APPLICATION OF SIMULATION FOR MANUFACTURING SYSTEM MANAGEMENT - A CASE STUDY

Rishi H. Singhania
Mumbai University

Vijay S. Bilolikar
Mumbai University

The paper presents operating strategies for manufacturing systems using simulation. An existing manufacturing facility plagued with productivity issues is replicated in a virtual environment using Arena Simulation software. The analysis of the system is performed by varying input parameters such as Batch Size, Target Stock Level and Reorder Point of Inventory. The impact of the changes in the input parameters on the system evaluation parameters such as System Output, Resource Utilization, Inventory Status and Bottleneck Operations are studied. New strategies are hence developed and suggested to improve the performance of the plant.

INTRODUCTION

Operating strategies of manufacturing systems are decided with the intension of maximizing the productivity and cutting down the idle situations, however the growth of the company over a period render these strategies rather debatable. This dilemma of whether to follow the old planning schedule and underutilize the true capabilities of the plant; or whether to introduce a new strategy, but risk losing steady production, is taken care of by Simulation. By replicating the physical setup in a virtual environment, we can simulate any scenario we wish to see results for. Present study is an attempt toward a simulative application of operation planning and scheduling tools in a Punches & Dies manufacturing system to analysis the impact of changes in the input parameters on the system evaluation parameters such as resource utilization, inventory status and bottleneck operations and new strategies were developed. Utilization defines the operational performance to the rated performance normally expressed as percentage. It is the proportional engagement time of the resource for production against the total available time. It is a useful manufacturing indicator for performance of a manufacturing facility. Lower utilization ratio means the less returns on investment and it is an indicator of inefficiency of the manufacturing operation. This study is an attempt towards identifying the utilization level of the resources in a production process and suggest an alternative manufacturing strategies to improve them.

A discrete event simulation based solution methodology is used. Simulation modeling is an experimental technique and applied methodology which is simple, flexible and ease to apply. It helps to establish system behaviour and predict system response there by establish theories for forecasting future actions or impacts from changes in operational inputs. Simulation modeling avoids the need to set many assumptions unlike most analytical techniques. It enables to test the effects of changes of system inputs without disturbing the real operation and help to identify and solve problems of certain phenomena.

LITERATURE REVIEW

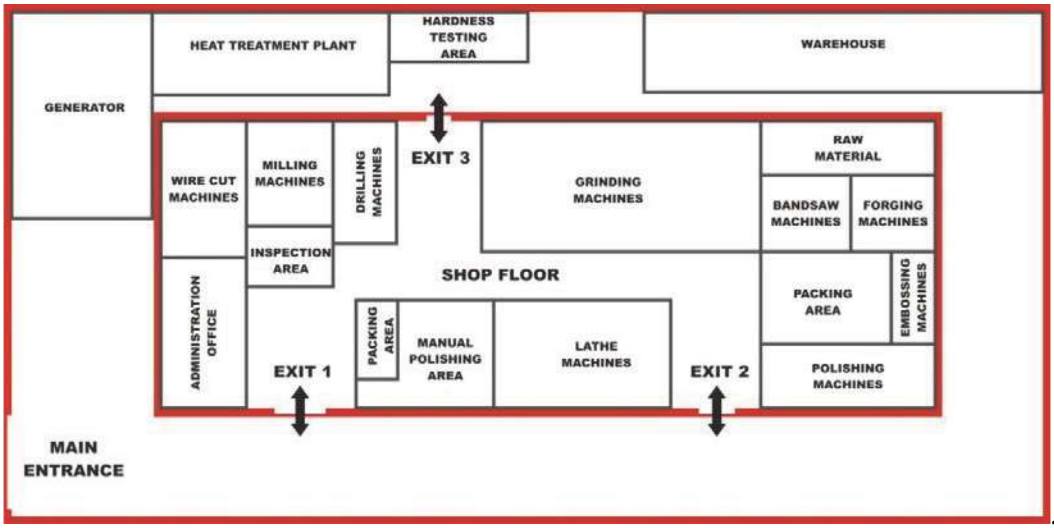
Smith (2003), surveys on modelling and development aspects pertaining to manufacturing systems simulation. Franco Cicirelli et al. (2011), focus on the use of statechart actors for communicating with each other in order to take care of the dynamic nature of the discrete event simulation under study. Ali Yalcin et al. (2005), writes about achieving control over a flexible manufacturing system using object oriented programming. His framework formulates inter object relationships on a real-time basis, controlling loss during resource failures and also facilitates deadlock resolution. Terkaj and Urgo (2015), designed an ontology based structure using VFF and put forth how important simulation can prove to be in a manufacturing shop. Yu Guo et al. (2005), developed a framework in a simulation environment using an optimization sub system. His object-oriented model offers control over the manufacturing system in real time. Long CheMak et al. (2014), studied the effect of lot size and operator competence on the production line. Pankaj & Ajai (2015), analyse a job shop scheduling problem by testing out different dispatching rules to improve results on makespan, mean flow time, mean tardiness, number of tardy jobs, mean setup time, etc. Yogesh & Vijay (2015) present a case study of a batch type manufacturing system to improve performance parameters like resource utilization, delivery time and inventory.

MANUFACTURING SETUP DETAILS

The experimental study has been carried out in a manufacturing setup which goes by the name of Imperial Pharmachines Pvt Ltd., located in Navi Mumbai, India. It has various manufacturing resources to transform the product. It includes machines like CNC Lathes, CNC Milling Centres, CNC Engraving Machines, CNC Wire Cut, Profile Grinders, Profile Honing, Fluidised Bed Furnace, Precision Grinders, Spark Erosion, Hot Forging Machine, together rounds up to more than fifty-five different resources. The total workforce is more than fifty. Though majority of the work is carried out on automated machines, a small portion of the work is still done manually. Skilled workers mainly occupy the shop floor while unskilled workers are merely 2-3 per shift with the only goal to ease out transportation of goods within the facility.

Schematic layout of the plant is depicted in Figure (1). The layout can be deemed as a modified version of a cellular manufacturing system; resources performing similar operations are grouped together and are also kept adjacent to the ones with which they interact frequently. Raw material enters the facility through the main entrance and then goes for storage. After machining on bandsaw cutters, jobs are forged, machined on lathe, and sent for embossing. After further machining on lathe and milling centres, jobs are sent for heat treatment. Here jobs are tempered, heated up to high temperatures, quenched and cleaned. Hardened jobs are now machined on high precision grinding machines, followed by automated polishing. Jobs are then laser marked and sent for quality checks. Approved batches are packed and shipped to the customer.

FIGURE 1:
SCHEMATIC LAYOUT OF THE PLANT



The company boasts a broad spectrum when it comes to its product catalogue. The products manufactured by the company are listed later in Table (1). To begin with the replication of the factory's working in a virtual environment, we picked up a product which is responsible for majority of the work load in the factory, i.e. Tablet Compression Tools. Due to the growing state of India in the pharmaceutical sector, many tablet making companies have introduced themselves to this market, hence the requirement of tools flourishes and it remains the most frequently ordered product this company responses to.

TABLE 1:
LIST OF THE VARIOUS PRODUCTS MANUFACTURED IN THE PLANT

Product List			
Tooling	**Tablet Press**	**Quality Control Equipments**	**Other Pharmaceutical Machines**
Special Tools	R & D Press	Inspection Kit	Siefter
Special Shapes	Single Rotary Tablet Press	Polishing Kit	Roll Compactor
	Double Rotary Tablet Press	Storage Cabinet	Granulator / RMG
	De-Dusters & Dust Collector	Computerized tool Inspection	Fluid Bed Dryer / Processor
	High Speed Mega Press	Auto Punch Polisher	Blender
		Ultrasonic Punch & Die Cleaning Machine	Coating equipment
			Blister Packing machine
			Blister change parts
			Strip Packing machine
			Multimill

With the vision of automating majority processes, the company owns a number of CNC Machines. CNC Lathes, Milling Centres, Wire Cut Machines, Engraving Machines, etc. are part of the wide spectrum of resources this company boasts. Table (2) enlists the resources which help meet the client's demand on time.

TABLE 2:
MANUFACTURING RESOURCES AVAILABLE IN THE PLANT

Machine Name	Quantity
CNC Lathe Machine	3
CNC Milling Machine	2
CNC Engraving Machine	1
CNC Wire Cut Machine	1
Drilling Machine	5
Conventional Lathe Machine	2
Bandsaw Cutting Machine	2
Embossing Machine	2
Centreless Grinding Machine	2
Cylindrical Grinding Machine	5
Surface Grinding Machine	4
Internal Grinding Machine	1
Head Forging Machine	1
Micro Polishing Machine	2
Buffing Machine	3
Heat Treatment Plant	1
Hardness Tester	2
Laser Marking Machine	1
Computerised Inspection System	2
Ultrasonic Cleaning Machine	3

DATA COLLECTION

In order to module the physical setup accurately, most of the data was collected first hand. Collecting processing time on all the resources per product accounted for 5 to 6 months of rigorous supervision. Secondary data like layout plan of the facility, were collected from senior members of the organization, while standards and product list were obtained from the company website. Data collected are classified into Primary, Secondary and Tertiary type in Table (3) below.

TABLE 3:
CLASSIFICATION OF DATA COLLECTED FOR SIMULATION SETUP

Data Type		
Primary	**Secondary**	**Tertiary**
Processing Time	Overall Plant Layout	Product List
Setup Time	Working Hours Per Day	Material Information
Flow Time	Demand Pattern	Systems Used
Batch Sizes	Number of Resources	Tools Used
Modifications in Plant Layout	Overall Process Flow of Products	Standards Used
Detailed Process Flow of Similar Products	Inventory Stock Information	Throughput Time
	Material Information	
	Dispatching Rules	
	Scheduled Maintenance	

Each product is customized as per the client's requirement, hence making it difficult to classify the production lines. However, after careful study of the work that is being carried out on the resources, and by analysing the demand pattern over the past few years, it can be safely assumed that the majority of the production is handled by 10 production lines. Number of processes per line varies from 21-47. For the confidentiality purpose the product names and the process names are coded and Table (4) illustrates the sequence of these processes followed in the production of these products.

TABLE 4:
PRODUCT TYPES & THEIR SEQUENCE OF OPERATION.

Product Type	Station Sequence (Machine Number)	Number of Processes
P1	6-7-60-46-9-2-13-13-62-13-13-12-30-28-29-38-46-33-41-61-16-63-63-14-14-64-59-36-59-63-57-57-10-48-64-57-50-49-8-48-37-36-59-50-51-47	47
P2	6-7-60-46-9-2-13-13-62-13-13-12-30-46-33-41-61-16-63-63-14-14-64-59-36-59-63-46-57-10-48-64-57-50-49-8-48-37-36-59-50-51-47	44
P3	6-7-60-46-9-2-62-13-13-33-41-61-16-14-64-22-63-14-63-57-10-48-64-50-49-8-48-37-36-50-51-47	33
P4	6-7-60-46-9-2-62-13-13-33-41-61-16-14-64-22-63-14-63-57-10-48-64-50-49-8-48-37-36-50-51-47	33
P5	6-7-60-46-9-2-62-13-13-28-29-38-33-41-61-16-14-64-22-63-57-10-48-64-50-49-8-48-37-36-59-50-51-47	37
P6	6-7-60-46-9-2-62-13-13-33-41-61-16-14-64-22-63-14-63-57-10-48-64-50-49-8-48-37-36-50-51-47	33
P7	6-7-13-17-43-13-13-33-41-16-14-58-64-22-63-14-63-57-10-48-64-50-49-8-48-37-36-50-51-47	31
P8	6-7-13-17-43-13-13-33-41-16-14-58-64-22-63-14-63-57-10-48-64-50-49-8-48-37-36-50-51-47	31
P9	7-15-15-33-41-17-18-3-44-52-31-42-54-45-54-53-31-36-59-36-50-51-47	24
P10	7-15-15-33-41-17-24-52-17-18-3-53-44-31-36-59-36-50-51-47	21

SIMULATION ENVIRONMENT

The software used in this research is Arena. It is a powerful tool developed by Rockwell Automation Inc. used to provide preeminent solution for better business decisions using discrete event simulations. By testing out ideas in the computer laboratory Arena can help us predict the future with confidence and without disrupting our current business environment. Any business environment, from customer service to manufacturing to health care, can be simulated using this software. And whether it is an existing supply chain or a new emergency room layout, we followed five steps with Arena for creating a virtual model of the manufacturing set up.

Step 1: Using Arena software provided modules a basic model of the setup is created. Arena's modules are dragged into the model window and connected them to define process flow. Blocks are used from Basic Processes, Advance Processes and Advance Transfer menu. Each block and the input parameter set in it are listed in the Table (5). Using all these blocks from the Project Bar, a framework representing the job shop manufacturing shop was created.

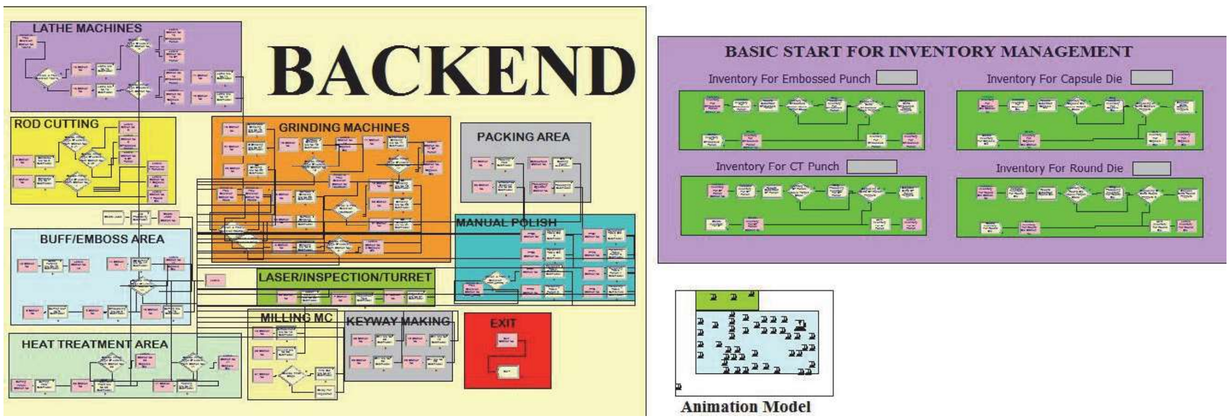
TABLE 5:
INPUT PARAMETERS

Module Name	Input Parameters	Modelled Inputs
Create	Entity Type	Job 1, Job 2, Job 3, Job 4, Job 5.
	Inter Arrival Time	Random, Uniform, Constant.
	Entities per Arrival	1, 30, 50, ...
	Max Arrivals	Infinite.
Decide	By Chance	66%-34%, 41%-28%-13%-18%.
	By Condition	Expressions Comparing Resource Queue, Entity Type, ...
Process	Action	Seize, Delay, Release, Seize-Delay-Release.
	Resource Name	Resource 1, Resource 2, Resource 3, ...
	Resource Quantity	1, 2, ...
	Delay Type	Triangular, Uniform, Constant, Expression.
	Allocation	Value Added.
Batch	Batch Type	Temporary.
	Batch Size	20, 30, 40, ...
	Rule	By Attribute.
Separate	Separate Type	Split Existing Batch.
	Member Attributes	Retain Original Entity Values.
Assign	Attribute	Entity Sequence, Stage Value.
	Entity Type	P1, P2, P3, P4, ...
	Entity Picture	Red Ball, Blue Ball, Yellow Ball, ...
Record	Record Type	Count.
Dispose	Dispose Name	Dispose 1, Dispose 2, Dispose 3, ...
Seize	Resource Name	Resource 1, Resource 2, Resource 3, ...
	Resource Quantity	1, 2, ...
	Allocation	Value Added.
Delay	Delay Type	Triangular, Uniform, Constant, Expression, ...
	Allocation	Value Added.
Release	Resource Name	Resource 1, Resource 2, ...
	Resource Quantity	1, 2, ...
Search	Search Type	Batch, Queue.
	Conditions	Start Value, End Value, Expression.
Hold	Hold Type	Scan for Condition.
Station	Station Name	Station No 1, Station No 2, Station No 3, ...
Route	Destination Type	By Station, By Sequence.
Enter	Allocation	Non-Value Added.
	Transfer In	None, Free Transporter.
Leave	Allocation	Non-Value Added.
	Transfer Out	None, Request Transporter.
	Transporter Name	Cart.
	Connect Type	Transport, Route.

Step 2: Once the basic model is created, the real-world data is applied to the model. In the first step we created the framework which represents the real system, but without refining the model one cannot achieve the same output. The model's accuracy now dependents on the authenticity of the data we input. To create a more realistic picture of our system, we have replaced the animation icons that Arena automatically supplies with graphics of our own. The simulated model of the setup is shown in Figure

(2). The model can be broken down into three parts, Backend, Inventory Management System and Animation Model. The Backend is the network which handles all the logics and decision making which happen on the shop floor to facilitate job flow. Inventory Management section deals with the triggering of the plant to start or to stop producing semi finish goods. It checks the inventory status level and triggers raw material into the system automatically. Animation Model represents the plant layout and imitates the movement of jobs in actuality.

FIGURE 2:
ARENA MODEL

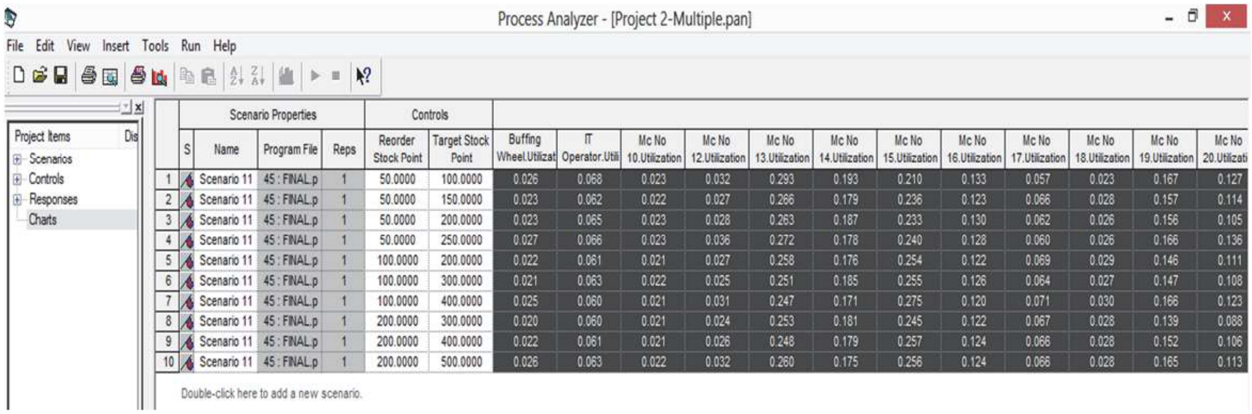


Step 3: Once the model is ready, we run the simulation to verify that the model properly reflects the actual system. Parameters like Number of Replications, Replication Length, Warm-Up Period, Hours per Day, etc. are set here. After validating our virtual setup, we identify bottlenecks and communicate with other modules through the dynamics of Arena's graphical animation.

Step 4**:** Now the model is analysed by Arena and automatic reports on common decision criteria, such as resource utilization and waiting time are generated. Alternative ideas suggested are tested using process analyser. This feature of Arena is the most powerful of all as it gives us the control of changing the input values of certain parameters and observe its effect on the overall output of the system. Many scenarios were simultaneously tested on a click of a button using process analyser and the results were compared on a single screen. Figure (3) shows the process analyser running 10 scenarios simultaneously each having a different set of values for stock reorder point and target stock value for the inventory. The results generated help us understand the pattern in which the system responses to the change in the control values. In the figure, we can notice the system is subjected to 2 controls, reorder point varying from 50 to 200, and target stock point varying from 100 to 500. A total of 10 scenarios were run and responses like machine utilization, system output and average waiting time of each type of job were noted.

Step 5: After running the process analyser for different case scenarios, we now choose the set of parameter settings best fit to achieve our goal of managing inventory stock level and smoothening machine utilization. The model and analysis output is validated.

FIGURE 3:
PROCESS ANALYZER

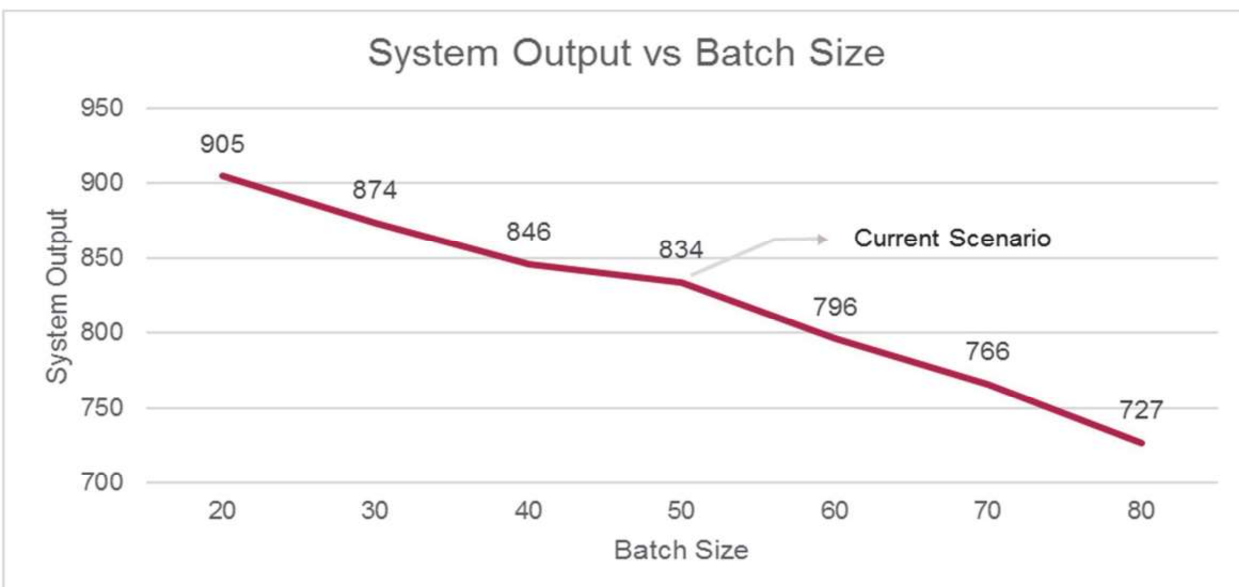


	Scenario Properties				Controls													
	S	Name	Program File	Reps	Reorder Stock Point	Target Stock Point	Buffing Wheel.Utilizat	IT Operator.Utili	Mc No 10.Utilization	Mc No 12.Utilization	Mc No 13.Utilization	Mc No 14.Utilization	Mc No 15.Utilization	Mc No 16.Utilization	Mc No 17.Utilization	Mc No 18.Utilization	Mc No 19.Utilization	Mc No 20.Utilizati
1		Scenario 11	45 : FINAL.p	1	50.0000	100.0000	0.026	0.068	0.023	0.032	0.293	0.193	0.210	0.133	0.057	0.023	0.167	0.127
2		Scenario 11	45 : FINAL.p	1	50.0000	150.0000	0.023	0.062	0.022	0.027	0.266	0.179	0.236	0.123	0.066	0.028	0.157	0.114
3		Scenario 11	45 : FINAL.p	1	50.0000	200.0000	0.023	0.065	0.023	0.028	0.263	0.187	0.233	0.130	0.062	0.026	0.156	0.105
4		Scenario 11	45 : FINAL.p	1	50.0000	250.0000	0.027	0.066	0.023	0.036	0.272	0.178	0.240	0.128	0.060	0.026	0.166	0.136
5		Scenario 11	45 : FINAL.p	1	100.0000	200.0000	0.022	0.061	0.021	0.027	0.258	0.176	0.254	0.122	0.069	0.029	0.146	0.111
6		Scenario 11	45 : FINAL.p	1	100.0000	300.0000	0.021	0.063	0.022	0.025	0.251	0.185	0.255	0.126	0.064	0.027	0.147	0.108
7		Scenario 11	45 : FINAL.p	1	100.0000	400.0000	0.025	0.060	0.021	0.031	0.247	0.171	0.275	0.120	0.071	0.030	0.166	0.123
8		Scenario 11	45 : FINAL.p	1	200.0000	300.0000	0.020	0.060	0.021	0.024	0.253	0.181	0.245	0.122	0.067	0.028	0.139	0.088
9		Scenario 11	45 : FINAL.p	1	200.0000	400.0000	0.022	0.061	0.021	0.026	0.248	0.179	0.257	0.124	0.066	0.028	0.152	0.106
10		Scenario 11	45 : FINAL.p	1	200.0000	500.0000	0.026	0.063	0.022	0.032	0.260	0.175	0.256	0.124	0.066	0.028	0.165	0.113

RESULTS AND DISCUSSIONS

The model was subjected to 3 controls and 1 response variable. Batch Size, Target Stock and Reorder Point severed as the controls in the systems to analyze response in terms of System Output. First the system was tested for its reaction on various batch sizes. Model was run for batch sizes of 20,30,40,50,60,70 and 80. Results suggests that reduction in batch size provides smoother flow of operations, fewer bottlenecks and improved load distribution among all the resources, hence better response values were obtained. Figure (4) shows the effect of system output on all the batch sizes.

FIGURE 4:
BATCH SIZES VS SYSTEM OUTPUT



As we can see from the plot above, the system gave out maximum output when the batch sizes were the smallest (i.e. 20). The reason being, smaller batch sizes facilitate quicker flow of the jobs throughout the plant. For example, if the batch size is 80, the first job of the batch, after processing, has to wait till the next 79 jobs get processed, only then can the batch be moved to the next station. However, by changing the batch size to 20, the first job now has to only wait for the next 19 jobs before it gets transferred to the next scheduled station. But practically speaking, lower batch sizes have their own disadvantages. As the batch size goes on reducing, it increases the number of batches in circulation in the plant, this makes things difficult to manage in terms of transportation and management. Hence, we reach a consensus with a batch size of 50, to maintain a good output and at the same time not create a chaos on the shop floor.

Target Stock Level and Reorder Point however do not give us such a clear picture. The results are fluctuating in nature and one cannot draw a direct conclusion from it. The basic logic suggests that higher the level of semi-finished goods in the inventory, the smoother the operations would flow, resulting in better productivity. However, when we run the simulation for the different scenarios, we notice that there is no such direct relation among the two.

FIGURE 5:
TARGET STOCK & REORDER POINT VS SYSTEM OUTPUT

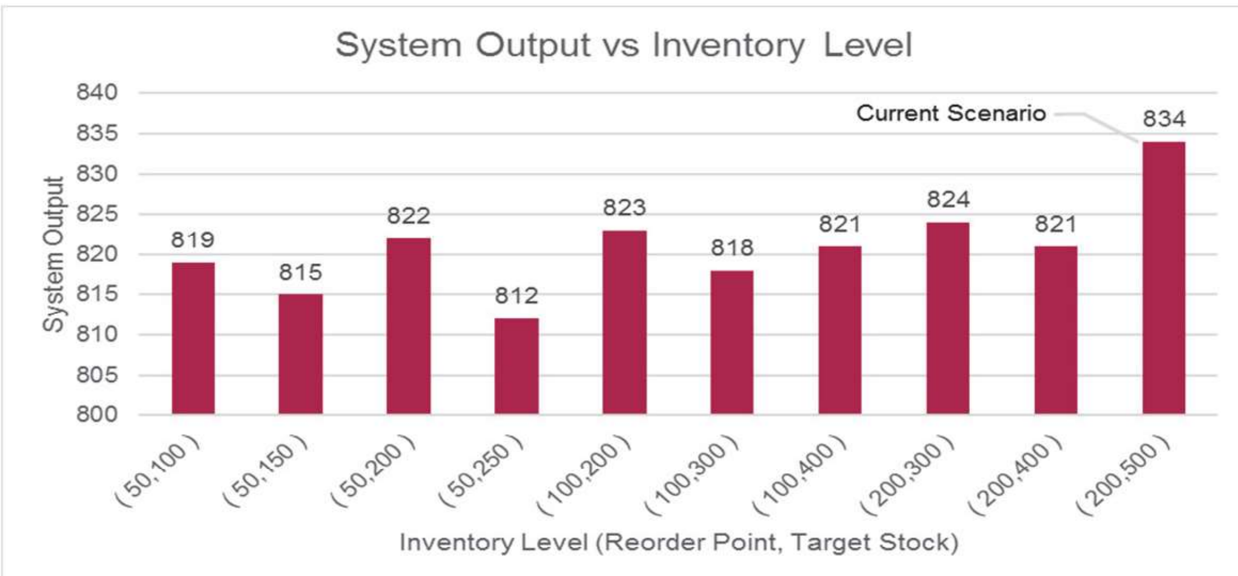


Figure (5) plots the variation in system output for all the 10 cases studied. The system was tested on reorder point values & target stock values of, (50,100), (50,150), (50,200), (50,250), (100,200), (100,300), (100,400), (200,300), (200,400) and (200,500) respectively. As we can see from the plot, the results do not suggest the winning combination, but give us a sense about the strategy one can obtain to get the system to respond in the most productive way. Maintaining a higher reorder point is beneficial provided we do not keep a very high target stock level. Higher the difference in the two levels, means the more number of semi-finished jobs the unit has to produce once it reaches the reorder point. This makes the resources concentrate more on making the semi-finished jobs to replenish the inventory and in turn hamper the productivity of the finished jobs. Meanwhile, factors like demand pattern, procurement lead time and preventive maintenance of resources, suggest we keep a healthy supply of stock in the inventory. Further research is being carried out in this area where all such factors can be accounted for and an optimal level for reordering decisions and target stocks level decisions can be made.

CONCLUSION

A batch type production manufacturing set up, plagued with productivity issues, is studied using simulation. The analysis of the system is performed by varying the input parameters like Batch Size, Target Stock Level and Reorder Point of inventory. The impact of changes in the input parameters on the system evaluation parameters such as system output, resource utilization, inventory status and bottleneck operations are studied. The results from the simulation study are verified with the actual production figures. The simulative study of the production set up gave a deeper insight into the operation for improvement. The alternative solution strategies for the manufacturing facility with improved resource utilization are suggested. The performance indicators under study are system output, resource utilization and work in process inventory. Future study can include more parameters like waiting time, performance, production based real time, impact of product mix, and layout changes etc. on the utilization of resource with simulation.

REFERENCES

Cicirelli F, Angelo Furfaro, Libero Nigro. (2011). Modeling and simulation of complex manufacturing systems using statechart-based actors. Simulation Modelling Practice and Theory, 49: 203-214.

Gadinaik Y, Vijay S. Bilolikar. (2015). Simulation Based Analysis of job shop manufacturing planning.

Guo Y, W. Liao, X. Cheng, Liang Liu. (2005). SimOpt: A new simulation optimization system based virtual simulation for manufacturing system. Simulation Modelling Practice and Theory, 14: 577–585

Negahban. A, Jeffrey S. Smith. (2014). Simulation for manufacturing system design and operation: Literature review and analysis. Journal of Manufacturing Systems, 33: 241–261

Production Operation Management Society 26th Annual Conference, Washington DC, USA.

Sharma S, Ajai Jain. (2015). Performance analysis of dispatching rules in a stochastic dynamic job shop manufacturing system with sequence-dependent setup times: Simulation approach. CIRP Journal of Manufacturing Science and Technology.

Smith, S. (2003). Survey on the Use of Simulation for Manufacturing System Design and Operation. Journal of Manufacturing Systems, 22: No. 2.

Terkaja, T., M. Urgo. (2015). A Virtual Factory Data Model as a support tool for the simulation of manufacturing systems. Procedia CIRP, 28: 137 – 142

Yalcina, Y., Ravi KalyanNamballa. (2005). An object-oriented simulation framework for real-time control of automated flexible manufacturing systems. Computers & Industrial Engineering, 48: 111–127.691-706.

CONTACT AUTHORS:

Rishi Singhania (+91 9820007827) 1101, Orchid, Vasant Valley, Near Dindoshi Depot, Film City Road, Malad (East), Mumbai – 400097. singhaniarishi.rs@gmail.com

Vijay Bilolikar (+91 9619730243) A6/301, Rutu Enclave, Near Mutchala Polytechnic College, Anand Nagar, Ghod Bunder Road, Thane – 400615. bilolilkar@frcrce.ac.in