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Improving Productivity Employ Simulation Model: A Case Study of a Steel Pipe Manufacturing Company

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ABSTRACT

Productivity improvement in the manufacturing industry of piping is a key challenge facing manufacturers in today's competitive markets. Improving productivity in the pipe manufacturing companies by implementing manufacturing principles that utilize simulation modeling was the purpose of this study. To improve productivity, an approach that focuses on the workstations and workforces process was suggested. The suggested approach's goal was to increase productivity by providing customer prerequisites and leaving some products for other customers in the store. Based on the data has been gathered from the company of steel pipes, Bansal Ispat Tubes Private Limited in India, a simulation model was utilized to enhance its performance of operational. The investigation methodology consists of a simulation model, acceptable distribution, and data investigation. By simulating individual workstations and evaluating all relevant processes according to the data collected, the simulation model was built. Actual employment data were gathered from the line of manufacturing and supervisory workers, with observations carried out throughout the process of manufacturing. The used method involves videotaping of the process and interviewing workers using a video-camera. The superior continuous distributions were picked to fulfill a convenient statistical model. The results could be helps to ameliorate the manufacturing industry productivity. Furthermore, the outcomes could assist to solve the problems of scheduling in pipe manufacturing "simulating and modeling" which reveals active ways in enhancing pipe manufacturing productivity. Consequently, the findings might support well competition among companies.

1. Introduction

In the competitive world, performance-improving of businesses and industries is fundamental to retain them. Low-efficiency is one of the several challenges faced by manufacturing companies in competitive markets. Bansal Ispat Tubes Private Limited's presence in one of the largest steel markets in India required effective production planning to improve the production procedure to achieve increased competence [1]. The final product plays a significant character in guaranteeing the prosperity of the production procedures since it may be applied to define the higher quality of the available product. Owing to higher quality requirements along with the increased demand for the products, the company management considered various ways to improve the all-line production. The increase in customer demand has caused several problems in the production of the pipes. Scheduling work is one of these problems. Therefore, additional shifts have been added by the pipe manufacturer to increase production. These additional

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shifts resulted in an increase in the work-in-process, which leads to further bottlenecks in the line of manufacturing. Moreover, operational effectiveness with minimal cost is affected by maintenance policies [2]. To meet the demands of the market, the companies tried to improve productivity and increase production. Modelling and simulation techniques of manufacturing may assist to build an understanding of the processes and may also help in recognizing and testing ways that lead to maximum production efficiency [3, 31]. The ability to accurately identify all inputs and outputs as financial value highly impacts the process of constructing the productivity measurement model [4]. Therefore, several types of simulation modelling software exist in the market to improve and develop complicated manufacturing systems [5-13].

For decades, modelling and simulation have been employed by companies worldwide to improve the design, evaluation, and development of the operation of complicated systems [11, 14-15]. Many industries and businesses require effective production planning to enhance their products to keep their businesses in the global competitive. Performance might be applied to specify product availability and grow quality. Therefore, performance plays a crucial method in guaranteeing that the success of the operation for the production steps company [16]. The modelling and simulation software called pro-model has grown to be a useful tool for numerous applications in real-world engineering [17-20]. The pro-model designed to model manufacturing systems applies from small job workshops and machining cells to large mass production and supply series systems [21-22]. Discrete simulation modelling can also be applied to improve productivity [23]. The advantages of utilizing discrete-event simulation have been the focus of several studies [5, 17, 20, 24 -29].

These studies were able to identify the benefits of simulation discrete events, such as the level of system deviation, changes in system performance, and effects of changing process variables including labor and machines. Thus, this study aimed to increase the quantity of production and simulate the time that is required to achieve customers' requirements. Furthermore, the model can assist in understanding processes, decisions, and resources.

2. Approach and Methodology

2.1. Background on the Manufacturing Steel Pipe Company

The line of production is made up of two main operations including the slitting operation and the conversion operation for the production of finished products. There are three major entities correlated with Mild Steel (MS) pipes manufacturing. Also, they use mother coil steel as the raw material, slatted coil as the intermediate material, and the different sizes of the pipes are the final product that will be stored and delivered to customers.

To manufacture the pipes, other essential tools were also used as entities for the process to be complete. The first process, which is slitting, consists of seven locations, an operator, a foreman, and 4 fulltime labors. It involves three units like the mother coil, the slitting instrument, and the silted coil. The second process which is the transformation to pipes involves sixteen locations, one operator, one foreman, and 6 fulltime laborers. It involves five units like the silted coil, the stamps, the welding rolls, the deburring tools, and the MS pipes. The process requires running at a certain speed and a particular quantity of heat for the welding. To change it to a different type of material takes twelve hours of change time and a large amount of scrap is subsequently generated. Therefore, one type of material is completed first. The company works 24 hours per day with three eight-hour shifts each.

2.2. Identify Components and Analyze the Model

A working Pro Model simulation model contains the following elements Table 1.

2.3. Collecting and Analysing Data

All information available throughout this study was claimed by the supervision workers. Data collected throughout this study are identified the times of admission, dynamic symbol reports, quick response interferences, and expulsion was required to estimate deterioration probabilities, charges, and products. The results involved machine workers' cycle times, the number of clientele, in system and line, dispensation times, and capitals downtime. Subsequently, the model was constructed; the model simulation was in progress to define a statistical model with a suitable fit. Furthermore, a number of the deciding factors which were including commuting among locations, allocation of the workforce, skills and proficiency of the workers, operating environment and temperatures, machines number in the system, and speed of the tools setup were implemented.

Table 1. Elements of Pro Model simulation model

Entities	1	Mother Coil (Raw Material)
	2	Slited Coil (Intermediate Material)
	3	MS Pipes (Final Product)
	4	Sliting Tool
	5	Stamps
	6	Welding rolls
	7	Deburring tool
Locations	1	Warehouse 1(Mother coil)
	2	Tool Storage
	3	Decoiler (sliting process)
	4	Straightening Machine
	5	Sliter
	6	Separators
	7	Recoiler
	8	Warehouse 2(slited coil)
	9	Decoiler (Conversion Process)
	10	Stacks
	11	Stamper
	12	Vertical Forming
	13	Horizontal Forming
	14	Welder
	15	Deburrer
	16	Measurement sensors
	17	Pipe cutter
	18	Grinder(Finishing process)
	19	Testing machine
	20	Warehouse 3(MS Pipes)
	21	Warehouse 4(Scrap)
	22	Weighing Machine
	23	Exit
Resouces	1	Ten labors
	2	Two operators
	3	Two foreman's equipment
Attributes	1	(Machine) faster - high capacity
	2	(Welder) speed – breakdown rate- capacity
	3	(Employer) faster-responsible- reliable.
	4	(Tools) Different sizes-Material-Type
State Variable	1	Status of Machines (working /idle)
	2	Operator's availability
	3	Number of pips is being welded.

2.4. Method for Collecting the Data

The data is collected from a Real-Life System, which is the manufactory of pipe. The actual job-shop data were gathered from the production line of the machinery with observations through the plant. The used techniques implement videotaping of the operation, interviewing workers by using a video recorder camera. This type of data is very important in creating the simulation model. Therefore, to be able to get all the data required to perform the simulation, the first step to collect data was Building the Excel Data File. The Excel data file consists of one spreadsheet. This spreadsheet contains information about the manufacturing processes that take place on the Manufacturing. After that, we have started with the collection date.

As the process is a continuous process so we have some run time that is not collected as part of this experiment. The data collected is shown for the first 30 observations of each element respectively. For instance, one mother coil produces 6-8 slitted coils, to Produce 30 slitted coils we need only 4-5 coils max, so to have the data much more information we divided it into 2 different processes, and the data collection process is also different respectively. The first 30 customers regardless of what material it is shipping. The slitting process and conversion Process consists as shown in Tables 2 and 3, respectively.

Table 2. Slitting process consists of 4 major elements

Slitting process	Time	System
Setup time (change time)	20 – 35 min	It is the data of the entire process as the thickness and width of raw material changes the entire machine has to go some changes such as Resizing the slitters, separators and Recoiled, realignment of the pinch rolls etc. therefore these changes come under change time of the process.
Coil loading	15 – 30 min	This is the process of loading the mother coil (Raw material) at the start of the machine (Decoiler).
Processing time	25 - 45 min	This includes many sub processes such as: Decoiling Process [5–10min] >Straightening process [5 – 10 min] > slitting process [5 – 8 min] > separating process [2 – 4 min] > recoiling process [8 – 13 min].
Packing and shipping to warehouses	5 – 35 min	In this process, the slitted coil is welded or packed by a special packing strip and removed from the Recoiled with use of Hydraulics which is sent to the warehouse without getting it damaged.

Table 3. Conversion Process consists of 5 major elements

Main processes		Type of suitable distribution
Slitting	Processing	Weibull (-37.8, 17.9, 73.8)
	Welding	Gamma (-5.5, 28.8, 0.957)
	Coil loading	Lognormal (2.11, 2.89, 0.196)
	Setup of machine	Lognormal (-115, 4.95, 2.71e-002)
Conversion	Testing	Weibull (-6.79, 14.1, 11.7)
	Customer Facility	User-Defined Discrete distribution
	Processing	User-Defined Discrete distribution
	Coil Loading	User-Defined Discrete distribution
	Assembling	User-Defined Discrete distribution
	Setup of machine	Lognormal (31.1, 3.18, 0.659)

2.5. Appropriate Distribution

To get a suitable statistical model, the best continuous distributions to suitable the input information, investigate maximum likelihood assessments for these distributions, exam the outcomes for the quality of fit, and demonstration the distributions in the instruction of their comparative rank were chosen. In this study, each station and product with their respective times was presented successfully. It was observed utilizing a tool called Stat Fit was a serious step to program the simulation applying Pro-Model and the technique used to procedure all the information. Describing the distribution of process waiting time in each procedure was required. All needed information could be input in this tool, and it could process and examine throughout all the various functions to select the suitable statistical function that fits input data. Then, it provides the descriptive details from the data and more explanation information, like scatter plots and graphics, as shown in Figure 1. As can be seen in the figure, the observations are independent of all distributions selected for each process. The collected data for the setup time before running the slitting process seems to fit.

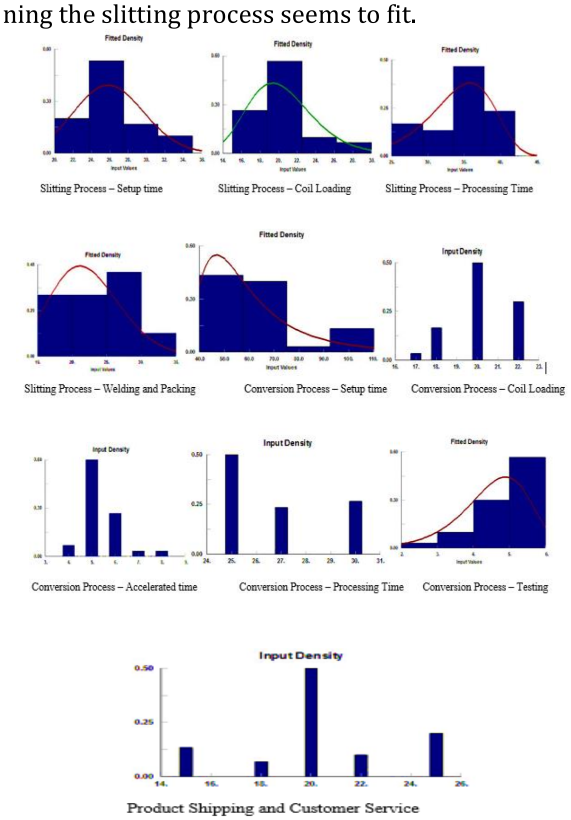

Figure 1. Process Flow Chart of MS Pipe Manufacturing model

The collected data for this process does not fit any built-in discrete and continuous distributions so; a user-defined distribution is preferable. Whereas a good rank typically shows that the suitable distribution is an adequate demonstration of the input data. It is also known as an absolute indication for the quality of fit, as shown in Table 4.

Table 4. Procedures and chosen distributions

Conversion Process	Time	System
Setup time (change time)	40 – 110 min	It is the data of the entire process as the thickness and width of raw material changes the entire machine has to go some changes such change the rolls, changes related welding and deburring etc. therefore these Changes comes under change time of the process. These differ depending on some Factors such as thickness and width of the coil. If both factors have to be changed it Takes near 100 min approx. if only thickness is to be changed it takes approx. 50 min.
Coil loading	17 – 22 min	This is the process of loading the slitted coil (intermediate material) at the start of the machine (De-coiler).
Stacking process	4 – 8 min	In this process, the coil is rushed into the stacker so that the process continues without any kind of disturbance to the main speed.
Processing time	25 - 30 min	This includes many sub processes such as: Decoiling Process [5 – 6 min] >Stamping process [3 min] > cold forming process [6 –8 min] > welding process [4 – 5 min] > deburring process [2 min] > cooling Process [3 min] > cutting process [2 - 3 min].
Testing	2 – 6 min	This process includes random inspection of 2 or 3 pipes in the lot. Before shipping it to the customer.
Customer loading	15 – 25 min	This is the process in which the final product is loaded on the carriages of the customer using crane which involves the small arrangement of vehicle, picking the goods and dropping the goods in the vehicle etc.

3. Results and Discussion

3.1. Model Application with Pro-Model

The simulation model is built depending upon a full list of assumptions. To manufacture finished goods, the line of manufacturing includes two essential processes which are the slitting process and conversion process. Moreover, there are five main entities are associated with MS pipes manufacturing. The first step is to build several locations containing buffers, machines, conveyors further, and workstations. The locations include four full-time laborers, an operator, and a foreman. Also, the locations have three entities which are mother coil, silted coil, and slitting tool. The conversion to pipes is represented in the second step and it is consisting of a foreman and six full-time laborers. Also, this step involves five entities which are welding rolls, stamps, the silted coil, MS pipes, and deburring tools. For the welding, the process has to turn on at a determined speed at a particular quantity of heat. The company doings in three shifts per day, each shift works eight hours. The entities are described in the third step. The entities include raw materials, loads, piece parts, finished products, assemblies, operators, orders, machines, pipes, and labels. The fourth step is represented by building the entities' arrival patterns. The fifth step includes developing the model which is employing additional resources and consistent path networks that are required to transfer entities among locations.

3.2. Verification and Validation of Simulation Model

Before initiating the validation study, the engineers and the firm owners were consulted to obtain all the information required to fully describe the actual production processes. It was uncovered that the processes should include two lines, to increase productivity. As this is not practical, the simulation model was an alternative solution. The simulation was thus based on the monthly estimated requests for dissimilar products. The model was validated by (1) monitoring production line behaviour, (2) examining the output/statistics, (3) utilizing "debug" and "trace" software tools, and (4) conducting a code/model review.

3.2.1. Simulation Model Verification

The model structure was developed by simulating each workstation and assessing all relevant processes. Next, the model was debugged and its ability to recognize errors in work procedures was assessed. Several issues were identified, as discussed below.

3.2.1.1. Pipes Accumulation at Warehouse 4

All produced pipes should be shipped directly to the customer. Practically, the "watch the animation for correct behaviour" and "trace" software tool showed that is not practical to accumulate up to 300 pipes once.

3.2.1.2. Utilization of the Location "Weightier" Was Zero (0)

A 2 mm, 3 mm, and 4 mm pipe was used in this investigation. By using the method "Checking for reasonable output/statistics," we determined that we were not using the weighing machine. The customer's vehicle had to wait for some time to record the weight of the purchased pipes for accounting purposes. This was observed by using the second technique: checking for reasonable output/statistics. Figure 2 shows using trace facilities with the software.

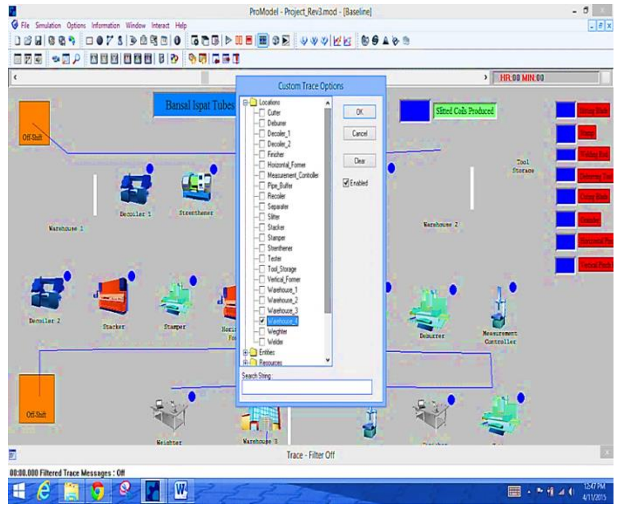

Figure 2. Using trace facilities with the software

3.2.1.3. For the Tool Storage, We Changed the Command

The command rand () 8 to 9 times was used which made more complicated and the results had only minor changes. User-defined functions and tables to assign attributes for each type of tool were utilized. These had been used to conduct model code reviews. Figure 3 shows the model before the tool's storage, whereas Figure 4 shows the model after the tool's storage.

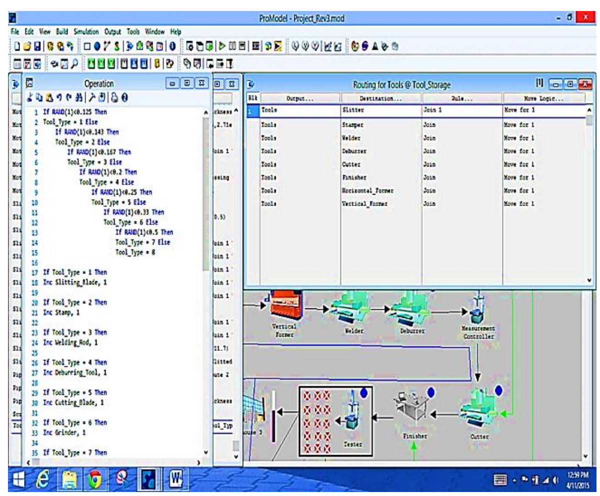

Figure 3. The model before the tools stage

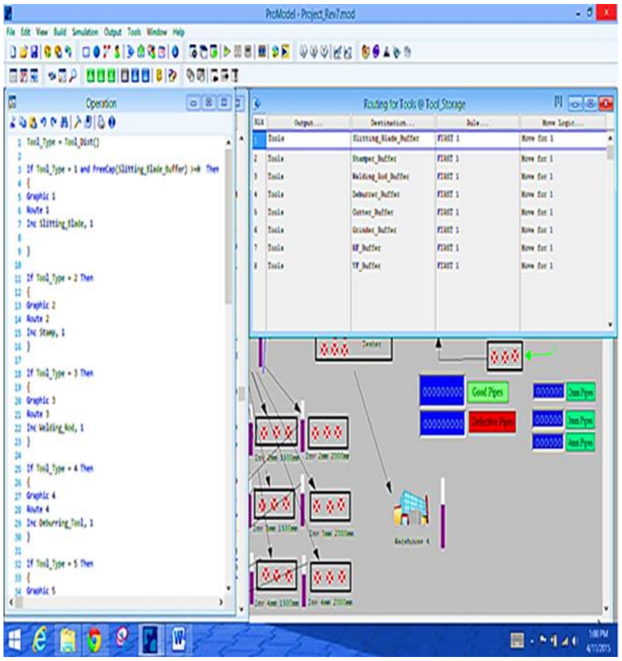

Figure 4. The model after the tools stage

3.2.1.4. Using Two Labourers/Workers at One Location

At some locations, we used two labourers since the job cannot be done with just one worker in real life; we were unsure how to use 2 labourers for one location using the "use" command. We changed that to the get > use > release command. Figure 5 shows the model after the changed labour command.

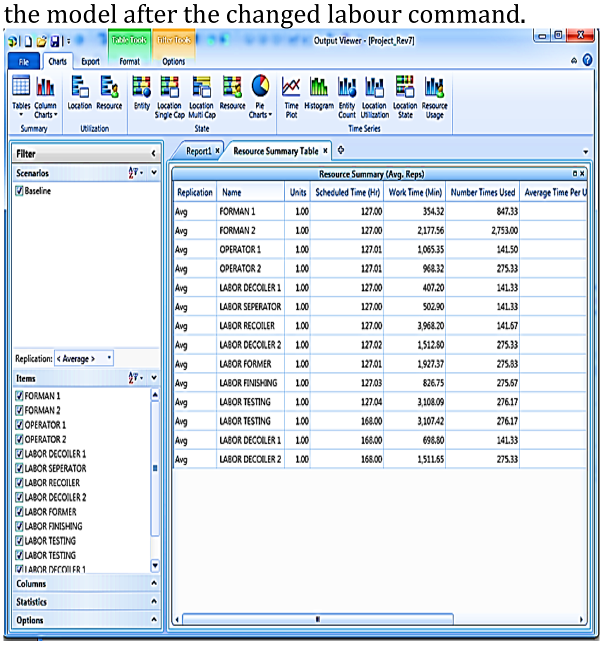

Figure 5. The model after the tools stage

3.2.1.5. Different Lengths of Pipes Not Included

Previously, at the cutter location, each length difference, including 750mm, 1000 mm, 1500 mm, and 2000 mm, was not assigned to each pipe, which was a problem; this issue was rectified by using the debugging tool.

3.2.2. Validity of the Simulation Model

The results of this simulation are comparable to an actual life situation because this study simulates a process that already exists. A model's validity can be investigated by determining the resemblance between the outcomes of the simulation and those of the real system. Thus, to determine the validity of our model, a confidence interval test for each station was performed and compared with real-life values. In this way, the validity was determined by following the running time for each product at each station. Comparing the results of a real-world system with a simulation model is considered a reliable approach. The process of validation is as follows:

- Based on the time-series plot on the output, the model required a warm-up period of around six weeks to reach a steady-state. Data collection began in the 7th week and weekly validated results were obtained, including throughputs and Wished in pipes (WIPs).
- The simulation model was run using historical input data. The experiments involved running six replications of the process before making the necessary calculations.
- The calculations used statistical methods to compare the real-world data with that from the simulation. The confidence-interval approach was used to compare the data of the real-world system with the simulation results.

Tables 5 - 6 show the performance confidence and WIP for the pipes (good and bad). Confidence-interval testing was done for 750 mm, 1000 mm, 1500 mm, and 2000 mm pipes and used the number of weekly good pipes (thickness = 2 mm, 3 mm, and 4 mm). In most tests, an alpha of 0.05 was utilized as the cut-off for importance. Since the P-value was more than 0.05, we accepted the null hypothesis (H0) that there was a variation between the means and concluded that a significant difference does not exist. If the P-value was less than 0.05, the null hypothesis had to be rejected. The observations of the input and output of random variables in the system and the model were statistically identical. Since we accepted H0, we tentatively accepted the model as valid. This approach resulted in the model and system outputs being positively correlated. The members of the project team ensured that the models were sufficiently accurate.

Table 5. Performing the confidence interval testing

Weekly throughput						
	thickness	α =5%	Mean, $\bar{x}$	t-value	P-value	Decision
# Good 750 mm	2mm	real	2511	1.5	0.195	Accept
		model	2429			
	3mm	real	2465	0.22	0.833	Accept
		model	2411			
	4mm	real	2150	-0.29	0.786	Accept
		model	2167			
# Good 1000 mm	2mm	real	1377	-1.52	0.185	Accept
		model	1672			
	3mm	real	2354	0.32	0.703	Accept
		model	2300			
	4mm	real	4930	0.29	0.782	Accept
		model	4850			
# Good 1500 mm	2mm	real	1383	0.67	0.533	Accept
		model	1345			
	3mm	real	1706	2.38	0.063	Accept
		model	1590			
	4mm	real	3891	1.01	0.361	Accept
		model	1516			
# Good2000 mm	2mm	real	395.8	-0.42	0.695	Accept
		model	416.2			
	3mm	real	475	0.48	0.650	Accept
		model	448.5			
	4mm	real	504.2	0.80	0.458	Accept
		model	452.8			

Table 6. WIP for pip (good &bad)

Weekly throughput						
	thickness	α =5%	Mean, $\bar{x}$	t-value	P-value	Decision
# Good 750 mm	2mm	real	43.15	1.07	0.334	Accept
		model	21.13			
	3mm	real	37.77	0.93	0.396	Accept
		model	37.24			
	4mm	real	39.89	-0.27	0.785	Accept
		model	40.08			
# Good 1000 mm	2mm	real	56.29	0.43	7.16	Accept
		model	55.28			
	3mm	real	57.71	1.76	0.138	Accept
		model	56.63			
	4mm	real	60.06	0.81	0.953	Accept
		model	59.57			
# Good 1500 mm	2mm	real	34.65	1.59	0.173	Accept
		model	33.93			
	3mm	real	38.24	0.92	0.399	Accept
		model	37.81			
	4mm	real	59.57	-0.61	0.567	Accept
		model	35.5			
# Good2000 mm	2mm	real	26.41	3.87	0.012	Model Refined
		model	25.33			
	3mm	real	25.34	-0.38	0.177	Accept
		model	24.74			
	4mm	real	28.07		0.332	Accept
		model	27.61	1.07		

3.2.3. The Design of the Experiment

This paper documents experiments using a simulation model and the statistical analysis of the output from the simulation runs. The simulation model in this study can be classified as a non-terminating simulation of the general manufacturing processes. Thus, the experiments were conducted by running multiple replications of the period of interest. Trying many 'what-if' scenarios based on output interpretations, such as the percentage of resource idling time, percentage of each entity blocked in each process, etc., leads to too many experimental results. In order to reduce the number of experimentations, each factor was studied and the tasks related to each factor were identified. The different parameters and run simulations were carried out on the scenario manager in order to check whether the throughput was improved. Eventually, the following three main scenarios that may have affected the weekly throughput were ended:

Policy 1: Increase in the conversion process capacity from 1 to 2.

Policy 2: Increase in the raw material arrival rate from every 96 hours to every 48 hours.

Policy 3: Both policies were implemented simultaneously.

The process was non-terminating. The simulation was allowed to run for some time before the output on the time-series plot was interpreted to determine when we needed to start collecting the weekly throughput. The system ran at a steady rate from the 7th week onward, indicating that the simulation had a six-week warm-up period. The batch-means method was used to split weeks 7 to 17 into pieces of 1 week to collect the week throughput as in the real system.

The baseline models, as well as three additional models implemented with three policies, were run to observe the effects on the weekly number of the passed MS pipes. We used ten replications of weekly throughput for each scenario for the design of experiments output analysis. Subsequently, we started with a simulation output analysis phase. Here, three scenarios were considered that were suspected to have some positive effects on the throughput, as shown in Table 7. To prove the validity of the base model and to prove its accuracy, simulated modelling runs were applied. The validation process of the current base model was specified by comparing the company's actual productivity to the base model simulation's productivity, as shown in Table 7. This test verifies that the H0 for equal averages:

H0: µ1 -µ2 = 0

H1: µ1 -µ2 ≠ 0

with the confidence of 95%, and the consequences show that there is no considerable variance between the existent system and the simulation model. The statistics were applied by using ten weekly evaluations.

Table 7. Scenario of simulation data

Two-way ANOVA	Low	High
Conversion Process Capacity	1	2
Arrival	96 hrs	48 hrs

4. Experimental Results and Discussion

The experimental method is used to design scenarios and the comprehensive factorial method. Numerous factors were measured, and it was statistically determined if those factors affected the weekly number of good pipes. The model was examined to discover possible impact factors, and we discovered that the throughput of good pipes is a crucial variable in the output. Therefore, it is important to improve the throughput of good pipes to significantly improve the system output. The model was simulated in such a way as to determine the amount of output within a given amount of time. This was achieved by using various inputs. Then, the outputs were compared to choose the model that produces the highest productivity.

4.1 2-Way ANOVA

In this study, 2-way ANOVA was used to determine the significant factors and interaction among A and B on the response variable, and paired t-tests were used for the baseline model and the three scenarios. Table 8 demonstrates that p-values for interaction between Mother Coil Arrival Rate and Conversion Process Capacity equal to 0.67 which is greater than 0.05. Therefore, all suggestions for the difference have been ineffective to be excluded.

Table 8. Results of 2-way ANOVA

Cause of Variation	*F*	*P-value*
Conversion Process Capacity	*0.073*	*0.78*
Arrival Rate of Mother Coil	*642.2*	*0 **
Conversion Process Capacity * Arrival Rate of Mother Coil	*0.188*	*0.67*

The statistical outcomes show that there is no significant difference between the Mother Coil Arrival Rate and Conversion Process Capacity and. Also, the results reveal that the combined models, Mother Coil Arrival Rate, and Modelling Conversion Process Capacity have great influences on the simulation outcomes.

Moreover, the outcomes of both simulation models are similar [30]. These results refer to an understanding that there is no important evidence between the interaction of Mother Coil Arrival Rate and the Conversion Process Capacity factor. So, the null hypothesis fails to reject. These findings would lead to retain H0 and understand that there is no remarkable evidence for a supplement that there is the interaction between factor Conversion Process Capacity Factor Arrival Rate of Raw Material interaction since p-value = 0.67 is greater than α = 0.05), so we fail to reject the null hypothesis. Likewise, since F = 0.188 < F critical, then fail to reject Ho. (See the interaction plot) to test the main factors.

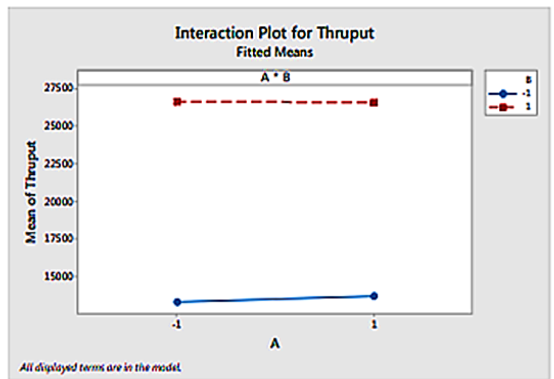

Figure 6. Interaction between factor Conversion Process Capacity (A) and factor Arrival Rate of Raw Material (B)

Hypotheses: (Conversion Process Capacity)

Ho: Main factor Conversion Process Capacity is not significant.

Ha: Main factor Conversion Process Capacity is significant.

P-value = 0.78 > 0.05, we failed to reject the null hypothesis and concluded that there is strong evidence that the main factor Conversion Process Capacity is not significant. In other words, the conversion process capacity does not statically affect the throughput.

It can be noted that F equals 642.21 and the p-value equal zero is lesser than the importance level. Subsequently, the p-value equal is zero and less than 0.05, we excluded the null hypothesis. There is a significant effect of the main factor Arrival Rate of Raw Material on the response. Consequently, hypotheses must be excluded and achieve that there is a significant difference between the interaction of the Arrival Rate of Mother Coil and Conversion Process Capacity productivity, as shown in

Figure 7. Thus, there is an important outcome of the main factor Mother Coil Arrival Rate on the response.

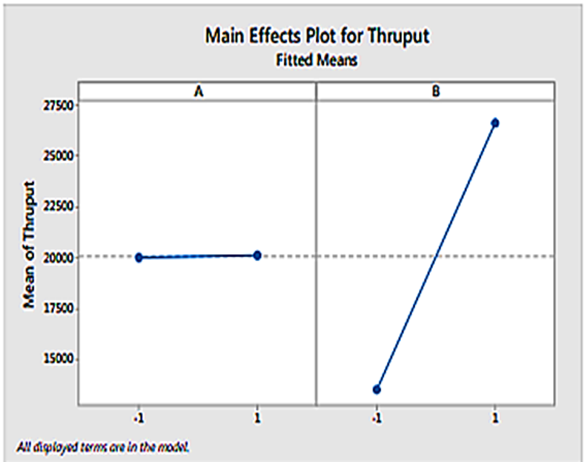

Figure 7. Main effects between (A) factor Conversion Process Capacity and (B) factor Arrival Rate of Raw Material

4.2 Paired t-Test: Two-Sample (Supplementary)

An initial number of replications of 10 were used for the simulation runs in Pro-Model Compared with the current or baseline model, each scenario while assuming a confidence level of 95% is as follows. Table 9 shows a comparison between the baseline model and each scenario. At the alpha level of 0.05, P-value was 0.620 > 0.05. After failing to reject Ho, the outcomes show that there is no crucial difference between the throughput of the baseline simulation model and policy 1 implementation. So, to begin with the first scenario, the rejection of the hypotheses must be done and then specify that there is a considerable variance between the baseline model productivity and the first Scenario. In scenario 2, at the alpha level of 0.05, P-value was 1.96082E-09 < 0.05. Then, Ho is rejected and concluded that there is an important variance in the throughput of the model baseline and the model after the policy 2 implementations. While as in scenario 2, at the alpha level of 0.05, P-value 1.08829E-09 < 0.05. Then, Ho is rejected and concluded there is a remarkable difference in the throughput of the model and the baseline model after the policy 3 implementation.

Table 9. Comparison between baseline model and each scenario

Scenario	*p-value*	*t-sate*	*Design*
Bassline Scenario 1	*0.6201*	*-0.513*	*Reject Scenario 1*
Bassline Scenario 2	*1.96E-09*	*-23.78*	*Accept Scenario 2*
Bassline Scenario3	*1.08E-07*	*-15.06*	*Accept Scenario 3*

However, scenarios 2 and 3 demonstrated that the hypotheses have been unsuccessful to be rejected and reveal that there is no important variation between the baseline model productivity and the model's scenario (second and third). The simulation predicts improves the productivity of the general system, and the production average rate rises. The model for the proposed scenario was simulated in order to establish that the system reached a steady state. Furthermore, the state of stability was recognized after the ten weeks of running production. The results illustrate that there is a variation between the capacity of conversion process, productivity, and interaction of the mother coil arrival rate. Thus, the company must increase the rate of arrival to ameliorate productivity in the absence of increasing the conversion process capacity. Furthermore, it displays that the simulation of conversion process capacity, mother coil arrival rate, and combined models influence the simulation model results, and both models yield an identical simulation result.

5. CONCLUSION

In this paper, we have presented a case study on improving productivity in the pipe manufacturing industry. What modern simulation software tools can achieve is for improving the productivity of the current industrialist schemes by ascertaining the system performance. Consequently, possible enhancements inside the production line were known and applied in an improved framework model. This study has established that the amount of current production might not meet the demand for the next few years, and that, as a result, the company only needs to increase the rate of arrival to enhance productivity. The study has also shown that the simulation manner could be employed by using a computer, which would assist in decision making. The simulation models have suggested a significant improvement in the throughput of manufacturing. We would recommend increasing the arrival rate only and improving productivity without growing the conversation process capacity related with some large amount of investment depending upon the simulation sample, even though the company is now manufacturing steel pipes according to its capacity. Furthermore, in order to meet the project objective, it will be necessary to negotiate with the raw material supplier and conduct a feasibility study of the capacity increase. The limitation of this study is that the scenarios have only focused on improving the productivity of the manufacturing system, whereas some additional important factors, such as minimizing the waiting time, should also be considered. Future studies must focus attention on recognizing the problems of each subsystem, such as downtimes that are associated with labour-intensive operations—e.g., an operator starting his shift late or an operator finishing his shift early—and must devise solutions to develop the manufacturing process.

In conclusion, therefore, this study enables managers to gain a wider perspective on the ability to simulate complex systems and to present alternatives to improve the process, which will provide strong forecasts for future manufacturing. The study concludes that the rate of arrival of the mother coil to the warehouse seriously acts on the throughput. In general, the study also shows that the application of manufacturing principles with the help of the simulation model could add significant value to the establishment and increase of operational productivity. This work can be easily modified or adapted to other industrial businesses in order to identify the inefficiencies in the manufacturing procedure.

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