ISEN-625-600 SIMULATN METHODS APP

*Final Project*

*Title- Simulation Model to Determine Staffing Strategy and Warehouse Capacity for a Distribution Center*

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# Contents

# 1 Executive Summary

`Paper Title`- Simulation Model to Determine Staffing Strategy and Warehouse Capacity for a Local Distribution Center

Link-`http://www.jatit.org/volumes/Vol95No2/6Vol95No2.pdf`

This research paper focuses on the effects of workforce staffing strategies employed in the warehouse operations of a beverage distribution center located in the Bio-Bio The region, Chile. The workforce is responsible for unloading and storing inbound product shipments from distant production plants, as well as retrieving and preparing outbound product shipments for local delivery. A simulation model was built using SIMIO and is used to guide how to improve warehouse operations as measured by load preparation time, workforce staffing costs, and maximum storage capacity utilization.

The process starts with the various supplying plants scheduling production according to a monthly forecast. Once produced, the output is dispatched by truck to the distribution center where the product will be unloaded, placed into stock, later retrieved for the load preparation process, and placed on a local delivery truck. Once dispatched, a truck will leave the distribution wide array of products, including bottle containers of different materials, which are uniquely identified using a total of 324 stock keeping units (SKUs). Additionally, warehouse operations restrict the maximum stacking height due to product packaging integrity concerns, which imposes a constraint on the storage capacity. At the same time, company policy stipulates that products dispatched to customers must be more than 30 days away from expiration. To avoid shortages that would result in sale losses, sufficient stock must be kept on-hand at the warehouse to cover not only the customer demand but also to replace the discovered aged product that cannot be dispatched to customers.

SIMIO experiments were developed taking all the above factors into consideration to obtain approximations for the load preparation time and maximum warehouse capacity size. The resulting simulation model was used to perform a series of experiments based on well-defined scenarios to evaluate the effect of facility storage capacity, and workforce staffing strategies have on productivity and cost and **concluded that increasing warehouse pallet storage capacity to improve efficiency**.

# 2 Introduction

Taking the work done in the above research paper into consideration, the current project's model is created and is simulated in python focuses on determining the capacity for a distribution center. The process starts with the various supplying plants scheduling production according to a monthly forecast. Once produced, the output is dispatched by truck to the distribution center where the product will be unloaded, placed into stock, later retrieved for the load preparation process, and placed on a local delivery truck. Once dispatched, a truck will leave the distribution of a wide array of products, including bottle containers of different materials. This variety contributes to the complexity of warehouse operations since both the container material and expiration dates must be considered. Additionally, warehouse operations restrict the maximum stacking height due to product packaging integrity concerns, which imposes a constraint on the storage capacity. At the same time, company policy stipulates that products dispatched to customers must be more than 30 days away from expiration. To avoid shortages that would result in sale losses, sufficient stock must be kept on-hand at the warehouse to cover not only the customer demand but also to replace the discovered aged product that cannot be dispatched to customers.

The resulting simulation model was used to perform a series of experiments based on well-defined scenarios to evaluate the effect of facility storage capacity, and concluded that increasing warehouse pallet storage capacity improves efficiency.

# 3 Methods

## 3.1 Code location

(`https://github.com/kirankondisetti/ISEN_625_PROJECT.git`)
The above link is for the repository for the source code used to generate the results in this report.

## 3.2 Constraints, Metrics and Data Distribution

### 3.2.1 Constraints

The following constraints are imposed on the system in order to simulate the desired model:-

**a.** Maximum warehouse capacity which will determines the maximum stacking height in the warehouse.

**b.** Sufficient stock must be in hand in-order to meet the daily demand.If the daily demand is not fulfilled on a particular day, that day will be considered as an unfulfilled demand day.

**c.** Each product that leaves the facility must have at least 30 days away from its expiry days.

**d.** The number of days the stocks come into the warehouse from different distribution centers.

### 3.2.2 Metrics

Taking the above-mentioned constraints into consideration the following metrics have been selected to assess the quality of the model:-

**a.** Wastage Stock(wastage)

It is defined as the stock that was wasted because of the expiry date constraint that is imposed on the system. It gives us the total number of discarded stocks that had an expiry date of fewer than 30 days because of which they were not shipped out of the warehouse. To keep a track of this metric a variable named wastage is defined in the simulation model and an array named wastage_array is being used to collect the wastage across a year.

```
wastage=0
wastage_array=[]
```

**b.** Number of unfulfilled days(unfullfilled_days)

This metric gives us the total of days that the demand is not met due to the above constraints. In order to keep a track of this, a variable named unfullfilled_days is defined in the model building.

```
unfullfilled_days=0
```

### 3.2.3 Data Distribution

A Poisson's distribution with a mean of 150 has been taken in order to simulate the daily demand that the warehouse gets each day. This implies that on average the warehouse that has been built gets a demand of 150 stocks in a given time period. A variable named day_demand is used to simulate the daily demand.

```
day_demand = poisson.rvs(mu=150)
```

## 3.3 Structure of the code

The simulation model for this project is developed using python. The model is generated using the flow chart displayed below(Figure 2).

The function simulation_model defined below simulates the model by taking the input max_stock and stock_arrival(significance of the variables are explained below) to give us the metrics(wastage_array and unfulfilled days) as the output to determine the optimal warehouse capacity.

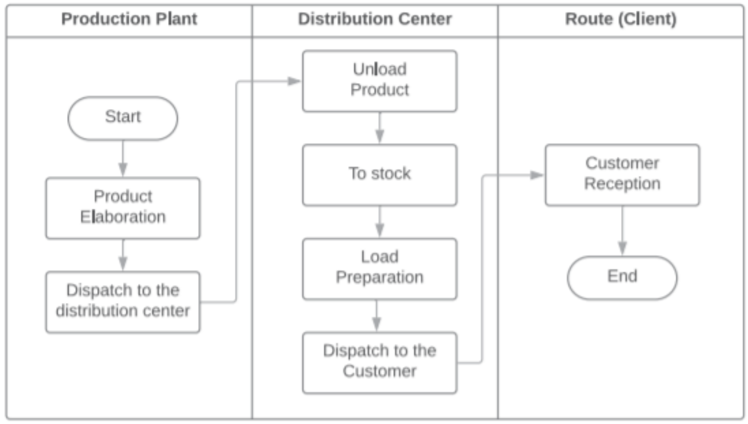


Figure 2: Major Steps in the supply chain.

```
from scipy.stats import poisson
def simulation_model(max_stock,x):
  #defining the variables
  life_of_product=80
  available_stock=max_stock
  stocks =[0]*(life_of_product+1)
  stocks[-1] = max_stock
  stock_arrival=5
  required_exp_date=30
  demand = 0
  unfullfilled_days=0
  wastage_array=[]
  wastage=0
  for m in range(91):
    for i in range(stock_arrival):
      #calculating the wastage in the process and appending it into the array
      wastage += sum(stocks[:required_exp_date])
      wastage_array.append(wastage)
      # simulating the distribution of the demand
      day_demand = poisson.rvs(mu=150)
      demand+= day_demand
      available_stock -= wastage
      # when avaialable stock is less than daydemand
      if available_stock < day_demand:
        unfullfilled_days += 1
        available_stock = 0
      else:
        available_stock-=day_demand
      #discarding the stock have expiry date less than or equal to 30
      for j in range(len(stocks)-1,required_exp_date-1,-1):
        if stocks[j] >= day_demand:
          stocks[j] -= day_demand
          day_demand = 0
          break
        else:
          day_demand -= stocks[j]
          stocks[j] = 0
      for k in range(1, len(stocks)):
        stocks[k-1] = stocks[k]
      stocks[-1] = 0
    if available_stock == 0:
      stocks[-1] = max_stock
    #calculating the wastage
    else:
      stocks[-1] = demand + wastage
    wastage = 0
    for l in range(required_exp_date):
```

```
        stocks[l] = 0
      available_stock = max_stock
    #returning the metrics
    return    wastage_array,unfullfilled_days
```

Apart from the above variable, the following variables have been defined to keep a track of different inflows to the systems:-

**a.** Life of the product(life_of_product)

It is the expiry date of the stocks that are brought into the warehouse from the distribution centers. The life of the product is defined by a variable called life_of_product and is set to 80 days through the whole simulation. This means that every stock that comes into the distribution center has a life span of 80 days

```
life_of_product=80
```

**b.** Available Stock(available_stock)

The available stock tells the total amount of stock that is present in the warehouse at a given time frame. It is represented by available_stock and is initialized to the maximum stock present in the warehouse since the total amount of stock available is the maximum amount present at the start of the simulation.

```
available_stock=max_stock
```

**c.** Stocks(stocks)

Stock is an array defined in order to satisfy the expiration date constraint. It has a length of (life_of_product + 1) with the index representing the days that the available stock is present in the warehouse and is updated after every day. The stocks get discarded when it reaches the 30th index of the array satisfying the constraint. The 90th index of the array is initialized to the max stock present in the warehouse.

```
stocks  =[0]*( life_of_product +1)
stocks [-1] = max_stock
```

**d.** Stock Arrival (stock_arrival)

Stock arrival tells us the number of days after which the stocks arrive at the warehouse from the distribution centers. It is indicated by the variable and is initialized to 5. This means that the stocks arrive to the distribution center every five days.

```
stock_arrival =5
```

**e.** Required Expiration Date (required_exp_date )

It indicates the expiry date after which the stocks are discarded. It is initialized to 30 days. This is done to meet the constraint defined on the system. Using this variable changes to the stocks array are made

```
required_exp_date =30
```

# 4 Analysis and Determining the Optimal Warehouse Capacity and Point Estimates

## 4.1 Analysis

To determine the optimal warehouse capacity multiple models are run over multiple values of maximum stock present in the warehouse. This is done by varying the variable max_stock in the simulation_model function in python.

```
max_stock =
    [400,450,500,550,600,650,700,750,800,850,900,950,1000,1100,1200,1300,1400]
stock_arrival = [5]
```

The above model is being simulated over varying warehouse capacity using a list max_stock ranging from 400 million units to 14000 million units as displayed above to capture the metrics i.e number of unfulfilled days and wastage stock. Since the mean of the demand distribution is 150 million units the minimum-maximum storage used for simulation is 400 million units. The simulation code is displayed below

```
max_stock =
    [400,450,500,550,600,650,700,750,800,850,900,950,1000,1100,1200,1300,1400]
stock_arrival = [5]
results=[]
temp = []
for i in range(len(max_stock)):
  for j in range(len(stock_arrival)):
    a,b = simulation_model(max_stock[i],stock_arrival[j])
    temp.append([sum(a),b])
  results.append(temp)
  temp=[]
```

The wastage stock and the number of unfulfilled days for each storage capacity are stored in a list named results, which will be used to generate graphs to determine the optimal storage capacity

## 4.2 Optimal Warehouse Capacity

In any optimizing algorithm, the lowest point of the loss function curve drawn in hypothesis space gives us the minimum values for the function that one is trying to optimize. Taking this concept into consideration, the warehouse capacity that gives us the least amount of wastage and unfulfilled days is the optimal warehouse capacity. To determine this, The following line graphs are drawn.

### 4.2.1 Warehouse Capacity vs Wastage Stock

A line graph is drawn between warehouse capacity and wastage stock to determine the warehouse capacity at which the wastage is minimal. The graph is displayed below in Figure 3.

From the below graph, it is visible that the wastage is zero initially up till 650 and reaches a peak at 710. After reaching the peak the wastage decreases and gradually increases for the rest of the graph. This makes sense because when the warehouse capacity is less there won't be any products that will be wasted because of the expiry date constraint imposed on the model. But the wastage increases as the warehouse capacity increases. The wastage is at its lowest when the warehouse capacity is 800 and 850 million stocks.

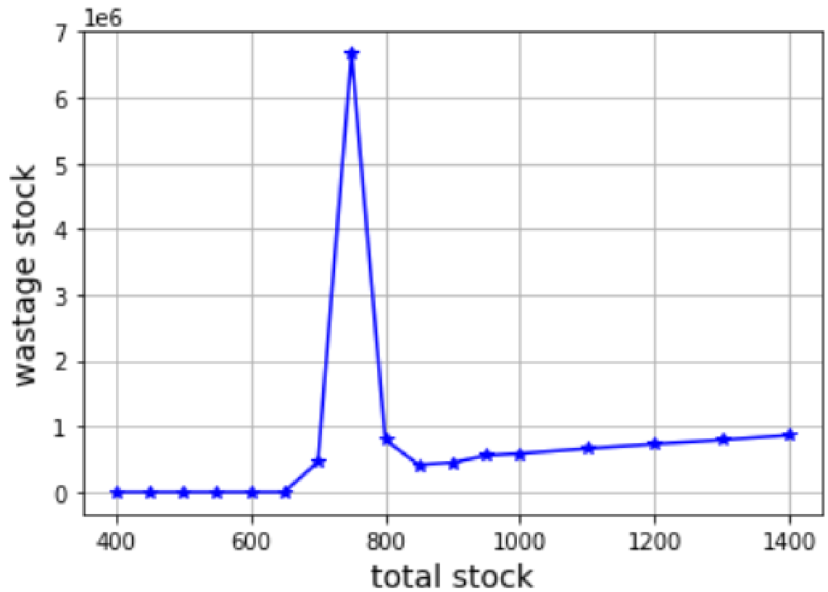


Figure 3: Warehouse Capacity vs Wastage Stock

#### 4.2.2 Warehouse Capacity vs Number of Unfulfilled Days

A line graph is drawn between warehouse capacity and the number of unfulfilled days to determine the warehouse capacity at which the number of unfulfilled days is less. The graph is displayed below in Figure 4.

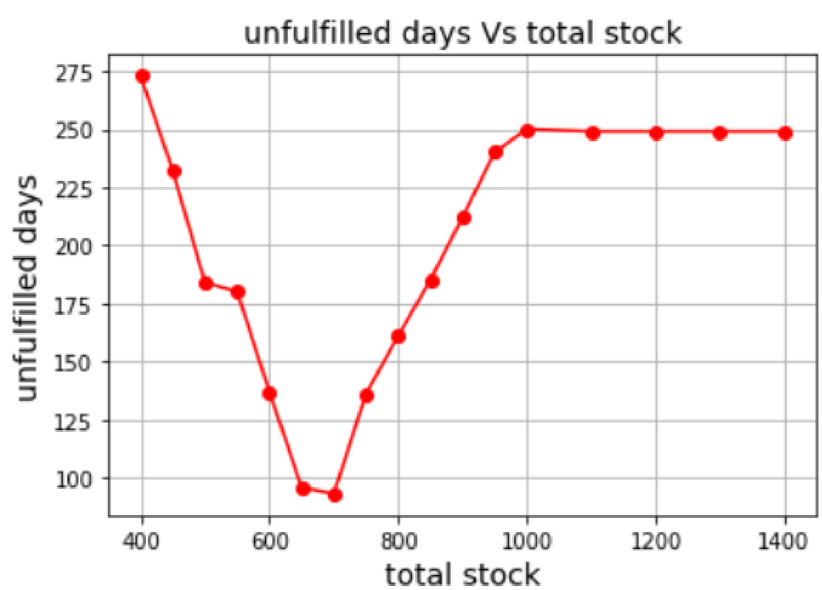


Figure 4: Warehouse Capacity vs Unfulfilled days

As displayed in the above graph the number of unfulfilled days increases at the start and decreases gradually at the later part of the graph. This makes sense because the stock at hand is very less to meet the demand on a few days during the initial part of the graph and increases gradually at the later part of the graph because the stocks are being discarded since it reached the expiry date constraint.

### 4.3 Optimal Warehouse Capacity

From the above two graphs, we can conclude that the optimal warehouse capacity for the facility under examination is 850 million units because the number of unfulfilled and wastage stock at that point is less when compared to the rest. If the stock is greater or lesser than 850 million units, then the unfulfilled days and wastage increase because of the expiry date constraint imposed on the model.

This can be better visualized by a 3-d graph displayed below in Figure 5.

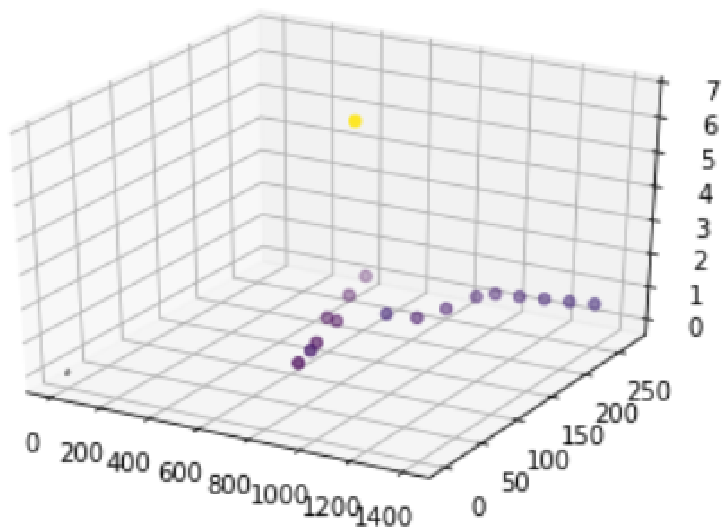


Figure 5: Warehouse Capacity vs Wastage Stock vs Unfulfilled days

### 4.4 Point Estimates for the Metrics

Point estimates give the metric of the models during their life span and will tell us that how the model performed over the years. The code to perform this test is in the colab notebook submitted. Here are the point estimates of the metrics.

**a.** Wastage stock over an year- mean=1091.1868131868132
95%confidence interval=(353.53769387003535, 1828.835932503591)

**b.** Unfulfilled days over an year- mean=187.1324
95%confidence interval=(179.34278, 195.45695)

## 5 Limitations of the Study

**a.** The expiry date for all the products in the model built is the same but in real life, this is not the case. This is one of the limitations of the study because the expiry date of all products for the entire study is taken as constant and is the same for all the products. A model could be constructed with varying expiry dates but sufficient data wasn't there and is a bit difficult to construct it in python since there are a lot of parameters to keep a track of.

**b.** The stock arrival time(lead time) for the facility is taken as constant but in the real world, this won't be the case because of which this imposes a limitation on the study.

**c.** The facility(warehouse) receives the same stock(product) from different facilities but in the real world, several different products will arrive at the distribution center which will be a limitation on the model built. That being said this model is optimal when the varying quantity of single products come to the facility.

**d.** The demand to the warehouse is kept constant throughout the model which will pose a limitation on the system because the demand may vary in the real world.

## 6 Conclusion

To summarize, the main goal of this project is to determine the optimal warehouse capacity of a distribution center. This distribution center is bounded by some constraints around which metrics i.e. Total wastage stock and the number of unfulfilled days are defined to access the performance and also to determine the optimal warehouse capacity.

A model is developed satisfying the constraints mentioned above and to keep track of the model performance metrics. The optimal warehouse capacity is found using the model by drawing plots between the metric and varying warehouse capacity, after which the optimal profitable warehouse capacity is determined to be 850 million units and the point estimates of the metric are calculated.

Further study of the model can be done by considering varying expiry dates for different products that are present in the facility which would be a case in the real world. The model can be optimized by considering the scenario where a wide variety of products comes to the facility with varying lead time.

## 7 References

**1.** Simulation Model to Determine Staffing Strategy and Warehouse Capacity for a Local Distribution Center-`http://www.jatit.org/volumes/Vol95No2/6Vol95No2.pdf`