

**IE 400 Term Project**

**Principles of Engineering Management**

**Cargo Truck Delivery**

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## Introduction

This project aims to define a route for a truck on an island which will deliver its cargo. There are 30 locations on the island including the one that truck starts at. There are roads between each location. Roads can be made of three materials: asphalt, gravel and concrete. Each material allows the truck to move in certain speed. Also, there are storms on the island which are in circular shape. Storms may obstruct the roads and make them unavailable for the truck. Truck needs to travel each location exactly once and return back to the starting location. Route optimization is an example of the Travelling Salesman Problem (TSP). Considering that, this problem is modelled as a TSP.

## Sets

locations = {1,2,...,30}, This represents the set of locations in the problem.

## Parameters

$d_{ij}$ : distance between location i and j  $\forall j \text{ in } (1...30), \forall i \text{ in } (1...30)$

$s_{ij}$ : speed of the truck on the road between i and j (in unit/hour)  $\in \{35, 65, 100\}$   
 $\forall j \text{ in } (1...30), \forall i \text{ in } (1...30)$

$a_{ij} : \begin{cases} 1, & \text{if the road between i and j is available} \\ 0, & \text{otherwise} \end{cases}$   $\forall j \text{ in } (1...30), \forall i \text{ in } (1...30)$

- $d_{ij}$  is calculated by using the Cartesian coordinates of locations. It has no unit.
- $s_{ij}$  is calculated by the given road material. According to data, it can be 35 units/hour for gravel, 65 units/hour for concrete and 100 units/hour for asphalt.
- $a_{ij}$  is determined by considering the storms on the island. If a road includes a point that is in the range of a storm, it becomes unavailable.

## Decision Variables

$X_{ij} : \begin{cases} 1, & \text{if truck moves directly from location i to j} \\ 0, & \text{otherwise} \end{cases}$   $\forall j \text{ in } (1...30), \forall i \text{ in } (1...30)$

$O_i$ : Visiting order of location i  $\forall i \text{ in } (1...30)$

travel\_time : Total time spent during the delivery (in hours)

## Model

*minimize (travel\_time)*

*subject to*

$$X_{ij} \leq a_{ij} \quad \forall i \text{ in } (1...30) \quad \forall j \text{ in } (1...30) \quad (1)$$

$$\sum_{i=1}^{30} X_{ij} = 1 \quad \forall j \text{ in } (1...30) \quad (2)$$

$$\sum_{j=1}^{30} X_{ij} = 1 \quad \forall i \text{ in } (1...30) \quad (3)$$

$$X_{ii} = 0 \quad \forall i \text{ in } (1...30) \quad (4)$$

$$O_i - O_j + 1 \leq (1 - X_{ij}) * 30 \quad \forall i \text{ in } (1...30) \quad \forall j \text{ in } (1...30) \quad (5)$$

$$O_1 = 1 \quad (6)$$

$$travel\_time = \sum_{i=1}^{30} \sum_{j=1}^{30} X_{ij} (d_{ij} / s_{ij}) \quad \forall i \text{ in } (1...30) \quad \forall j \text{ in } (1...30) \quad (7)$$

$$X_{ij} \in \{0, 1\} \quad \forall i \text{ in } (1...30) \quad \forall j \text{ in } (1...30) \quad (8)$$

$$O_i \text{ is integer} \quad (9)$$

## Explanation of Constraints

- (1) A road can be chosen only if it is not obstructed by a storm.
- (2) Truck leaves each location exactly once.
- (3) Truck comes to each location exactly once.
- (4) Truck's next destination cannot be its current location.

- (5) & (6) These constraints are the MTZ constraints that are introduced to eliminate subtours that may be formed during the truck's tour.
- (7) Total travel time is the sum of durations on roads travelled by the truck. A duration is found by dividing the distance between starting and ending locations to the speed that the truck can achieve on that road.
- (8) Ensures that  $X_{ij}$  is binary
- (9) Ensures that  $O_i$  is integer

### Solution

We got our solution using FICO Xpress Workbench version 3.3

The route for the cargo truck is as follows:

1 → 7 → 14 → 17 → 25 → 26 → 21 → 30 → 15 → 27 → 12 → 19 → 8 → 29 → 9 → 10  
→ 20 → 11 → 16 → 24 → 18 → 28 → 6 → 4 → 3 → 5 → 22 → 2 → 13 → 23 → 1

Minimum possible time to travel all 30 locations on the island is 19.89922695 ≈ 19.9 hours

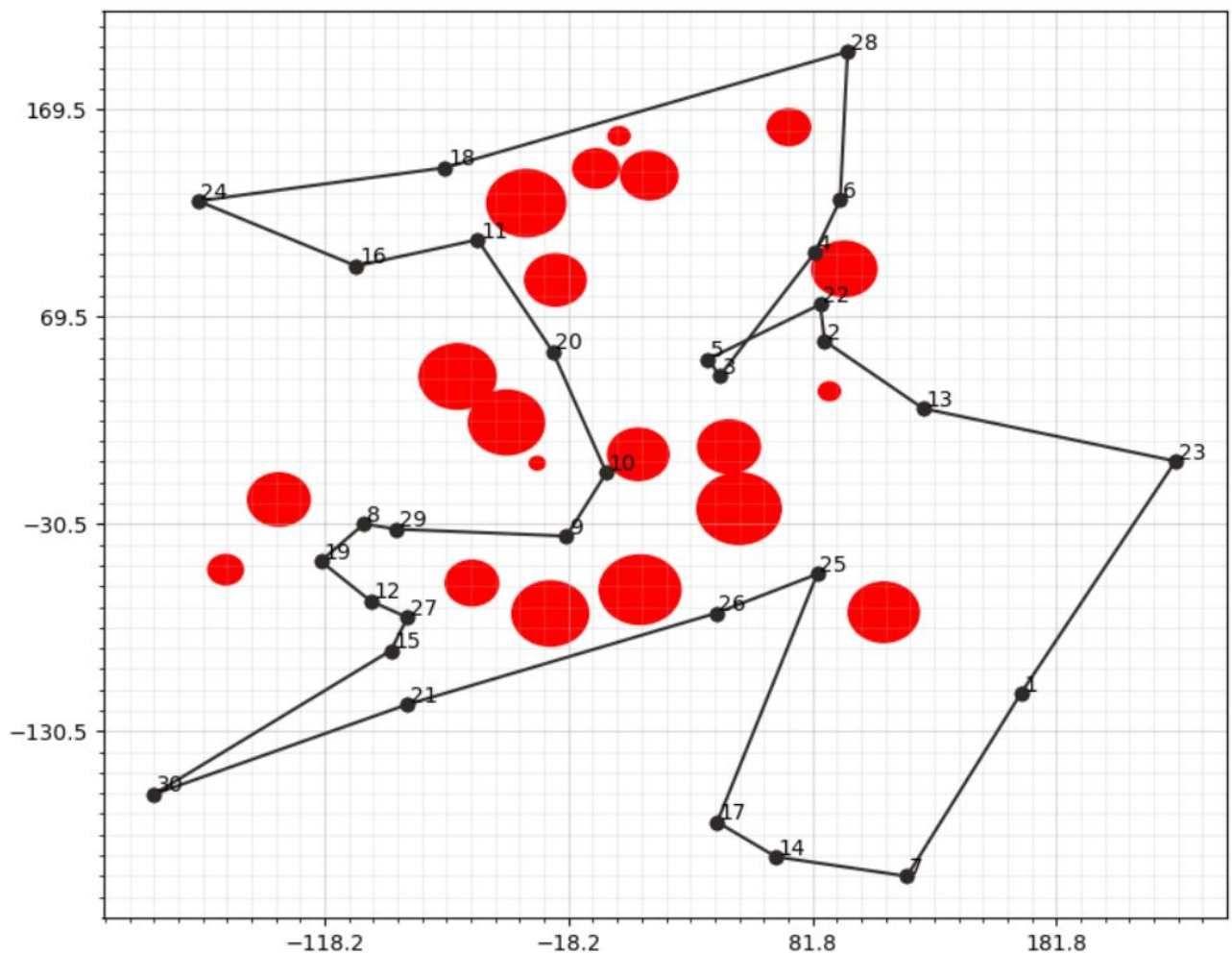


Figure 1 : Screenshot of the simulated path. Red circles represent storms. Black dots represent locations.