Optimization of “We-Doo” Delivery Operations

*Note: Sub-titles are not captured in Xplore and should not be used

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***Abstract*—This report represents the findings of a simulation study conducted for “We-Doo”, a startup company that uses cargo bikes for efficient last-mile delivery in suburban areas. This project aims to identify the optimal strategies for warehouse placement, route optimization and the scheduling of delivery locations to ensure operational efficiency and reduce cost. Through detailed simulations carried out using Python of a typical suburban environment, we evaluated different logistic setups to determine the most effective approaches. The approaches used in the simulations were specifically chosen to mirror real-life scenarios, to ensure that the recommendations are practical and applicable. The results of the findings provide “WE-Doo” with insights on optimizing delivery operations and importantly reducing cost.**

I. Introduction

“We-Doo” a startup company that emerged from a recent investigation, has secured significant seed funding and is seen as the future of last-mile delivery solutions. The company’s innovative approach allows standard delivery services to drop parcels at a central location in commuter townships. Then a local driver distributes the parcels with an electric cargo bike directly to customers in the evening. This method brings substantial savings for global delivery services as all deliveries can be dropped off at once at the local delivery centre. As “We-Doo prepares for roll-out in hundreds of small towns, a critical challenge arises: selecting optimal locations for the new local delivery centres. The next stage is crucial as the company needs to ensure that each delivery centre location is positioned to maximize efficiency and reduce cost. The primary objective of this study is to aid in the selection of the most cost-effective delivery centre location in each town, using simulation to analyze the impact of the various candidate locations on operational costs. The simulation involves evaluating how each location affects the length of delivery routes and the working time of the drivers. The simulation utilizes functions and parameters from class materials in Moodle [1] derived from the last four digits of my student ID (5640) to generate a map of the town, customer locations, and candidate warehouse sites. This approach ensures that each simulation is unique and reflects realistic layouts and challenges that "We-Doo" may face in actual deployments.

II. Literature Review

The methods and simulation models used for this work were derived primarily from existing simulation work provided on the student Moodle page, incorporating data and parameters specific to the "We-Doo" business process made available in the project outline. Key code/functions, and parameters for the simulation, such as the average number of parcels per customer and operational constraints such as cargo bike range, were taken from materials made available through student Moodle. This information provided foundational insights into the efficient route planning and cost management requirements for the last-mile delivery company.

III. Methodology

Before you begin to format your paper, The simulation involves several key steps, each designed to evaluate aspects of the delivery operation:

A. Step 1 Generate Map and Customer Data

This step provides an initial overview of the simulation project for the startup “We-Doo”. In this section, I used different Python functions to generate simulated maps that will help in determining customers' addresses and warehouse addresses. The Customer addresses are green dots on the maps while the warehouse addresses are blue interaction on the map. I use the last four digits of my student number (5640) to generate random seeds and to generate data for the map as shown in Fig. 1 below available in Step 1 section 2.3, cell 32 & 36in Jupyter Notebook.

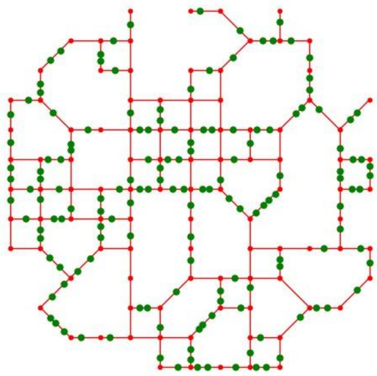

Fig.1

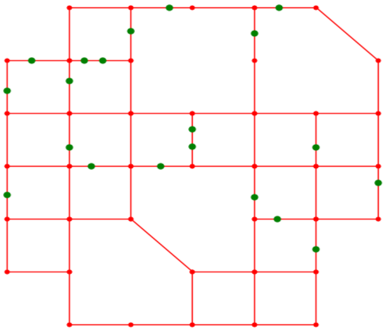

Fig.2

B. Step 2 Generating Delivery Data

This describes the process of generating delivery scenarios over several days based on a predefined customer set and the geographically mapped area developed in the previous project step using the following parameter.

def generateDeliveryData(p, C, n, seed=5640):

C. Step 3 Finding Shortest Path

This step focuses on developing and implementing an algorithm to find the shortest path for deliveries within the simulated map created previously. It made use of an *A Algorithm available in Moodle. I tested the algorithm in this section by plotting paths between randomly selected points, to ensure the algorithm's accuracy. Example is shown in Fig. 3 below available in Step 3 section 3.2 cell 21 in Jupyter Notebook.

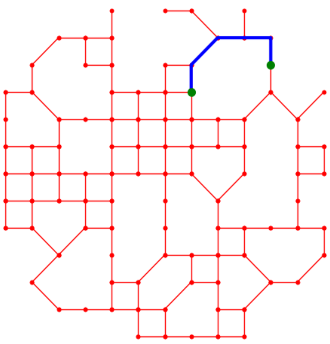

Fig. 3

D. Step 4 Finding Shortest Delivery Route

This step delves deeply into the method used to identify the most efficient delivery routes for the startup "We-Doo" within a simulated map environment. This step is very important is very important for cost reduction and optimization of delivery times. I added the Heuristic Rule 2 and Rule 3 to the Heuristic algorithm which was provided in the project class material available in Moodle to optimize the delivery route. You can find it in section 4.2.2, cell 69 of Step 4 in the Jupyter notebook file. I also utilize the Monte-Carlo method to test different warehouse locations and assess their impact on the delivery route's total length. The result shows that the Monte Carlo method produces a shorter length than the optimal Path method as shown in Fig. 4 and Fig. 5 below which is available in Step 4 section 4.4 cell 64 and cell 68 in the Jupyter Notebook.

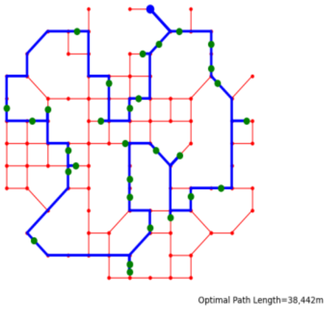

Fig. 4

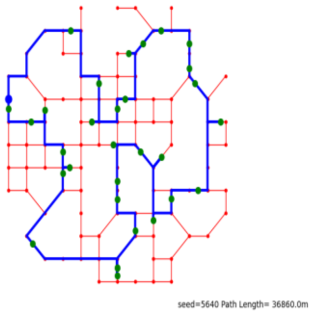

Fig. 5

E. Step 5 Developing Event Graph

As the name implies, this step involves developing event graphs for activities such as class parcel, class customer, class driver and class delivery centre. Different diagrams were used to explain the different class processes that take place during the simulation.

F. Step 6 Model Verification

This step provides a detailed guide to verifying the reliability and accuracy of the model developed in the earlier steps of the project.

The simulation process in this step involves the implementation of several Python Classes such as the Class Recorder which captures and records various simulation data, Class Parcel, Class Customer, Class Driver and Class Delivery Centre, all of which handle specific tasks within the simulation. In this step, I tested the simulation model to determine the efficiency of the delivery network.

I made use of the “generateDeliveryData” for my load generator and simulated for 20 days available in section 10.4. cell 40, step 6 in the Jupyter Notebook file.

- Class Parcel: It represents the parcel in the delivery Centre and explains how the life cycle of the parcel is managed through statuses like processing, in transit, ready for delivery, and delivered as shown in Fig. 6 available in Step 6 section 6 in Jupyter Notebook .

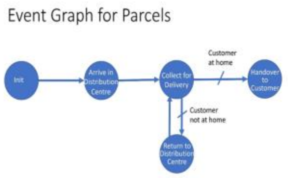

Fig. 6

- Class Customer: it represents the activities of the customer in the simulation like the location of the customer, if the customer is at home, if the customer answers the door when the delivery is attempted and how many parcels the customer receives as shown in Fig. 7 available in section 7 in Jupyter notebook.

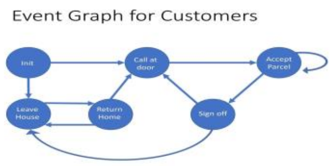

Fig. 7

- Class Driver: This process manages the daily activities of the driver from the delivery centre to the customer location and returning to the delivery centre. It shows the daily routine of the driver as shown below in Fig. 8 in section 8 in the Jupyter Notebook.

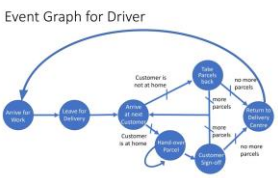

Fig. 8

- Class Delivery Centre: This process involves the management of all parcel-related operations in the central location like the list of parcels in the delivery centre ready for delivery, parcels that cannot be delivered the same day and are left over till the next day and the planned delivery route as shown in below Fig. 9 available in section 9 in Jupyter notebook.

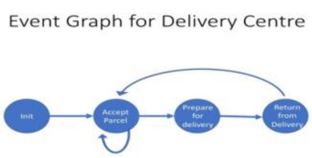

Fig. 9

G. *Step 7A Working Time*

The processes involved in this step are used to simulate and analyse the working time of the driver. The simulation utilizes the various class functions explained above.

My simulation environment was set up with predefined parameters and the simulation was implemented to run for 25 days for statistical significance as shown in Fig. 10 & 11 Step 7A section 10.4 cells 33 and 34 in Jupyter Notebook.

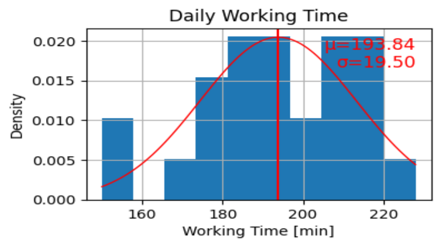

Fig. 10

Fig. 11

H. *Step 7B Route Length*

This step involves the method and procedures to carry out the simulation and analysis of the route length for deliveries. this step helps to optimize the delivery route to reduce operational costs. A series of Python functions are added to the class recorder to carry out this process. The result simulated the delivery of 578 parcels for 25 days to 150 customers as shown in Fig. 12 available in Step 7B, section 10.4. cell 67 in Jupyter Notebook.

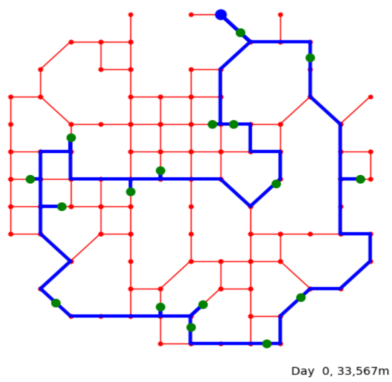

Fig. 12

I. *Step 7C Parcels Leftover*

The simulation carried out in this step shows how parcels that could not be delivered on the same day that they were received are being managed. A Python function called "recordParcelLeftOver" is added to the Class recorder to carry out this simulation as shown in Fig. 13 & Fig. 14 available in Step 7C, section 5, cell 20, Jupyter Notebook.

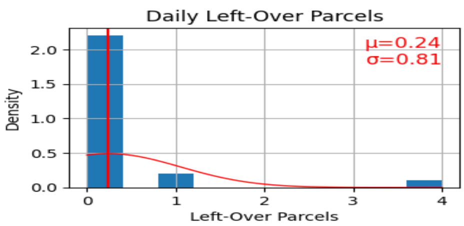

Fig 13

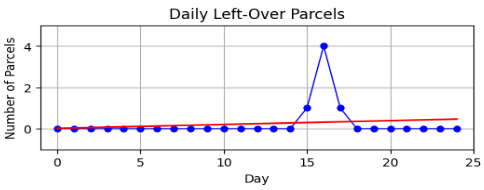

Fig. 14

J. *Step 7D Calculating Operational Cost and Drivers Pay*

In this step, I carried out the calculation for the operational costs and the driver's pay. I converted the distance covered by the driver from Meters to kilometres and the time from seconds to hours to calculate the operational cost and the driver's pay. I made use of a Python function which is found in section 10.5. in Jupyter Notebook to carry out this process. To calculate the operational cost, the drivers pay and to visualize the data, I made use of Python functions from Github [1]

I arranged all the warehouse distances from day 1 to day 25 into a Panda data frame which is a Python Library. I also did the same for the operational cost and then generated a box plot for operational cost against warehouse distance to check for the statistical significance which shows that there are statistical differences between the warehouse locations as shown below in Fig. 13 available in Step 7D, section 10.5. and 10.6, cell 35 – 42, Jupyter Notebook.

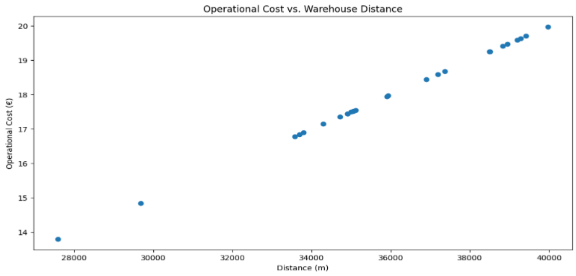

Fig. 15

K. *Step E Summary Statistics*

This step continues with the creation of visualization to gain insight into operational effectiveness and to provide insight into areas of improvement.

IV. Results and Interpretations

The detailed simulation provided actionable insights into many aspects of "We-Doo's" operations, from route optimization, cost control, and to delivery scheduling. Not only did the project provide operational efficiencies but also laid a strong foundation for scaling the business by making strategic decisions informed by robust, data-driven analytics The approach ensures that the "Wee-Doo". has the resources to meet expansion requirements while maintaining a high level of service and cost efficiency.

V. Reflection and Future Work

The research demonstrated the potential for significant cost savings and efficiency improvements with the correct placement of delivery centres. Future studies could explore the integration of real-time traffic data and adaptive routing algorithms to further enhance delivery efficiency. Additionally, expanding the range of cargo bike constraints or exploring other delivery methods could address some of the limitations posed by current operational constraints.

References

[1] [2]

[1] Github, "github.com," 15 August 2022. [Online]. Available: www.github.com. [Accessed 16 April 2023].

[2] C. M. a. i. Moodle, *Project,* Dublin, 2023- 2024.