A Simulation-Based Approach for We-Doo's Sustainable Parcel Logistics

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***Abstract*—This research presents a simulation-based approach to optimize delivery operations for We-Doo startup company that is delivering parcel in commuter town. Now increase of online shopping focus on selecting optimal warehouse location, best delivery services and with minimum time delivery. By using data modeling and simulation techniques, this study identifying best location for warehouse and using optimal routes for delivery. By using a Monte Carlo optimization technique, this study evaluates different warehouse locations based on performance metrics such as total delivery time, cost efficiency and parcel handling capacity. Additionally, sensitivity analyses are conducted to assess the strength of the proposed solutions and identify key factors those are influencing delivery operations. Results shows that the proposed simulation technique gives best warehouse placement and route planning. Location of the warehouse having coordinates (4000,2880) is the lowest cost (65.23€) and less delivery time 1.52 hours. On the other hand, the warehouse location with the coordinates of (6240,6240) showing highest cost (74.20€) and maximum delivery time 2.02 hours. Furthermore, this study highlights the importance of the environmental sustainability, scalability and human factors in parcel logistics optimization.**

***Index Terms*—Parcel logistics, Simulation modeling, Optimization, Monte Carlo method.**

I. Introduction

Warehouse location is very important part in supply chain management. Data modeling and simulation is use for the complex workings of delivering goods. We can use this for calculating shortest path in the final section that is known for its last-mile delivery and it is crucial part. This thing always gain more importance with the rise of online shopping and that is changing the way of shopping and supply chain. In this project we are focusing We-Doo and it looks into how to make their last-mile delivery. Its Services better in the places where people live but work in different places that is called commuter towns. We-Doo stands out by offering delivery services that is using electric cargo bikes. Which is not only help the environment but also tackle the challenges of delivering in crowded areas of the cities and towns. In this study our aim is to help We-Doo and find out out the best places to set up delivery centers in commuter towns. It is considering the unique situations these towns present. We-Doo depend on local delivery centers where is big delivery companies can leave packages in towns and cities. By using these center We-Doo can handle the part of the delivery that is ensuring it is done efficiently and with minimum effect on environment. We Do wanted to expand into different small towns and choosing where to add these centers because it is crucial for its success. The main part of this project is to defined last four digits of roll number as a seed which is 8688. This will help to create a simulation which is reflects the real challenges We-Doo faces. It includes things town map and customers location and location of the warehouse and how many packages are expected. Different detail which is cargo bikes can go and how long it takes to deliver packages. It is also checking how much time is needed to prepare packages and the cost of simulation. This project is divided into eight parts that is starting with gathering map data and it is ending with finding of the best place for the warehouse. It is also involve creating the delivery of the data and finding. The shortest routes which leads to optimizing delivery path and making graphs and checking the model works as well which is adding the tool for visualization purpose. This introduction part shows the importance of picking the right place for We-Doo delivery center. By using this simulation, it is based on specific parameters which tied to my student ID e.g. 8688. Our aim to offer insights that could really help We Do grow and do it better in the competitive world of last mile delivery.

II. Literature Review

Order picking from warehouse location is depends on location of the warehouse and its customers. It is very crucial aspects in selecting right location for right delivery of the goods. There are many other crucial factors involved as selecting shortest route for the delivery [2]. Efficiency is becoming main point in logistic transportation system. The aim of this study is to highlight the future research where needed [4]. Online shopping has very well growth in developed countries and it is slow in developing countries due to some barriers. These barriers can be infrastructural such as internet as well as social and cultural aspects [3]. It is also very important to select good location for warehouse. Most of the people buy products depends on the delivery of the services and price of the product. Statistics is used for evaluating and effectiveness of the different models and F-statistics and Analysis of Varianc (ANOVA) is technique that is used to assess the statistical significance [1]. Use of simulation in logistic and supply chain management playing very important role for restructuring the whole delivery process and it offers comprehensive way for testing and validating model on real world problem [5]. Simulation is use for complex problem and it is making integral part for optimization of the project focused on the last mile delivery.

III. Methodology

In first step it is explaining that how we are creating map data. We first bring in important math and randomness and the plotting tools. After that we will define methods to calculate distances. Then find the nearest point and trying to manage spatial data to make a simulated map. Then we will use a last four digit of the roll number e.g. 8688 to make sure that the results are consistent each time and we run the simulation. After that we will carefully use functions to generate, organize and show the data points. which are given to us as a good idea of how the map might look in real life. After first step, we will perform second step which is to create delivery data. It is building on the map data from the previous step. We will use similar techniques for making randomness. In this phase we will create delivery scenarios that match the map's features. By addition of roll number, we will make sure the simulation's result is the same each time. It will help us to simulate the delivery point, route and conditions perfectly. In third step we will focus on finding the shortest route on the simulated map with the delivery of the data which we have created. We use will use algorithm to find the best delivery route and building on the data. We then keep changing the special number just to confirm that results are consistent across simulations. It can show how important it is to find the best path efficiently. Next step will use to find the shortest delivery routes by using different methods. We will make some changes just to check that algorithm is working perfectly. Then we bring in data from Step 1 to Step 4 to make sure everything fits together. This type of changes we will do just to ensure accuracy and efficiency. In 6th step model verification was perform. It is a big part where we will check our model is accurate and reliable or not. We then compare it with our simulation results with the real-world data or set standards to make sure our model is good performing or not. We can use number to make sure our results are consistent each time while running the simulation. It is very important that we can make sure our simulation reflects real-world situations perfectly or not. Next 7th step is analyzing the delivery process of different parts which include time and route. We will use number for having result consistent. This step will address the how much details use to analyze the data and how to improve the process. Last step is Monte Carlo Optimization in which we use advance methods just to improve delivery and process. We added last four digit of roll number e.g. 8688. This is crucial part because it is use to find best solution by running simulations. Then we make sure that our result is reliable.

A. *Parameters from Specification*

In this part of the project many assumptions and parameters are defined. These parts play very important role in our project. These parts are explained below:
AVERAGE SPEED: This parameter is using for average speed of the delivery vehicle which is converted kilometers per hour (km/h) to meters per second (m/s). It is set at 15 km/h that is equal to approximately 4.17 m/s.
PREPARATION TIME PER PARCEL: This parameter is used for checking cumulative time which is required for each parcel to be delivered. It will include plaining, sorting and packing. We will assume its time 50 seconds per parcel.
RETURN TIME PER PARCEL: This step will explain the time which is required for process to be returned at delivery point. It will use some sort of return procedure and 30 seconds per parcel is allocated for this step.

AVERAGE TIME ANSWER DOOR: This parameter will represent the average time that a customer will takes to answer the door when the delivery is arrived. It is defined 40 seconds which is reflecting the time of the customer interaction during the delivery time.

WAIT TIME IF CUSTOMER DOESN'T ANSWER DOOR: If any customer could not answer at door when delivery is reached on the location. Delivery person will wait 60 seconds at the location.

B. *Generate Input data*

This step indicates the generation of delivery data; first it presents the average number of the parcel which is expected to reach in customer location per day. This is the crucial part because it shows overall volume of the parcel to be handled within the simulation. Secondly it shows the number of the customers who received delivery. It shows scope and the scale of the simulation. Lastly, days shows the duration for delivery data is to be generated. These input parameters play important role for evaluation of the delivery performance and efficiency.

C. *Simulation*

A simulation is developed to model and analyse the delivery process. It is a series of the functions and processes to replicate the real world delivery and its performance evaluation. Simulation project is started with road network, warehouse location and customer. It is also presenting average number of the parcel per day delived to the customers and duration of the simulation and random seed is defined last four digit of the student Id which is 8688. Delivery data will be generated using generate delivery data function based on the parameters. A generator process is used to define for generating parcel input data that is delivered to its destination. The simulation is executed within the defined environment just to analyse the delivered parcel.

D. *Table and Map shows the Simulation result*

Simulating delivery of 484 parcels over 20 days to 150 customers generated. Each day results and map showing below.

Day	Distance (m)	Day	Distance (m)
0	34,213	10	34,702
1	34,979	11	30,271
2	34,572	12	34,980
3	34,447	13	34,990
4	34,341	14	34,824
5	34,882	15	34,867
6	33,118	16	34,827
7	34,496	17	34,468
8	32,500	18	34,788
9	34,406	19	31,496

Fig. 1. Image

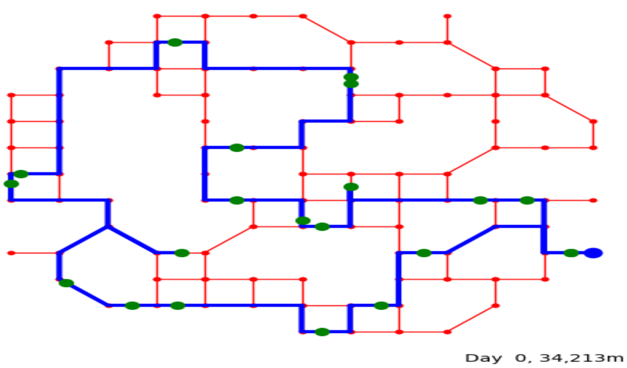

Fig. 2. Image

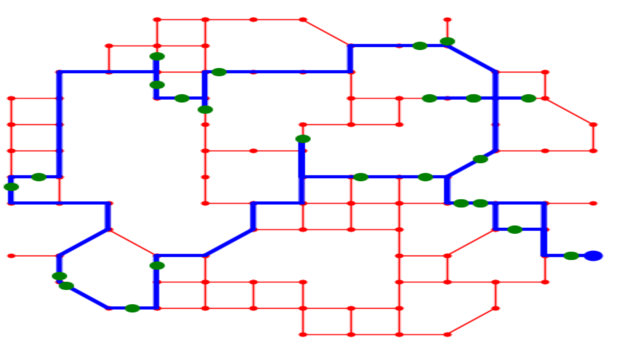

Fig. 3. Image

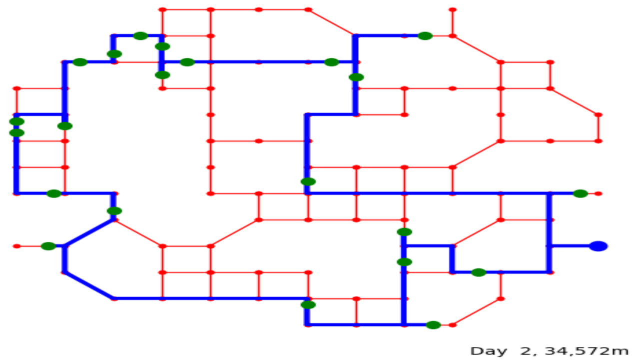

Fig. 4. Image

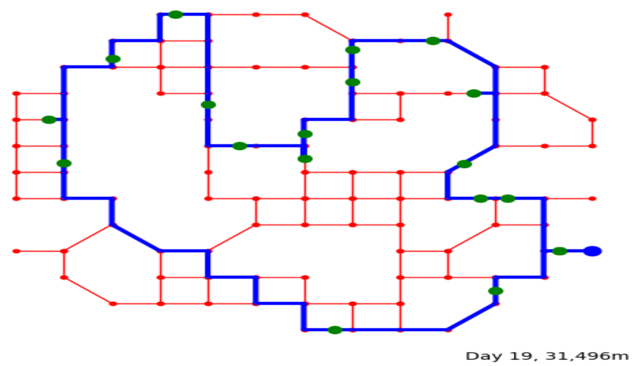

Fig. 5. Image

E. History of daily working time

It is statistical measure that shows the working time. Three functions were called to generate a distribution of the working time. Line plot use to visualize the trend of the working times in the duration of the simulation. Working time is showing in minutes and vertical scale showing density. Density starts from 0.00 to 0.04 and working time represents the scale from 170 to 210. Mean (average) working time is calculated which is 188.6 minutes that is indicating the duration time spent on the delivery activities in per day. Median value is 187.0 minutes that represents the middle value in the distribution which is suggesting that half of the observed working times were less than or equal to this value. Standard deviation result is 10.76 minutes that quantifies the spread or variability of the working times.

Output: (188.6, 187.0, 10.762508023103557)

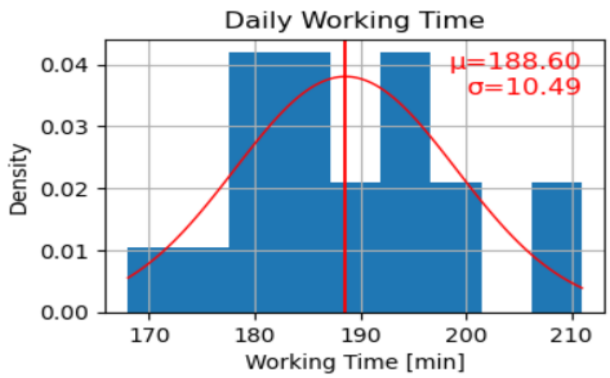

Fig. 6. Image

Fig. 7. Image

F. History of daily tour length

In this phase we will calculate daily tour length. Results are showing, Mean tour length is 34108.35 meters that is indicating the average distance travelled by the delivery person. After that median value is calculated that is 34534.0 meters which is showing middle value in the distribution. It suggests that half of the tour length were less than or equal to the median value. Standard deviation is also calculated which is approximately 1281.29 meters. Results are showing in visualization form. Output: (34108.35, 34534.0, 1281.2886718169002)

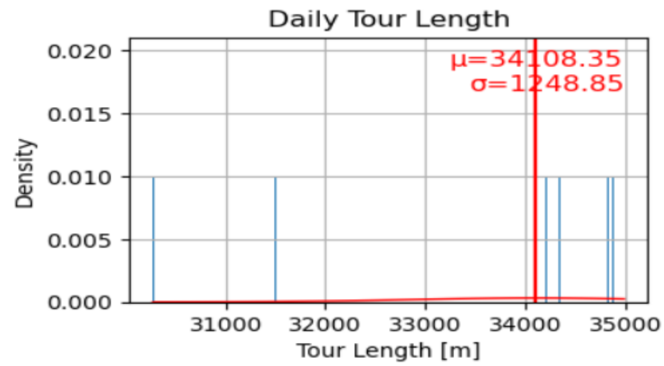

Fig. 8. Image

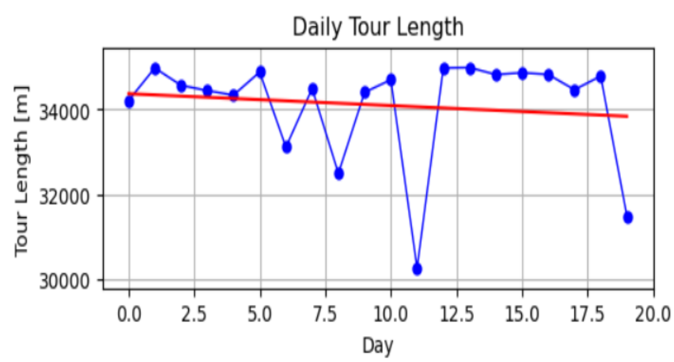

Fig. 9. Image

G. History of Left over parcel

Daily leftover parcel showing that how much parcels are undelivered at the end of each day. A function is called just to calculate the leftover parcels occurred through the simulation process. Then line plot visualize the trend of the left over parcels. Mean value is calculated that is 2.30 which is indicating the average number of parcels remaining undelivered at the end of each day. Then median value is calculated which is 1.0. It shows middle value in the distribution that half of the observed days had fewer than or equal to this number of leftover parcels. Lastly, standard deviation is calculated which is 2.49. It is quantifying the spread or variability of leftover parcel.

Output: (2.3, 1.0, 2.494203807145468)

Fig. 10. Image

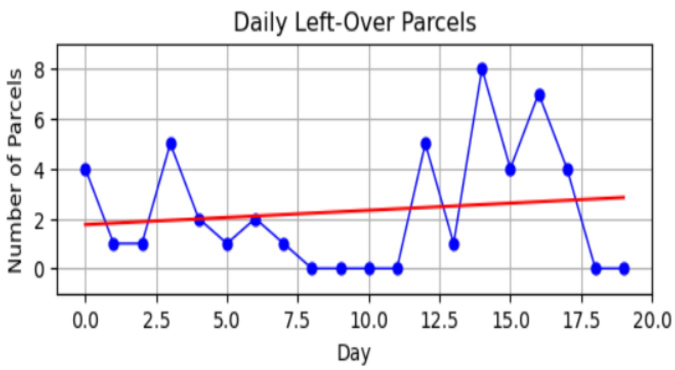

Fig. 11. Image

H. Total Time

A function is used to calculate total time which is recorded as 1232.57 seconds that is cumulative of the all phases of the simulation. The majority of the time is 1222.05 seconds. It is essential for generating efficient delivery routes. Smaller time which is calculated is 10.22 seconds.

```
==== t: 1232.57s Total
==== ΣΔt: 1222.05s createLoop
==== ΣΔt:   10.22s addTarget
```

Fig. 12. Image

IV. Results and Interpretation

Simulation results shows various metrics for performance for each warehouse location. In this phase our aim is to identify best position for the warehouse within the delivery area. Firstly, data is loaded then adding network area and customer locations. After that best location for warehouse is selected. Candidate site is evaluated by using a Monte Carlo simulation technique. Result is showing in below graph. In the Monte Carlo simulation, each candidate warehouse location is undergo to a series of delivery simulations. This involves simulating the delivery process from each warehouse location over a specified period that is assessing the mean tour length as the objective function.

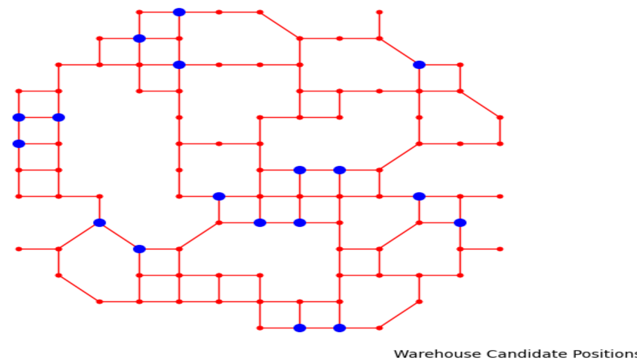

Fig. 13. Image

After getting warehouse candidate positions simulation, we are getting feedback on each location's performance, indicating whether it represents an improvement or is equivalent to the current best-performing location. Ultimately, this process identifies the warehouse positions that is minimizing the mean tour length and it is analytic of more efficient delivery routes showing below.

```
Simulate Delivery from Warehouse (1760,2880)
  improved position:   (1760,2880) f=33020.00
Simulate Delivery from Warehouse (6240,3440)
Simulate Delivery from Warehouse (4560, 640)
Simulate Delivery from Warehouse (6240,6240)
Simulate Delivery from Warehouse ( 640,5120)
Simulate Delivery from Warehouse (4000,2880)
Simulate Delivery from Warehouse ( 640,4560)
Simulate Delivery from Warehouse (2320,2320)
Simulate Delivery from Warehouse (3440,3440)
  equivalent position: (3440,3440) f=33020.00
Simulate Delivery from Warehouse (1200,5120)
  equivalent position: (1200,5120) f=33020.00
Simulate Delivery from Warehouse (2880,7360)
Simulate Delivery from Warehouse (5120,4000)
Simulate Delivery from Warehouse (2320,6800)
Simulate Delivery from Warehouse (2880,6240)
Simulate Delivery from Warehouse (5120, 640)
Simulate Delivery from Warehouse (4560,4000)
Simulate Delivery from Warehouse (4560,2880)
Simulate Delivery from Warehouse (6800,2880)
```

Fig. 14. Image

Finally, we are calculating output of the best warehouse position on the map. Graph visualization gives clear representation of the best warehouse position.

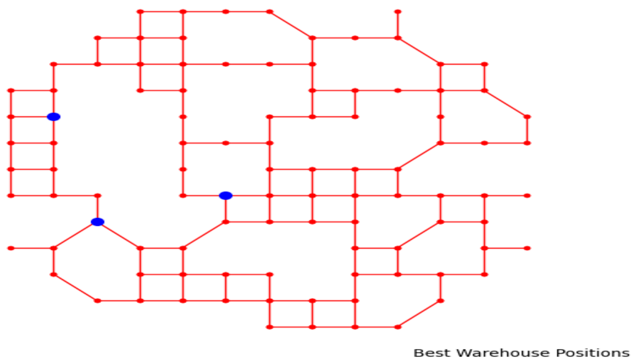

Fig. 15. Image

It includes total cost, delivery time of the parcel, how many parcels are delivered in per day and how many parcels are leftover. Results for locations (1760,2880), (6240,3440), (4560, 640), (6240,6240), (640,5120), and (4000,2880) showing differences in average total cost, delivery time, and parcels delivered.

Additionally, analysis of variance (ANOVA) to is used for checking statistical results of the observed differences among the warehouse locations. The ANOVA test produces an F-value and a p-value. F values is 8.4 and p value is 1.2, suggesting no significant difference in total costs between the given warehouse locations. The warehouse location having coordinates (4000,2880) is the lowest average total cost (65.23€) and delivery time is (1.52 hours) which showing its good location as compare to other locations. On the other hand, the warehouse location with the coordinates of (6240,6240) gets the highest average total cost (74.20€) and delivery time (2.02 hours), it is bad location as compare to other locations.

Best result: coordinates (4000,2880)
Cost: average total cost (65.23€)
Bad result: coordinates of (6240,6240)
Cost: average total cost (74.20€)

Results for Location (1760,2880):
Average Total Cost: 66.23€
Average Total Delivery Time: 1.72 hours
Total Parcels Delivered: 50
Total Parcels Left Over: 0

Results for Location (6240,3440):
Average Total Cost: 67.23€
Average Total Delivery Time: 1.82 hours
Total Parcels Delivered: 62
Total Parcels Left Over: 0

Fig. 16. Image

A. *Interpretation*

According to the results it shows simulation can help for warehouse parcel delivery operations very effectively. If any single route change it impact overall delivery time and cost. Monte carlo optimization are very powerful techniques can be used to solve logistic problems they are use to improve efficiency. In this problem we don't just highlight that how to improve logistic problem, also high light the importance of simulation for parcel delivery services.

V. Reflections and Future Work

In this research the simulation methodology is use to optimizing delivery operations for We-Doo in commuter towns, however, there are many different factors that can be help to improve in future research:

A. *Enhanced Realism*

Simulation is provided a structured approach to analyzing delivery operations. For instance, considering traffic patterns, road conditions, and weather effects can impact on fastest delivery.

B. *Un attended Customer*

delivery person must ensure call before move to the customer location just avoiding to un availability of the customer.

C. *Environmental Factors*

Although in this problem there is use of electric cargo bikes aligns with We-Doo's sustainability goals, furthermore we can research to explore the environmental impact in detail.

D. *Integration of Real-Time Data*

we can use real time traffic data from google map and other sources just to improve delivery time.

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