Application of Discrete-Event Simulation to Increase Throughput of Manufacturing System—A Case Study

Prasad V. Thete and Ramesh R. Lekurwale

Abstract This paper underlines use of discrete-event simulation to increase throughput of a manufacturing facility. The literature survey shows brief information about the recent work done by the various researchers in application of discrete-event simulation in manufacturing industries. The methodology followed while doing study is a stepwise procedure of a simulation study. A case study shows the way to solve the problems in manufacturing by using discrete-event simulation. Alternate possible scenarios are compared, and best scenario is selected as a solution of the problem.

Keywords Discrete-event simulation · Manufacturing · Throughput · FlexSim

1 Introduction

Discrete-event simulation is a process of replicating the physical system in the virtual environment by using computer software program. It is possible to perform number of experiments without disturbing the ongoing process using discrete-event simulation [1].

A case study is performed in which FlexSim (discrete-event simulation software) is used to model the manufacturing system to improve the performance measures of the manufacturing system. Firstly, the current scenario needs to be studied. To understand the current scenario, it is necessary to consider the ongoing process. The company produces various parts of automotive transmission system. For a component, they want to increase their throughput capacity.

The process of producing the component is as follows.

The process flow and layout of the manufacturing facility is shown in Fig. 1.

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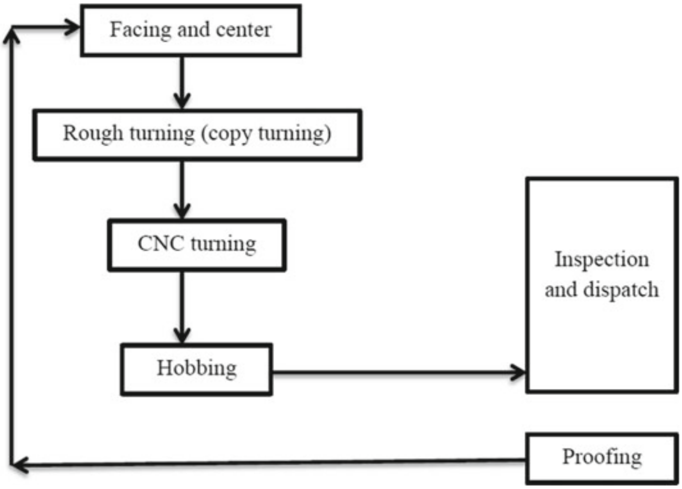

Fig. 1 Layout of manufacturing shop

Process flow

- **Proofing**: Proofing is the process in which rough-turning of the collar of component is done. It is necessary to ensure the proper clamping of spline plug on face and center machine. For this operation, a conventional lathe is used. The lathe has hydraulic circuit, customized chuck and mandrel to clamp a job.
- **Facing and Center**: Facing of the job (on either side or both sides) as well as center drilling is done using a special-purpose machine. It is an important operation; because, all the references are taken from the center and face.
- **Rough-turning**: Rough-turning is also known as copy turning. In this process, enough profile is turned using master. This operation is necessary to reduce the cycle time on CNC machine.
- **CNC turning**: In the first cycle, rough-turning is done which is followed by finish turning. Hence, the component is ready for Hobbing.
- **Hobbing**: In this process, splines are cut using a hob cutter. After completing this Hobbing process, splined plug is ready for inspection and dispatch.
- **Inspection and dispatch**: As the machining is completed, the component is inspected for the quality, and then it is dispatched.

Currently, the company produces 48 components per shift (144 components per day). They want to increase their capacity to 300 components per day.

2 Literature Review

Liufang Yao et al. [2] simulated steel production system using FlexSim to solve scheduling problems which are too difficult to solve using analytical methods. Zang Libin et al. [3] made FlexSim model for optimizing the production line completely which enter would reduce the cost involved in maintenance too. Pawel Pawlewski et al. [4] used simulation to solve a problem related to inventory and material handling in automotive industry. Yogesh.Y. Gadinaik et al. [5] modeled the job shop manufacturing system using arena. The experiments were performed to analyze performance measures like inventory management and machine utilization of newly developed system. Rishi H. Singhania et al. [6] used arena to model a manufacturing facility in virtual environment. Alternate plans were analyzed to select the best plan to improve performance measures of the manufacturing system. Sławomir Kukla [7] used arena to model a sports equipment production system to solve issues related to manufacturing. Tomasz Bartkowiak et al. [8] performed simulation investigation into enhancement of floor-board manufacturing to increase material efficiency. Adrian Jakobczyk et al. [9] modeled soap production system using FlexSim and develops alternate system to increase flexibility and to solve other issues of the old system manufacturing planning to improve production rate. Slawomir Klos et al. [10] studied the effect of buffer stock in production line to improve the performance of production process. V. K. Manupati et al. [11] studied sustainable manufacturing system using FlexSim analyzed the effect of work load allocation of multiple components.

3 Methodology

The flow chart of methodology is shown in Fig. 2.

Study starts with problem statement. Then, the objective of study and the overall plan of the study are decided. Then, collection and modeling of data are done. The data consist of information about available resources, process times and location of machines. After modeling the inputs, FlexSim model is built. After that, model is tested for the validation. If model is validated, the process is continued further. If model is not validated, then the data are collected again, and the process is repeated until the model is validated. Once model is validated, alternate scenarios can be model and tested for the desired output. The process is repeated until the system matches the desired output.

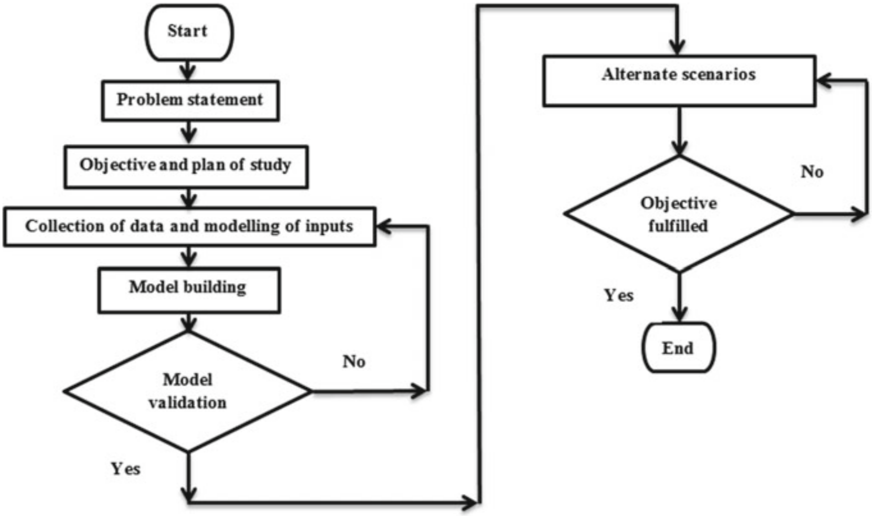

Fig. 2 Flow chart of methodology

4 Case Study

4.1 Problem Definition

The company produces 144 components per day (48 components per shift) on normal days. Now, they have to meet the demand of 300 components per day. To meet this increase in demand, the company wants to increase their capacity.

The problem statement given by the company is as follows:

Develop a strategy to increase the throughput of the manufacturing facility.

4.2 Setting of Objectives and Overall Project Plan

It is decided that the study will be performed to increase the throughput of the system from 144 components per day to 300 components per day.

Following assumptions are made to perform the study:

1. All machines are working (Breakdowns are ignored).
2. All operators are present (Absenteeism is ignored).
3. Raw material is available any time (Shortage is ignored).
4. The operator or worker is considered to be medium-skilled worker.
5. The production line is dedicated for one product.

Table 1 Modeled process time for all operations

	Process time in seconds				
Machines	Lathe	Facing center	Copy turning	CNC	Hobbing
Mean	74.44	117	232.4	265.88	531.36
Standard deviation	8.0212	6.3442	21.0178	15.2488	20.0122

Firstly, the current strategy is to be studied. For this, data (like available resources, process time and location of machines) are collected. Current facility will be modeled in FlexSim. Once the model is validated, alternate strategies will be studied using that model.

4.3 Collection and Modeling of Data

After setting the objective of study, the data required to make a complete model are collected and modeling of input data is done. Firstly, the resources allocation (type of machines and number of machines) needs to be considered. Scenario 1 refers to the current facility of the company. The process time considered to be normally distributed. Table 1 shows modeled data of process time (in seconds) for each machine, their mean and standard deviation.

4.4 Making a Model in FlexSim and Its Validation

The model-making process starts with setting the units for the model. The unit for time and distance is set to be seconds and meter, respectively. Then, existing facility is modeled.

4.5 Existing Set-up (Scenario 1)

To model the existing manufacturing facility, the object from the library is dragged and dropped in the 3D space. The raw material is modeled as source. The machines are modeled as processors. The fork lift is modeled as transporter. The operators are also modeled wherever necessary. The output is modeled as sink. The various waiting lines are modeled as queue. The properties such as location and process time are modeled, respectively. The FlexSim model for Scenario 1 is shown in Fig. 3.

After running the model, following outputs are obtained:

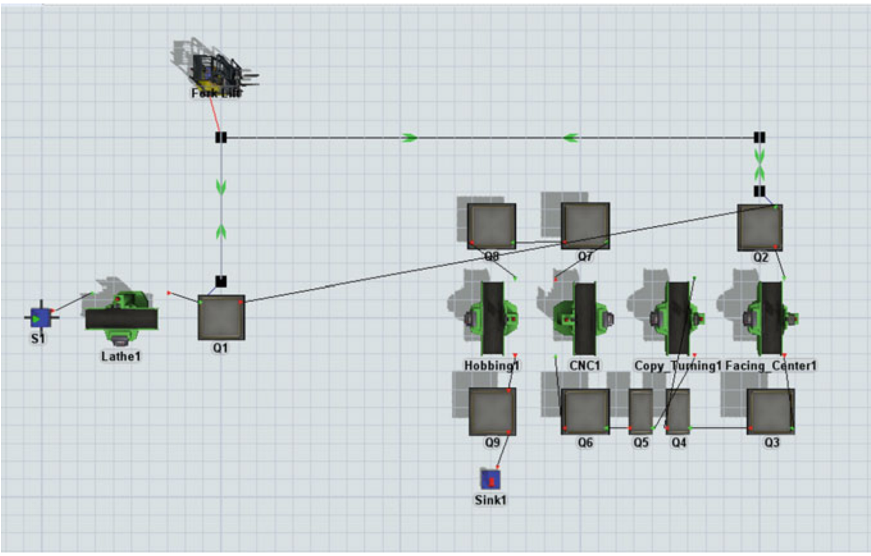

Fig. 3 FlexSim model of existing set-up (scenario 1)

The utilization of Lathe1 is 100%, Facing_Center1 and Copy_Turning1 is 92%, CNC1 is 91% and Hobbing1 is 90%.

The throughput of Lathe1 is 373, Facing_Center1 is 228, Copy_Turning1 is 113, CNC1 is 98 and Hobbing1 is 48 components.

The total number of components produced per shift is 48.

4.6 Validation

As stated in problem definition, the company produces 48 components per shift, and the model is producing the same output that is 48 components per shift.

Therefore, the model is said to be validated. And, the model can be used for further experimentation.

4.7 Modeling of Alternate Set-up Scenario 2

As a bottleneck is observed at Hobbing machine, a second-Hobbing machine, Hobbing2 is added to the model. The FlexSim model for Scenario 2 is shown in Fig. 4.

After running the model, following outputs are obtained:

The utilization of Lathe1 is 100%, Facing_Center1 and Copy_Turning1 is 92%, CNC1 is 91%, Hobbing1 is 90% and Hobbing2 is 89%.

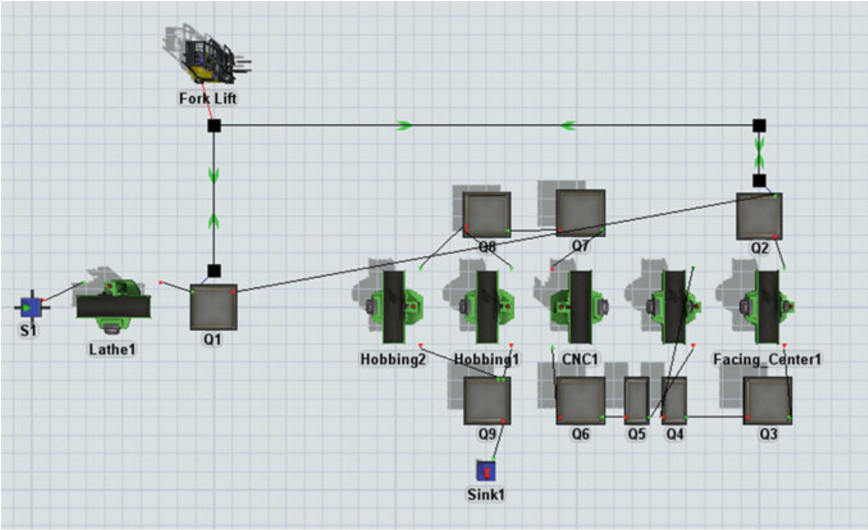

Fig. 4 FlexSim model of alternate set-up scenario 2

The throughput of Lathe1 is 373, Facing_Center1 is 228, Copy_Turning1 is 113, CNC1 is 98 and Hobbing1 and Hobbing2 is 48 components.

The total number of components produced per shift is 96.

By adding a Hobbing machine, the total throughput per shift is increased to 96 components per shift.

4.8 Modeling of Alternate Set-up Scenario 3

As it is seen that, throughput can be increased by adding Hobbing machines. Therefore, more Hobbing machine should be added to increase throughput. As the total output from CNC machine is 98 components and total output from Hobbing machine is 96 components, there is a need to increase the number of CNC machines as well. As per the resource allocation, Hobbing3 and CNC2 are added to the model is shown in Fig. 5.

The utilization of Lathe1 is 100%, Facing_Center1 and Copy_Turning1 is 92%, CNC1 is 54%, CNC2 is 50%, Hobbing1 is 71%, Hobbing2 is 70% and Hobbing2 is 64%.

The throughput of Lathe1 is 373, Facing_Center1 is 228, Copy_Turning1 is 113, CNC1 is 58, CNC2 is 54, Hobbing1and Hobbing2 is 38 and Hobbing3 is 34 components.

The total number of components produced per shift is 110.

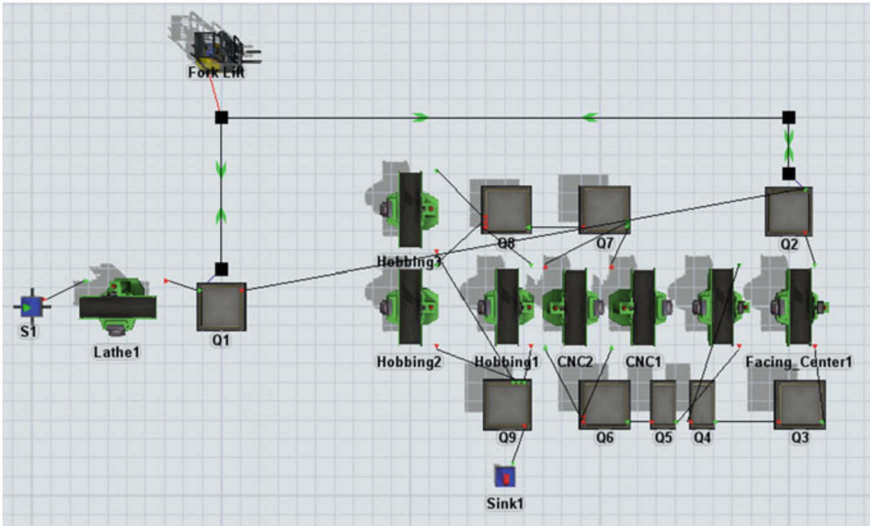

Fig. 5 FlexSim model of alternate set-up scenario 3

By adding a CNC and Hobbing machine, the total throughput per shift is increased to 110 components per shift.

5 Results

The various scenarios and their respective throughputs are given in Table 2.

Table 2 Comparison of scenarios based on throughput

Scenario number	Number of machines					Throughput	
	Lathe machine	Facing and center	Copy turning	CNC machine	Hobbing machine	Per shift	Per day
Scenario 1	1	1	1	1	1	48	144
Scenario 2	1	1	1	1	2	96	288
Scenario 3	1	1	1	2	3	110	330

6 Conclusion

In this paper, manufacturing system is studied. Performance measures of current manufacturing facility are observed. Alternate scenarios are designed, simulated and analyzed in order to improve throughput of the system to a desired value. The FlexSim software is used to model the current and alternative scenarios. By performing this study, not only throughput is increased, but also bottlenecks are avoided. By using discrete-event simulation, the risk associated with physical trials is avoided. It can be seen that some machines are under-utilized. More research can be done to improve resource utilization.

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