

Enhancing Productivity of the Pipe Manufacturing Industry: a Simulation Model

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Abstract: Improving productivity in the pipe manufacturing industry is a major challenge that manufacturing companies in contemporary competitive markets face. The purpose of this study was to improve productivity in the pipe manufacturing industry by applying manufacturing principles that employ simulation modeling. An approach to improve productivity focuses on the process of workstations and workforces was proposed. The proposed approach's target was to boost the productivity of providing clients' prerequisites and leaving a few products in the store for other clients. A simulation model based on the data collected from the steel pipe company, Bansal Ispat Tubes Private Limited's in India, was used to improve its operational performance. The research methodology included a pro-simulation model, suitable distribution, and investigating data. The simulation model was created by simulating each workstation and assessing all relevant processes depending on the collected data. The real job-shop data was collected from the machinery production line and supervision workers with observations made during the manufacturing process. The techniques used include videotaping of the operation, interviewing liber by a video camera. The best continuous distributions were chosen to achieve a suitable statistical model. The outcomes maybe contribute to improving the productivity of the manufacturing industry. Moreover, the results might help solve scheduling problems in modeling and simulating pipe manufacturing, revealing effective strategies to enhance productivity in pipe manufacturing. Thus, the findings could encourage healthy competition between businesses and industries.

Keywords: Simulation Model, Pro-Model, Productivity, Pipe Manufacturing Industry

1. INTRODUCTION

In the competitive world, businesses and industries have to improve their performance to retain themselves. 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 crucial role in ensuring the success of the operation in production processes since it could 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 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 help to create an understanding of the processes and can also assist in identifying and testing strategies that lead to maximum efficiency in production [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]. Also, performance is identified as a critical success factor related to the company. Therefore, several types of simulation modelling software exist in the market to improve and develop complicated manufacturing systems [5], [6], [7], [8], [9], [10], [11], [12], [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 improve their performance to retain their businesses in the competitive world. Performance could be used to specify product availability and increase quality. Therefore, performance plays a crucial role in ensuring the success of the operation for the production processes 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], [18], [19], [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], [25], [26], [27], [28], [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, while leaving some stock in the

warehouse for new customers. A pipe manufacturer in India was modelled to increase line production by decreasing direct labor hours per machine. Furthermore, the model can assist in understanding processes, decisions, and resources. The model can also help in identifying and examining the strategies that increase production efficiency.

2. APPROACH AND METHODOLOGY

A. 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 labor. 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.

B. Identify Components and Analyse the Model

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

Entities	1	Mother Coil (Raw Material)
	2	Slitted Coil (Intermediate Material)
	3	MS Pipes (Final Product)
	4	Slitting Tool
	5	Stamps
	6	Welding rolls
	7	Deburring tool
Locations	1	Warehouse 1(Mother coil)
	2	Tool Storage
	3	Decoiler (slitting process)
	4	Straightening Machine
	5	Sliter
	6	Separators
	7	Recoiler
	8	Warehouse 2(slitted 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
Resources	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.

Table 1. Elements of Pro Model simulation model

C. Collecting and Analysing Data

All information available throughout this study were 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 both 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.

D. Method for Collecting the Data

The data is collected from a Real-Life System, which is the manufactory of pipe. We collected real job-shop data from the Machinery production line with observations made during the plant. The techniques used include videotaping of the operation, interviewing liber by a video 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

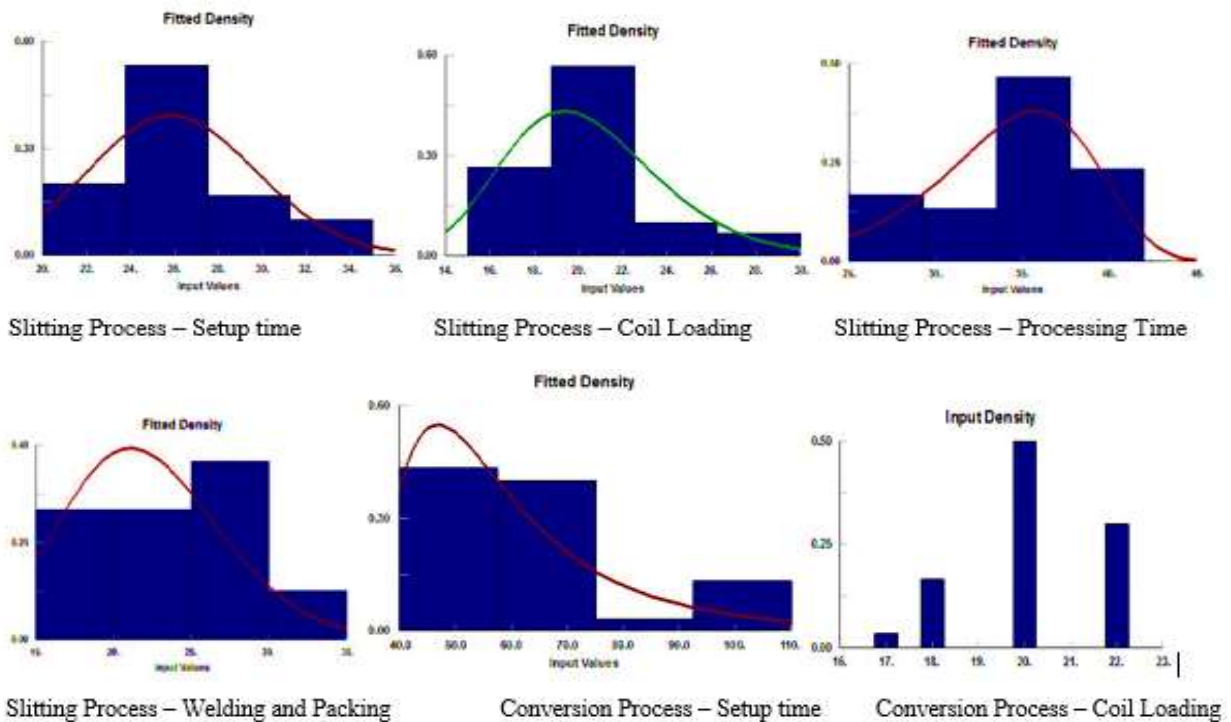
Slitting process	Time	System
Setup time (change time)	20 – 35 min	It is the data of the entire process as the thickness and width of raw material changes the entire machine has to go some changes such as Resizing the slitters, separators and Recoiled, realignment of the pinch rolls etc. therefore these 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

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.

E. 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.



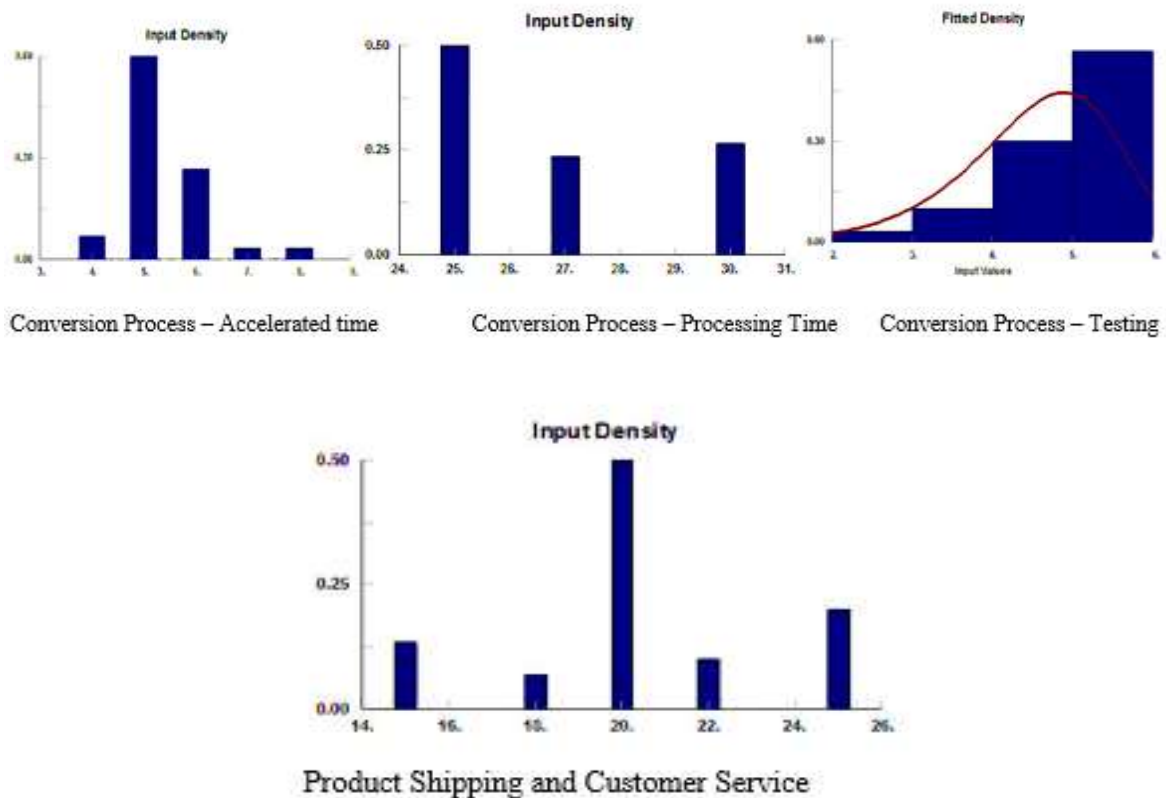


Figure 1. Process flow chart of MS pipe manufacturing model

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

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)

3. RESULTS AND DISCUSSION

A. 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 does 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.

B. 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 behavior, (2) examining the output/statistics, (3) utilizing "debug" and "trace" software tools, and (4) conducting a code/model review.

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.

a) 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.

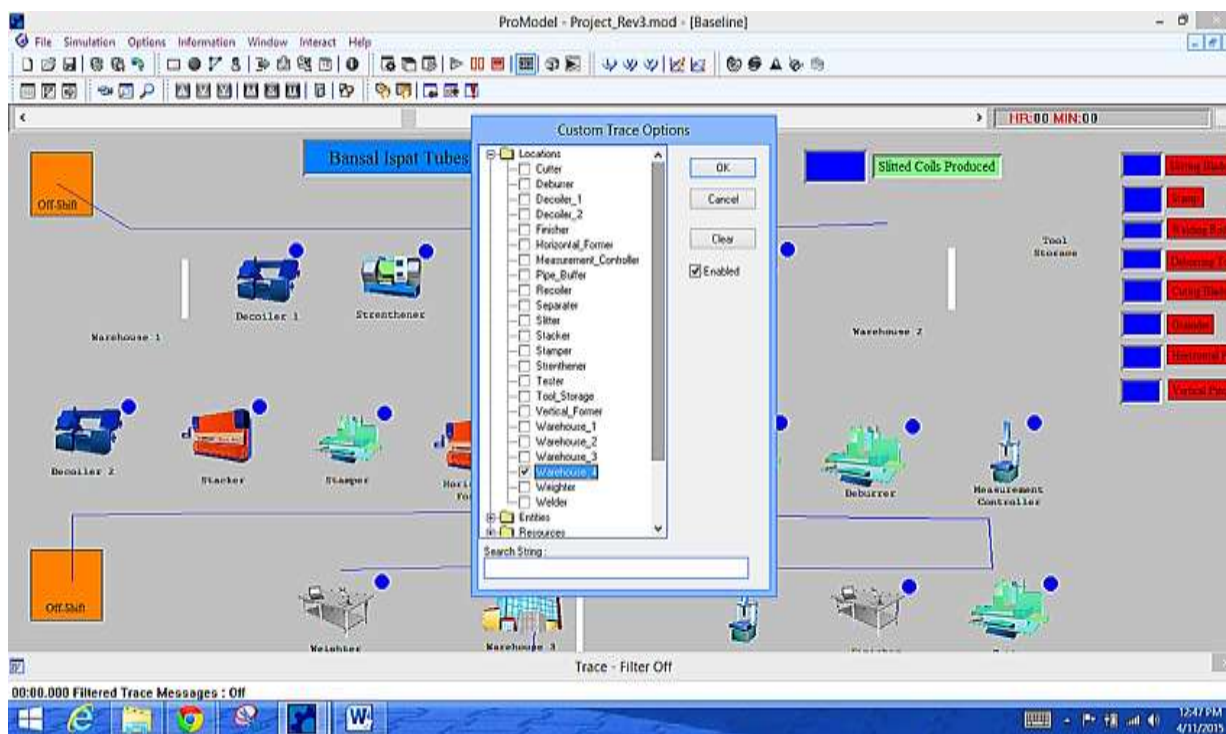


Figure 2. Using trace facilities with the software

b) Utilization of the Location "Weightier" Was Zero (0)

We used 2 mm, 3 mm, and 4 mm pipes. 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.

c) 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.

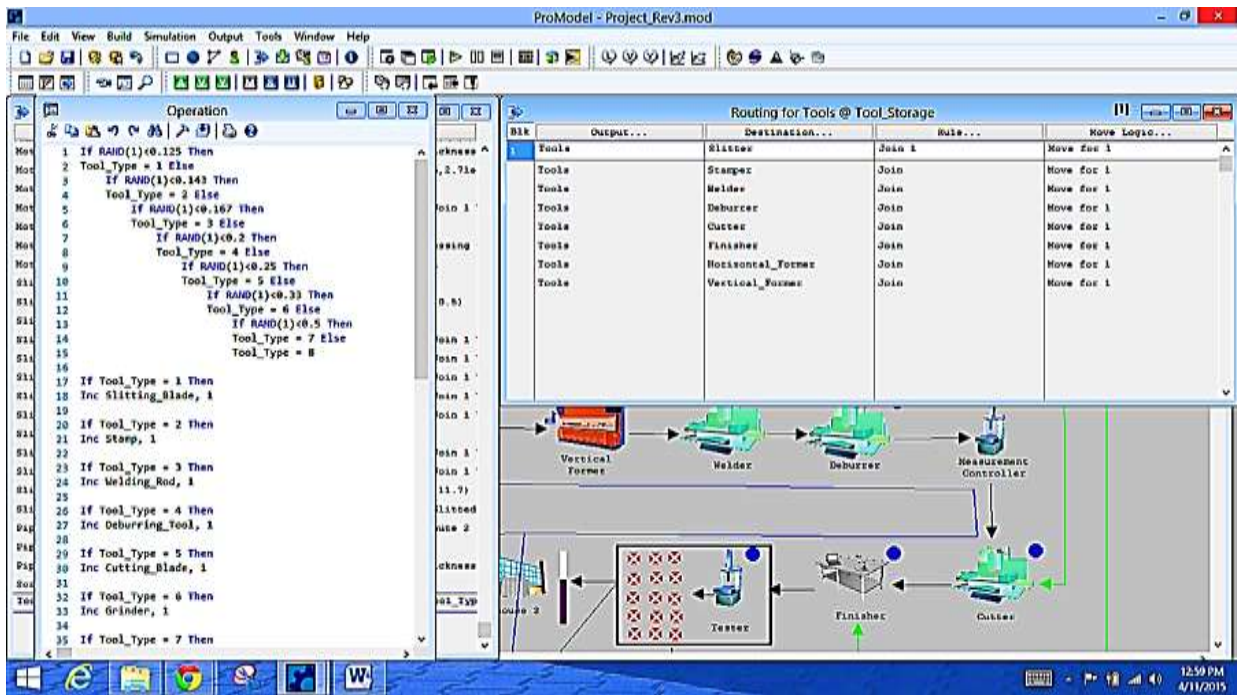


Figure 3. The model before the tools stage

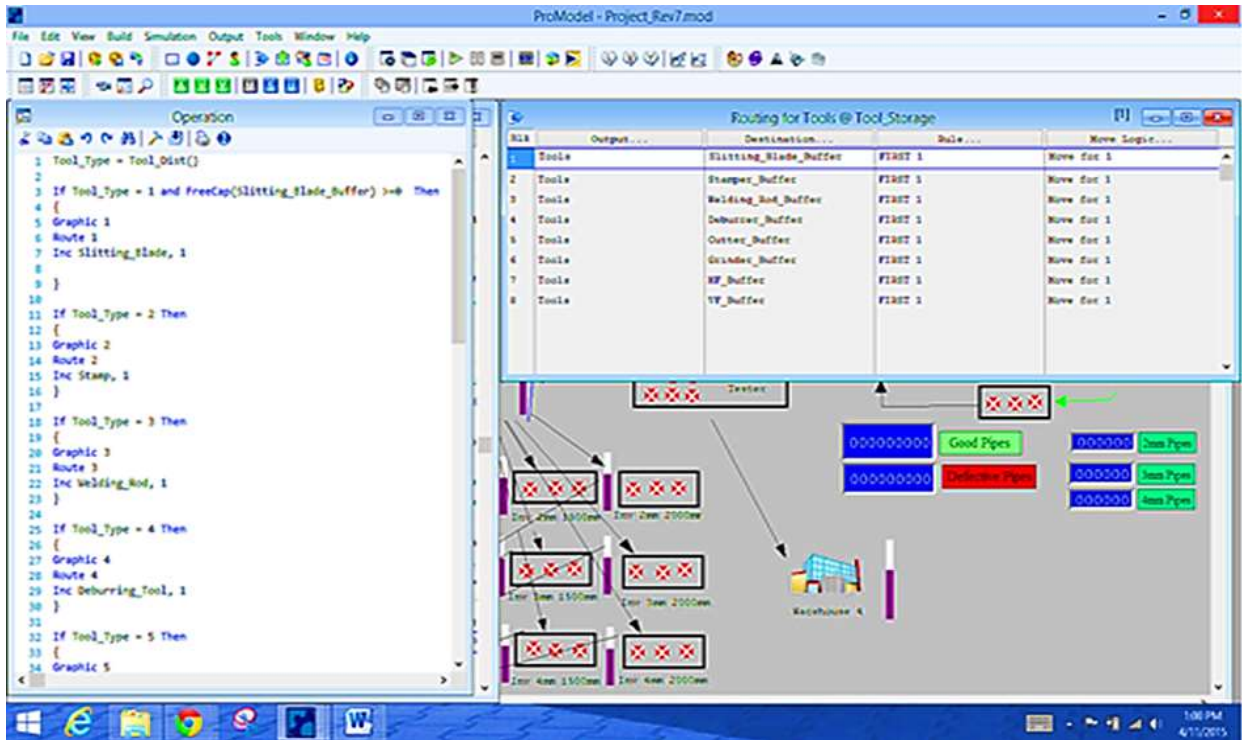


Figure 4. The model after the tools stage

d) Using Two Labourers/Workers at One Location

At some locations, we used two laborers since the job cannot be done with just one worker in real life; we were unsure how to use 2 laborers 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.

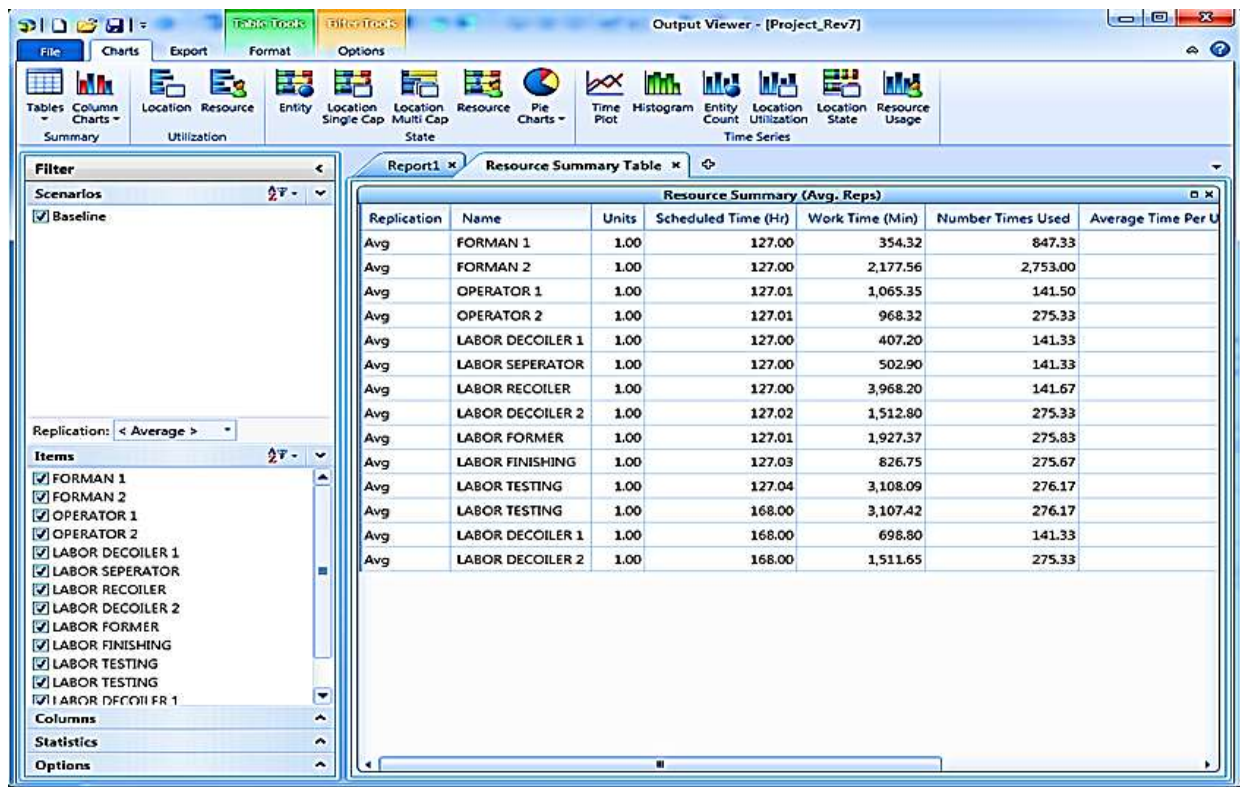


Figure 5. The model after the tools stage

e) *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.

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 and 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 analyses, an alpha of 0.05 was used as the cut-off for significance. Since the p-value was more than 0.05, we accepted the null hypothesis (H0) that there was a difference 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	$\alpha = 5\%$	Mean, \bar{x}	t-value	P-value	Decision
# Good 750 mm	2mm		2511	1.5	0.195	Accept
			2429			
	3mm		2465	0.22	0.833	Accept
			2411			
4mm		2150	-0.29	0.786	Accept	
		2167				
# Good 1000 mm	2mm		1377	-1.52	0.185	Accept
			1072			
	3mm		2354	0.32	0.700	Accept
			2300			
	4mm		4930	0.20	0.742	Accept
			4850			
# Good 1500 mm	2mm		1383	0.67	0.533	Accept
			1345			
	3mm		1706	2.38	0.063	Accept
			1590			
	4mm		3891	1.01	0.361	Accept
			1516			
# Good 2000 mm	2mm		395.8	-0.42	0.695	Accept
			416.2			
	3mm		473	0.48	0.630	Accept
			448.5			
	4mm		504.2	0.80	0.438	Accept
			452.8			

Table 6. WIP for pip (good & bad)

Weekly throughput						
	thickness	$\alpha = 5\%$	Mean, \bar{x}	t-value	P-value	Decision
# Good 750 mm	2mm		43.13	1.07	0.334	Accept
			21.13			
	3mm		37.77	0.93	0.396	Accept
			37.24			
	4mm		39.89	-0.27	0.785	Accept
			40.08			
# Good 1000 mm	2mm		36.29	0.43	0.676	Accept
			35.28			
	3mm		37.71	1.76	0.138	Accept
			36.63			
	4mm		60.06	0.81	0.953	Accept
			59.57			
# Good 1500 mm	2mm		34.65	1.59	0.173	Accept
			33.93			
	3mm		38.24	0.92	0.399	Accept
			37.81			
	4mm		39.57	-0.61	0.567	Accept
			35.5			
# Good 2000 mm	2mm		26.41	3.87	0.012	Model Refined
			25.53			
	3mm		25.34	-0.38	0.177	Accept
			24.74			
	4mm		28.07		0.332	Accept
			27.61	1.07		

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 model, 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:

$$H_0: \mu_1 - \mu_2 = 0$$

$$H1: \mu1 - \mu2 \neq 0$$

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.

A. 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 $\alpha = 0.05$, so we fail to reject the null hypothesis. Likewise, since $F = 0.188 < F_{critical}$, then fail to reject H0. (See the interaction plot). To test the main factors.

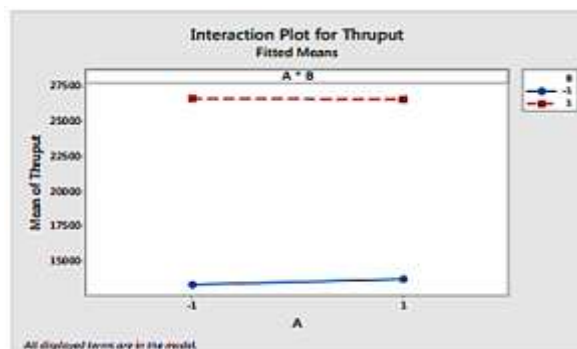


Figure 6. The interplay between the factor of the capacity of Conversion Process (A) and factor of Raw Material Arrival Rate (B)
Hypotheses: (Conversion Process Capacity)

H_0 : Main factor conversion process capacity is not significant.

H_a : 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 to zero is lesser than the importance level. Subsequently, the p-value equal is zero and less than 0.05, we excluded the null hypothesis. The response is significantly affected by the factor of the Arrival Rate of Raw Material. Consequently, hypotheses has to be excluded and achieve that there is an important variance between the interaction of the Mother Coil Arrival Rate and productivity of Conversion Process Capacity, as shown in Figure 7. Thus, there is an important outcome of the fundamental factor of Arrival Rate of Mother Coil on the response.

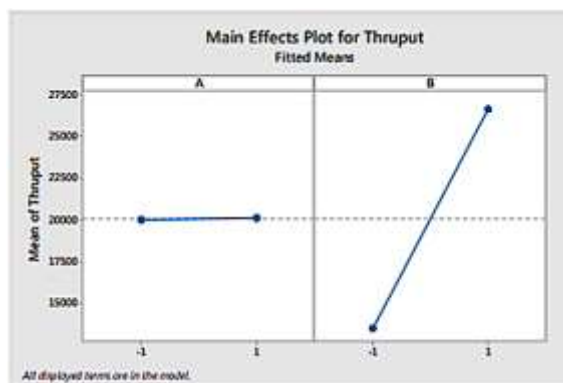


Figure 7. Main effects between factor of Conversion Process Capacity (A) and factor of Arrival Rate of Raw Material (B)

B. Paired t-Test: Two-Sample (Supplementary)

An initial number of replications of 10 was 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 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 regain 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 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	0.6201	-0.513	Reject
Scenario 1			Scenario 1
Bassline	1.96E-09	-23.78	Accept
Scenario 2			Scenario 2
Bassline	1.08E-07	-15.06	Accept
Scenario3			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 to afford solutions for improving the productivity of the current manufacturer schemes by ascertaining the performance of the system. Thus, possible improvements inside the production line were recognized and applied in an improved scenario 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 labor-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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REFERENCES

- [1] INFORMATION AND CREDIT RATING AGENCY (2017) *Bansal Ispat Udyog*. [Online] Available from: <https://www.icra.in/Rationale/ShowRationaleReport/?Id=34489> [Accessed 15/01/20].
- [2] RUIZ, R., GARCÍA-DÍAZ, J.C., and MAROTO, C. (2007) Considering scheduling and preventive maintenance in the flowshop sequencing problem. *Computers & Operations Research*, 34 (11), pp. 3314-3330.
- [3] ALMAMLOOK, R., ALDEN, A.Y.Q., FREFER, A., KNEW, S.H., and AGARW, Y. (2019) A Simulation Model for Productivity Efficiency Improvement Using Pro-Model: Case Study of Pipe Factory. *Revista Austral de Ciencias Sociales*, 26 (1), pp. 133-142.
- [4] FREFER, A., ALMAMLOOK, R.E., and SUWAYD, M. (2017) Productivity Analysis of the General Electric Company of Libya. *American Journal of Management Science and Engineering*, 2 (6), pp. 192-198.
- [5] ANAND, G. and KODALI, R. (2009) Simulation model for the design of lean manufacturing system: a case study. *International Journal of Productivity and Quality Management*, 4 (5-6), pp. 691-714.
- [6] ABU-TAIEH, E.M.O. and EL SHEIKH, A.A.R. (2007) Commercial simulation packages: A comparative study. *International Journal of Simulation: Systems, Science and Technology*, 8 (2), pp. 66-76.
- [7] OGUDO, K.A., NESTOR, D.M.J., KHALAF, O.I., and KASMAEI, H.D. (2019) A device performance and data analytics concept for smartphones' IoT services and machine-type communication in cellular networks. *Symmetry*, 11 (4), 593.
- [8] CLARK, R. and KRAHL, D. (2011) Roadmap to success: Your first simulation model. In: *Proceedings of the Winter Simulation Conference, Phoenix, Arizona, December 2011*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, pp. 1470-1480.
- [9] ABDULSAHIB, G.M. and KHALAF, O.I. (2018) An improved algorithm to fire detection in forest by using wireless sensor networks. *International Journal of Civil Engineering and Technology*, 9 (11), pp. 369-377.
- [10] TEARWATTANARATTIKAL, P., NAMPHACHAROEN, S., and CHAMRASPORN, C. (2008) Using ProModel as a simulation tools to assist plant layout design and planning: Case study plastic packaging factory. *Songklanakarinn Journal of Science and Technology*, 30 (1), pp. 117-123.
- [11] RZAYAG, A.Y. (2007) Effect of strain rate on tensile fracture behaviour of viscoelastic matrix (polyester) and reinforced composites. *Journal of University of Anbar for Pure Science*, 1 (1), pp. 44-54.
- [12] EL-KHALIL, R. (2009) *Optimization of Flexible Body Shop System*. Doctoral thesis.
- [13] LU, M. and WONG, L.-C. (2005) Comparing PROMODEL and SDESA in modeling construction operations. In: *Proceedings of the Winter Simulation Conference, Orlando, Florida, December 2005*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers.
- [14] DIAMOND, R., HARRELL, C.R., HENRIKSEN, J.O., NORDGREN, W.B., PEGDEN, C.D., ROHRER, M.W., WALLER, A.P., and LAW, A.M. (2002) The current and future status of simulation software (panel). In: *Proceedings of the Winter Simulation Conference, San Diego, California, December 2002*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, pp. 1633-1640.

- [15] SUPSOMBOON, S. and HONGTHANAPACH, K. (2014) A simulation model for machine efficiency improvement using reliability centered maintenance: Case study of semiconductor factory. *Modelling and Simulation in Engineering*, 2014, 956182.
- [16] FREFER, A.A., MAHMOUD, M., HALEEMA, H., and ALMAMLOOK, R. (2018) Overview success criteria and critical success factors in project management. *Industrial Engineering & Management*, 7, 244.
- [17] KHALAF, O.I., ABDULSAHEB, G.M., SULAIMAN, N., ZMEZM, H.F., and ZMEZM, H. (2015) Improving Video Transmission Over Heterogeneous Network by using ARQ and FEC Error Correction Algorithm. *Indian Journal of Science and Technology*, 30 (8), pp. 24-27.
- [18] SALMAN, A.D., KHALAF, O.I., and ABDULSAHEB, G.M. (2019) An adaptive intelligent alarm system for wireless sensor network. *Indonesian Journal of Electrical Engineering and Computer Science*, 15 (1), pp. 142-147.
- [19] GRANT, D. (2002) A Winder View of Business Process Reengineering. *Communications of the ACM*, 45 (1), pp. 85-90.
- [20] EL-KHALIL, R. (2013) Simulation and modelling: Operating and managing a new axle manufacturing system. *International Journal of Industrial and Systems Engineering*, 12 (2), pp. 219-232.
- [21] HARRELL, C.R. and PRICE, R.N. (2002) Simulation Modelling Using PROMODEL Technology. In: *Proceedings of the Winter Simulation Conference, San Diego, California, December 2002*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, pp. 192-198.
- [22] KHALAF, B.A., MOSTAFA, S.A., MUSTAPHA, A., MOHAMMED, M.A., and ABDUALLAH, W.M. (2019) Comprehensive review of artificial intelligence and statistical approaches in distributed denial of service attack and defense methods. *IEEE Access*, 7, pp. 51691-51713.
- [23] EL-KHALIL, R. (2014) Simulation analysis for managing and improving productivity: A case study of an automotive company. *Journal of Manufacturing Technology Management*, 26 (1), pp. 36-56.
- [24] KHALILI, M.H. and ZAHEDI, F. (2013) Modeling and simulation of a mattress production line using ProModel. In: *Proceedings of the Winter Simulations Conference, Washington, District of Columbia, December 2013*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers.
- [25] YAHAMED, A., IKONOMOV, P., FLEMING, P.D., PEKAROVICOVA, A., GUSTAFSON, P., ALDEN, A.Q., and SAIF (2016) Mechanical properties of 3D printed polymers. *Journal of Print and Media Technology Research*, 5 (4), pp. 273-289.
- [26] MAHDI, O.A., AL-MAYOUF, Y.R.B., GHAZI, A.B., MOHAMMED, M.A., WAHAB, A.W.A., and IDRIS, M.Y.I. (2018) An Energy-Aware and Load-Balancing Routing Scheme for Wireless Sensor Networks. *Indonesian Journal of Electrical Engineering and Computer Science*, 12 (3), pp. 1312-1319.
- [27] QAYYUM, K.D. (2012) *Improving Manufacturing Systems through Use of Simulation*. Newcastle: Newcastle University.
- [28] Yargholi M. System Level Simulation of Energy Detection Based UWB Receivers
. SJIS, 2020; 2(4): 10-14. <https://doi.org/10.47176/sjis.2.4.10>
- [29] KHALILI, H.H. and ZAHEDI, F. (2013) Modelling and Simulation a Mattress Production Line Using ProModel. In: *Proceedings of the Winter Simulation Conference, Washington, District of Columbia, December 2013*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, pp. 2598-2609.
- [30] ALDEN, A.Y.Q. and ALMAMALOOK, R. (2018) Impact of fuselage cutouts on the stress and deflection behavior: numerical models and statistical analysis. *IOP Conference Series: Materials Science and Engineering*, 454 (1), 012063.
- [31] YAKUBOVSKAYA, S.V., KRASOVSKAYA, N.I., and SILNITSKAIA, N.Y. (2018) Simulation of the Stress-Strain State for Long-Length Flexible Pipes. *Periodico Tche Quimica*, 15 (30), pp. 670-677.