Simulation Model for Productivity, Production and Cost Improvement in an SME

P. M. Kinge and U. C. Jha

Abstract Every industry endeavoring its best to turn into smart intellective manufacturing to sustain the competition predicated on development following industry 4.0. Smart intellective manufacturing is predicated on smart intellective decision making. Smart intellective decisions can be taken with lots of paperwork, brainstorming, presentations, etc., and the utilization of these traditional techniques results in decremented productivity. Simulation software is the implement that fortifies astute decision making to amend productivity, production, and cost in a manufacturing unit. The perspicacious decision making is predicated on the analysis of data amassed from various activities of the manufacturing unit. This paper aims to spread vigilance about the utilization of such implements in Indian small medium enterprises (SMEs) for enhancing organizational performance. In this paper, the research work is predicated on modeling the problem of the plastics processing industry utilizing Arena simulation software to amend productivity, production, and cost. The selected manufacturing unit produces around 30 components and supplying them mainly to the furniture-making industry. The conception is to develop a simulation model that can be facilely utilized by the working executives of the SME. By changing various process parameters, different scenarios can be obtained with different outputs. The decision to select the best scenario with the optimum output can be utilized for implementation on the shop floor.

Keywords SMEs · Arena · Simulation model (SM) · Framework

1 Introduction

For so many years, various advanced implements are in industrial practices for system modeling. They are efficaciously used to model various industrial quandaries to ascertain various scenarios with transmuting parameters. All the scenarios are compared to get the best one afore being implemented in authentic practice. Arena simulation

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is utilized to model the effect of the number of machines on resource utilization and the solutions obtained are acclimated to frame the dispatch rules Yang and Hsieh [1]. The majority of manufacturing units are endeavoring their best to become keenly intellective and want to follow the framework proposed by various researchers following Industry 4.0. Considerable research is done for developing a framework by many researchers concerning the practices followed in the industries. One such framework, Operator–Workstation Interaction 4.0 is developed by Golan et al. [2]. This framework consists of three subsystems: 1. observing and accumulating data on working of operator and workstation, 2. analyzing the data for engendering output, 3. replication system. As a component developing models of manufacturing systems, the discrete event simulation model is developed with all multifarious features which in turn can develop various scenarios afore being implemented. With the affordability of the simulation software, their utilization plays a vital role in the amelioration of efficiencies across various verticals in the SMEs Aggogeri et al. [3].

Recently, since last decade utilization of simulation software got momentum in many industries to develop the different strategies by varying input parameters. There is an ease in the utilization of this software as compared to the mathematical models developed for various industrial problems.

A generalized production inventory mathematical model is developed by Yang [4]. The objective of this model is to find optimum production restart and stop time by keeping the cost as low as possible. The approach utilized in developing such a mathematical model differentiates considerably with the approach by the researcher or industrial utilizer who develops models with the simulation software. Similarly, a mathematical model was developed by Zhang et al. [5] and explicates the integration of the production inventory system. The objective of this model is to ameliorate supply chain efficiency. When you compare the development of this model with the model which can be developed utilizing simulation software with the same problem, you may find that the second approach is very efficient and time-preserving over the first one.

Simulation implements are widely utilized in developing models in the product design process, for minimizing development time, truncate errors, and optimize the process. Such an implement is utilized by Tosello et al. [6] for the optimization of raw material input into the hopper of the powder injection molding process. A logical framework can additionally be developed to ascertain the solution to various industrial problems. One such framework is developed by Huang et al. [7] and predicated on the reproductive property of probability distribution to ascertain the optimum production rate and lot size.

Lie and Jia [8] developed EPQ models to ascertain the optimum production lot size and backorder quantity. They utilized a traditional approach to develop the EPQ mathematical model and tested two numerical with authentic industrial data. Wang et al. [9] developed a framework for task scheduling. The framework integrates all the smart resources of the manufacturing unit so that all the activities are coordinated in authentic time. The utilization of advanced technology and their interface with each other is the base of this framework. The framework proposed is tested with a case study.

The role of SMEs in the economic development of any country and adaptation of Industry 4.0 by the SMEs and its impact on their prosperity along with risk associated is well explicated by Moeuf et al. [10]. The effect of Industry 4.0 technologies (I4T) on sustainable organizational performance (SOP) with lean manufacturing practices (LMP) as the variable is a component of the research done by Kamble et al. [11].

Alkhoraif et al. [12] elongated the Systematic Review Methodology (SRM) for understanding the effect of lean implementation in SMEs. A mathematical model was developed by Giri and Sharma [13] for determining optimum production and shipment policy. Li [14] developed a mathematical model of production inventory to ascertain optimum inventory levels and production rates to minimize total cost.

2 Problem Statement

The SME under consideration for research work is the plastic processing industry producing around 30 components and supplying mainly to the furniture-making industry. The unit is mostly flooded with orders containing varying demands for sundry products produced by the industry. For each product, there is discrete mold and it requires to be set on a particular machine. There are a total of 13 machines with two types of capacities 100-ton and 50-ton. A total of 3 machines are with 100-ton capacity and 10 machines with a 50-ton capacity. Lots of paperwork needs to be done by the production executive for deciding which machine to stop for production and when to stop as the number of products is more than the number of machines. The product demands are varying with time. The simulation model abbreviates this paperwork to a great extent additionally helps in is deciding the optimum quantity for production so that all the customer demands are met. There is cost associated with the inventory of so many products; the simulation model answers the optimum inventory for each product.

3 Action Plan for Development of the Simulation Model

The simulation model (SM) is divided into two components, inventory, and production. The inventory part of the SM accepts customer orders with product demands as input, checks the demands against inventory for that product, and sets the product targets accordingly. The product demand and rejection data are stored in the excel file during the simulation run. This data is utilized to find rejection for each product. The production part of the SM contains an individual model for 13 machines. There are only two types of machines 100-ton and 50-ton. Total 3 machines are 100-ton and the remaining 10 are 50-ton plastic injection molding. The products are produced on these 13 machines according to their production targets. Each machine's production data is stored in the excel file during the simulation run. The data is utilized for deciding the loading and unloading of molds on the 13 machines. The flow chart for the development of simulation model is shown in Fig. 1.

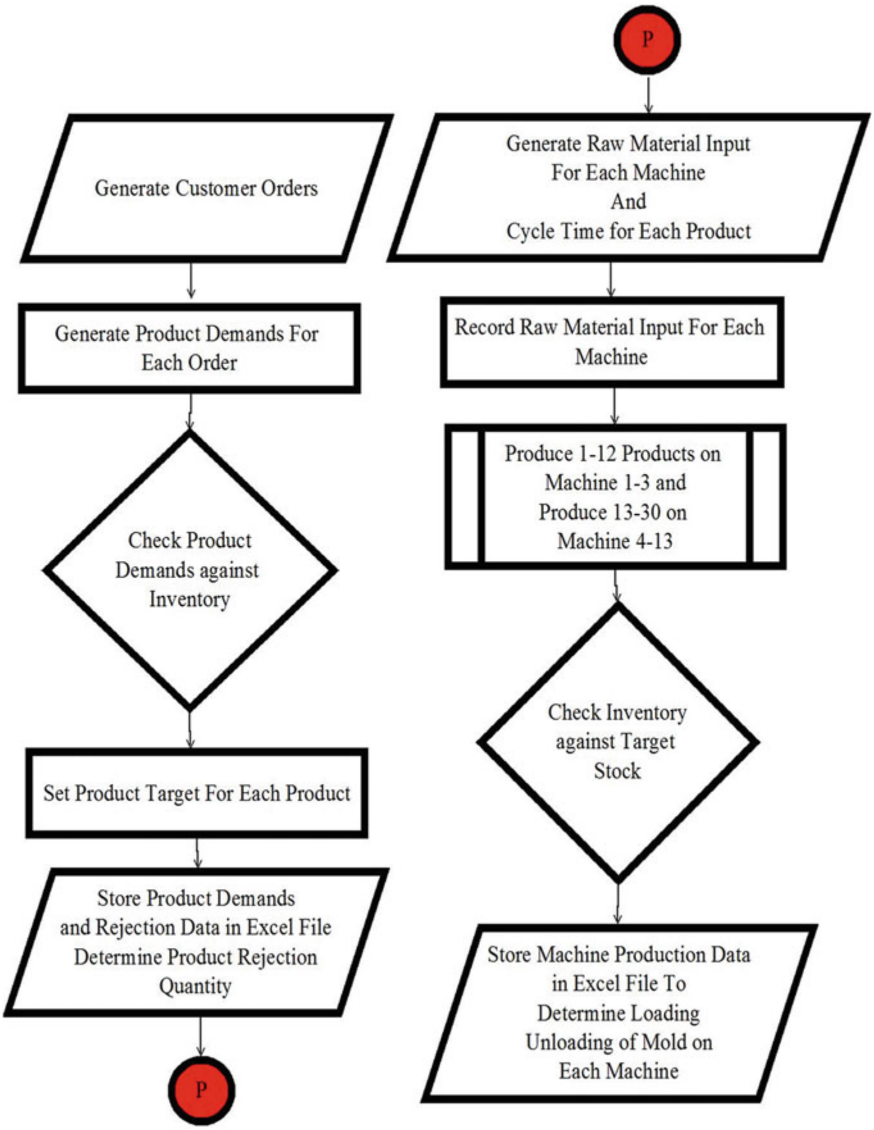

Fig. 1 Action plan for development of simulation model

4 Design of the Simulation Model

The simulation was designed utilizing Arena simulation software. For the inventory part of the model, the input is inter-arrival times for customer orders, product demands for each order. Similarly, for the production part of the model, the input is the inter-arrival time for raw material on each machine and cycle time for each product. The factory under consideration runs in 3 shifts of 8 h each for 6 days in a week. The simulation run is taken for 30 days. The statistical distribution expression for each input is developed based on data accumulated from the plastics processing industry under consideration. A total of 13 machines are there and 30 products are produced on these machines. 12 products are produced on 3 machines with 100-ton designation, and the remaining 18 products are produced on 10 machines with the 50-ton designation. Without this simulation model, the production management of 30 products on 13 machines is tedious. The simulation model provides a solution for time-based loading and unloading of product mold on a particular machine so that the rejection of the orders is minimized.

5 Results and Discussion

The data recorded as a component of the output in the excel file is for product demands and rejection. An excel file was created with a macro written for finding the rejection for each product for a simulation run of 30 days. Concerning the data product numbers 2, 3, and 20 got maximum rejection. The simulation model has built an implement denominated process analyzer. By utilizing this implement, one can vary the input controls and after run replications are engendered in the form of output. Here, in our case, it is required to reduce the rejection of product numbers 2, 3, and 20. The following self-explanatory Table 1 explains the input control and output responses for the 3 scenarios run in the process analyzer of Arena simulation. As product numbers, 1 to 12 are produced on machines 1 to 3, and product numbers 13 to 30 are produced on machine 4 to 13. With the process Analyzer, it is very easy to find optimum inventory and target stock for each product by running the number of scenarios within a few minutes.

The production data of each machine is recorded in an excel file. A time-based decision can be taken for loading and unloading of mold on the categorical machine. As the simulation model is run for 30 days with new customer order entering into the system with every 6 days. The production on 13 machines for 30 products took place for 615 h. The output generated by the simulation model is validated by implementing the solution for 2 consecutive months in the SME under consideration. Table 2 shows the production of product numbers 1 to 12 on 3 machines (100 tons each).

Table 3 shows production of product number 13 to 30 on remaining 10 machines (50 ton each).

Table 1 Product target and product rejection scenario

	Input controls						Output response		
	Inventory(2)	Target stock (2)	Inventory (3)	Target stock (3)	Inventory (20)	Target stock (20)	Products rejected Qty (2,2)	Products rejected Qty (3,2)	Products rejected Qty (20,2)
Scenario 1	600	5000	600	3500	1122	2200	3149	4597	4172
Scenario2	1000	7000	1000	5000	1800	4000	3149	2414	1375
Scenario3	600	4500	600	4500	1122	4000	3149	2414	1375

Table 2 Production on 3 machines (100 ton each)

Machine 1				Machine 2			Machine 3		
Product No	Qty Produced	Time		Product No	Qty Produced	Time	Product No	Qty Produced	Time
1	2800	3.26		2	3800	3.92	3	2300	2.78
6	5332	6.55		7	7527	7.33	5	5346	6.09
1	2030	146.37		6	3142	145.97	3	2068	146.49
4	299	290.64		12	995	147.80	2	3844	291.97
6	3008	292.50		1	2886	291.35	10	2471	296.54
2	447	432.47		7	2086	292.30	4	46	432.42
7	7541	435.89		12	1040	294.22	6	4922	435.47
5	568	576.37		5	3618	434.26	7	4055	577.86
10	1014	578.25		12	1383	436.82	12	458	578.71
				4	381	579.31			

Note Time is in hours

Table 3 Production on 10 machines (50 ton each)

Machine 4			Machine 5			Machine 6		
Product No.	Qty produced	Time	Product No.	Qty produced	Time	Product No.	Qty produced	Time
15	3300	2.59	16	3504	2.76	18	2024	1.44
26	1154	433.21	29	242	433.27	18	2895	578.05
28	1634	579.96	25	398	578.68			
Machine 7			**Machine 8**			**Machine 9**		
Product No.	**Qty produced**	**Time**	**Product No.**	**Qty produced**	**Time**	**Product No.**	**Qty produced**	**Time**
18	2823	146.00	20	1924	147.18	17	893	290.98
15	2717	290.14	16	2649	290.10	20	1853	579.07
15	1865	433.48	17	42	432.15			
16	1620	577.29	17	639	578.11			
Machine 10			**Machine 11**			**Machine 12**		
Product No.	**Qty produced**	**Time**	**Product No.**	**Qty produced**	**Time**	**Product No.**	**Qty produced**	**Time**
18	2204	289.55	26	742	288.78	18	695	432.50
16	512	432.41	14	639	434.36	14	6	576.04
26	1766	577.83	27	360	578.62	29	314	577.65
Machine 13								
Product No.	**Qty produced**	**Time**						
25	161	497.50						
15	823	614.58						

The objective of batch production is to produce an optimum quantity of each product at the right time so that the demand for maximum products is met. The output obtained in the excel file for production facilitates the same.

6 Conclusion and Future Scope

The productivity of the shop floor manager has been improved to a great extent by eliminating the tedious job of manual production scheduling. There is an improvement on the production front, the optimum inventory, and target stock for each product can be found by running various scenarios with inventory and target stock as input controls to produce the replications in the form of rejection quantity for each product. Last but not the least there is cost associated with the inventory of the products, and when you hold an optimum quantity of inventory for each product obviously the total inventory cost is optimum.

As a part of quantitative findings, the simulation model assists to process the huge machine data in few minutes, in our case it is for 13 machines, in other production floor it may consist of around 100 machines. The machines may run virtually for few days to years in the simulation model and generate the required output. As a part of qualitative findings, the productivity of the shop floor manager improved to great extent by eliminating the preparation of manual production schedule. Since there is change from manual work to the solution obtained from simulation model, so there are no comparison results between the existing and proposed product.

This simulation model contains two components inventory and production. As in normal practice, there is customary machine maintenance or breakdown, so there is scope for integrating a maintenance model into this existing model. The reports produced by this simulation model provide insights into resource utilization. The cost analysis can easily be obtained in these reports if the cost input data is provided by the industry. There is scope affixing the operator schedule to each machine and ascertain their instantaneous utilization. The effect of addition or reduction of resources like human, machine, material, etc., on the cost can easily found and optimum numbers can be found by running various scenarios.

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