplot of productivity for current system v/s proposed plan I

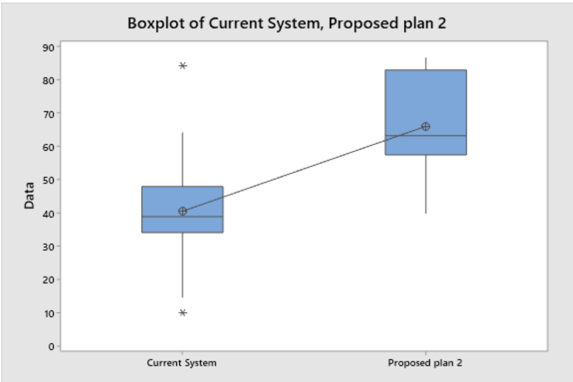

Fig 4(b): Boxplot of productivity for current system v/s proposed plan II

line and 3,500 pieces per day were produced. It is the current system production with a usage of 95 workers; the total number of workers in one line was 19. By implementing the proposed plan I, every line produces the same output with less input, i.e., with 14 workers per line instead of 19 per line. Similarly, the total workforce utilized in proposed plan one would be 70 (14 workers per line) instead of 95. The remaining workforce would be used in the proposed plan III (scenario I). Therefore, plan III (scenario I) can be implemented if the proposed plan I is implemented. In proposed plan III (scenario I), one more line would be added, resulting in 6 total lines, producing 4,206 pieces per day instead of 3,500 pieces per day with - a difference of 706 pieces without hiring any new workforce.

By implementing proposed plan II, every line produces the 716 (excess of 16 pieces) output with less input, i.e., 12 workers per line instead of 19 per line. As a result, the total number of workforces utilized in proposed plan II would be 60 (12 workers per line) instead of 95. The remaining workforce would be used in the proposed plan III (scenario II). Therefore, plan III (scenario II) can be implemented if proposed plan II is implemented. In proposed plan III (scenario II), two lines would be added, resulting in a total of 7 lines, producing 5,012 pieces per day instead of 3,500 pieces per day - a difference of 1,512 pieces without hiring any new workforce. The cost detail of proposed plan III (scenarios I and II) is shown in Table 8.

The lasting department depends on the production of the closing department, which is the internal supplier of the lasting department. The closing department sends 3,500 pieces per day. Now, if new lines were added in the lasting department, the closing department must increase its production. Similarly, the closing department depends on the production of the cutting department, and the cutting department relies on the supply of materials from the suppliers.

Therefore, the lasting department production in proposed plan III (scenarios I and II) could only be increased if the production of previous departments could also be increased. The tabular summary of the proposed plan III (scenarios I and II) is shown in Table 9.

Table 8: Proposed plan III (scenarios I & II) costing

Proposed Plan III			
Scenario I		**Scenario II**	
Piece Rate	0.575 PKR	Piece Rate	0.575 PKR
Workers	14 per line	Workers	12 per line
Lines	6	Lines	7
Production	701 pcs per line	Production	716 pcs per line
Cost (PKR)		**Cost (PKR)**	
Per line	5643	Per line	4940
Per day	33858	Per day	34583
Per year	12188988	Per year	12449808
Current system (per year)	13765500	Current system (per year)	13765500
Saving per year	1576512	Saving per year	1315692

Table 9: Summary of proposed plan III (scenario I & II)

Lasting Department					
Current System		**Proposed Plan III**			
		Scenario I		**Scenario II**	
No. of lines	5	If same = 5	6	If same = 5	7
Workstations	19	14	14	12	12
Crews/ Workers	19	14	14	12	12
Total Workforce	95	70	84	60	84
Production	3500 pcs / day	3500 pcs / day	4200 pcs / day	3580 pcs / day	5012 pcs / day
Arrival Rate	No Change	No Change	Change	Change	Change
Initial Cost	No	No	Yes	Yes	Yes

Proposed plan I is selected for the time being because it improved productivity and met the one-day production targets with minimum input. The annual cost saving of proposed plan I would be PKR 3,608,010. In the long term, the firm would focus on implementing plans II and III as they will take time. Also, additional capital in proposed plan III (scenarios I and II) is required to purchase the equipment. Therefore, the annual cost saving for proposed plan II after implementation would be PKR 4,872,780, PKR 1,576,512 for proposed plan III (scenario I), and PKR 1,315,692 for proposed plan III (scenario II).

The purpose of selecting proposed plan I now is that it is easy to shift the current system to one and has a short-term time horizon for implementation. Also, no initial investment is required for implementation. It achieves the current system objectives with less input, i.e., 14 workers instead of 19. So, after the successful implementation of plan I, the firm should move from proposed plan I to II. Similarly, when the firm fully adopts and sustains proposed plan II, it should move to proposed plan III. It follows the philosophy of "Kaizen" to make small continuous improvements [28].

4. Conclusion

The organization's current system faced many problems like low productivity and irregular flow of shoe pieces. These problems would be overcome after the successful implementation of the proposed plans. Production of the lasting department is optimized with the help of process simulation. A total of three proposed plans were developed to optimize the current system. In the proposed plan, I and II workstations are combined. The workstations are combined based on their cycle time [27]. All Proposed plans do not affect the physical orientation of the processes, so there is no need to develop a whole new system to change the orientation of the processes. The combination of the workstations meets precedence requirements.

In proposed plan III (Scenario I), one line is added to the lasting department to increase production from 3500 pcs /day to 4206 pcs /day. The annual cost saving for scenario I is 1,576,512 RPs /year. In proposed plan III (Scenario II), the two lines are added to the lasting department, increasing the production from 3500 pcs /day to 5012 pcs /day. The annual cost saving for scenario 2 is 1,315,692 RPs /year. Production capacity, better utilization of resources, and smooth flow of the shoe pieces are achieved after implementing the proposed plan. So, it is better for the company firstly to shift from the current system to plan I as it is not required any initial investment and achieves its objective, for example, the same output with less input (with less than five workers) when plan I is sustained, and objectives are met then organization should move from plan I to plan II.

And similarly, when an organization fully adopts and sustains plan II, it should consider plan III. According to the theory of "Kaizen," they make small improvements, sustain them and move on for further improvement. In this way, it would not be a burden on the organization. It would seem attractive and practical to the organization to move successively from plan I to plans II and III because, in the first step, there will be no initial investment and, utilization of the workforce will improve, production will be smooth. After successfully implementing plan I, the organization willingly moves towards plans II and III. This study is focused on lasting department only. This study did not accommodate the other department processes, the flow of shoe pieces, and productivity.

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APPENDIX - A

Table I: Data collection & analysis of each process

Sr. #	Pro	CT	S.D	P Value	Dist.	Sr. #	Pro	CT	S.D	P Value	Dist.
1	Pro # 01	24.48	2.72	18.3%	N	11	Pro # 11	18.45	5.53	2.5%	LN
2	Pro # 02	14.29	5.25	18.2%	N	12	Pro # 12	3.84	0.64	2.5%	LN
3	Pro # 03	7.42	1.37	38.4%	N	13	Pro # 13	17.29	3.49	1.4%	LN
4	Pro # 04	15.53	5.43	4.7%	LN	14	Pro # 14	13.27	1.87	2.5%	LN
5	Pro # 05	5.60	0.69	71.8%	N	15	Pro # 15	13.17	1.66	30.7%	N
6	Pro # 06	22.12	8.29	26.8%	N	16	Pro # 16	14.98	0.78	1.5%	LN
7	Pro # 07	14.59	2.82	1.6%	LN	17	Pro # 17	15.67	3.93	0.5%	LN
8	Pro # 08	32.39	1.21	0.5%	LN	18	Pro # 18	9.60	1.14	7.4%	N
9	Pro # 09	13.89	2.41	38.3%	N	19	Pro # 19	21.82	2.78	0.457	N
10	Pro # 10	17.32	4.07	25.7%	N						

Key: Pro – Process, CT – Cycle Time *(Seconds)*, S.D – Standard Deviation, Dist. – Distribution, N – Normal, LN – Log-Normal

APPENDIX - B

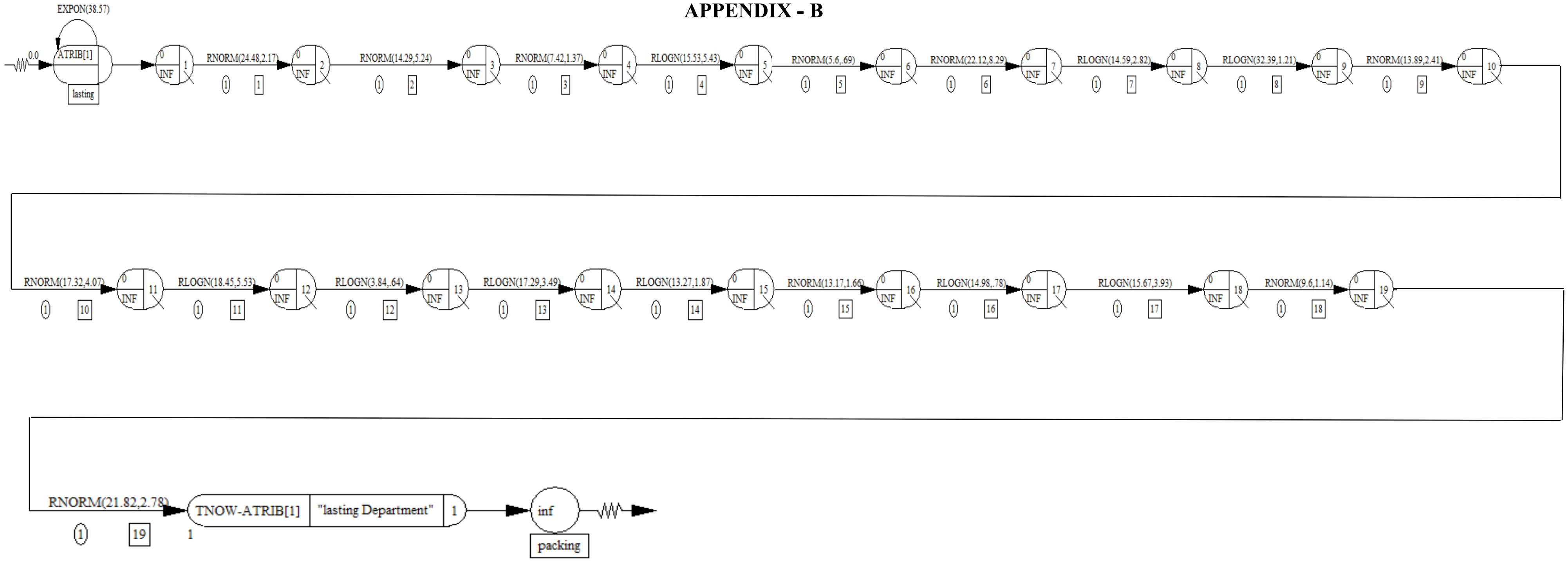

Fig I: Network modeling of the current system

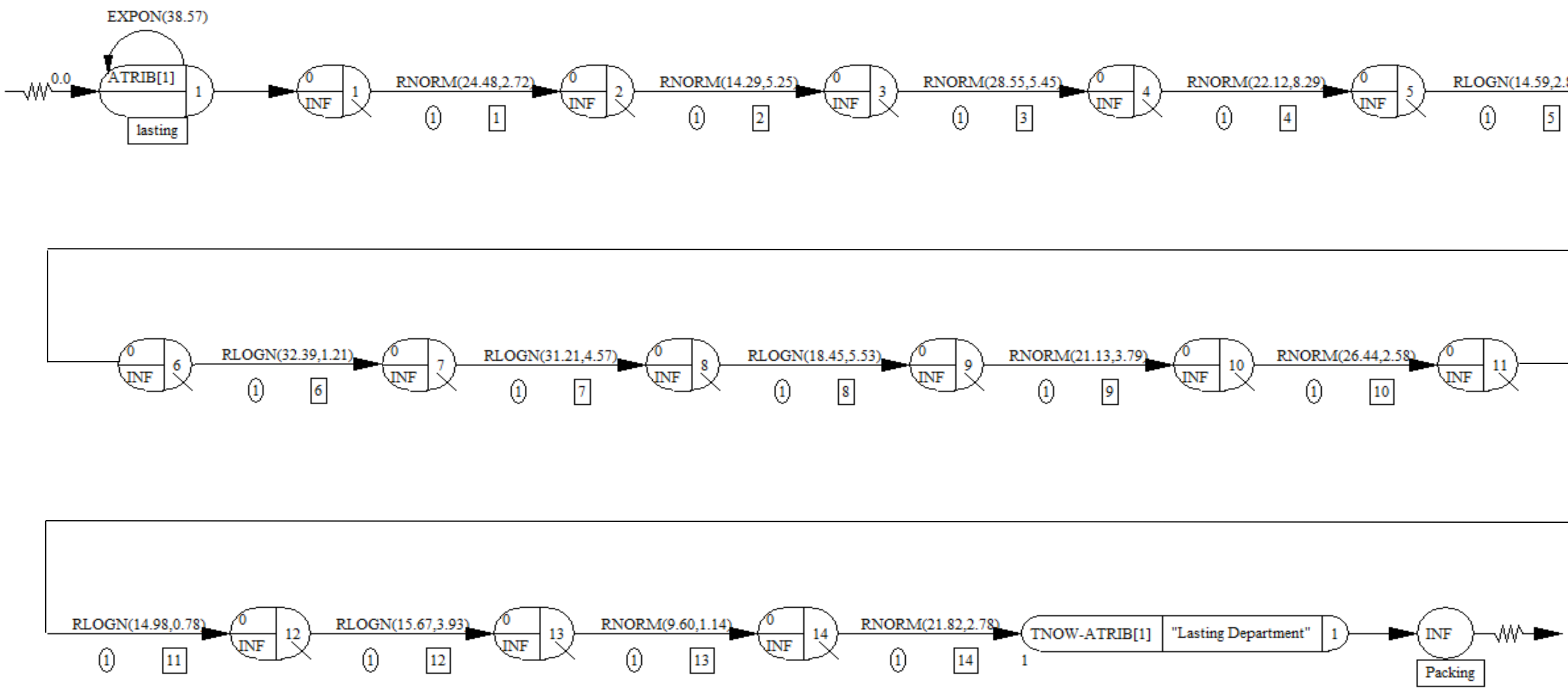

Fig II: Proposed plan I network modeling

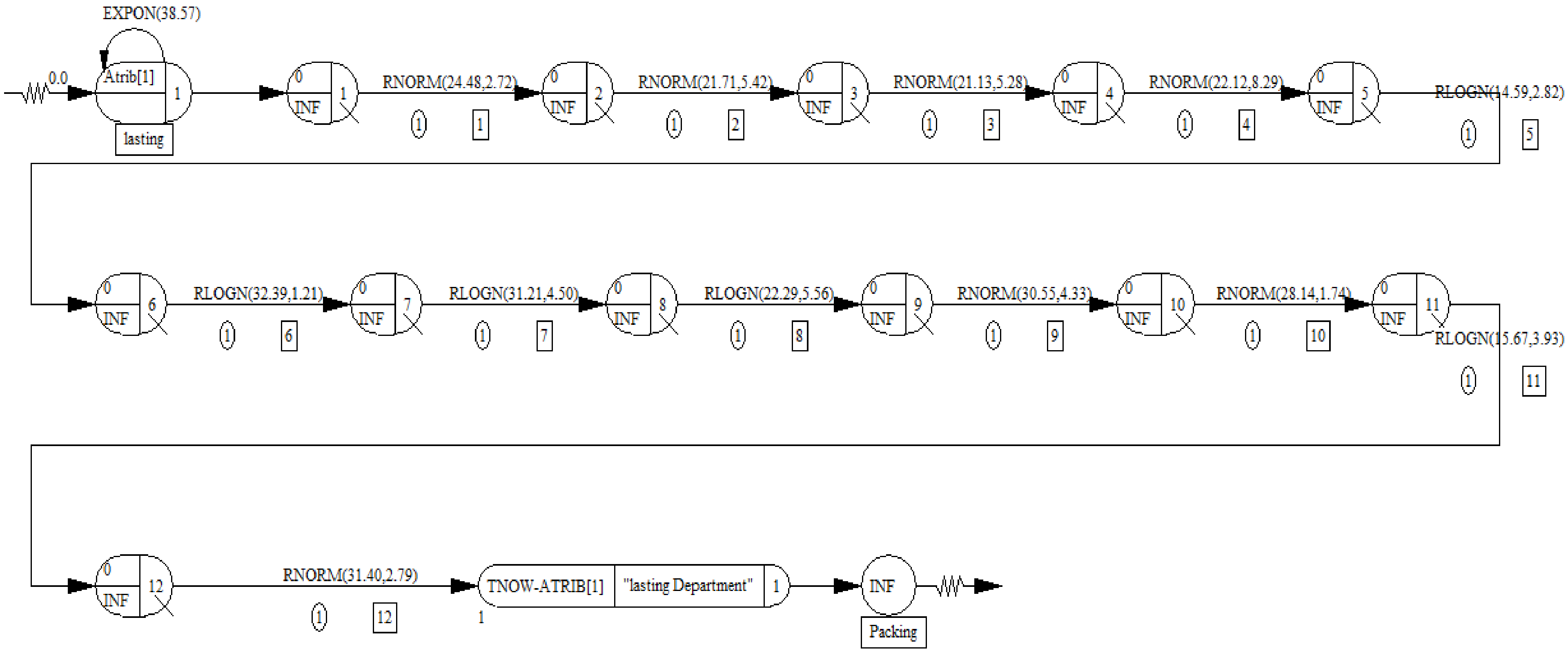

Fig III: Proposed plan II network modeling