Optimization of an Illegal Food Delivery Service in a University Campus

Project Proposal

CIE 5015 Operations Research

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About the Problem

Due to a so-called "unfair competition", the association of restaurants inside NTU pushed to prohibit delivery inside the campus by the evil and capitalist brands Food Koopa and Bowser Eats. Understanding that this restriction created an emergent market for smuggled food, Mario and Luigi plan to sell hamburgers to a list of customers inside the campus previously contacted online. To be successful, the brothers need to choose the best route to deliver the food to customers in different buildings before the police inside the campus catches them. Each has his own vehicle and may traverse different routes before exiting the campus. Bikes and cars are considered for delivery, each with different speeds, capacity, and accessibility to roads since barriers restrict the free passage of cars in certain areas.

This mission is initially deemed to be insurmountable given the very tight security inside the university campus. Understanding this challenge, Mario and Luigi hired the services of Yoshi to help disable all security cameras and remove all batteries from the security's two-way radios. As a result, the average response time of the police increased from 5 minutes to 20 minutes. This means that Mario and Luigi each have to finish their entire trip and leave the campus within this threshold; otherwise, they will be sent to jail where the evil Wario is waiting. The time begins as soon as the first delivery is made (i.e., a bystander will report to the police once an illegal transaction is conducted).

In addition, Mario and Luigi want to avoid the possibility of being trapped inside the university campus when the police decide to close the gates. As such, they asked Princess Peach to serve as a watchdog and possibly distract the police with her beauty at their chosen entry point. While they have total freedom to choose where to enter, the brothers must begin and end their trip at the exact same portal to ensure their escape.

The potential delivery points are shown in Figure 1 below.

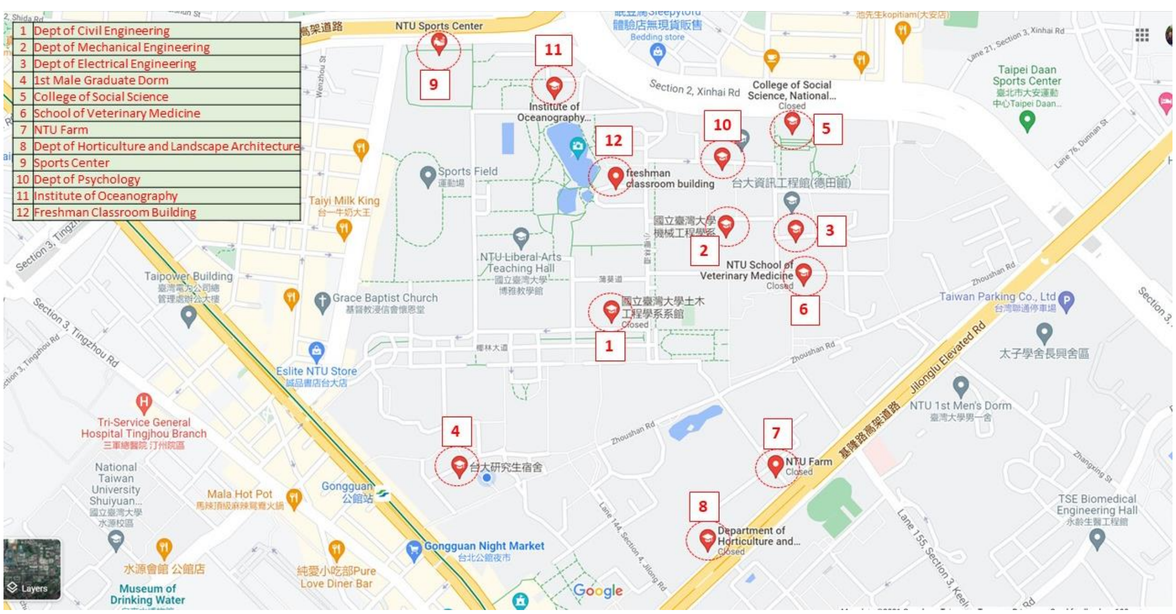

Figure 1. Potential delivery points within the NTU campus

Objectives

The study aims to maximize the net income for an illegal food delivery service inside a university campus. The net income is defined as the difference between the gross profit (i.e., product between the unit cost of hamburger and demand catered) and the total costs incurred (e.g., cost of fuel, parking fee).

In order to achieve this, the model must be able to determine the most optimal way – which route must each person traverse? Which mode of transport shall be ideal for each person, provided that each mode presents a tradeoff when it comes to capacity, time, access and cost? – that will yield the greatest net profit.

While the problem was formulated in a bizarre and odd way to spark interest, the researchers believe that the study has real-life implications underneath. For instance, the proposed model has the potential to help small-time food business owners kickstart their expansion through a local delivery service.

Since it would be too costly for small businesses to partner with existing online food platforms, these types of optimization models would aid the owners in their decision-making when it comes to the design of a small-scale delivery service to their most loyal customers within their area. Similar to the initial problem, real-life food delivery services would be bounded by time constraints; however, instead of the possibility of being caught by the police, these will be in the form of (1) maximum acceptable waiting time for customers and/or (2) the maximum time before the quality of food diminishes. Furthermore, the study is deemed to be more relevant now that cities are actively pushing for sustainable modes of transport, and bicycles have now been utilized for delivery services.

Model Formulation

The initial model formulation is shown below. The model may still be subject to changes depending on the progression of the project.

1. Binary parameters

2. Integer parameters

P_k: capacity of vehicle k k=1,2,3

C_k: cost of vehicle k of per unit distance k = 1,2,3

V_k: velocity of a vehicle k k=1,2,3

D_{ij}: distance between any pair of node i ,j $\in$ N

P: price of a burger

Q_i: burger demand of a node i $\in$ N

Tk: maximum total travel time allowed for vehicle k

3. Binary variables

Xij : =1 if the salesman goes from node i to j ∈ N, otherwise = 0

Umk = 1 if use car, motorcycle, bike ,otherwise = 0, k=1,2,3

Ulk = 1 if use car, motorcycle, bike ,otherwise = 0, k=1,2,3

Ui and Uj: subtour elimination variables for MTZ method

pa :to be the maximum number of nodes that can be visited by any salesman

4. Interger varibles

Mi: Mario sells burger at point i ∈ N

Li: Luigi sells burger at point i ∈ N

Mathematical model

Max earning

Max z = $\sum(Mi + Li) * P$ - $\sum \ \sum \sum Xij * (Umk + Ulk) * Ck$

s.t

#########one Vehicle constraint###################

$\sum Umk = 1\ from\ 1\ to\ 3$ Mario chose one vehicle

$\sum Ulk = 1\ from\ 1\ to\ 3$ Luigi chose one vehicle

#######mTSP constraint##############################

$\sum xij = 1\ from\ i = 1\ to\ N$ every node only get one in

$\sum xij = 1\ from\ j = 1\ to\ N$ every node only get one out

$\sum xi1 = 2\ from\ i\ to\ N$ 2 two get into the campus from entry

$\sum x1j = 2\ from\ j\ to\ N$ 2 two get out the campus from exit

Include subtour elimination constraints (Miller-Tucker-Zemlin)

ui−uj+pa·xij≤pa−1,∀2≤i≠j≤n

##########vehicle capacity constraint #################

$\sum Mi\ from\ i\ to\ N \leq \sum \mathrm{Pk} * \mathrm{Umk}\ \ \mathrm{k} = 1{,}2{,}3$ the burger Mario sells smaller equal to the capacity of the vehicle he choose

$\sum Li\ from\ i\ to\ N \leq \sum \mathrm{Pk} * \mathrm{Ulk}\ \ \mathrm{k} = 1{,}2{,}3$ the burger Luigi sells smaller equal to the capacity of the vehicle he choose

################ node demand constraint############

Mi+Li<=Qi for every i the burger sells at the node i is smaller equal to the demand

################Time constraint####################

$\sum\ \sum\ \sum\left(\frac{xij*dij}{Vk*Umk}\right) \leq \sum\ (\mathrm{Tk} * \mathrm{Umk})$ Mario's time constraint

$\sum\ \sum\ \sum\left(\frac{xij*dij}{Vk*Umk}\right) \leq \sum\ (\mathrm{Tk} * \mathrm{Umk})$ Luigi's time constraint

##############Start End point constraint##############

Hamiltonian cycle with a dummy node

Future Work

Extensive work will be conducted by the researchers to ensure that the demand and travel time between each point will be closer to real-life values. Similarly, once the problem has been solved, the students will conduct an actual simulation of the delivery service to validate the results.

Should there be remaining time, the students would be interested to expand the problem and gradually increase its difficulty and complexity through the following:

- Introduction of more demand points
- Consideration of the effect of weight carried to the bicycle velocity (i.e., the greater the weight carried, the slower the bicycle will be)
- Consideration of other modes of transport including, but not limited, to horses. Horses may lead the brothers to being caught faster (i.e., riding horses will definitely catch a lot of attention), but at the same time will attract greater demand from the students (students love horses) which opens the possibility to increase prices.

References

https://cs.adelaide.edu.au/~optlog/research/ttp/2015gecco-ttp.pdf

https://cs.adelaide.edu.au/~zbyszek/Papers/TTP.pdf

Multiple Traveling Salesman Problem (mTSP) | NEOS (neos-guide.org)