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The Design of a Novel Bearing Manufacturing Line Based on Simulation

Abeshek Ram Natarajan

Department of Mechanical Engineering, SSN College of Engineering, Chennai, India
Email: abeshek13001@mech.ssn.edu.in

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Abstract

This paper is a case study of the production line at an automotive ancillary manufacturing plant. At first, the production line is studied for possible areas of improvement. Time study data are collected for each process and the best set-up is calculated to make the plant leaner. Furthermore, suggestions are made to procure machines from the market that make the plant leaner and more efficient. To make the suggestions indubitable, a time study calculation is done for the new machine layout.

Keywords

Production Line, Simulation, GPSS, Throughput

1. Introduction

Kaizen-Continuous improvement is the essence of successful manufacturing industries worldwide. There always exist some scopes for improvement in the company, hence efforts to improve should never be allowed to cease. The manufacturing industry is a major contributor to the growth of the Indian economy. Also, amongst the manufacturing industries, it is the automotive industry that contributes a larger percent. Despite having continued this trend for decades, the automotive industry still faces the difficulty of improving production. When the automotive industry is only predicted to grow from here, it is only obvious that its contribution to India's GDP will increase. However, this also means that the country's reliance on the industry will increase. Therefore, in this age of price competitiveness, it is important to avoid the company's profit slip due to the inability to produce parts on time. Hence, efficient balancing of the production line is of utmost importance. This paper uses simulation approach to effectively improve the output rate of the plant to satisfy the production goal of a bearing manufacturing company.

2. Literature Review

This section reviews literature of simulation approach for improving the productivity of different production/service systems.

Panneerselvam and Veerapandian [1] considered the simulation of a season ticket issue counter of a transport organization at Chennai. They analyzed the behavior of male queues and female queues at different time intervals (one hour interval) from 3 P.M. to 8 P.M. and suggested to operate variable number of counters depending on the estimated queue length. The simulation logic has been implemented in FORTRAN language. Senthilkumar [2] developed an algorithm for multiple AGVS (Automated Guided Vehicle System) scheduling, which uses Floyd's algorithm as a subroutine to find the shortest distance between any pair of nodes in the distance network of the shop floor where the AGVs operate. This uses simulation approach to sample the demand points. The simulation logic has been implemented in Basic language. Panneerselvam and Senthilkumar [3] developed a text book titled 'System Simulation, Modeling and Languages', which presents several practical examples and case studies where the simulation approach can be used. The examples cover applications in shop floors and service systems using high level languages, GPSS (General Purpose Simulation System), Arena, etc, which is instrumental in understanding the use of GPSS. Gordon Geoffrey [4] and Jerry Banks [5] gave the concept of simulation and introduce different simulation languages. Furthermore, Panneerselvam [6] [7] gave a brief introduction to simulation and presented case studies which have been essential to learning the method of simulation. Moreover, Scriber [8] gave a complete account of GPSS covering all the blocks. Khalili and Zahedi [9] presented a simulation model for a mattress production line using Promodel simulation software. They analyzed the existing system and modified the system using simulation to cope with the demand of mattress for the next five years. Gingu and Zapciu [10] considered a layout design problem and obtained bottleneck locations using simulation to obtain a revised cellular layout.

The literature presented above justifies the need of simulation in industries and also presents foundations of the simulation approach. In this paper, the application of the simulation approach using GPSS to improve the throughput of a production line manufacturing a bearing is presented.

3. Problem Identification

The output of the line manufacturing an engine thrust bearing is unable to meet the demand of its customers. Moreover, the line supervisor is not convinced about the optimality of the lot size that is fixed while producing the bearing. The process times of different operations of the production line of the bearing are probabilistic. Hence, in this paper, an attempt has been made to simulate the production for the existing layout of the production line. After an analysis of the results about the average waiting time and average waiting number of jobs before different operations of the production line, another simulation model is to be constructed again to minimize the time taken which will improve the production volume of the line.

4. Data Collection

This section presents data that are collected from the production line of the bearing (job). The inter-arrival time of the job to the first machine of the line follows uniform distribution with a mean of 6.79 sec and a half width of 0.375 sec.

The different machines/operations of the production line manufacturing engine thrust bearings as per their sequence to manufacture that product are shown in Table 1. The processing time of each of the facilities shown in the Table 1 follows uniform distribution. The parameters of the uniform distribution of the processing times of the facilities are shown in Table 2. The block diagram of the facilities manufacturing the thrust bearing is shown in Figure 1.

Table 1. Machines/operations to manufacture engine thrust bearings.

Order of operation	Name of set up
1	Blanking
2	Deburring
3	Flattening
4	Grooving
5	End-chamfer
6	IDC
7	ODC
8	Grinding
9	Vibro-finishing
10	Flattening
11	Washing
12	Packing

Table 2. Processing times of facilities.

Name of the facility	Parameters of uniform distributions (A ± B)	
	Mean(seconds)	Half-width(seconds)
Blanking	1.5	±0
Deburring	1.5	±0
Flattening	7	±0
Grooving	5	±0.2
End-Chamfer	5	±0.2
IDC	9	±1
ODC	10	±1
Grinding	20	±0.2
Vibro-Finishing	15	±1
Flattening	2	±0.2
Washing	2	±0.2
Packing	3.5	±0.5

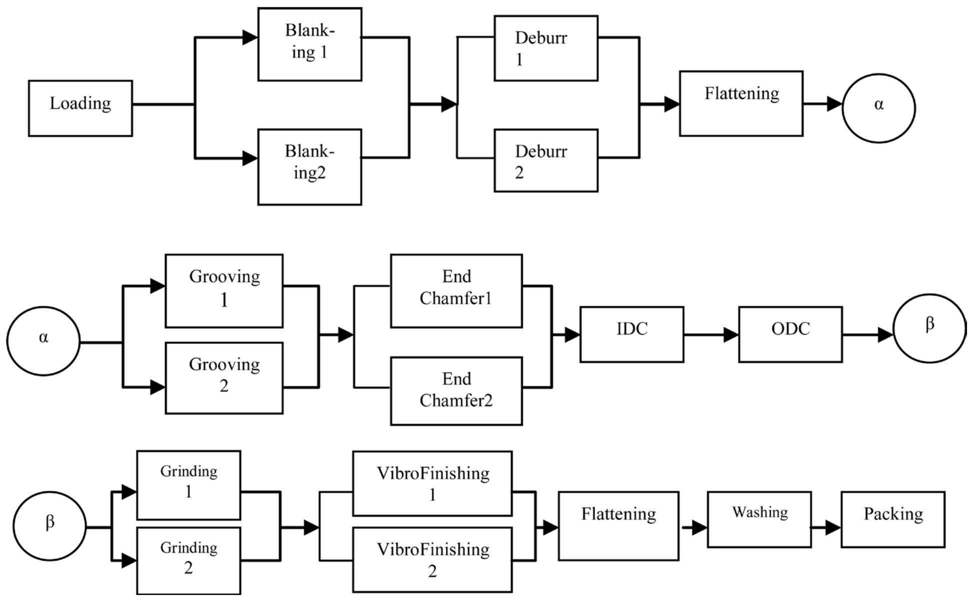


Figure 1. Block diagram of facilities manufacturing engine thrust bearings.

5. GPSS Simulation Model for Existing System

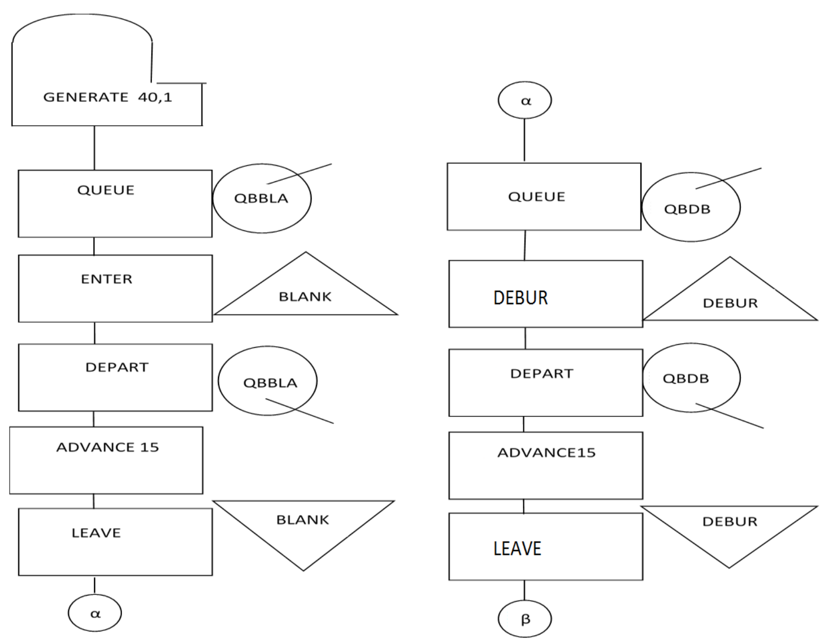
The inter-arrival time at the first operation of the bearing line as well as the processing time of each operation follows uniform distribution. Hence, use of empirical formula to obtain the standard results, viz. average waiting time of the job in front of each operation of the production line, the average waiting number of jobs bearings waiting in front of each operation of the production line and the percentage utilization of the operations, cannot be used. Therefore, the last resort to obtain such results of the production line is the use of simulation, which can provide these results. This section gives the simulation of the existing system whose particulars are shown in Table 1, Table 2 and Figure 1. The legends used in Figure 3 are shown in Figure 2. The GPSS block diagram to simulate production system considered in this paper is shown in Figure 3. The Figure 4 gives the timer segment. The corresponding GPSS program is shown in Figure 5. This contains the names of the GPSS blocks required to simulate the system shown in Figure 3. The simulation model is run for 80 hours, which is 288,000 seconds.

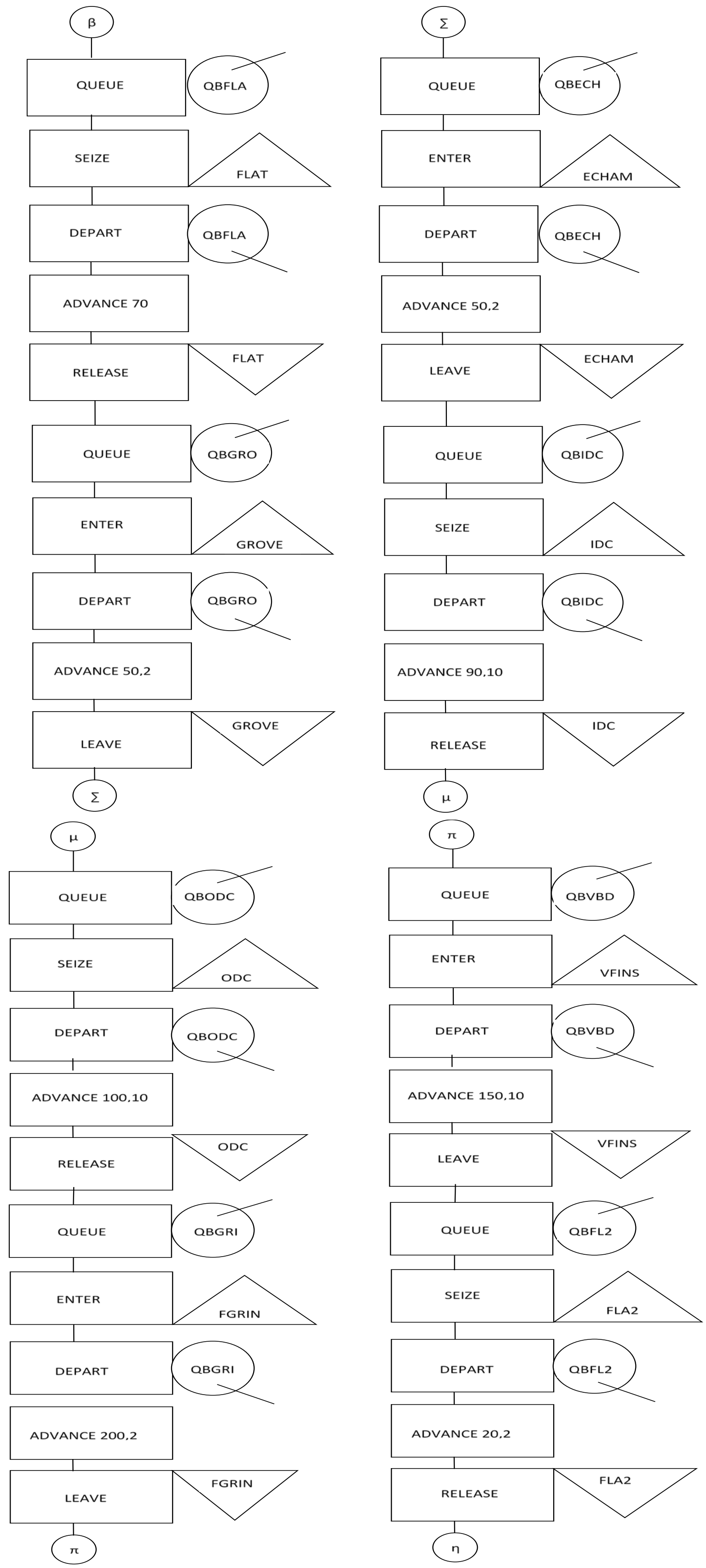
Result of Simulation

The execution of the GPSS program in Figure 5 gives these results for selected facilities and the corresponding queues are shown in Table 3 and Table 4. From Table 3, the number of transactions passing through the "packaging block", which corresponds to the last operation of the production line manufacturing the bearing, gives the production volume of the production line, which is 2870 units. From Table 4, it is clear that the maximum average waiting time per transaction is 1542.107 seconds for the facility "flattening". If the processing time for the operation on this facility is reduced by installing one more facility of the same type in parallel, the average waiting time per transition at this stage can be minimized. The next section discusses the improved system.

Symbols	Function
GENERATE	Jobs are generated as per a defined probability distribution
QUEUE	Adds the job into the queue
ENTER	Makes an attempt to check whether at least one of the facilities is free
DEPART	When a facility becomes free, the job moves from the queue and enters the facility for service
ADVANCE	Increments the clock time by the service time required for the job
LEAVE	Frees a facility our of parallel servers
SEIZE	Makes an attempt to capture the facility for a job to be done
RELEASE	Makes an attempt to free the facility after job is done
	Adds a customer into the queue
	Removes a customer from a the queue
	Connector of flow chart
TERMINATE	Sends the job out of the production line

Figure 2. Legend for the given flowchart




β
QUEUE
QBFLA
SEIZE
FLAT
DEPART
QBFLA
ADVANCE 70
RELEASE
FLAT
QUEUE
QBGRO
ENTER
GROVE
DEPART
QBGRO
ADVANCE 50,2
LEAVE
GROVE
Σ
Σ
QUEUE
QBECH
ENTER
ECHAM
DEPART
QBECH
ADVANCE 50,2
LEAVE
ECHAM
QUEUE
QBIDC
SEIZE
IDC
DEPART
QBIDC
ADVANCE 90,10
RELEASE
IDC
μ
μ
QUEUE
QBODC
SEIZE
ODC
DEPART
QBODC
ADVANCE 100,10
RELEASE
ODC
QUEUE
QBGRI
ENTER
FGRIN
DEPART
QBGRI
ADVANCE 200,2
LEAVE
FGRIN
π
π
QUEUE
QBVBD
ENTER
VFINS
DEPART
QBVBD
ADVANCE 150,10
LEAVE
VFINS
QUEUE
QBFL2
SEIZE
FLA2
DEPART
QBFL2
ADVANCE 20,2
RELEASE
FLA2
η

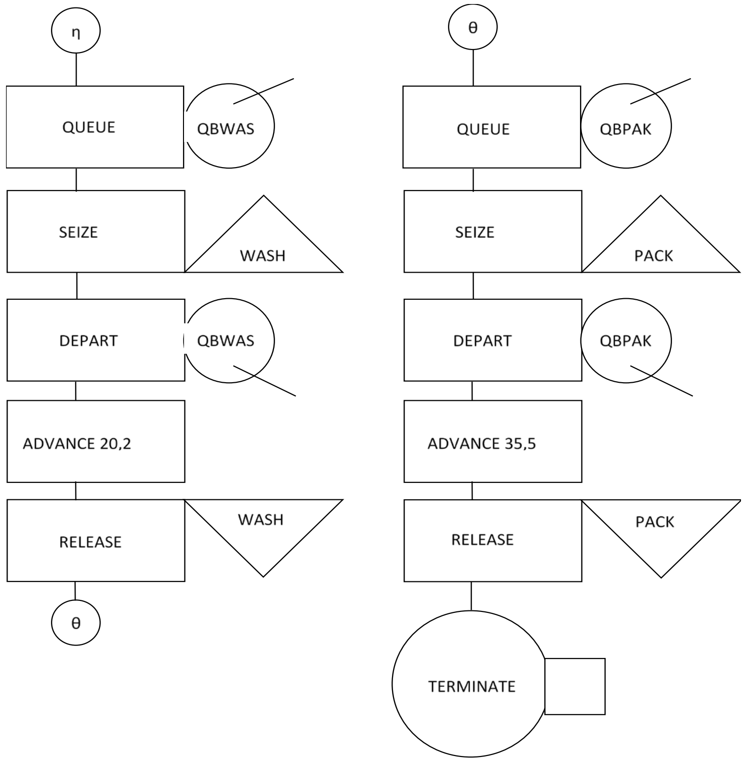


Figure 3. Main model segment.

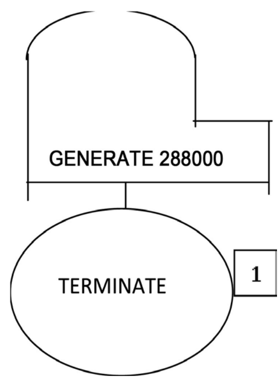


Figure 4. Timer diagram.

6. Simulation of an Improved System

The revised block diagram of the production line after incorporating a parallel facility for the first "flattening" stage is shown in Figure 6. The GPSS program for the revised system is shown in Figure 7. The execution of the GPSS program shown in Figure 7 gives the results for selected facilities and the corresponding queues are shown in Table 5 and Table 6. From Table 5, the number of transactions passing through the "packaging block", which corresponds to the last operation of the production line manufacturing the bearing, gives the production volume of the production line, which is 6377 units. From Table 6, it is clear that the maximum average waiting time per transaction is 390.479 seconds for the facility 'ID chamfering'. The revised design of the line manu-

```
1 BLANK    STORAGE    2
2 DEBUR    STORAGE    2
3 GROVE    STORAGE    2
4 ECHAM    STORAGE    2
5 FGRIN    STORAGE    2
6 VFINS    STORAGE    2
7          GENERATE   40
8          QUEUE      QBBLA
9          ENTER      BLANK
10         DEPART     QBBLA
11         ADVANCE    15
12         LEAVE      BLANK
13         QUEUE      QBDB
14         ENTER      DEBUR
15         DEPART     QBDB
16         ADVANCE    15
17         LEAVE      DEBUR
18         QUEUE      QBFLA
19         SEIZE      FLAT
20         DEPART     QBFLA
21         ADVANCE    70
22         RELEASE    FLAT
23         QUEUE      QBGRO
24         ENTER      GROVE
25         DEPART     QBGRO
26         ADVANCE    50,2
27         LEAVE      GROVE
28         QUEUE      QBECH
29         ENTER      ECHAM
30         DEPART     QBECH
31         ADVANCE    50,2
32         LEAVE      ECHAM
33         QUEUE      QBIDC
34         SEIZE      IDC
35         DEPART     QBIDC
36         ADVANCE    90,10
37         RELEASE    IDC
38         QUEUE      QBODC
39         SEIZE      ODC
40         DEPART     QBODC
41         ADVANCE    100,10
42         RELEASE    ODC
43         QUEUE      QBGRI
44         ENTER      FGRIN
45         DEPART     QBGRI
46         ADVANCE    200,2
47         LEAVE      FGRIN
48         QUEUE      QBVBD
49         ENTER      VFINS
50         DEPART     QBVBD
51         ADVANCE    150,10
52         LEAVE      VFINS
53         QUEUE      QBFL2
54         SEIZE      FLA2
55         DEPART     QBFL2
56         ADVANCE    20,2
57         RELEASE    FLA2
58         QUEUE      QBWAS
59         SEIZE      WASH
60         DEPART     QBWAS
61         ADVANCE    20,2
62         RELEASE    WASH
63         QUEUE      QBPAK
64         SEIZE      PACK
65         DEPART     QBPAK
66         ADVANCE    35,5
67         RELEASE    PACK
68         TERMINATE
69         GENERATE   288000
70         TERMINATE  1
```

Figure 5. GPSS program to simulate system shown in Figure 3.

Table 3. Results of facilities.

Name of facility/storage	Number of storages	Number of transactions through facility	Percentage utilization
Blanking	2	7199	18.70
Deburring	2	7199	18.70
Flattening	1	4114	100.00
Grooving	2	4113	35.70
End-Chamfering	2	4112	35.70
IDC	1	3203	99.99
ODC	1	2887	99.99
Grinding	2	2874	99.80
Vibro-finishing	2	2872	74.80
Flattening	1	2872	19.99
Washing	1	2871	19.99
Packing	1	2871	34.80

Table 4. Results of queues.

Name of queue	Average number of waiting jobs	Average waiting time(seconds)
Blanking	0	0.000
Deburring	0	0.000
Flattening	3085	1542.107
Grooving	0	0.000
End chamfering	0	0.000
ID Chamfering	908	453.756
OD Chamfering	325	162.347
Grinding	2	1.171
Vibro-finishing	0	0.000
Flattening 2	0	0.000
Washing	0	0.000
Packing	0	0.000

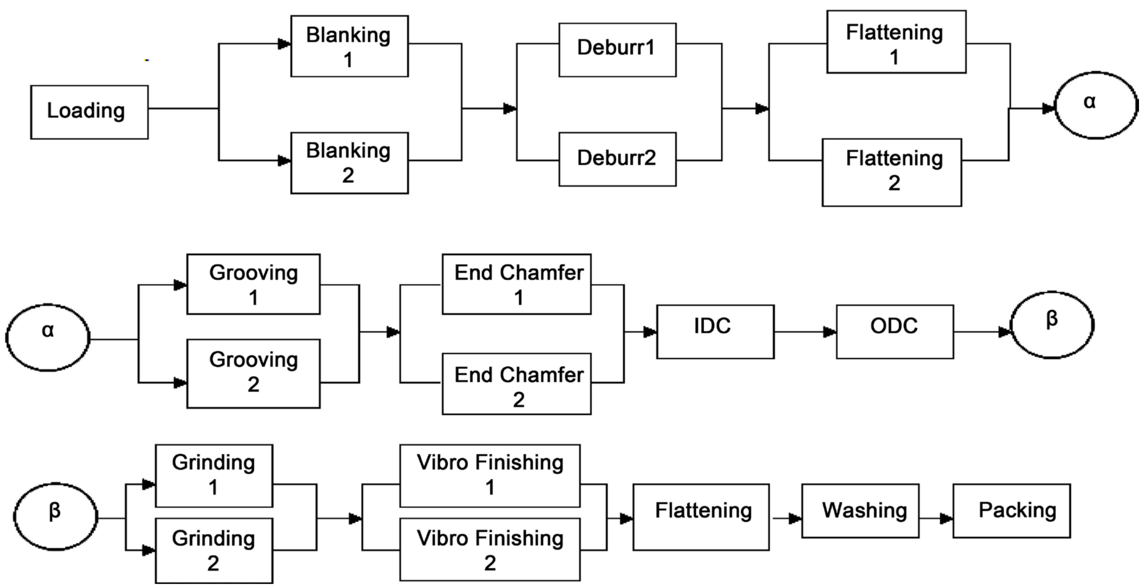


Figure 6. Improved Block diagram of facilities manufacturing engine thrust bearings.

facturing the bearing gives a tremendous improvement in the production volume from 2870 units to 6377 units.

7. Conclusion

The productivity is the key concern of any manufacturing system. In this particular line which manufactures the engine thrust bearing, the existing production volume is very low. Hence, in this paper, in the first phase, the existing system has been simulated to find the critical operation(s). Then, the existing system of production of the bearing has been modified based on the suggestions of the first phase of this study. Then the revised

```
1 BLANK    STORAGE    2
2 DEBUR    STORAGE    2
3 GROVE    STORAGE    2
4 ECHAM    STORAGE    2
5 FGRIN    STORAGE    2
6 VFINS    STORAGE    2
6.5 FLAT   STORAGE    2
7          GENERATE   40
8          QUEUE      QBBLA
9          ENTER      BLANK
10         DEPART     QBBLA
11         ADVANCE    15
12         LEAVE      BLANK
13         QUEUE      QBDB
14         ENTER      DEBUR
15         DEPART     QBDB
16         ADVANCE    15
17         LEAVE      DEBUR
18         QUEUE      QBFLA
19         ENTER      FLAT
20         DEPART     QBFLA
21         ADVANCE    40
22         LEAVE      FLAT
23         QUEUE      QBGRO
24         ENTER      GROVE
25         DEPART     QBGRO
26         ADVANCE    50,2
27         LEAVE      GROVE
28         QUEUE      QBECH
29         ENTER      ECHAM
30         DEPART     QBECH
31         ADVANCE    50,2
32         LEAVE      ECHAM
33         QUEUE      QBIDC
34         SEIZE      IDC
35         DEPART     QBIDC
36         ADVANCE    45,10
37         RELEASE    IDC
38         QUEUE      QBODC
39         SEIZE      ODC
40         DEPART     QBODC
41         ADVANCE    45,10
42         RELEASE    ODC
43         QUEUE      QBGRI
44         ENTER      FGRIN
45         DEPART     QBGRI
46         ADVANCE    60,10
47         LEAVE      FGRIN
48         QUEUE      QBVBD
49         ENTER      VFINS
50         DEPART     QBVBD
51         ADVANCE    60,10
52         LEAVE      VFINS
53         QUEUE      QBFL2
54         SEIZE      FLA2
55         DEPART     QBFL2
56         ADVANCE    20,2
57         RELEASE    FLA2
58         QUEUE      QBWAS
59         SEIZE      WASH
60         DEPART     QBWAS
61         ADVANCE    20,2
62         RELEASE    WASH
63         QUEUE      QBPAK
64         SEIZE      PACK
65         DEPART     QBPAK
66         ADVANCE    35,5
67         RELEASE    PACK
68         TERMINATE
69         GENERATE   288000
70         TERMINATE  1
```

Figure 7. GPSS program for improved system involving adding of new IDC, ODC, Grinding, and Vibro-finishing machines.

Table 5. Results of facilities.

Name of facility/storage	Number of storages	Number of transactions through facility	Percentage utilization
Blanking	2	7200	18.70
Deburring	2	7199	18.70
Flattening	2	7199	50.00
Grooving	2	7198	62.50
End Chamfering	2	7196	62.50
IDC	1	6412	99.99
ODC	1	6383	99.99
Grinding	2	6382	66.50
Vibro-finishing	2	6380	66.50
Flattening	1	6379	44.3
Washing	1	6378	44.3
Packing	1	6378	77.5

Table 6. Results of queues.

Name of queue	Average number of waiting jobs	Average waiting time (seconds)
Blanking	0	0.000
Deburring	0	0.000
Flattening	0	0.000
Grooving	0	0.000
End chamfering	0	0.000
ID Chamfering	783	390.479
OD Chamfering	28	16.439
Grinding	0	0.000
Vibro-finishing	0	0.001
Flattening 2	0	0.002
Washing	0	0.000
Packing	0	0.043

model has been simulated and it is found that the revised model gives tremendous improvement in the production volume for the engine thrust bearing line.

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