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ENHANCING MANUFACTURING INDUSTRY SCHEDULING PERFORMANCE FOR AN ELECTRONIC ASSEMBLY AND TEST SYSTEM USING ARENA SIMULATION

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ABSTRACT

Simulation is a powerful tool to investigate many production scheduling alternative solutions, helping decision maker to take right decisions for resource optimization or enhancing industry performance. Simulation offer flexibility in the production planning and scheduling. It is an easier way to build up models to represent real life scenarios and to enhance system performance. In this paper, we have used simulation to model an electronic assembly and test system. The rework process was excessively used and this leads to slow throughput. Modifications such as increasing the resource capacity or considering the machine failure situation are made to enhance the efficiency and throughput. Results show that, modifications in the sealer and rework operations provide great improvement in terms of queue statistics, utilization factors, cycle times, and number of parts produced. The Arena7.0 simulation software is used to model and simulate the considered system.

Keywords: Electronic assembly & test system, Bottleneck, Waiting time, Arena simulation

1. Introduction

Scheduling is a decision making process to arrange activities in order to meet one or more objectives. It concerns the allocation of limited resources to tasks over time. In manufacturing industries, scheduling problems are very complex in nature. The development of a mathematical model and the evaluation of the system performance are very difficult especially when the system has a stochastic nature. Many scheduling algorithms such as integer programming, dynamic programming, branch and bound, neural network, genetic algorithm, simulated annealing and other heuristic approaches have been attempted to solve the problems. However, most of these approaches consider only one criterion and generate many alternative scheduling solutions. These alternative solutions could be analyzed in detail with respect to many other performance criteria and resources. Simulation is a powerful tool to investigate all these alternative solutions and reach to a rational decision of resource optimization or enhancing manufacturing industry performance. Simulation refers to as a broad collection of analysis methods and applications to mimic the behavior of real systems, usually using computer software. Simulation has many advantages like visualization of production activities that could be clearly observed through animation and graphics before introducing in the real production system. Also, modifications can be easily incorporated in the model to gain better understanding of how the system behaves in particular conditions. Simulation has been commonly used to study the real world manufacturing system to gain better understanding of the behavior of that system for a given set of conditions to identify the underlying problems. In other words, simulation is a program that can be used to numerically evaluate the real life system' operations or characteristics over certain time [3]. A simulation model is an easier way to build up models to represent real life scenarios, to identify bottlenecks, to enhance system performance in terms of productivity, queue length, resource utilization, cycle time, lead time, etc.

In many manufacturing industries, the competitive environment has resulted in a greater emphasize on automation to improve productivity and quality. And, since the automated systems are more complex, they typically can only be analyzed by simulation. Therefore, simulation modeling is more widely applied to manufacturing systems more than any other application area [1]. However, few works consider the use of simulation modeling in industries, focusing on the analysis of production planning and control issues. Vaidyanathan et al [4] use simulation as a daily production scheduling tool in a coffee manufacturing process. Li et al. [5] developed a simulation-based-optimization technique for a hybrid flow shop. Li et al. [6] proposed a new method which couple the simulation software and the advanced meta-heuristic. Ibrahim and Ahmed [7] use simulation to study industrial problem by analyzing the capacity of resources, number of transporters and their speed. Saeheaw et al. [8] present result of implementing simulation model to design hard disk drive manufacturing process.

In this paper, we have used simulation to model an electronic assembly and test system. The system performance is analyzed and we have identified the bottleneck. Modifications such as increasing the resource capacity or considering the machine failure situation are made to enhance the efficiency and throughput of the production process. Results show that, modifications in the sealer and rework operations provide great improvement in term of queue statistics, utilization factors, time in system and number of parts produced. The Arena7.0 simulation software is used to model and simulate the considered system.

2. Electronic Assembly and Test System

In the electronic assembly system considered, the arriving parts are cast metal cases. The system studied (Fig 1) represents the final operations of the production of two different sealed electronic units [3]. Parts of type A arrive with inter-arrival times following an exponential distribution with a mean of 5 minutes, Expo (5). The part is then transferred to the Part A Prep area, where the mating faces of the cases are machined, deburred and cleaned. The processing times for the combined operations at the Part A Prep area follow a triangular distribution with parameters 1, 4 and 8 minutes, TRIA (1, 4, 8). The part is then transferred to the sealer. Produced in a different building, the parts of type B are held until a batch of four units is available. The batches arrive with inter-arrival times following an exponential distribution Expo (30). Upon arrival, the batch is separated into the four individual units, and the parts are processed individually to the Part B Prep area. As at the Part A Prep area, the processing at the Part B Prep area has the same three operations. The processing times for the combined operations at the Part B Prep area follows a triangular distribution TRIA (3, 5, 10). The part is then transferred to the sealer. At the sealer operation, the cases are assembled and sealed, and the sealed unit is tested. The total processing time for these operations depends on the part type. This total processing time follows the triangular distribution TRIA (1, 3, 4) for part of type A, and the weibull distribution WEIB (2.5, 5.3) for part of type B. 92 % of the parts pass the inspection and are sent out of the system to the shipping department. The remaining parts are transferred to the rework area, where they are disassembled, repaired, cleaned, assembled, and re-tested. The processing time for rework operations is independent to the part type and follows an exponential distribution Expo (45). At the rework area, 80 % of the parts are salvaged and transferred to the shipping department, and the remaining parts are sent to the scrap. For both parts A and B, we assume that the first arrival is at time 0 and all transfer times are negligible.
We use simulation to model this system to represent real life scenarios, to identify bottlenecks, and enhance system performance in terms queue length, resource utilization for each area and collect the cycle time for exiting parts. We will initially run the simulation for six consecutive 8-hours shifts, or 2,880 minutes.

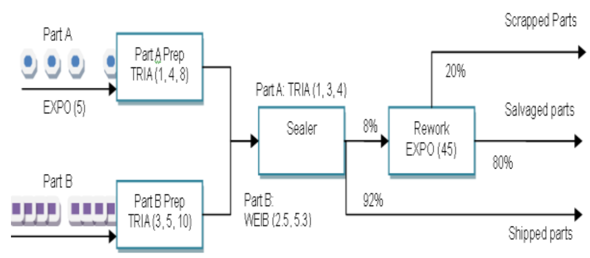


Fig. 1 Electronic Assembly & Test System

3. Modeling and Performance Evaluation

3.1. Building the Model

To generate the arriving parts, we have used two create modules, one of each part. We also have two Assign modules to define the attribute sealer time that will be assigned to the appropriate sealer processing time after the parts are generated by the create modules. When the parts are processed at the sealer operation, we will use the time contained in the sealer time attribute for processing time. Each of the two prep areas and the sealer operations will be modeled with their own process modules. We have used the decide module with the pass or failed result to an inspection performed after the sealer operations have been completed, with results in parts going to different places. The rework area will be modeled with process and decide modules, as it also has a pass or fail option. The part departure will be modeled with three separate record and dispose modules (shipped, salvaged and scrapped). The final model is shown in the following model window (Fig. 2).

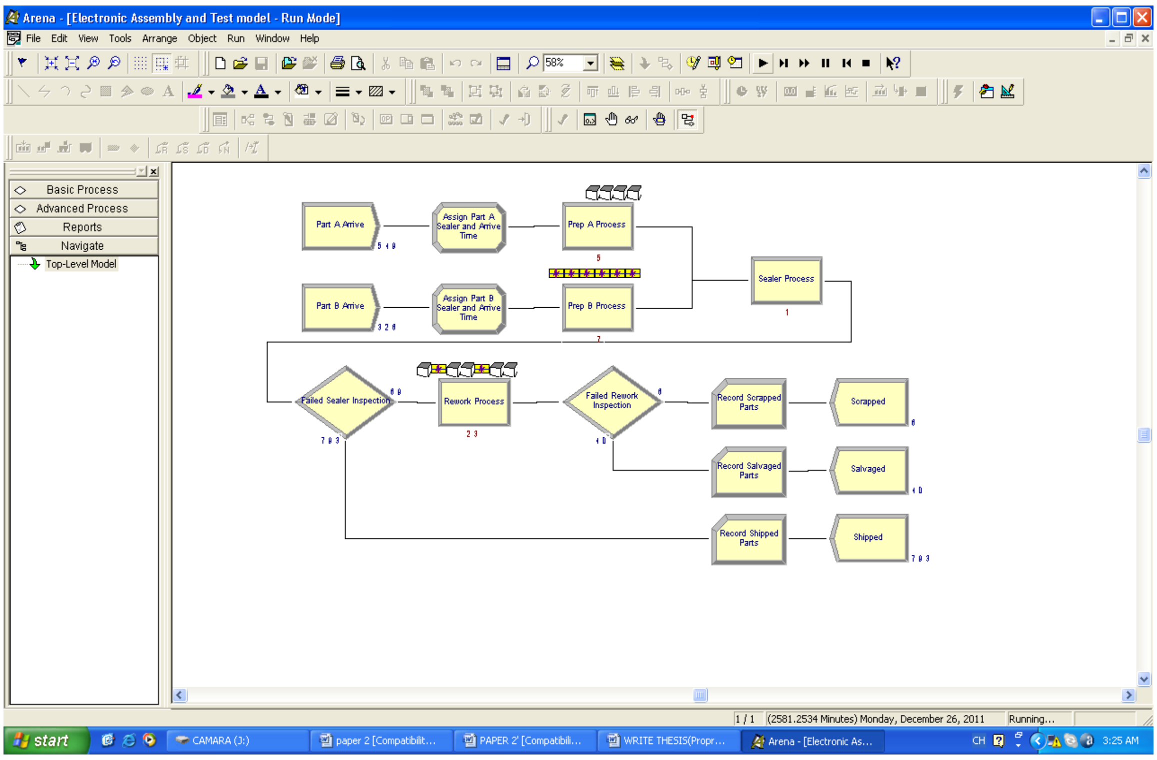
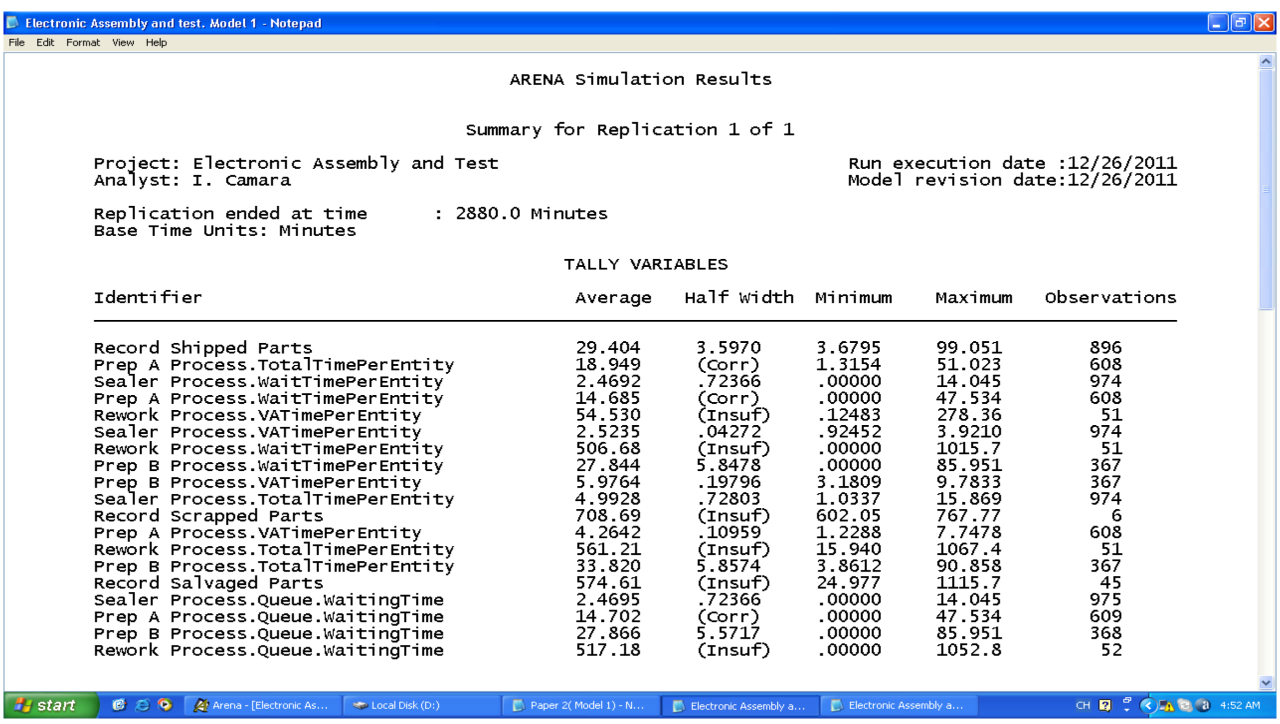


Fig. 2: Final Model for Electronic Assembly & Test System



ARENA Simulation Results

Summary for Replication 1 of 1

Project: Electronic Assembly and Test　　Run execution date :12/26/2011
Analyst: I. Camara　　Model revision date:12/26/2011

Replication ended at time : 2880.0 Minutes
Base Time Units: Minutes

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
Record Shipped Parts	29.404	3.5970	3.6795	99.051	896
Prep A Process.TotalTimePerEntity	18.949	(Corr)	1.3154	51.023	608
Sealer Process.WaitTimePerEntity	2.4692	.72366	.00000	14.045	974
Prep A Process.WaitTimePerEntity	14.685	(Corr)	.00000	47.534	608
Rework Process.VATimePerEntity	54.530	(Insuf)	.12483	278.36	51
Sealer Process.VATimePerEntity	2.5235	.04272	.92452	3.9210	974
Rework Process.WaitTimePerEntity	506.68	(Insuf)	.00000	1015.7	51
Prep B Process.WaitTimePerEntity	27.844	5.8478	.00000	85.951	367
Prep B Process.VATimePerEntity	5.9764	.19796	3.1809	9.7833	367
Sealer Process.TotalTimePerEntity	4.9928	.72803	1.0337	15.869	974
Record Scrapped Parts	708.69	(Insuf)	602.05	767.77	6
Prep A Process.VATimePerEntity	4.2642	.10959	1.2288	7.7478	608
Rework Process.TotalTimePerEntity	561.21	(Insuf)	15.940	1067.4	51
Prep B Process.TotalTimePerEntity	33.820	5.8574	3.8612	90.858	367
Record Salvaged Parts	574.61	(Insuf)	24.977	1115.7	45
Sealer Process.Queue.WaitingTime	2.4695	.72366	.00000	14.045	975
Prep A Process.Queue.WaitingTime	14.702	(Corr)	.00000	47.534	609
Prep B Process.Queue.WaitingTime	27.866	5.5717	.00000	85.951	368
Rework Process.Queue.WaitingTime	517.18	(Insuf)	.00000	1052.8	52

Fig. 3: SIMAN Summary Report for Electronic Assembly & Test System

3.2 Performance Evaluation

After the model run to completion, Arena produce a very compact report to our simulation results called SIMAN summary report as shown in Fig. 3

We can also see the summary report in the category overview report that give us graphic for the averages, as shown in Table 1 and Fig. 4.

Looking at these results, it is found that the rework resource is excessively used, which lead to slow throughput. In fact, we can observe that for the waiting time and number waiting in queue, the rework station is plagued by waiting times and queue lengths that are much longer for the other stations. This may drastically reduce the number of parts processed out of the rework machine and increase the work in process of the system

Table 1: Queue Detail Summary

Process Queue	Average waiting time	Average number waiting
Prep A Process.Queue	14.70	3.17
Prep B Process.Queue	27.87	3.61
Rework Process.Queue	517.19	14.25
Sealer Process.Queue	2.47	0.84

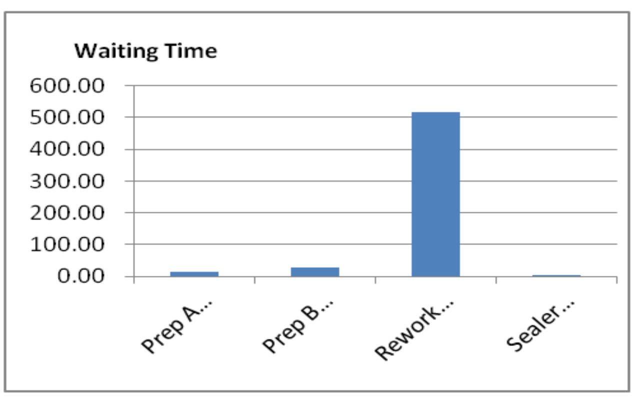


Fig. 4 Graphic for Average Waiting Times & Bottleneck in Rework

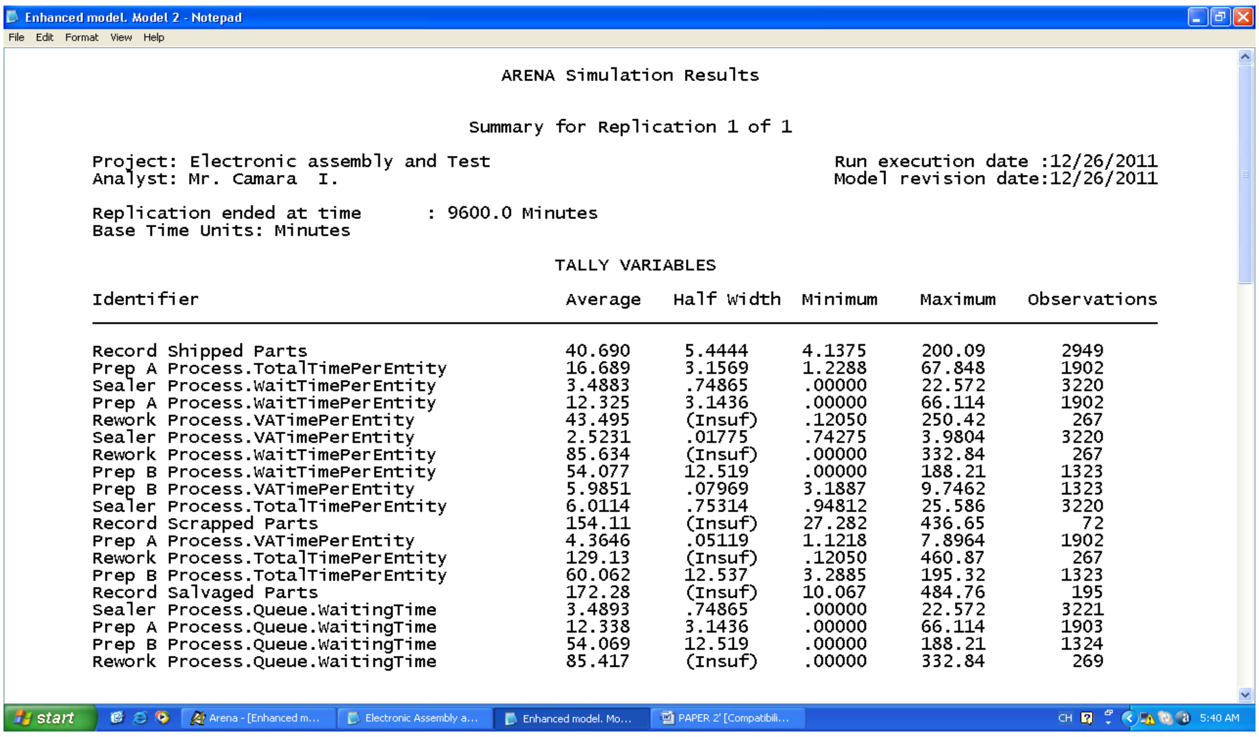
4. Enhanced System

The bottleneck occurs in the rework machine because it might not have enough capacity to handle its work. Therefore, modifications such as increasing the rework capacity can be made to the existing system. In addition, to enhance the efficiency and throughput of the production process, we will consider a failure situation for the sealer machine to see how the system behaves in this particular condition. We have considered that the sealer machine breaks down periodically, and repair time is needed to restore the machine in operating state.

In the previous developed problem definition, the system operates for six consecutive 8-hours shifts, or 2,880 minutes. To decrease the queue statistics (average waiting time and average number waiting in queue) for the rework operation, we have an option to increase the number of machine in this station. For doing so, we considered that the system operates for two 8-hours shifts a day, and we assign two operators to the rework operation on the second shift. This would explain our earlier observation when we thought that the rework operation might not have enough capacity. We will run the model for ten days, i.e., 9600 minutes. For the failure problem considered at the sealer operation, the mean uptime is assumed to be exponentially distributed with the mean of 120 minutes, and the time to repair also follows an exponential distribution with the mean of 4 minutes. After incorporating theses changes in the previous model and running the enhanced model, the results are partially given in SIMAN summary report as shown in Fig.5.

5. Experiments and Results Analysis

The simulation results are used to compare the output of original electronic assembly and test system (Model 1), and the enhanced model (model 2). The queue statistics and the utilization factor of each resource, the time in system and the number of parts produced are observed. As result, the output report in Table 2 presents the averages and shows the comparison of the two models.



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Enhanced model. Model 2 - Notepad
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                              ARENA Simulation Results

                            Summary for Replication 1 of 1

Project: Electronic assembly and Test                    Run execution date :12/26/2011
Analyst: Mr. Camara  I.                                  Model revision date:12/26/2011

Replication ended at time      : 9600.0 Minutes
Base Time Units: Minutes

                                    TALLY VARIABLES

Identifier                              Average   Half Width  Minimum    Maximum   Observations
_______________________________________________________________________________________________

Record Shipped Parts                    40.690    5.4444     4.1375     200.09       2949
Prep A Process.TotalTimePerEntity       16.689    3.1569     1.2288     67.848       1902
Sealer Process.WaitTimePerEntity        3.4883    .74865     .00000     22.572       3220
Prep A Process.WaitTimePerEntity        12.325    3.1436     .00000     66.114       1902
Rework Process.VATimePerEntity          43.495    (Insuf)    .12050     250.42        267
Sealer Process.VATimePerEntity          2.5231    .01775     .74275     3.9804       3220
Rework Process.WaitTimePerEntity        85.634    (Insuf)    .00000     332.84        267
Prep B Process.WaitTimePerEntity        54.077    12.519     .00000     188.21       1323
Prep B Process.VATimePerEntity          5.9851    .07969     3.1887     9.7462       1323
Sealer Process.TotalTimePerEntity       6.0114    .75314     .94812     25.586       3220
Record Scrapped Parts                   154.11    (Insuf)    27.282     436.65         72
Prep A Process.VATimePerEntity          4.3646    .05119     1.1218     7.8964       1902
Rework Process.TotalTimePerEntity       129.13    (Insuf)    .12050     460.87        267
Prep B Process.TotalTimePerEntity       60.062    12.537     3.2885     195.32       1323
Record Salvaged Parts                   172.28    (Insuf)    10.067     484.76        195
Sealer Process.Queue.WaitingTime        3.4893    .74865     .00000     22.572       3221
Prep A Process.Queue.WaitingTime        12.338    3.1436     .00000     66.114       1903
Prep B Process.Queue.WaitingTime        54.069    12.519     .00000     188.21       1324
Rework Process.Queue.WaitingTime        85.417    (Insuf)    .00000     332.84        269
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Fig. 5 SIMAN Summary Report for Enhanced Model

Table 2: Comparison of Model 1 and Model 2

Process	Model 1	Model 2	Model 1	Model 2
	Average waiting time		**Average number waiting**	
Prep A Process.Queue	14.70	12.34	3.17	2.47
Prep B Process.Queue	27.87	54.07	3.61	7.47
Rework Process.Queue	517.19	85.42	14.25	2.40
Sealer Process.Queue	2.47	3.49	0.84	3.49
	Average total time/entity		**Resource Utilization**	
Prep A Process	18.95	16.69	0.90	0.86
Prep B Process	33.82	60.06	0.76	0.83
Rework Process	561.21	129.13	0.97	0.81
Sealer Process	4.99	6.01	0.85	0.85
	Average number in		**Average number out**	
Prep A Process	620.00	1,914.00	608.00	1,902.00
Prep B Process	376.00	1,332.00	367.00	1,323.00
Rework Process	78.00	271.00	51.00	267.00
Sealer Process	975.00	3,225.00	974.00	3,220.00
Exiting parts	**Average time in system**		**Number of parts produced**	
Record Shipped Parts	29.4041	40.6904	896	2,949
Record Salvaged Parts	574.61	172.29	45	195
Record Scrapped Parts	708.70	154.12	6	72

In the model 1, we did not perform any change in Prep A and Prep B areas. However, maybe due to the differences in the run lengths, the Prep B area become more congested as the time goes on, making the time in the queue to build up. The increase of the prep B waiting time from 27.87 to 54.07 affects its number waiting and total time per entity. Because we added a second unit on the rework resource in the second shift of each day, the waiting time in queue for the rework operations is reduced from 517.19 to 85.42, which is great improvement. This considerably decreases the number waiting from 14.25 to 2.40 and the total time per entity form 561.21 to 129.13. For the sealer operation, the queue statistics and the total time per entity display substantial congestion. This makes sense because we have considered the failure situation in the sealer machine. The increase of the number of machine for the rework operation reduces the utilization factor form 97% to 81%. The utilization statistics for the sealer operation are not much different across the two models, because when the sealer fails, its unavailability period is not counted against the sealer utilization. The changes at the sealer and rework operations have their effect on the average times in system for the three exiting parts and the number of parts produced. The slower sealer operation increases the time in the system for shipped parts from 29.40 to 40.69. However, Salvaged and scrapped parts enjoy a much faster trip through the rework operation that decreases considerably their times in the system and increases the number of part produced out of the system.

6. Conclusion

Simulation has been commonly used to study the real world manufacturing system to gain better understanding of the behavior of systems for a given set of conditions and to identify the underlying problems. The simulation technique can be applied in the real systems to analyze the system performance more efficiently. It is a powerful tool to investigate all production scheduling alternative solutions, helping decision maker to take right decisions for resource optimization or enhancing industry performance at an appropriate time.

In this paper, we have used simulation to model an electronic assembly and test system. The system performance is analyzed and we have identified the bottleneck. The rework process was excessively used. This leads to slow the throughput of the production process, and may drastically reduce the number of parts produced out of the system and increase the WIP. We have attempted to enhance the performance of the system, and modifications such as increasing the resource capacity or considering the machine failure situation are made to enhance the efficiency and throughput. The results show that, although the slower sealer operations display substantial congestion in the sealer machine, the modifications in the rework capacity provide great improvement in terms of queue statistics, utilization factor and time in system for rework operations. Also the number of parts produced out of the system increase as the rework operations became much faster. The Arena7.0 simulation software is used to model and simulate the considered system.

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