Optimizing the Delivery Network of Roadster Diner: Merging with Sister Companies

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Roadster Diner is the leading national casual diner and offers food delivery services all over Lebanon. However, their delivery network faces profit losses and timing problems. This paper revolves around one main objective: the optimization of Roadster's delivery network, which in turn leads to a major increase in their productivity and profitability. This study tests the feasibility of merging the delivery network of the two sister companies Zaatar W Zeit and Bar Tartine with that of our stakeholder. This paper will focus on three main topics studied. First, the optimization of the delivery operations. Second, the improvement of internal operations in the kitchen of delivery centers. This Final Year Project revolves around finding engineering methods to provide our stakeholders with the fastest delivery service for the least possible cost. Furthermore, the paper will discuss the results obtained from our pilot research, and the results expected by the end of the year. [1]

Keywords— Industrial Engineering, Vehicle Routing Problem, Insertion Heuristic, Savings Heuristic, Motion Studies, and Facility Planning.

I. Introduction

Demand for food deliveries is increasing dramatically with an increase of 20 percent year-to year and a total of approximately 20,000 food delivery orders per day, according to the Syndicate of Owners of Restaurants, Café Nightclubs and Pastries in Lebanon [6].

Roadster Diner is a leading national casual diner and offers a delivery service all over Lebanon. It was first founded in 1998 and opened its first delivery center in 1999 in Beirut. Based on the meeting we set with Roadster Diner, they informed us that they generate 70% of total revenues per year from food delivery services, which indicates the significance of optimizing the process. With this high demand for delivery services, Roadster expanded its delivery centers and now has one located in Antelias and another in Metn. The delivery centers of Roadster receive a large number of orders per day, summarized in the Table I.

Table I: Data Collected

Location	Areas covered	Average orders/day	Number Drivers	Peak Days	Peak Hours
Antelias	Dora-Ashrafieh	600	35	Friday - Sunday	12-3pm 7-9pm
Ain el Mreisseh	Tabariss-Hamra/Verdun	800	35	Friday - Sunday	12-3pm 7-9pm
Metn	Antelias-Rabieh	400	25	Friday - Sunday	12-3pm 7-9pm

Roadster's main focus is customer satisfaction, and customers expect on-time delivery of their orders. Therefore, time constraints are highly sensitive for food delivery networks. This sensitivity is a challenge that we are faced with since our methods should result in both time and cost savings. Management at Roadster's has asked us to prioritize getting the order on time rather than saving on costs. Therefore, we are restricted to a time window throughout our study. This has led us to our two main objectives. First, we worked on the external operations to reduce the on-route time to deliver the food. Second, we focused on the internal operations to reduce the time it takes to cook the meals (kitchen time).

Using industrial engineering methods, we were able to generate an algorithm that checks the feasibility of merging the delivery centers of the sister companies. We then coded the algorithm onto python. Moreover, we will optimize the internal operations using both facility layout planning and time and motion studies.

II. Background

The vehicle routing problem is classified as an NP-hard problem. In other words, it is difficult to solve these problems using exact optimization methods. In order to get solutions in determining routes which are realistic and very close to the optimal solution, heuristics and metaheuristics are adopted.

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The insertion heuristic defines the addition of a customer into a pre-assigned route, and the effect it will have on the whole system. Campbell and Savelsbergh discuss the complicating constraints that are added to the heuristic: time windows, shift time limits, variable delivery quantities, fixed and variable delivery times, and multiple routes per vehicle [1]. This logic tests the hypothesis of inserting a customer as feasible, and checks whether it complies to specified constraints.

The savings method heuristic on the other hand, expresses the cost savings obtained by joining two routes into one route. The costs can be defined in terms of time or distance, in our study we analyze both. Solomon uses the savings heuristic but modified to consider the time window constraint [9]. The savings heuristic could find it profitable to join two customers very close in distance but far apart in time, so it is important to account for both the spatial and temporal closeness of customers.

The main focus of our study is the Vehicle Routing Problem with Time Windows as well as the Multiple Depot Vehicle Routing Problems. Thus, the algorithm that we generated was inspired by the combination of both insertion and savings heuristics to find a modified model for our system. The specific modifications will be elaborated in section III-A.

Moving forward, other industrial engineering tools we will apply to improve our study are facility planning, time studies, and quality control. All of which will be applied to the internal operations of the kitchen. These are our spring objectives and will be worked on till the end of the year.

III. Methods

A. Vehicle Routing Algorithm

The first step of our project was to collect data from delivery centers in order to simulate a real-life example of merging the delivery network of the sister companies.

During the fall semester, we limited our study to the Antelias area and to the insertion of two customers into a preassigned route. Consequently, one driver can have a maximum of two orders at a time. We took these assumptions so we would be able to tackle the issue on a manageable scale. However, we were unable to gather real data from Roadster. Fortunately, using Python and Google API, we were able to generate realistic data points based on the information collected from Roadster. The API creates random locations across the specified region, Antelias, using Google maps and a von mises distribution. A von mises distribution is a continuous distribution with a range of [0,2pi] that allows the API to randomly generate coordinates across the bounded area. After specifying the region, the code we generated randomly assigns a customer identity using an imported library containing names, a restaurant using the list we provided, an order time using random time intervals, and a random kitchen duration which represents the time to prepare an order. The kitchen duration was assigned randomly to each order using the Python algorithm. Based on the information that Roadster gave us, the kitchen time should be between 7 and 15 minutes. The code also generates the earliest and latest delivery time at which the order can reach the customer. All input variables used in the code are listed in Table II and all decision variables are listed in Table III. One of our objectives for the spring semester was to collect actual data from Roadster, however, due to the current situation we are faced with, Roadster will not be sharing this information. We do believe that the Google API simulation is a proper representation of the real scenario. In addition, we aim to expand the region our study is based on to have a more accurate representation of the delivery network.

Table II: Input Variables

Input Variable	Definition
R(i)	Location of restaurant from which customer *i* ordered
D(t)	Location of driver at order time *t.*
C(i)	Location of customer *i*
T(x,y)	Time to travel from location *x* to location *y*
D(x,y)	Rectilinear distance from location *x* to location *y*
OT(i)	Order time of customer *i*

Table III: Decision Variables

Decision Variables	Definition
E(i)	Earliest time a delivery can reach customer *i*
L(i)	Latest time a delivery can reach customer *i*
OR(i)	Time the order of customer *i* is ready to be delivered
Q	Capacity of motorcycle's delivery bag
V(i)	Volume of customer *i*'s order
q(r)	Remaining volume in the delivery bag after an order was placed
K(i)	Kitchen time of customer *i*'s order
U	Arrival time at first customer (*i* or *i-1*)
V	Arrival time at second customer

We used the Vehicle Routing Problem in order to test the feasibility of merging the delivery centers. In fact, there are many heuristics to solve such problems; however, we focused on the Insertion, Savings, and Multiple Depot Heuristics [3] [4]. We chose these heuristics since their combination defines our problem: inserting a customer into a preassigned route having three different restaurants (depots) while still generating savings (profits). Four of the decision variables present in Table III were generated using equations and are dependent on other variables. The equations used to derive the time the order of customer i is ready to be delivered, the earliest time a delivery can reach customer i, the latest time a delivery can reach customer i, and remaining capacity in the motorcycle's bag are present in Table IV.

Table IV: Equations

Equation	Definition
OR(i) = OT(i) + K(i)	Sum of the time customer i orders and the kitchen time needed to prepare order
E(i) = OR(i) + 1	Sum of the time the order is ready to be delivered + 1 minute (1 represents the minimum time it can take to deliver)
L(i) = OT(i) + 45	Sum of the order time of customer i + 45 minutes (45 represents the time window specified by Roadster)
q(r) = Q - V(i)	Total motorcycle bag capacity - volume of customer order

The algorithm is subject to several constraints that were inspired from the heuristics used. Mainly, we are subjected to three constraints: order time, capacity, and order arrival time. The constraints are checked at every iteration to test whether inserting a customer i into the preassigned route of customer i-1 is feasible. The last constraint is calculated using the decision variable U, discussed further on. Our constraints are summarized in Table V and presented in Table VI, lines (1), (2), and (4).

Table V: Feasibility Constraints

Constraint	Definition
OT(i) < E(i-1)	Order time of customer i should be less than earliest arrival time of customer i-1
V(i) < Q - q(r)	Order volume of i should be less than the remaining capacity in the delivery bag
U<L(i)	Order arrival time at all the assigned customers should be less than their latest arrival time

The initialization step of our algorithm presented in Table VI is defined as the first customer with the minimum order time. Lines (3) and (7) calculate the time needed to arrive at the first and second customer respectively after picking up the orders from the different depots. To calculate U, we first add the minimum ordering time between the two customers to the time the driver needs to go to the nearest restaurant from his current location. Second, we add the maximum between the arrival time of the driver to the restaurant and the time the order is ready. That is, if the driver arrives before the order is ready they will have to wait for the order before departure.. However, if the order is ready before the driver arrives, then they will just have to pick it up and leave. Third, we add the time to go from the first to the second restaurant in order to pick up the second order. Fourth, we add the maximum between the arrival of the driver to the second restaurant and the time the order is ready. Finally, we add the time to go from the second restaurant to the nearest customer. After defining U, which represents the time needed to arrive at the first customer, we have to check if it is less than the latest time of the corresponding customer, shown in lines (4) and (8). If U is within the range stated in the beginning of the algorithm, we continue. Otherwise, the insertion is not feasible.

Considering all feasible for the first customer, we have to check that the time window of the second customer is respected. Therefore, we let V be an equation to calculate the time needed to arrive at the second customer, shown in lines (5) and (9). First, we add to U the time needed to go from the first visited customer to the second, (T(x,y)). Then we check if V is less than the latest time of the corresponding customer, shown in lines (6) and (10). If V is within the range, we insert the customer onto the route. Otherwise, it is infeasible and the insertion of the new customer is disregarded. Note that these constraints are checked at every iteration.

Finally, after accounting for all constraints, if all pass, the code continues to calculate profitability. Profitability is defined as the savings in distance traveled (km) and number of drivers reduced. The output of the code shows all possible routes that a driver can take along with the profit at each route. Table VII shows two different possible savings derived from the algorithm. Given that those equations are written in terms of *i, x* and *y*, they combine all the possible routes that can be derived. Therefore, we can deduce the optimal route based on the maximum profit discussed in section IV.

In the first route presented in Table VII we are saving the distance to go from restaurant *i* to customer *i* and the distance to go from restaurant *i-1* to customer *i-1*. In addition, we are adding the distance to go from customer *x* to customer *y* and the distance to go from restaurant *i-1* to restaurant *i*. In the second route, we are saving the distance to go from restaurant *i* to customer *i* and the distance to go from restaurant *i-1* to customer *i-1*. Moreover, we are adding the distance to go from customer *x* to customer *y* and the distance to go from restaurant *i* to restaurant *i-1*. Note that in both routes we have saved one driver since both customers from different restaurants are being served by the same delivery driver.

Table VI: Pseudocode

```
    Input R(i), D(t), C(i), T(x,y), D(x,y), OT(i)
    OR(i) = OT(i) + K(i)
    E(i) = OR(i) + 1
    L(i) = OT(i) + 45
    C(x)= Max [D(R(i), C(i)), D(R(i-1), C(i-1))]
    C(y)= Min [D(R(i), C(i)), D(R(i-1), C(i-1))]
(1) If OT(i) < E(i-1)
(2) If V(i) < Q - q(r )
     If T [ D(t) , R(i) ] < T [ D(t) , R(i-1) ]
(3)    U= Min [OT(i-1),OT(i)] + T [D(t),R(i)] + Max[
       A(R(i)),OR(i) ] + T [R(i), R(i-1)] +
       Max[A(R(i-1)),OR(i-1)]j+ Min [T (R(i-1),C(i)), T
       (R(i-1),C(i))]
       T (R(i-1) , C(x)) =  Min [ T (R(i) ,C(i)) ,T (R(i), C(i-1))]
       T (R(i-1) , C(y)) =  Max [T (R(i) ,C(i)) , T (R(i) , C(i-1)) ]
(4)       If U < L(x)
(5)         V = U + T [ C(x) , C(y) ]
(6)           If V < L(y)
                Return D(t) →  R(i) → R(i-1) → C(x) →  C(y)
     ELSE
     If T [ D(t) , R(i-1) ] < T [D(t) , R(i) ]
(7)    U = Min [OT(i-1) , OT(i)]  + T [ D(t), R(i-1) ] + Max [
       A(R(i-1)) , OR(i-1) ] + T [ R(i-1) , R(i) ] + Max[A(R(i)) ,
       OR(i)] + Min [ T (R(i) , C(i)) ,   T (R(i) , C(i)) ]
        T (R(i) , C(x)) = Min [ T (R(i) , C(i)) , T (R(i) , C(i-1)) ]
        T (R(i) , C(y)) =  Max [ T (R(i) , C(i)) , T (R(i), C(i-1))]
(8)       If U < L(x)
(9)         V = U + T [ C(x) , C(y) ]
(10)          If V < L(y)
                Return D(t) →  R(i-1) → R(i) →  C(x) → C(y)
```

Table VII: Profitability

Route	Savings Equation
D(t)→R(i-1)→R(i)→C(x)→C(y)	D(R(i),C(i))+D(R(i-1),C(i-1))-D(C(x),C(y))-D(R(i-1),R(i))
D(t)→R(i) →R(i-1)→C(x)→C(y)	D(R(i),C(i))+D(R(i-1),C(i-1))-D(C(x),C(y))-D(R(i),R(i-1))

B. *Optimization of Internal Operations*

An important factor that plays a role in maintaining the time window is the efficiency of the internal operations of the delivery center kitchens. Thus, identifying the different types of wastes and analyzing the operations in the kitchen will allow us to improve the overall delivery network. The kitchen of Roadster is based on a pull system, which means that the food is only produced to meet customers' demand.This lean manufacturing strategy is used to reduce the waste in the process of production.

We performed a motion study on the kitchen staff to calculate the effective and ineffective time that a worker spends while preparing a certain meal. After meeting with Mr. Ayoub, the delivery center manager, he informed us that one of the most ordered items on the menu for delivery is the Cheese at Heart Burger, therefore, we decided to perform our study on this item. Our motion study consisted of studying the motions of the kitchen worker at the burger station and noting the time it takes to carry out each element of the process. The results found are discussed in section IV. In addition, we are going to evaluate the facility layout plan of the delivery center. This study will allow us to identify the important relationships between the stations in the kitchen to design an optimized layout considering the available space, the convenience of operations, and the safety of the staff.

IV. Results

A. *Algorithm and Code Results*

The algorithm results are summarized in Table VIII. The current situation represents the routing independent of the synergy, the improved scenario represents our algorithm, and the savings are the additional profits caused by the synergy.

Table VIII: Algorithm Results

	Current	Improved	Savings
Independent Routes	7	4	3
Drivers	7	4	3
Distance (km)	63.4	52.2	11.2

Using our algorithm, we were able to reduce the number of drivers by around 42% and save 11.2 km in distance through inserting a customer into a preassigned route and still respecting the time window of [0,45] minutes. The decrease in number of drivers and distance translates to savings in labor and fuel costs for the company. It is also important to note that reduction in fuel translates into fewer air pollution.

In addition, the python results are presented in Figure I. The first simulation S1 calculates the total distance travelled by two drivers as in the current situation of Roadster. On the other hand, simulations S2 till S7 represent the insertion of customers into the pre-assigned route. In every run and with every different simulation we got an alternative route that saves total distance travelled and decreases total number of drivers. One of the results after running the code is presented in Figure I. Savings of 7.3 km and one less driver.

```
Two Drivers Distance: 22.599999999999998 km
One Driver s1 20.699999999999996 Km
One Driver s2  16.8 Km
One Driver s3 15.6 Km
One Driver s4 15.299999999999999 Km
One Driver s5 17.0 Km
One Driver s6 15.899999999999999 Km
```

Figure I: Python Results

B. Optimization of Internal Operations

The motion study performed on the kitchen staff at the burger station showed the results summarized in Table IX. As we can see, the ineffective times on both hands are significantly larger than effective time. This is due to the process in which the worker prepares the Cheese at Heart Burger. First, he adds the toppings and sauce of the burger before cooking the meat, which leads to waiting time for the patty to cook. Instead, he can first cook the meat then prepare the bun. Second, the station in which the meat and chicken is cooked is far apart from where the burger is prepared. Therefore, this leads the worker to walk backtrack repeatedly in the kitchen. This leads us to the second objective under internal operations: facility layout planning.

Table IX: Motion Study Results

	Left Hand	Right Hand
Effective time in seconds	39	49
Ineffective time in seconds	185	175

Concerning the optimization of internal operations using facilities planning, we are expecting to reduce total kitchen time and making the food preparation process more efficient. This will allow us to have a greater time window in the delivery of the food and route time.

V. Discussion and Conclusion

The objective of this Final Year Project is to optimize the delivery network of the three sister companies: Roadster, Zaatar W Zeit, and Bar Tartine through a synergy. To do so, we used the Vehicle Routing Problem as a basis to generate an algorithm. The main heuristics used in solving this problem were the insertion, savings, and multiple depot heuristics. The assumptions we were limited to throughout our study were the regional boundary (Antelias) and the number of customers to insert (two customers only). The results of the algorithm were as expected. We were able to generate savings in terms of reduced total distance traveled and number of drivers used. Our next step is to expand the scope of our work and target a larger area across Lebanon and account for more than two customers.

In addition, the results under motion studies for the preparation of the Cheese at Heart Burger showed us that there is a significant opportunity of improvement in the kitchen operations. For example, if the worker at the bun preparation station cooks the meat before the bun, waiting time will decrease. We were limited to studying only one item on the menu, however, expanding to analyzing other popular meals will allow us to have a clearer image. In addition, we should not forget to account for human errors and the difficulty of training the staff on new methods to work.

As expected, all results generated showed that there is an area of improvement for both the external delivery network and the internal operations of our stakeholders. Combining both Industrial Engineering methods, coding, and logic allowed us to come a step closer towards an optimized overall delivery network.

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