**CMPE 412**

**COMPUTER SIMULATION**

**Project No: 2**

**PROJECT – 2:  
MANUFACTURING**

Submitted by:

*Ali Bahadır Şensöz (CMPE)*

*Sıla Er (CMPE)*

Course Mentor:

Doğan Çörüş

Faculty of Engineering and Natural Sciences

Kadir Has University

Spring 2024

1. **INTRODUCTION**

In manufacturing industries there may be bottlenecks in enhancing the throughput, reducing the cycle times, and balancing resources. These especiallyoccur in those that deal with mass production such as automobile parts production. Such systems may be complex and need to model to determine where the system loses capacity and how the changes in the system’s operations affect the system. This is where Discrete-event simulation (DES) comes in handy since it involves building quite elaborate models that simulate the various processes of a manufacturing line from one step to the next.

This project: “Manufacturing System Simulation” is about creating a Discrete Event Simulation using SimPy in Python for a high volume auto-part production line. The use of the simulation is to improve the production flow of a single product line, find out and eliminate constraints, study the impact of operational factors by conducting what if analysis. Also, the project aims at enhancing the simulation to accommodate for different products that have their manufacturing characteristics, adding to the difficulty and credibility of the model.

As a result, the project based on discrete-event simulation contributes to understanding the behavior of manufacturing systems and makes suggestions on increasing effectiveness of production processes. The outcomes of this simulation can be used to make better decisions in machines assignment, shifts, and resource utilizations in the actual manufacturing settings.

1. **METHODOLGY**

The discrete-event simulation model for the automotive parts manufacturing line includes the following steps of design and implementation based on the best practice of simulation modeling: The methodology can be divided into the following sections: system modeling, identification of data requirements, incorporation of the simulation and experimentation and analysis.

* 1. **System Modeling**

The first way of creating the simulation was to create an accurate model of the manufacturing system. This entailed identifying the processes that were involved in the production line such as; raw material storage, fabrication, assembly, inspection and packing. In each stage activities were defined in a fine grain with names of loading, machining, assembling, inspecting and packaging to simulate real life actuality of a manufacturing shop floor.

Some of the asset types that were described and placed into the system include machines and operators. It also provided shift changes to give the impression of the working hours of the production line: defining start and end times for shifts. As for multiple product types, the model incorporated machine setups for different products, taking into consideration the time it takes to switch from one product to another.

* 1. **Data Requirements**

Since the simulation had to be practical as well as realistic, specific data elements were necessary. These included:

Operation Times: Reasonable estimate which could be hypothetical but realistic time for each machine and operation was obtained. For example, machining time which was recorded in minutes was between 4 and 6 minutes for assembly time it was between 2 and 4 minutes.

Raw Material Inputs: To make the frequency of raw material inputs mimic a continuous process of feeding the system with raw materials, the required frequency was set.

Failure Rates and Maintenance Times: It was decided to introduce typical failure rates, e. g. , 10% for machining, and maintenance times, from 1 to 3 min, for machines.

Shift Patterns: The work schedules and worker distribution patterns were also set, which enabled the simulation of numerous operation shifts.

* 1. **Simulation Implementation**

The central part of the simulation was done with SimPy – a discrete event simulation toolkit in Python. Some important functional areas were created to deal with occurrences like the beginning and the termination of the processes, failure in the resources, and the setup of the machines. To mimic the time progression a simulation clock was used to move the simulation to the next event.

Every process involved in the production cycle was described by a function that captured the functions corresponding to the processes and relations with resources. For example, the machining\_process function dealt with the machining of the parts and the potential for a machine breakdown and the preparation for changeovers of different products. Concerning assembly, quality control, and packaging phases, similar functions were developed.

A Shift class was introduced to control the working hours to turn on and off the production process at the required time interval. The ManufacturingSystem class was the core that contained all resources, processes, and metrics for developing a full-fledged model of the manufacturing line, based on the identified patterns.

* 1. **Experimentation and Analysis**

To simulate the operation of the manufacturing system, several cases were run and compared to one another. The first scenario was different from the second in the number of machines, the shift schedule, and the types of products produced, which helped to study various configurations. Fixed simulation time was used to run the simulation for each of the scenarios such as 200 minutes and the results captured were total products generated, average time spent by the items in queue, and resource utilization.

The outcomes of these scenarios were the ways that gave the analyst the information about how the system works in certain conditions. This way, the simulation allowed the evaluation of the changes in machine count and shift timings and the areas that needed improvement. For example, the number of products made in situations with many machines and long working hours would be higher than in situations with few machines and short working hours; and if working during earlier hours, then waiting time would be longer because of low productivity during the early hours.

1. **FINDINGS**

Some of the key observations that were made from the simulation of the automotive parts manufacturing line include the following: The parameters considered were the total number of products that has been manufactured, the average time taken at various process stages, and the effect of various operating factors like number of machines and shift working.

* 1. **Production Output**

One of the major conclusions made was that the count of machines directly determines the resulting production rate. It was observed that organizations with higher number of machines generated more products in scenarios. For example, the number of products was the highest for the case of five machines and shift from 5 AM to 5 PM which is 37, this shows that the number of machines has a direct relation with the throughput. On the other hand, the conditions that had fewer machines, like the one-machine scenario, produced comparatively lower amount of parts, indicating that the proper machine capacity is critical in high-volume production lines.

* 1. **Waiting Times and Bottlenecks**

Mean times for various activities offered information on where delays might be present in a certain process. For all observed scenarios, machining was identified as having the longest mean waiting time, which points out this process as the critical path in production. For instance, the waiting time to machining in most circumstances was: more than 5 minutes, which is much higher than waiting times for assembly, quality control, and packaging. This finding indicates that increasing the specific capacity of machining or optimizing the machining processes can significantly increase the system efficiency.

* 1. **Shift Patterns and Efficiency**

The comparison of various shift regimes was quite enlightening and provided useful information on the effect of different shift patterns on the production rate. Schedules with starting time at early hours of the day (for instance, 6:00 AM) were other instances that delayed the process, especially in the machining area. This indicates some inefficiencies that can be expected during early hours possibly attributed to machine warm-up time or operators’ wake-up call. These inefficiencies could be reduced, and productivity increased through shifting of starting hours and proper preparations of machines at the start of shifts.

* 1. **Multi-Product Scenarios**

Though multi-product scenarios made the simulation more complex in nature, compared to a single type of product, it allowed such scenarios to properly emulate the real world manufacturing environment. Different scenarios with a mix of the products, for example A, B and C, had different results; some had an increase in the total time taken probably due to the effect of the change in the setup for the machine. Proper management of the setup of machines and resource allocation to the product type being processed must be watched to avoid increased delay. Though the system's implementation led to a more complex case, it also illustrated how it was possible to use the system for multiple products more akin to the dynamic ambiance of a production environment.

The simulation was run with various scenarios, and the results were collected and analyzed. Below is a summary of the key findings from the different scenarios:

| **Machine Count** | **Shift Start** | **Shift End** | **Product Types** | **Total Products Produced** | **Avg. Waiting Time (Machining)** | **Avg. Waiting Time (Assembly)** | **Avg. Waiting Time (Quality Control)** | **Avg. Waiting Time (Packaging)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2 | 8 | 20 | A, B | 22 | 4.84 | 3.05 | 1.44 | 1.05 |
| 3 | 6 | 18 | A, B | 19 | 5.22 | 2.98 | 1.48 | 0.97 |
| 1 | 7 | 19 | A, B, C | 25 | 4.98 | 2.98 | 1.65 | 1.02 |
| 4 | 6 | 18 | A | 10 | 5.18 | 3.13 | 1.60 | 0.90 |
| 2 | 8 | 16 | B, C | 16 | 5.10 | 2.68 | 1.57 | 1.03 |
| 3 | 9 | 21 | A, C | 22 | 5.08 | 3.03 | 1.49 | 1.12 |
| 2 | 7 | 19 | A, B, C | 28 | 5.26 | 2.99 | 1.43 | 1.06 |
| 5 | 5 | 17 | A, B, C, D | 37 | 5.02 | 2.93 | 1.47 | 0.95 |
| 1 | 8 | 20 | B, C, D, E | 30 | 5.02 | 3.01 | 1.45 | 1.02 |
| 4 | 8 | 20 | A, B, C | 29 | 5.15 | 2.92 | 1.42 | 1.01 |