Discrete Event Simulation for Digital Manufacturing Productivity

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Abstract: ***Production processes of every organizations and their product life cycle involved various complexity while explaining the product concept and its activities of work flow to outside the manufacturing unit same way, how to describe this process accurately to identify potential problems in the process effectively is extremely important for the inside people also. So the discrete manufacturing shows the complete activities in simulation form to understand the product flow. Discrete manufacturing shows clearly the process inefficiencies and errors in the work flow which gives the clear picture about the each and every function in the organization. Manufacturing Systems provide one of the most important applications of simulation. Simulation has been used successfully as an aid in the design of new production facilities and as well to evaluate suggested improvements to existing systems for the further improvement in manufacturing process. In this work the few capabilities available in the latest versions of discrete event simulation tool are to be used to support digital factory and to increase the productivity of the manufacturing by considering few cases of manufacturing situations Here the Tecnomatix plant simulation software is used to support the simulation and manufacturing process. Through which, user can optimize the material flow, resource utilization and logistic services for all levels of plant planning from global production facilities, through local plants for which, A typical case study in a small scale industry is taken up in presently for detail explanation of discrete manufacturing system through proper simulation software to improve the productivity of an organization is described comparing to earlier performance.***

Keywords: Discrete manufacturing; Process flow, Manufacturing efficiency

1. Introduction

Contemporary manufacturing systems should be subject to continuous upgrading consistent with the very fast transformation of market requirements and the frequent launch of technology innovation. Simulation is an important tool for planning, implementing, and operating complex manufacturing systemsand its process. Several trends in the global manufacturing such as increased product variety, product complexity, flexibility, shorter product cycles, shrinking lot sizes, competitive pressure demands for shorter planning cycles. Simulation is an excellent tool where simpler methods no longer provide useful results. In addition, the number of technical components in many products and as a consequence also the requirements for corresponding assembly processes and logistics processes increases. These requirements can be managed only by using appropriate digital Factory tools in the context of a product lifecycle management environment. Here, a discrete event simulation software like Tecnomatix Plant simulation will be used to build the simulation model and perform the simulation runs to show the throughput time of the system.Tecnomatix Plant Simulation is an object-oriented 3D program used to simulate discrete events, which allows to quickly and intuitively create realistic, digital logistic systems thus test the properties of the systems and optimize their performance. The application is manufactured by the German company Siemens PLM Software, which is the leading global supplier of software for PLM (Product Life Cycle Management) and MOM (Manufacturing Operations Management). The solutions provided by Siemens as part of Smart Innovation Portfolio which is used for production companies to optimize their digital optimization and its innovations. Discrete manufacturing is often characterized by individual or separate unit production. Units can be produced in low volume with very high complexity or high volumes of low complexity. Low volume/high complexity production results in the need for an flexible manufacturing system that can improve quality and time-to-market speed while cutting costs. High volume/low complexity production puts high premiums on inventory controls, lead times and reducing or limiting materials costs and waste. Discrete manufacturing is the production of distinct items. Automobiles, furniture, toys, smartphones, and airplanes are the examples of discrete manufacturing products. Discrete manufacturing is all about assembling things, and making things that are exact. The products are typically manufactured in individually defined lots, the sequence of work centers through production varying for each one of these. Thus in discrete manufacturing, the product is made by sequential steps made in the same process or by the same craftsman. Discrete manufacturing based on the production orders and products change frequently from order to order. Whereas process Manufacturing is when you have a product that requires a set of processes to be finished, yet each process requires certain needs, therefore, it is better to separate each process from the other while planning and setting the Manufacturing requirements thus the processes are better controlled and maintained if they are dealt separately. the best examples we can understand through the following sketch.

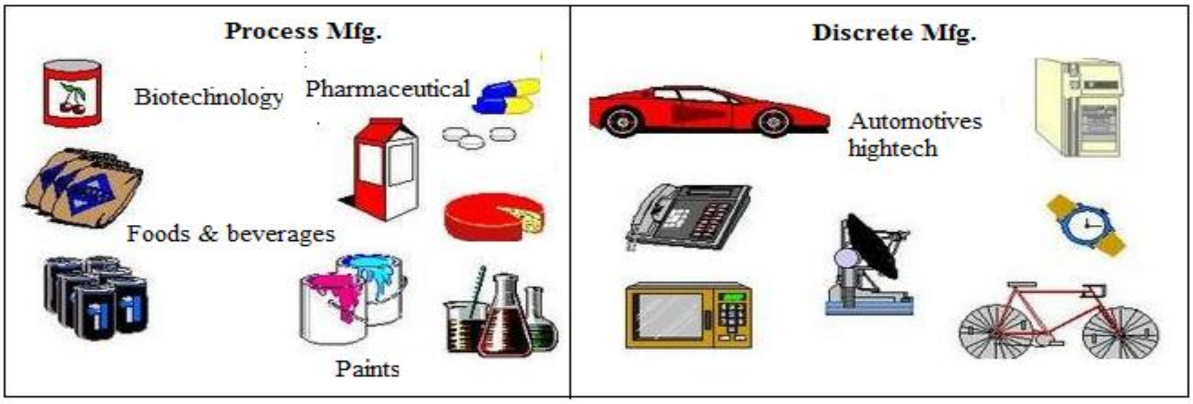

Figure1: Process and Discrete Manufacturing

1.1 Manufacturing Complexity and its reduction

In current manufacturing scenarios, internalprocesses and external environmental conditions are more comlex in nature due to high variety and varied volumes of the products. So that, manufacturing complexity depends on the internal and external drivers. There are two important types of complexities are defined with their relationships are discussed below. Complexity management is a business methodology related with the engineering system and its exploitation of variety and guidance of complex systems, hence complexity management can be understood as mastering complexity nearer to the product enhancement in easy way.

- **Inernal complexity:**

Complexity with in the company can be integrated with product, production production and market conditions related with various challenges. Which is interrelate from raw materials to finished poduct and finished product to customer.

- **External Complexity:**

Which means, Managing external requirements like customer needs, global competition, foresight, market turbulence and transferring them into product functions is a challenge in the current globalized world. Hence the complexity in the fields of market, product and production as well as their dependencies. To resolve the complexity, Modularization is one of the important which is studied by most of the researchers in their works. And they followed several methods which are important to overcome complexity. There are some of methods and processes in specific manner is followed to give process flexibilitiesto get the more prod Process modularization aims at standardizing manufacturinguctivity. [1]

1.2 Digital Manufacturing in Discrete industries

The various ditital transformations of the imformations to discrete events simulation methods are related with the process factors by using the modes with software discriptions are;

- **Vital insight for smarter decisions**

Manufacturers can gain unprecedented insight into upstream and downstream processes along the value chain. This end-toend insight enables them to both anticipate and respond to changes in demand. It also helps manufacturers make the right decisions to ensure business continuity, drive business outcomes, and enhance profit margins.

- **Adding digital capabilities to products**

There are excellent opportunities for manufacturers to enhance customer values and improve competitive factors. Predictive maintenance and servicing is the initial steps to define the process complexity. Digitally enabled and connected products can be leveraged to take proven methodologies like Failure Mode and Effects Analysis (FMEA) and its extension to Criticality Analysis (FMECA) to the next level. So that failures and ensure sustained customer satisfaction. The large amount of data must be need for analyzing the failure factors.

- **Embedded intelligence drives differentiation**

Here the possible communication between manufacturers and customers are very mportant. For which, Digital enabled products thus support manufacturers to improve the customer experience, strengthening their position in the marketplace, and preventing negative factors like duplication. So the specific needs of standard web interface and monitor operating parameters during the product lifecycle are very much usefull. Alternatively, manufacturers can offer software-based services and the Connected Service Experience (CSX) to optimize the uptime and performance of their smart products is more competitive in nature.

2. Literature Review

By the various author,s contributions in the field of Discrete manufacturing, findig better efficiency in the manufacturing process through the application of simulation methods to discrete industries are focused. In this context, the literature review focuses on the concepts of simulation techniques to discrete organizations were made through the efficient authors in this area as follows. The literature presents the possibilities and examples of using Tecnomatix Plant Simulation to simulate the production and logistics processes. The implementations of Tecnomatix Plant Simulation for modelling the process of nails production was described [2]. The conducted simulations pointed the bottlenecks of the whole production process and allowed for experimenting some optimizations and introduced the possibilities of increasing throughput of the plant..The significance of simulation tools used to support digital factory and to increase productivity in manufacturing by considering few cases in manufacturing. The integration of three tools. Data base management system and the simulation tool has been tested by considering a problem in manufacturing. [3]. The research focuses on the application of Tecnomatix Plant Simulation in the analysis of efficiency of a production line machining a specific kind of parts as part of a technological process which involves two operations and five technological procedures. [4]. The influence of failure-related machine stoppage on the efficiency of the whole production line was shown. Such a workstation blocks the next machines, so it is a bottleneck of the process. Discussed an example of computer simulation performed so as to analyse the capacity of production lines, and verifies how failures of individual workstations affect the whole production and efficiency of the production line. [5]

An interesting application of Tecnomatix Plant Simulation software was introduced by Borojevic, the work presents the outcome of simulation of production and assembly of crankshafts for saw engines. [6]. On the basis of the conducted analyses it was possible to introduce buffers storing the manufactured elements, to eliminate inefficient workstations, to reduce the time of transporting elements between the workstations, and to introduce extra machines. These actions considerably reduced the time of processing Discusses the case of balancing of flow lines in serial production using Tecnomatix plant simulation. An example of manu. acturing line of a sliding gear is taken and two possible solutions for reducing bottlenecks has been presented and hence the increase in productivity. The two solutions were to install a buffer between two stations with less processing time and to increase the number of workstations in parallel where the processing time is high [7]. A computer simulation performed so as to analyse the capacity of production lines, and verifies how failures of individual workstations affect the whole production and efficiency of the production line. [8]. The work presents the outcome of simulation of production and assembly of crankshafts for saw engines. Computer simulations allowed to identify production process bottlenecks, to show the lack of efficiency of certain workstations, and to minimize the duration of the whole process. On the basis of the conducted analyses it was possible to introduce buffers storing the manufactured elements, to eliminate inefficient workstations. [9]. In case of balancing of flow lines in serial production using Tecnomatix plant simulation. An example of manufacturing line of a sliding gear is taken and two possible solutions for reducing bottlenecks has been presented and hence the increase in productivity is clearly discussed [10].

3. Problem Discription

In recent years, digital manufacturing with simulation has been widely practiced normally in large scale industries. However its implementation in small and medium enterprises (SME's) is limited and also challenging in nature. The present work focuses on the investigation and study of existing problem in Sidvin engineering technologies, Bangalore which a process industry mainly concentrated on manufacturing of body and piston. In this case different processes are carried out. The total throughput time takes 30 days to complete the above parts. Hence, in this work our main intension is to reduce total throughput time by the implementation of simulation techniques using Tecnomatix Plant Simulation software in with kaizen implementation, which enables the simulation and optimization of production systems and processes.

4. Objectives

The goal of this project is to use Discrete Event Simulation to increase productivity in digital manufacturing system through the simulation techniques the following objectives were set

- To increase the throughput
- To reduce process inventories
- To increase the utilization of machines and workers
- To enhance the total cycle time

5. Research Methodology

This paper aims to identify and collect work process difficiencies and management practices in the process industry and also discrete manufacturing industry. The study examines current practices of various industries that informations collected by the various researchers in discrete manufacturing system of operations, product and supply chain activities involved in their process and analyzed in excellent manner to study the process factors for their improvements. The research approach to get the productivity follows the systematic methodological steps.

Problem formulation
Literature review
Formulate the objectives
Selection of simulation method
Data collection and analysis
Simulation study
Analysis and interpretation of the results
Conclusion

6. Experimental Analysis

6.1 Company Overview

Sidvin Engineering Technologies is a Sole Proprietorship company established in 2009 at Karnataka, India. The company has been working consistently and smoothly since so many years due to the efforts of our team of efforts. Our renowned company is engaged in manufacturing and offering Precision Turned Component,

Precision Machined Component, CNC Machined Component and many more.. We completely understand the demand of market and techniques to meet them with best possible ways. No compromise on the grounds of quality is done in our business. The credit to the successful working of our company goes to our highly dedicated team of professionals, technicians and mentor. We have become the first choice of clients due to our qualified and experienced team, strong domain expertise and regular delivery in the market. The company is governed by such a good managerial team that we face no problem to deliver allotted consignment without any delay. Comprehensive policies have been developed by our team of professionals as we are highly focused on maintaining highest quality standard in our range of products. The quality controllers at our unit always ensure that processing is carried out in compliance with industry standards and consistently
.

6.2 Data Collection:

The information regarding the process details of two products were collected from a case study conducted at Sidvin engineering technologies. The data collections of the products are shown below for our related work.

6.2.1 The details of the Product 2 and its Process Flow

Table 1: Details of of Product 1

Name	Specification	Material
Body	VBP5	EN8

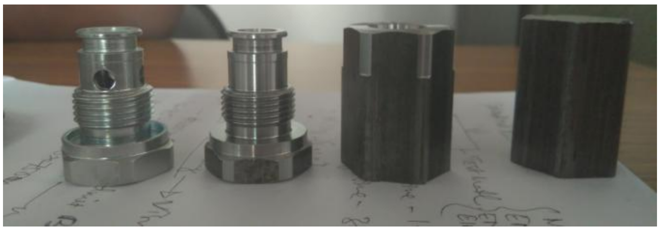

Figure 2: Body

Table 2: Process data of product 1

Processing Station	Operations	Processing Time	Setup Time
power hacksaw	cutting	30 sec	30 min
turning centre 1	facing and turning centre drilling boring thread cutting	2:30 min	2 hrs
turning centre 2	turning threading grooving centre drilling boring	3 min	3hrs
vmc	drilling	2 min	1 hr
bench grinder	grinding	3 min	
plating		2 days	
quality control	visual inspection	10 sec	
packing		2.5 days	

Loading and unloading time: 15 sec

6.2.2 The details of the product 2 and its process flow

Table 3: Details of of Product 1

Name	Specification	Material
Piston	**SAE862**	EN8

Figure 2: Piston

Table 4: Process data of Product 2

Processing Station	Operations	Processing time	Setup time
Power hacksaw	Cutting	30 sec	30 min
Power hacksaw	Cutting	12 sec	30 min
Turning Centre 1	Turning Grooving	2 min	2 hrs
Turning Centre 2	Turning	30 sec	2 hrs
Heat Treatment		3 to 4 days	
Vibro Finishing		2 hrs	
Grinding		3 days	
Quality control	Visual inspection	10 sec	
Roundness Tester		Soaking time 30 min 2 or 3 products- 2 hrs or 3 hrs	
Packing	Arranging	2 days	

Loading and unloading time: 15 sec. Total throughput time:30days.

6.3 Tecnomatix Plant Simulation

6.3.1 About Software

Tecnomatix Plant Simulation software enables the simulation and optimization of production systems and processes. Using Plant Simulation, you can optimize material flow, resource utilization and logistics for all levels of plant planning from global production facilities, through local plants, to specific lines. In times of increasing cost and time pressures in production, along with ongoing globalization, logistics has become a key factor in the success of a company. The need to deliver JIT (just-in-time)/ JIS (just-in-sequence), introduce Kanban, plan and build new production lines and manage global production networks (to name a few) requires objective decision criteria to help management evaluate and compare alternative approaches. Plant Simulation helps create digital models of logistic systems (e.g., production) to explore the systems' characteristics and to optimize their performance. The digital model enables users to run experiments.Using Tecnomatix Plant Simulation enables users to optimize material flow, resources for all levels of planning. The software allows comparison of complex manufacturing production options, including immanent logic processing, using computer simulation. Plant Simulation is used for individual production plans as well as multinational enterprises, mainly as a strategic planning

Layout, process control logic and complex dimensions of productive investment.

6.3.2 Properties of object oriented programming

- Heritage - Users create libraries with their own objects that can be re-used. Unlike copies, any change in the object class library is extended to some of the derived objects (children).
- Polymorphism - Classes can be derived and derived method can be redefined. It allows users to create complex models faster, easier and more transparent in the structure.
- Hierarchy - complex structures can be created very clear on several logical layers, allowing each layer to move between them by relevance. The program can import data from other systems, such as. Program Access, Oracle databases, Excel or SAP.

6.3.3 Use of integration of plant simulation

Import data from PLM systems, or can be directly used.

- Virtual enterprise putting into service
- Download data from AutoCAD, Micro station, Factory CAD, etc. directly into the simulation. It provides a clear analytical tools for detecting obstacles for monitoring material flow (Sankey diagram) or to detect oversized batteries (Chart).
- Experiment Manager automatically creates scenarios and evaluate the dependence of two input parameters.
- Genetic algorithms search large space solution.
- Neural networks show the connection between input and output parameters and can be used for forecasting.

6.3.4 Features of the program

- Recognize and show problems that might otherwise result in high cost and time consuming remedial measures in the start-up phase.
- Offers mathematically calculated Key Performance Indicators (KPI)
- Reduce investment costs for production lines without jeopardizing the desired quantity.
- Optimize the performance of existing production lines.
- Incorporate machine failure, availability (MTTR, MTBF) when calculating the numbers throughput and usability.
- Higher productivity planning, the program can be achieved by the Collection and management of knowledge within a single source of information will ensure the reuse of certified processes and cut costs for capital equipment.
- Ensuring and Troubleshooting in production systems that would otherwise require time-consuming and costly remedial measures at the onset of production.
- By limiting tasks associated with planning assembly, shortening, planning and reducing related costs.
- By sharing and analysing information within the digital environment, offering a detailed overview of the various stages of the development process and the impact of these processes.
- Streamlining communications can quickly adapt to customer requirements, the decision is based on facts.

6.4 Tools of Tecnomatix

6.4.1 The Program Window

A standard Plant Simulation window contains the following elements

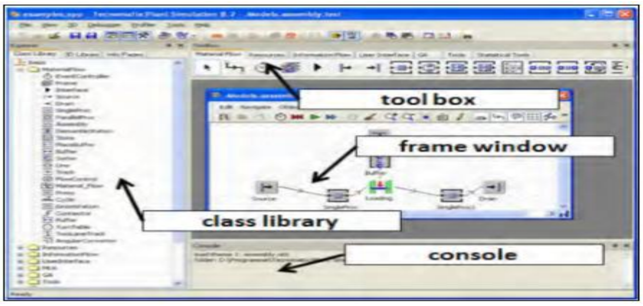

Figure 3: Program window

6.4.2 The Console

The Console provides information during the simulation (e.g., error messages).

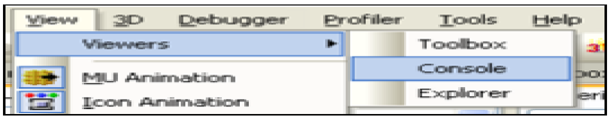

Figure 4: Console

6.4.3 The Toolbox and connector

The Toolbox provides quick access to the classes in the class library.and the connector is used to connect the objects along the material flow.

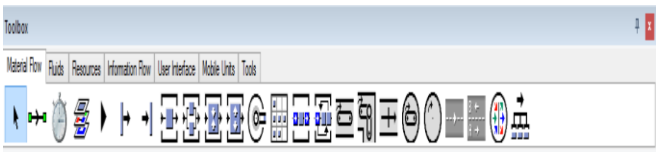

Figure 5: Toolbox

6.4.4 Event controller

The Event Controller coordinates and synchronizes the different events taking place during a simulation run. When a part enters a processing station, like a Single Proc, plant simulation computes the process time and events are entered in to scheduled events for the event controller. The main advantage of this approach is that it skips the time that elapses in real-time between the events. Imagine a time line where you insert markers at certain points.

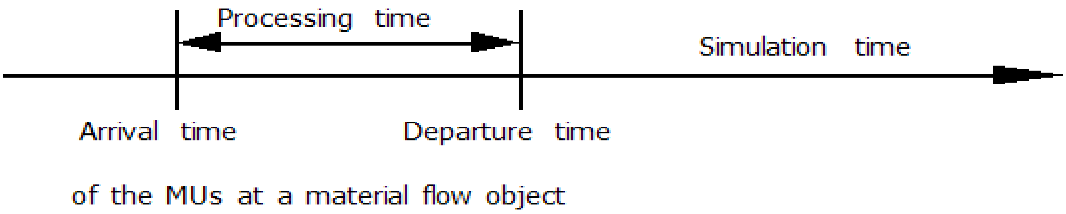

Figure 6: Event controller processing time

The Event Controller moves along the time line like the play-back head of a video recorder, and interprets messages relating to the events the objects execute. After the processing time has elapsed, the Event Controller passes on to the station that has to initiate an exit (Out) events, the Single Proc in our case. The part then moves on to the succeeding object in the flow of materials. There again, Plant Simulation calculates the exit time and passes it to the Event Controller. The marker at the point has to move to the next station. Plant Simulation repeats this process cyclically for all MUs located in the simulation model.

6.5 Modelling

Based on the data collected, a simulation model was built usng Tecnomatix Plant simulation software.

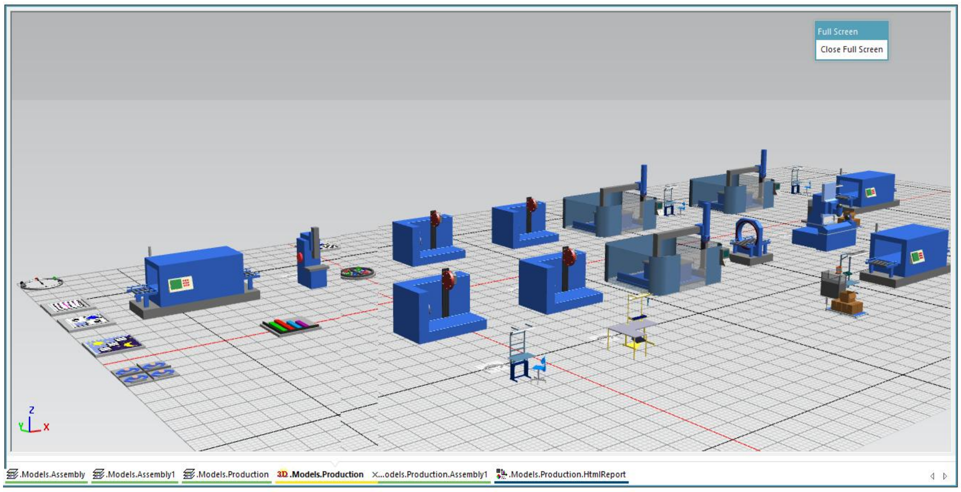

Figure 7: Simulation model-3D

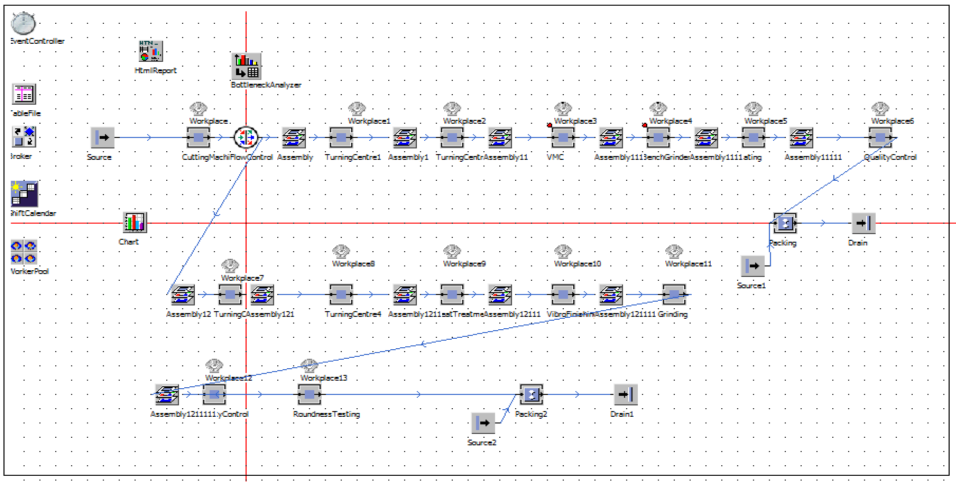

Figure 8: 3D Model

6.5.1 Important features of the model

- The simultaneous production of two product types is simulated.
- The Shift calendar is used to simulate 3 shifts per day each consisting of 8 workers each.
- The worker pool is used to simulate the workers who are necessary for the loading and unloading of parts.
- A chart is used to display the resource characteristics of the various workstations.
- The entities are generated in the source in a sequential way consisting of a batch of 1000 products of type 1 and a batch of 2000 products of type 2. There are 5 such batches of each type.

The throughput time was found out to be 579 hrs for product 1 and 720 hrs for product 2.

6.5.2 Objects used

- **Source:** The source creates mobile objects (MUs) according to the definition. The source can produce different types of parts in a row or in mixed order. For defining batches and determining the points in time, the program provides different methods. The source as an active object tries to transfer the produced MU to the connected successor.
- **Single proc:** The SingleProc accepts exactly one MU from its predecessor. After the setup, recovery, and processing time, the MU will be transferred to one of its successors. While an MU is located on the object, all other newly arriving MUs will be blocked. Only after a successor is free and not occupied, the MU will be transferred. It is used it to simulate all machines and jobs, which handle one part after another. One part at a time can be located on the workplace or the machine.
- **Drain:** The Drain is an active material flow object. The Drain has a single place and destroys MUs after processing them. The Drain collects a number of important statistical data such as throughput, number of destroyed parts, etc.
- **Assembly station:** The assembly station adds mounting parts to a main part or simulates assembly processes by destroying the single parts and generating the assembled part. The assembly station facilitates the simulation of assembly operations.
- **Dismantle station:**The DismantleStation dismantles added parts from the main part or creates new parts. It facilitates modelling dismantling operations.
- **Flow control:** The FlowControl itself does not process MUs. The Flow Control is always positioned between two or more other objects and defines the flow behaviour between these objects. It divides flow of mobile objects among its successors.
- **Broker:** The broker mediates between suppliers and demanders of services.You do not have to select settings in the broker. The machines as well as the resource pool must be propagated to the broker.
- **Worker pool:** The worker pool produces a number of workers according to a creation table and makes them available for the registered services after a request. If the workers do not work, Plant Simulation shows them on the worker pool.
- **Worker:** The worker performs the processing and setup operations. The Worker related settings have to be set in the class library because the instantiation of the worker is realized by the worker pool.
- **Shift Calendar:** The shift calendar is used to simulate the shifts in which a worker works in a day. 3 shifts of 8 hours a day 6 workers in each shift were simulated.

6.6 Outcome of Simulation run

The total throughput time for the batch production of two product types was found to be 720hrs.

Table 5: State statistics

Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
Source	0.00%	0.00%	70.73%	29.27%	0.00%	0.00%	0.00%	0.00%	0.00%	
CuttingMachine	19.56%	0.78%	67.70%	0.00%	0.00%	11.92%	0.00%	0.00%	0.00%	
TurningCentre1	32.60%	0.31%	53.97%	0.00%	0.00%	13.12%	0.00%	0.00%	0.00%	
TurningCentre2	23.47%	0.47%	64.05%	0.00%	0.00%	11.93%	0.00%	0.00%	0.00%	
VMC	26.08%	0.16%	65.97%	4.19%	0.00%	3.48%	0.00%	0.00%	0.00%	
BenchGrinder	39.12%	0.00%	44.23%	0.00%	0.00%	16.65%	0.00%	0.00%	0.00%	
Plating	7.51%	0.00%	85.39%	0.00%	0.00%	7.10%	0.00%	0.00%	0.00%	
QualityControl	0.00%	0.00%	91.47%	0.00%	0.00%	8.53%	0.00%	0.00%	0.00%	
Packing	9.39%	0.00%	90.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Source1	0.00%	0.00%	9.70%	90.30%	0.00%	0.00%	0.00%	0.00%	0.00%	
Drain	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
WorkerPool	0.00%	0.00%	75.48%	1.36%	0.00%	0.00%	0.00%	10.95%	12.21%	
TurningCentre3	52.16%	0.31%	47.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
TurningCentre4	13.04%	0.31%	86.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
HeatTreatment	11.27%	0.00%	88.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
VibroFinishing	0.31%	0.00%	99.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Grinding	11.27%	0.00%	88.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
RoundnessTesting	0.00%	0.39%	99.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Packing2	0.01%	0.00%	99.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Source2	0.00%	0.00%	25.16%	74.84%	0.00%	0.00%	0.00%	0.00%	0.00%	
Drain1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
QualtyControl	8.78%	0.00%	91.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SingleProc	15.65%	0.47%	78.03%	0.00%	0.00%	5.77%	0.00%	0.00%	0.00%	

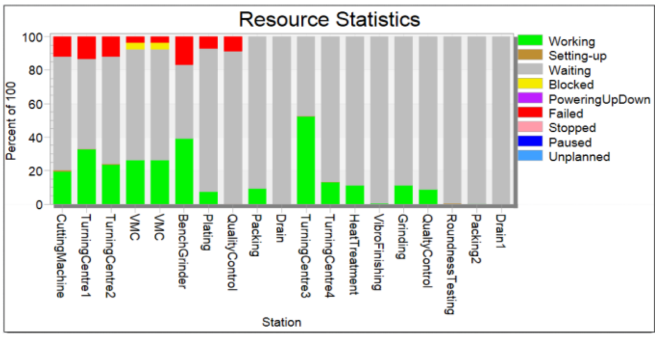

Figure 10: Resource Statistics

6.7 Optimization

From the simulation runs performed, the following parameters were considered for optimization:

1. Blocking time
2. Waiting time
3. Employee utilization

The kaizen approach was used to optimize the model. it refers to continuous improvement, i.e. to make the required changes in the workplace.

1. Buffers were introduced to reduce the waiting time.
2. A certain percentage of the products were transferred to a parallel workstation to reduce the blocking time

Figure 11: Optimized model-3d

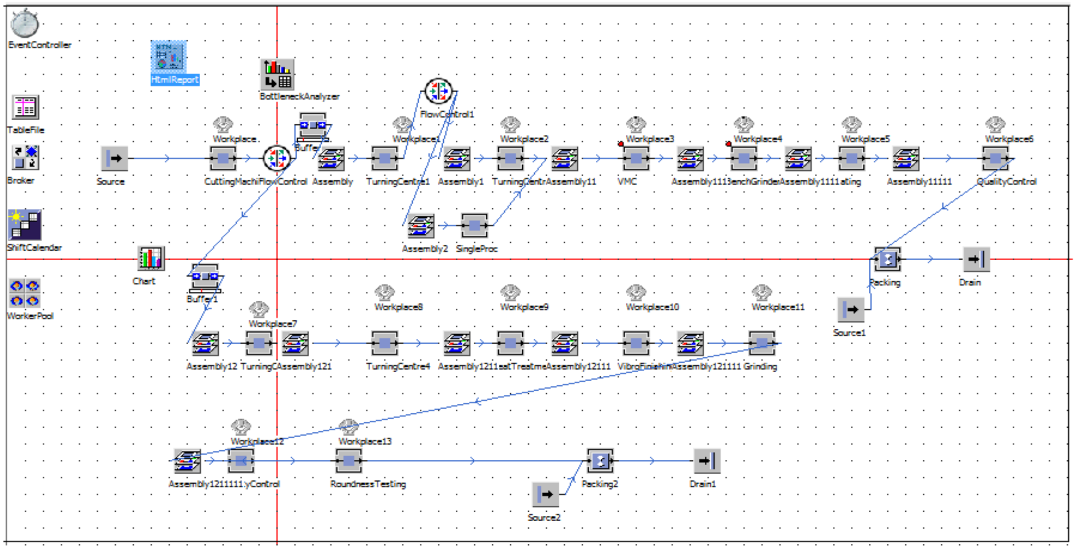

Figure 12: Optimized model-2d

7. Results and Discussions

The following changes were made:

- Two buffers were introduced after the cutting station each of capacity 5,000 and 10,000 respectively and the throughput time was found to be 647 hrs.
- An attempt was made to reduce the blocking time of vmc station by introducing buffers but the change in the throughput was not significant.
- Turning centre 5 was introduced in parallel to tc1,tc4 and tc3 but neither of those changes yielded any considerable increase in throughput.
- Turning centre 5 was introduced in parallel to tc2 where 60% of products were moved to tc2 and 40% to tc5 and the through put time was found to be 639 hrs.
- Batch size for sequential production was varied and was found to be optimal at 1000 for product 1 and 2000 for product 2.
- When the number of workers in each shift were reduced to 5 the throughput time for the optimized system was found to be 720 hrs.
- The percentage reduction in throughput time was found to be [(720 - 639) / 720] *100 = 11.25%]

Table 6: State Statistics of optimized model

Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
Source	0.00%	0.00%	70.73%	29.27%	0.00%	0.00%	0.00%	0.00%	0.00%	
CuttingMachine	19.56%	0.78%	67.70%	0.00%	0.00%	11.92%	0.00%	0.00%	0.00%	
TurningCentre1	32.60%	0.31%	53.97%	0.00%	0.00%	13.12%	0.00%	0.00%	0.00%	
TurningCentre2	23.47%	0.47%	64.05%	0.00%	0.00%	11.93%	0.00%	0.00%	0.00%	
VMC	26.08%	0.16%	65.97%	4.19%	0.00%	3.48%	0.00%	0.00%	0.00%	
BenchGrinder	39.12%	0.00%	44.23%	0.00%	0.00%	16.65%	0.00%	0.00%	0.00%	
Plating	7.51%	0.00%	85.39%	0.00%	0.00%	7.10%	0.00%	0.00%	0.00%	
QualityControl	0.00%	0.00%	91.47%	0.00%	0.00%	8.53%	0.00%	0.00%	0.00%	
Packing	9.39%	0.00%	90.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Source1	0.00%	0.00%	9.70%	90.30%	0.00%	0.00%	0.00%	0.00%	0.00%	
Drain	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
WorkerPool	0.00%	0.00%	75.48%	1.36%	0.00%	0.00%	0.00%	10.95%	12.21%	
TurningCentre3	52.16%	0.31%	47.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
TurningCentre4	13.04%	0.31%	86.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
HeatTreatment	11.27%	0.00%	88.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
VibroFinishing	0.31%	0.00%	99.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Grinding	11.27%	0.00%	88.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
RoundnessTesting	0.00%	0.39%	99.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Packing2	0.01%	0.00%	99.99%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Source2	0.00%	0.00%	25.16%	74.84%	0.00%	0.00%	0.00%	0.00%	0.00%	
Drain1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
QualtyControl	8.78%	0.00%	91.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SingleProc	15.65%	0.47%	78.03%	0.00%	0.00%	5.77%	0.00%	0.00%	0.00%	

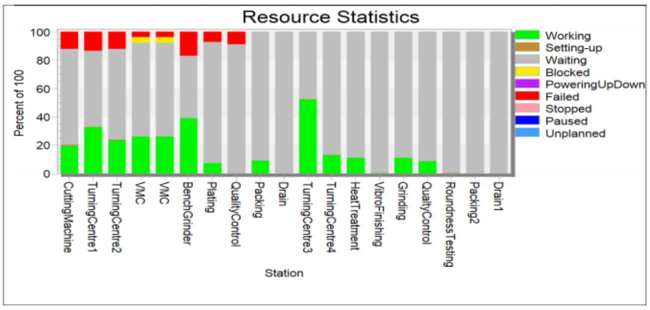

Figure 13: Resource Statistics of optimized model

8. Conclusions

- The final throughput time in the optimized model was reduced by 11.25%.
- The technique of Discrete Event Simulation is an effective tool simulating manufacturing systems.
- Several alternatives could be simulated in this tool without the need for making any changes in the actual system which is time consuming and economically not feasible.
- In the current digital era plant simulation plays a crucial role for the manufacturing systems to be flexible.

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