

## Design and Analysis of a Manufacturing System Using Promodel

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### ABSTRACT

Simulations have been found applicable in various spheres of disciplines including manufacturing systems, aerospace, process engineering, etc. This report detailed how PROMODEL software was used to design and analyze a typical manufacturing system. The design involves application of “LEAP”, a methodology proscribed by ProModel. Simulation outputs and their analysis are expounded in terms capacity utilizations and time-variants.

**Keywords** - ProModel, Manufacturing, Simulation, Design

Date of Submission: 25-05-2021

Date of Acceptance: 08-06-2021

### I. INTRODUCTION

According to Chung (2004), simulation refers to as a way of “imitating” the activities of a “real-world system”. Based on User Library, it has been attested that the use of simulation to manufacturing systems have been found to prevalent than other areas where it is being used. It could be used for design and optimization of various manufacturing systems such as flexible manufacturing systems, lean manufacturing systems, world class manufacturing systems, reconfiguration manufacturing, etc. Simulation is used in manufacturing for design and optimization.

A major motive behind using simulation is its ability to predetermine the performances of systems before embarking on the implementation of the design or changes. For example, the changes made in the workstation, material handling systems and layout can impact the performances negatively or positively. This impact can be first of determine by using simulation software.

#### 1.1 Fundamentals of ProModel

ProModel is a simulation tool for modeling business processes, manufacturing systems and service systems. Business processes such as customer service management, logistics systems, supply chains and information technology can be modeled by ProModel. Manufacturing systems like job shops, flexible manufacturing systems, manufacturing cells, just-in-time, Kanban systems and conveyors can be modeled by ProModel. Servicing systems like call center, banks, hospitals, warehouse, airport operations, retail stores can be modeled by ProModel.

ProModel can be used in evaluating ideals, alternative design and process maps before implementing them. It can also be used for modeling and evaluation of improvement in existing systems or design before actual implementation. It focuses are inventory levels, resource utilization and system capacity. It has a time resolution which can be controlled, and it is between 0.01hrs and 0.0000sec

According to ProModel User (2017), the simulation software was originally developed for modeling “discrete part manufacturing systems. It was invented for situations where systems events occur at a definite point in time. However, it could also be used for modeling process industries by converting bulk material into discrete units. In general, simulation can be used to predict and improve performance the existing or an abstract system by modeling it.

In ProModel, workstations of manufacturing systems are organized as processing locations where entities like spare parts are processed based on “processing logic”. Other things that may be included in ProModel are material handling units, operators, aisle-ways for mobility and buffers.

A typical example where ProModel is used is shown in Fig.1 below. It consists of six workstations which are NC lathe 1, NC lathe2, Receive, Inspect, Degrease and Rework. It has two entities which are Pallets and Blanks. Also, two operators and forklifts for transportation of parts.

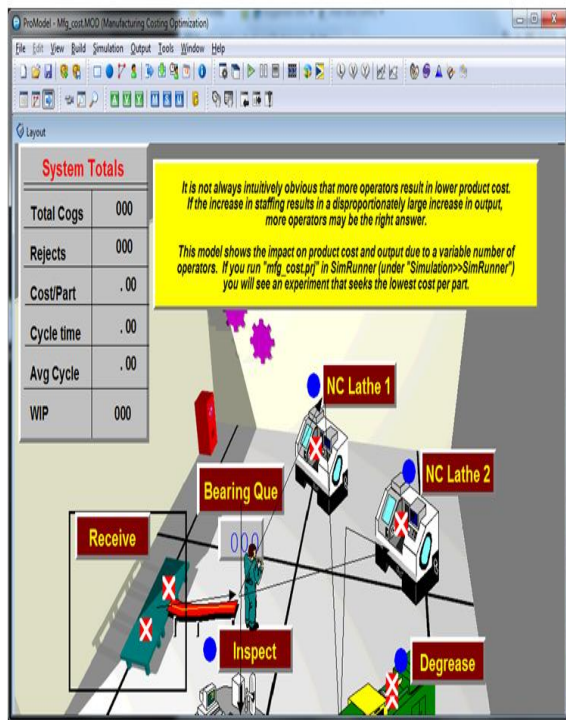


Fig 1: Use of Promodel (ProModel User, 2017)

## 1.2 Classification of Usage of Simulation in Manufacturing Systems

According to Averill and Michael (1997), simulation can be used in manufacturing systems in the following ways that are discussed below.

### 1.2.1 Determination of quantity of machinery and equipment

- i. Simulation can be used for determination of suitable number of machines to be used at a workstation to actualize the systems' purpose.
- i. It could be used to identify the types and quantity of material handling systems to be used in a system. Examples are automated guided vehicle, conveyors, pallet, robot.
- ii. The best location and type of inventory system can be determined by simulation.
- iii. Cost analysis of capital investment in simulation can be determined by simulation.
- iv. It is used in planning labor requirements.
- v. It can also be used in determination of impact of a single equipment.

### 1.2.2 Performance Evaluation

Simulation can be used in evaluating and analyzing performances in the following ways enlisted below.

- i. i.Evaluation of bottleneck along the production line

- ii. Analysis of throughput
- iii. Evaluation of time- in – system

### 1.2.3 Analysis of Modalities of Operation

Simulation is applicable to evaluation of different procedures used in operations. Examples of these applications are:

- i. Techniques used in quality control.
- ii. Analysis of production scheduling
- iii. Analysis of produces procedures used in operations.
- iv. Evaluation of policies used in inventory.
- v. Analysis of systems reliability

## 1.2 Types of Simulation Models

Mourtzis, et al (2014) classified simulation models into three. These classifications are:

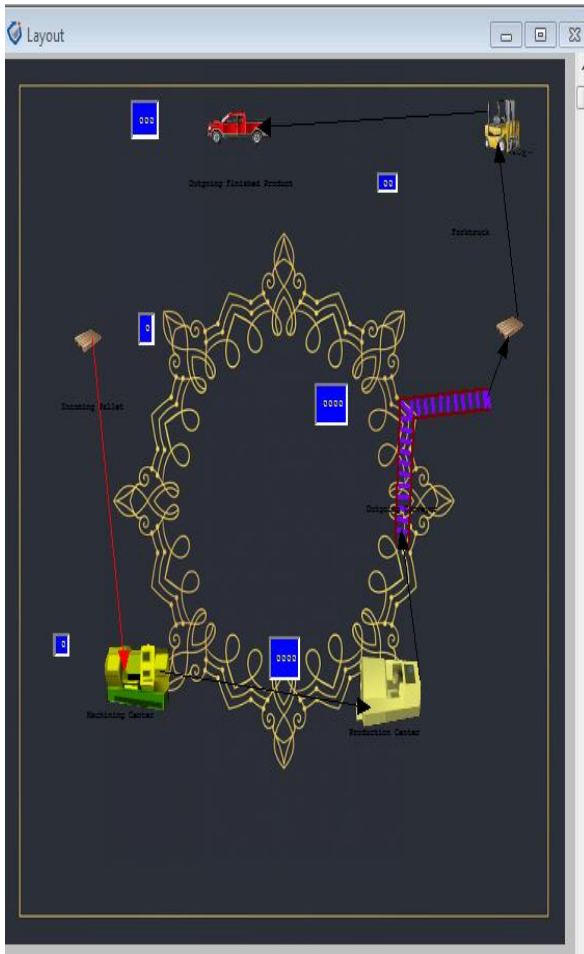
- i. Time change
- ii. Randomness
- iii. Data organization

However, based on time dependency, simulation can further be classified into static or dynamic simulation. Dynamic simulation is time dependent while static simulation is not time dependent. More so, dynamic simulation can be sub divided into continuous and discrete simulation.

## 1.3 Modelling of Systems Randomness

Systems may often behave randomly. The random behaviour or continuous distribution may be found in any of the following:

- i. Unloading and loading times
- ii. Time to failure of equipment or machines
- iii. Inter-arrival times of parts and raw materials
- iv. Times to repair equipment or machines.
- v. Changeover setup times of machines
- vi. Rework of failed jobs
- vii. Yield cases in products



**Fig 2:** Product Manufacturing Design Layout Using ProModel

## II. DESIGN AND ANALYSIS OF A MANUFACTURING SYSTEM USING PROMODEL

The principle of manufacturing systems design in ProModel 2011 follows an acronym known as “LEAP”.

Where:

L- Location

E- Entities

A – Arrival

P - Processing

The entire product manufacturing design layout using a ProModel is shown in figure 2.

### 2.1 System Locations

Entities like parts are usually routed to routing locations. Routing locations are of two types. These are single unit and multi-unit locations. A single unit location has a single machine while a multi-unit location has a group of similar machines doing the same operation simultaneously or parallelly. Routing location could have usage time (as in tool wear), usage time (such as dispenser

changes after every certain n cycles), material change (like machine setup). Routing location could have a capacity greater than one. It could also have periodic downtime (as in shift changes). Input rules are assigned to routing location to determine the sequence of process of entities while output rules are used for ranking (e.g., FIFO, LIFO) them.

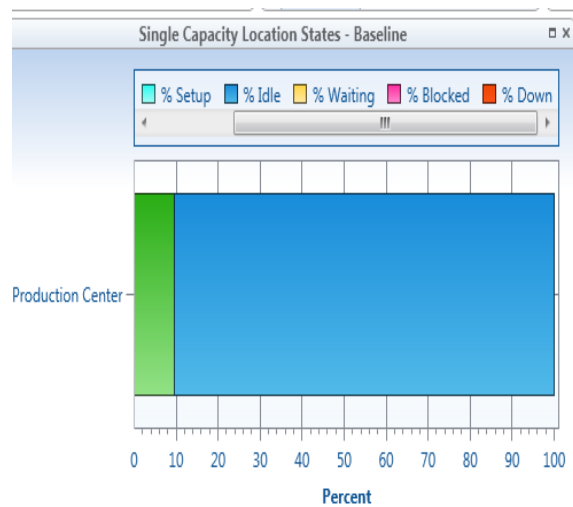
This design has the following locations:

- i. Incoming pallet
- ii. Machining Center
- iii. Conveyor
- iv. Fork truck
- v. Outgoing finished product location

Each location is assigned a capacity, units, statistics series and rules as shown in Fig. 3 below.

Icon	Name	Cap.	Units	Ma...	Sta...	Rules...	Notes...
	Incoming_Pallet	INFINITE	1	None	Time Series/Obest		
	Machining_Center	2	1	None	Time Series/Obest		
	Production_Center	1	1	None	Time Series/Obest		
	Outgoing_Conveyor	INFINITE	1	None	Time Series/Obest, FIFO		
	Outgoing_Pallet	INFINITE	1	None	Time Series/Obest		
	Forktruck	INFINITE	1	None	Time Series/Obest		
	Outgoing_Finished_Pr	INFINITE	1	None	Time Series/Obest		

**Fig 3:** Locations



**Fig. 4:** Capacity utilization of the machine at the production center

## 2.2 Systems Entity and Arrival

These are the items that are to be processed (ProModel Tutorial, 2011). Examples are parts, loads, WIP, raw materials, assemblies and finished products. Attributes can be assigned to entities and thereafter tested in making decisions. Changes could be made to graphics of entities to show physical change due to an operation during animation.

The entity selected for this design is named product. This entity will arrive at the incoming pallet location. Five quantity of the product is selected to arrive after 2hrs.

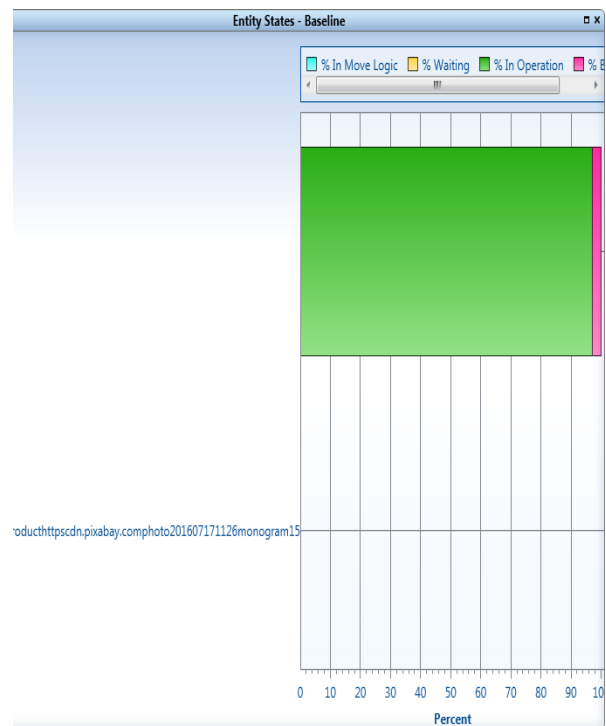
## 2.3 Systems Processing (or routing)

Processing elements defines the sequence of processing and flow logic between routing locations. Processing elements determines the resource requirements, operations time, processing logic, input and output relationship, routing conditions, move time, etc. Operations time can be defined using distributions, functions, attributes and constants. Operations logic such as loops, IF-THEN-ELSE statements, subroutine calls and nested statement blocks were used. Resource statements such as JOINTLY GET, USE, GET can be used. Built-in operation statements and Boolean expression like GROUP, JOIN, ACCUM are equally applicable for description of processing requirements.

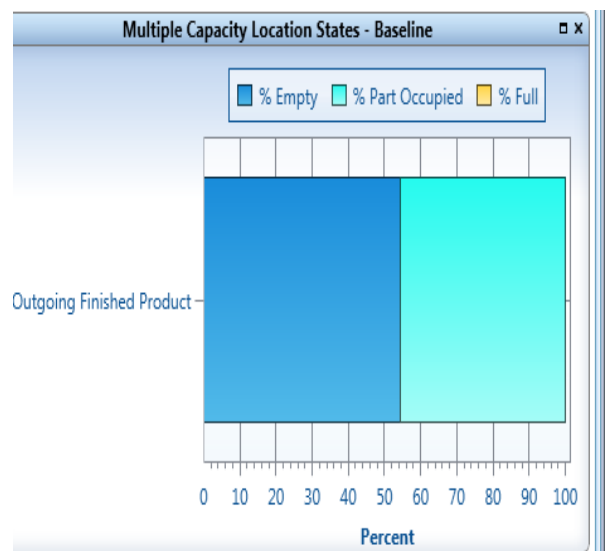
## 2.4 Simulation and Analysis

From figure 12, it shown that the incoming pallet has the capacity utilization of 93% as shown in Fig. 8. Machining center has the capacity utilization of 89% as shown in Fig. 10. The outgoing conveyor has the highest capacity utilization of 99% Fig. 11. The outgoing pallet and

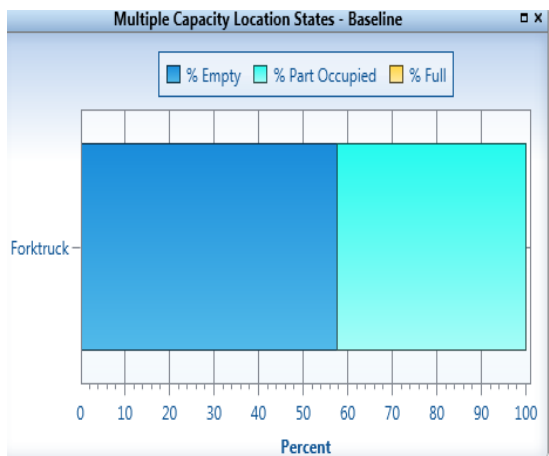
forklift have the capacity utilization of 55% and 58% respectively as shown in Fig. 6 & Fig.7. The combined capacity utilization is shown in figure 12. The time analysis is shown in Fig. 13 to Fig.16.



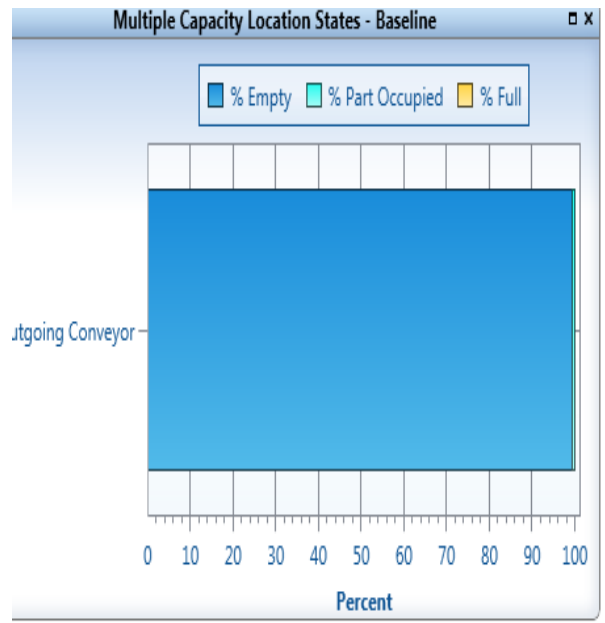
**Figure 5:** Entities waiting time and operational time.



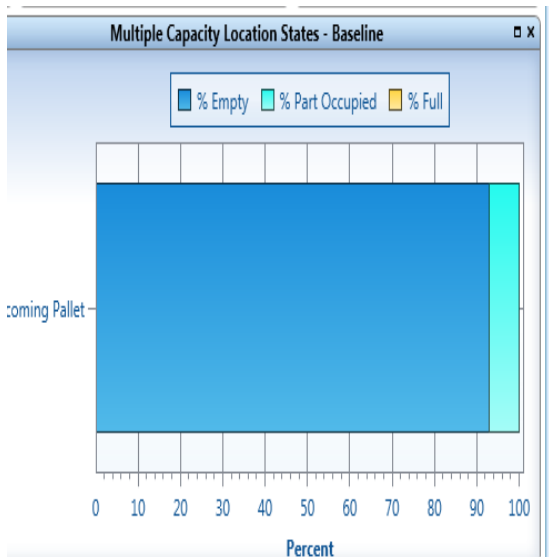
**Fig 6:** Capacity Utilization of the moving truck of the outgoing pallets



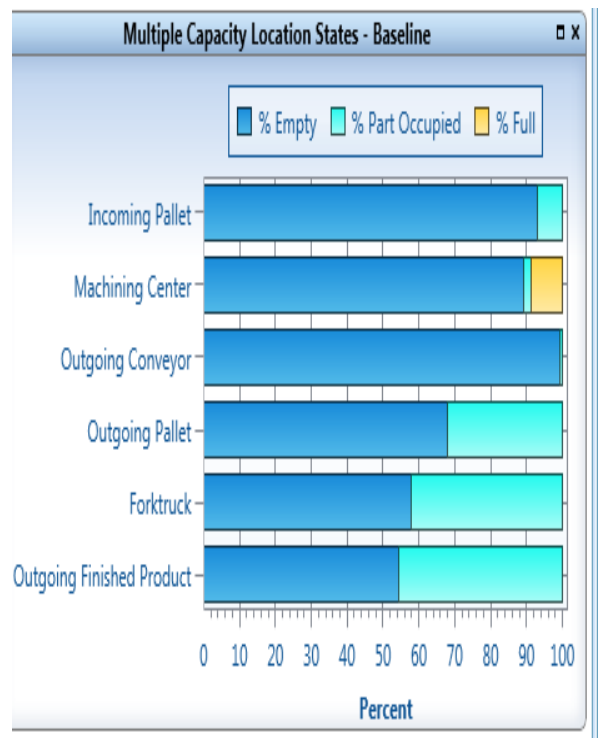
**Fig. 7:** Capacity Utilization of the Fork truck transporting products into the Outgoing Location Center



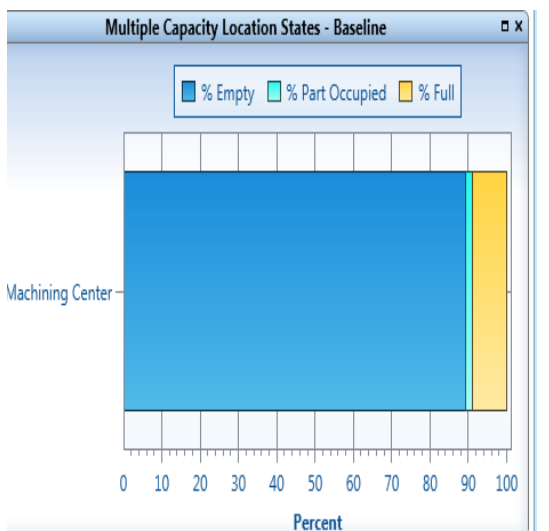
**Fig 11:** Capacity Utilization of the outgoing conveyor



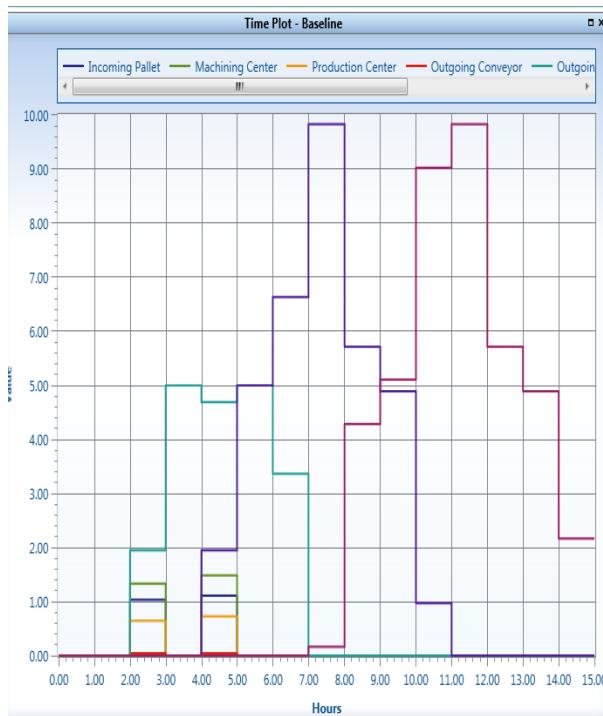
**Fig 8:** Capacity Utilization of the incoming pallet



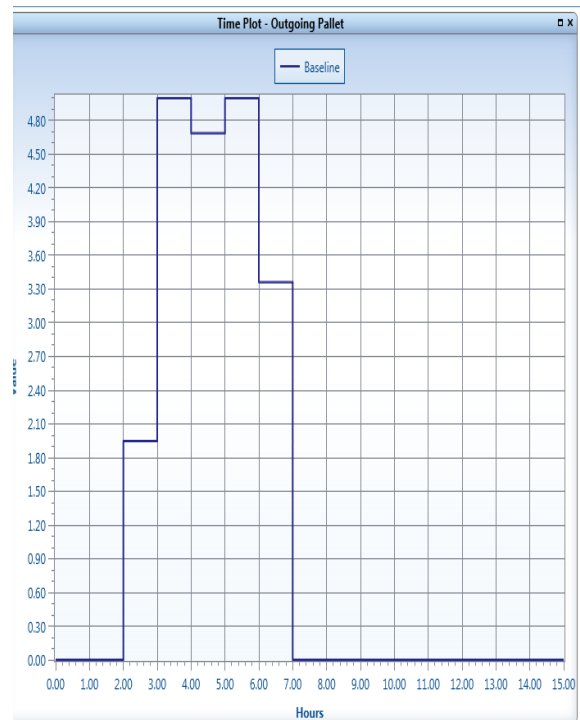
**Fig 12:** Combined capacity utilization of all the locations



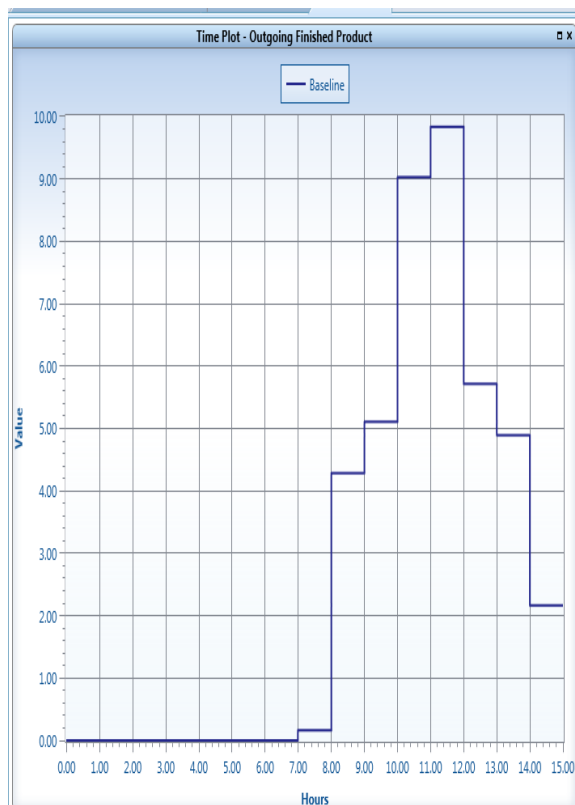
**Fig 10:** Capacity Utilization of the machining center



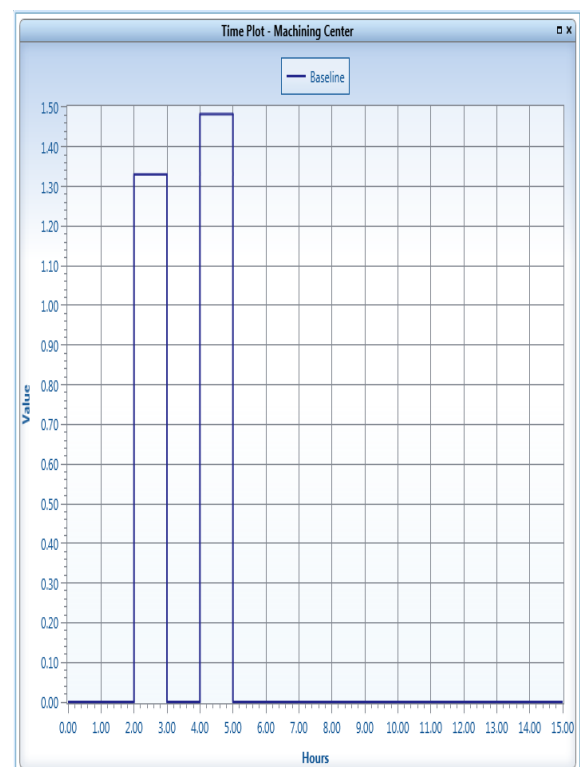
**Fig 13:** Overall time analysis



**Fig 15:** Time analysis of the outgoing pallets



**Fig 14:** Time analysis of the finished products



**Fig 16:** Time analysis of the machining center

### III. VALIDATING AND DEBUGGING.

#### 3.1 Verification by Tracing

Using Tracing from the Option menu, all the events that have occurred during the simulation

were displayed and verified. Variables and array elements were equally displayed in the trace list.

### 3.2 Debugging the Simulation Model

The debugger was used to track any all errors in the logic the designed model. The debugger was used to check through the logic statement systematically. Attributes and variables were equally checked for possible errors.

### 3.3 Advantages and Disadvantages of ProModel

No programming skill is needed to use ProModel. However, a short orientation may be needed. Its major disadvantage is that it requires tedious debugging process.

## IV. CONCLUSIONS AND RECOMMENDATION

The conclusions of this project are the following:

- i. Simulation is indispensable in the design and optimization of manufacturing systems.
- ii. Simulation can be used to design a virtual manufacturing system and analyse its performances.

It is recommended that the designed system be optimized to predict its randomness. Randomness such as bottlenecks and fluctuation in throughput can be predicted.

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ADEDEJI Bukola Peter, et. al. "Design and Analysis of a Manufacturing System Using Promodel." *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (6), 2021, pp 06-12.