Decision support with respect to facility location and fleet composition for FoodBank Cape Town

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Outline

What is Food Banking?

- Started by John van Hengel in late 1960s in Phoenix, Arizona, USA.
  Good food going to waste due to defect packaging or near expiration date.
- Distributed food to local agencies
  Agencies – NGOs that run feeding programmes
- Idea spread to others cities, other countries.

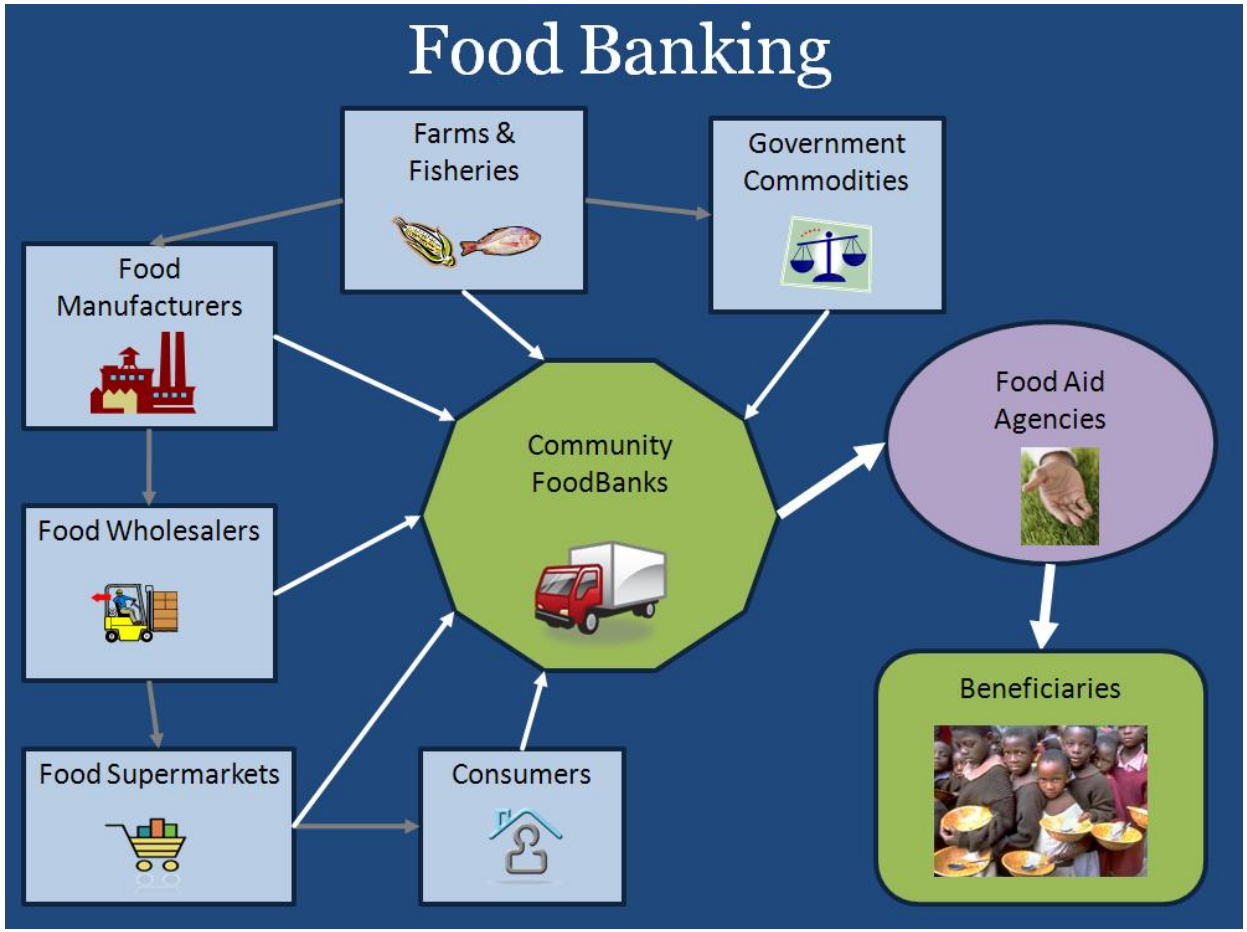


Figure: Sourcing & distributing flow diagram

Global Foodbanking Network

- Established in 2006
- Currently 41 countries

Mission

To work together to alleviate world hunger by developing national networks of foodbanks and strengthening foodbanking around the world

South African Context

Food Security

Access by all households at all times to adequate, safe and nutritious food for a healthy and productive lifestyle.

Approximately 40% of South Africa's population is vulnerable to food insecurity [2].

FoodBank South Africa

- Established in 2008
- Amalgamation of foodbanking organisations
- Currently located in Cape Town, Johannesburg, Durban and Port Elizabeth

Goal

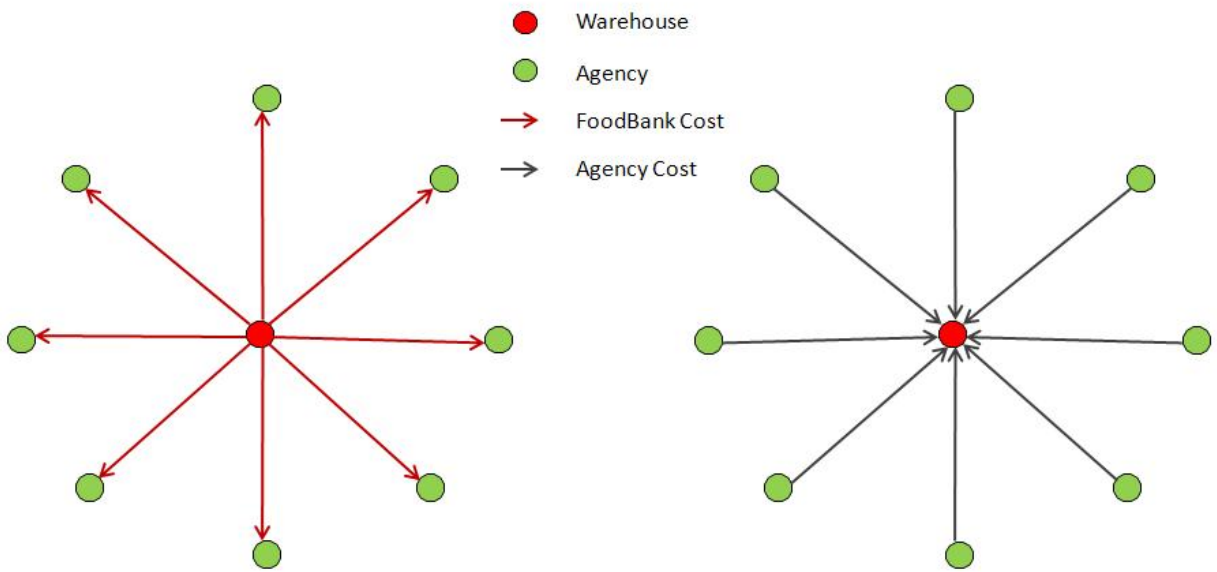
To establish nationwide network of community foodbanks in urban and rural areas, all working towards eliminating hunger and food insecurity

FoodBank Cape Town

- First in South Africa
- Launched on 2 March 2009
- Warehouse located in Philippi East [1]
- Majority of food sourced from DCs and retail sector
- Distributing to approximately 200 agencies on record

FBCT Project Focus

- Improving the efficiency of FBCT's logistical setup
- Focusing on the distribution of food to agencies
- Facility location model to find good locations for local distribution depots



- Vehicle fleet composition to distribute to depots

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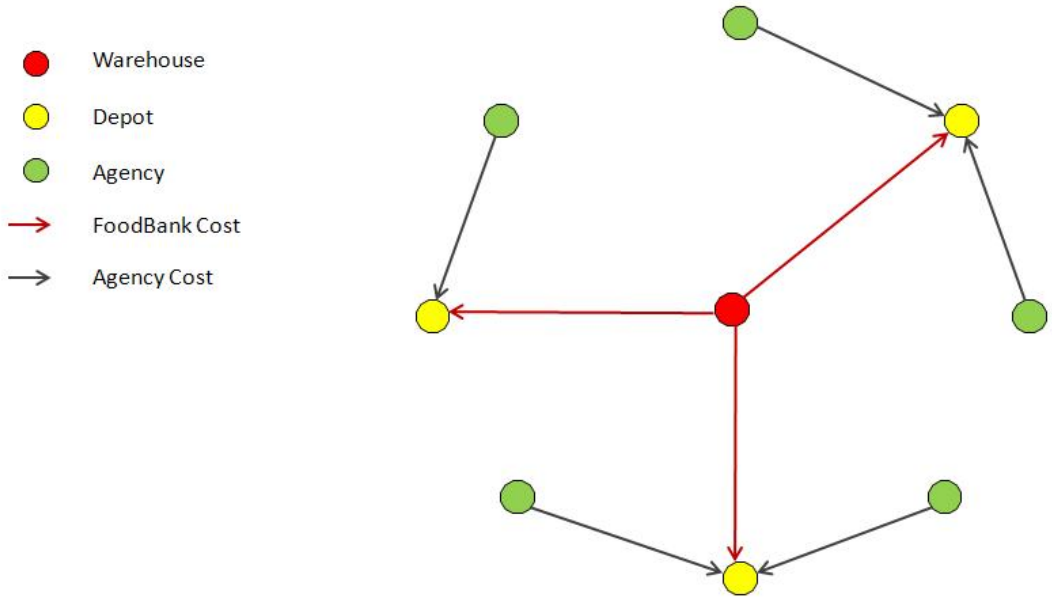

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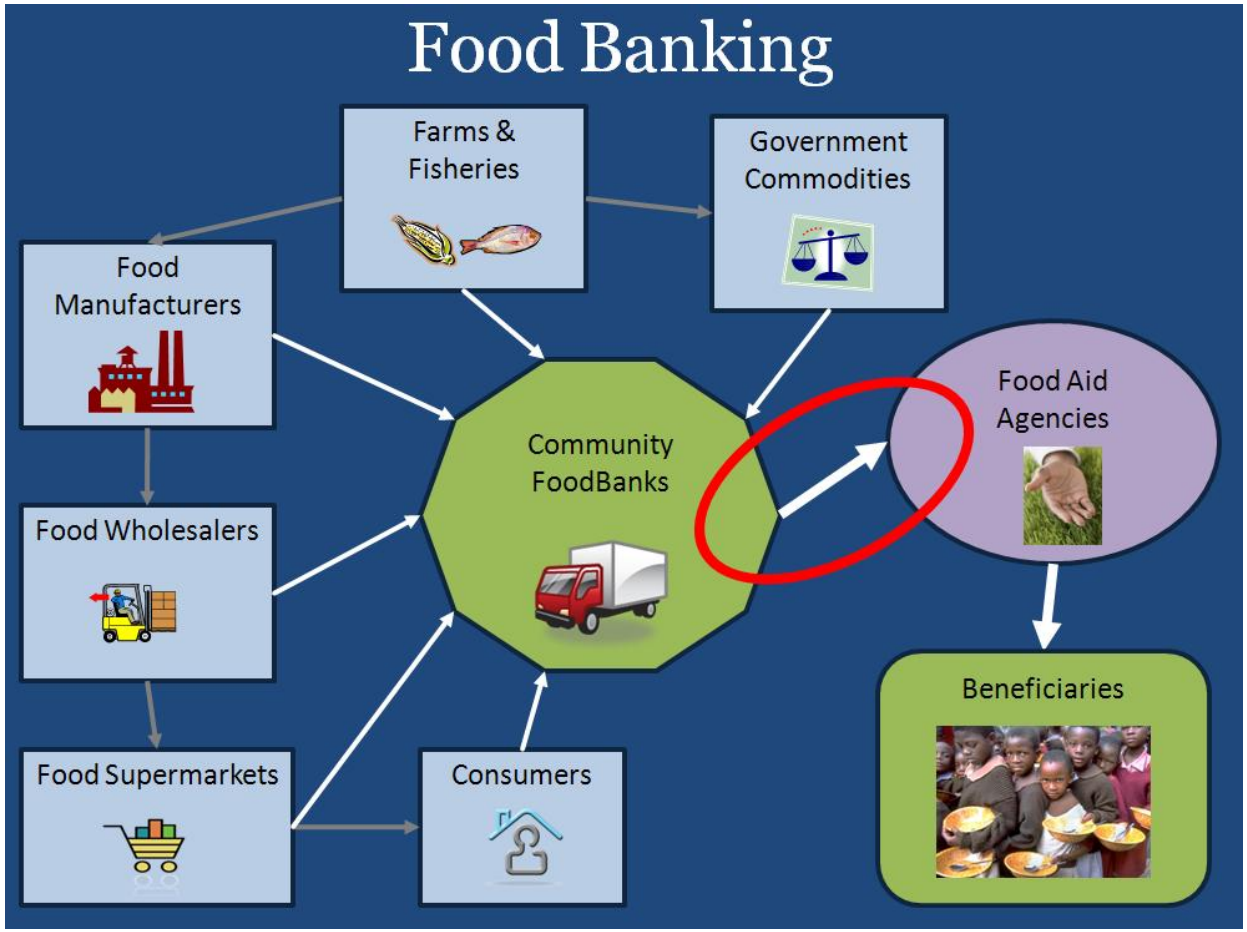

Figure: Sourcing & distributing flow diagram

Demand & Candidate Sites

Data

- GIS shape files
  - City of Cape Town population data for 40ha areas
  - National land cover
  - City of Cape Town road network – used to obtain travel distances
- Two agency databases – used to obtain geographical coordinates

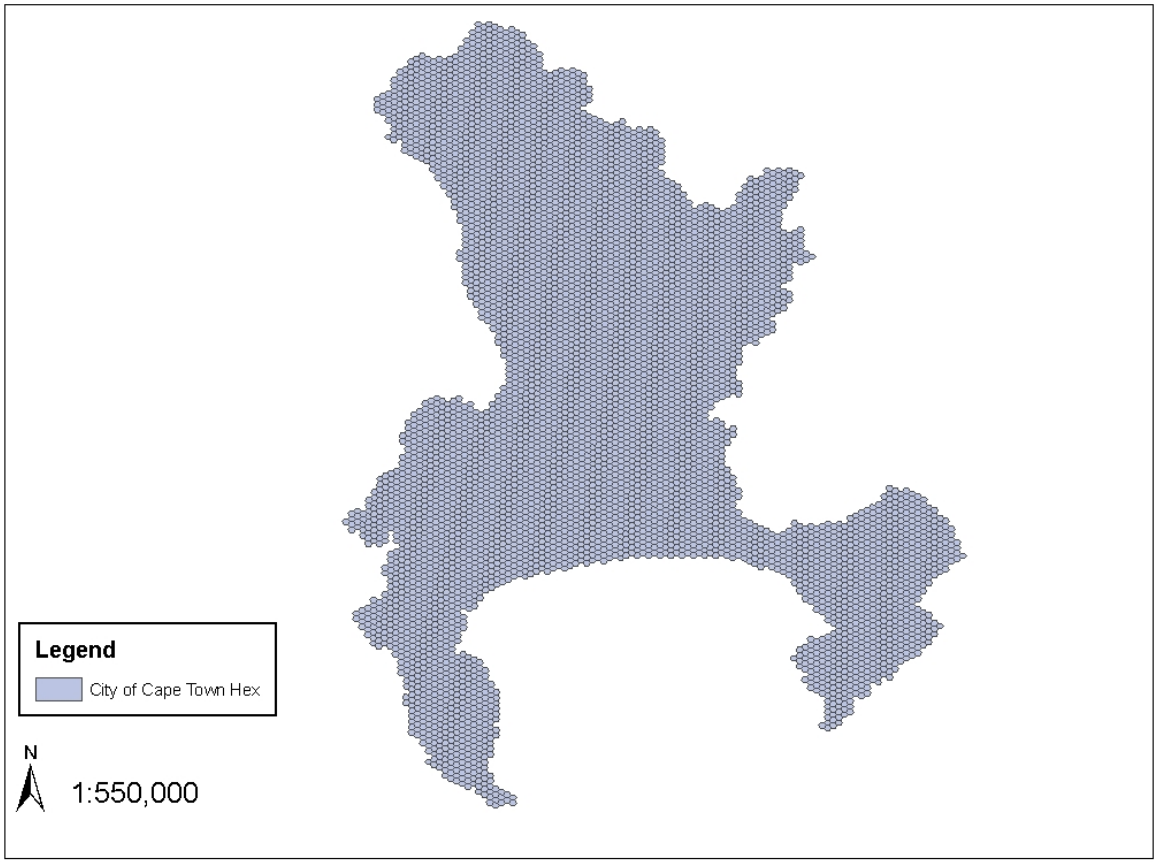

Figure: 6560 City of Cape Town 40ha hexagons

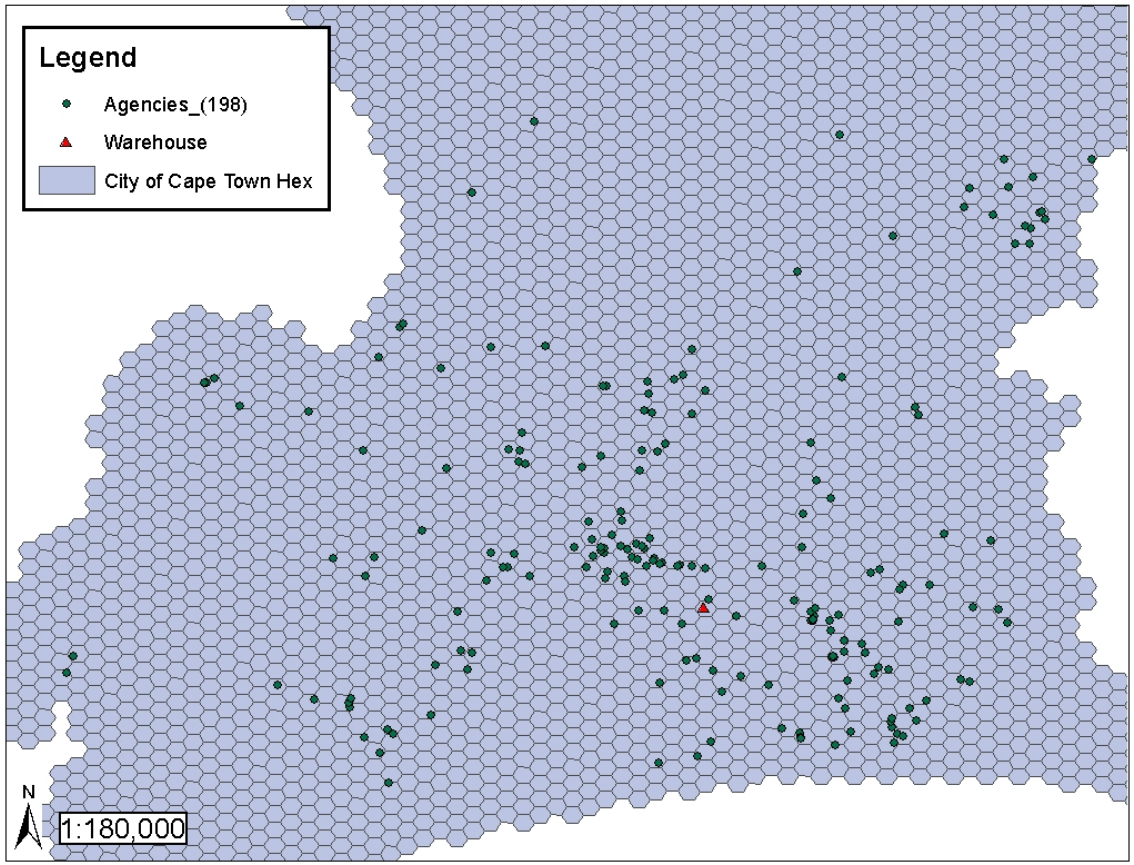

Figure: ArcMap: Location 198 agencies being serviced

Figure: Flowmap: Road network used to calculate distances from hexagon centroids

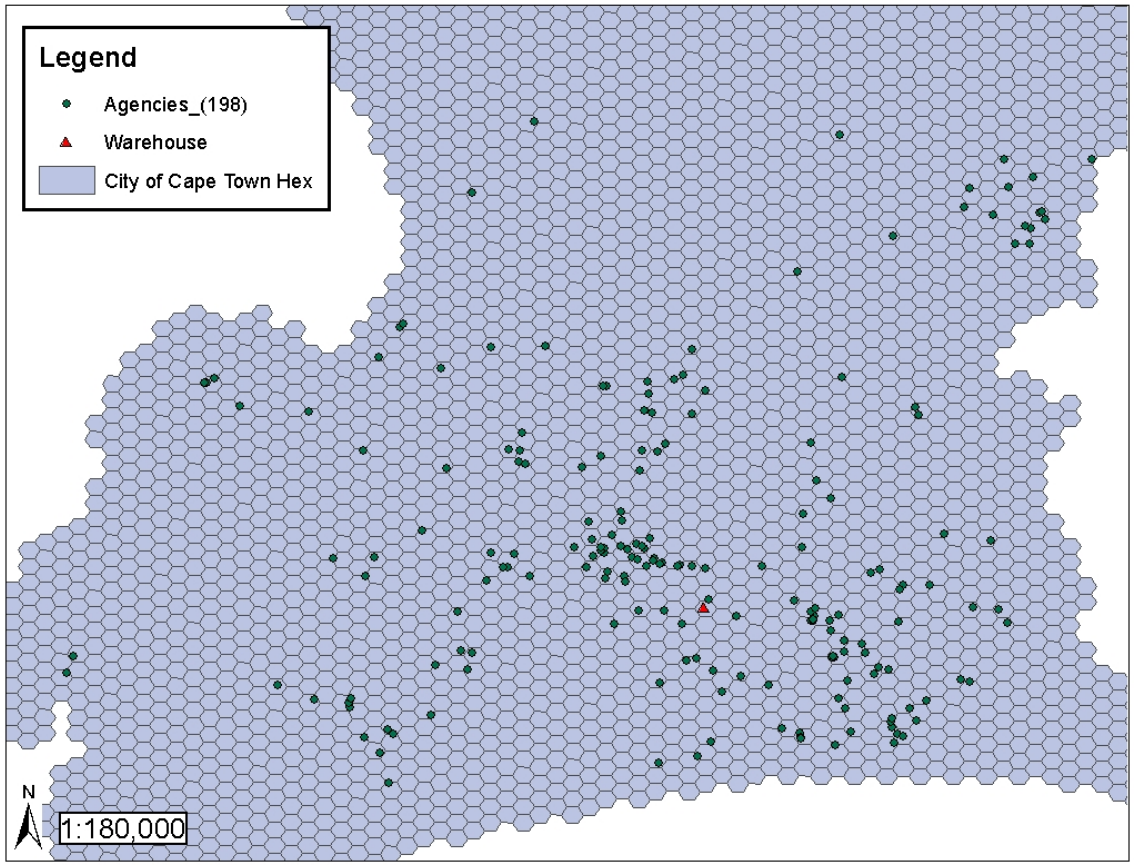

Figure: ArcMap:Location 198 agencies

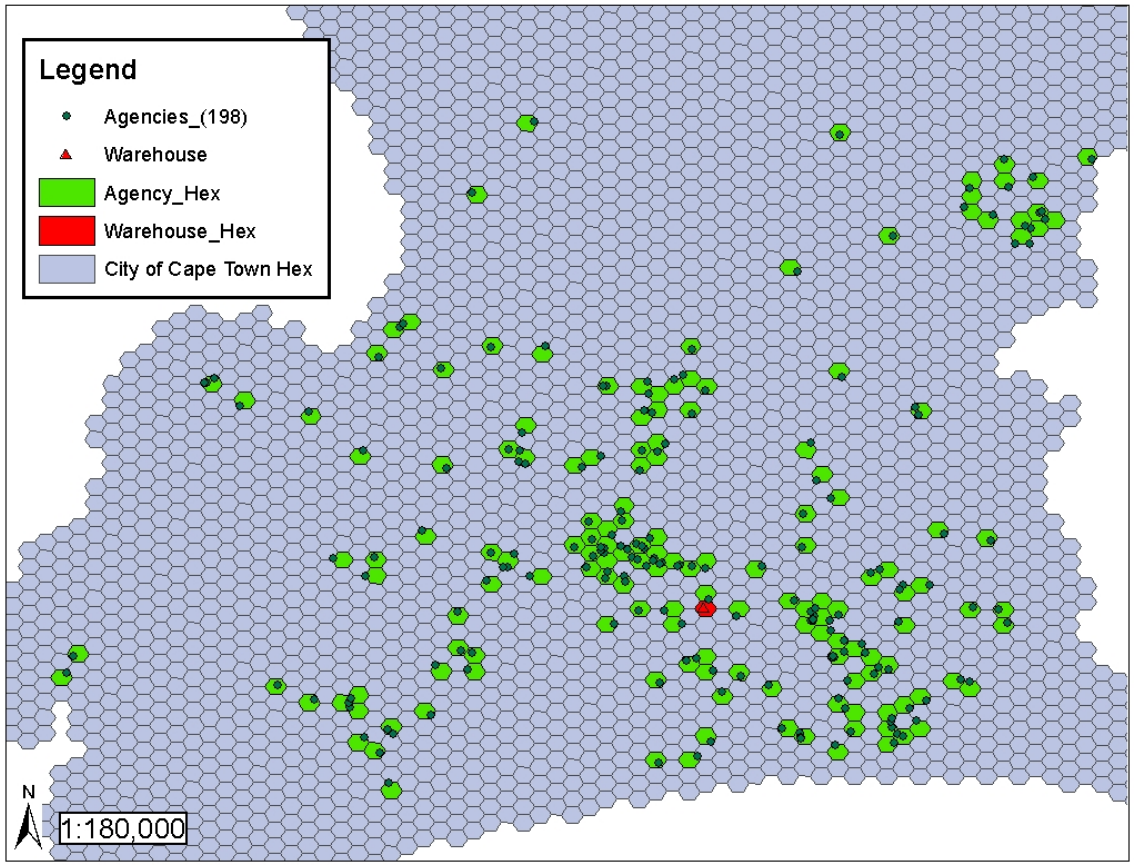

Figure: ArcMap: Agency demand allocated to hexagons

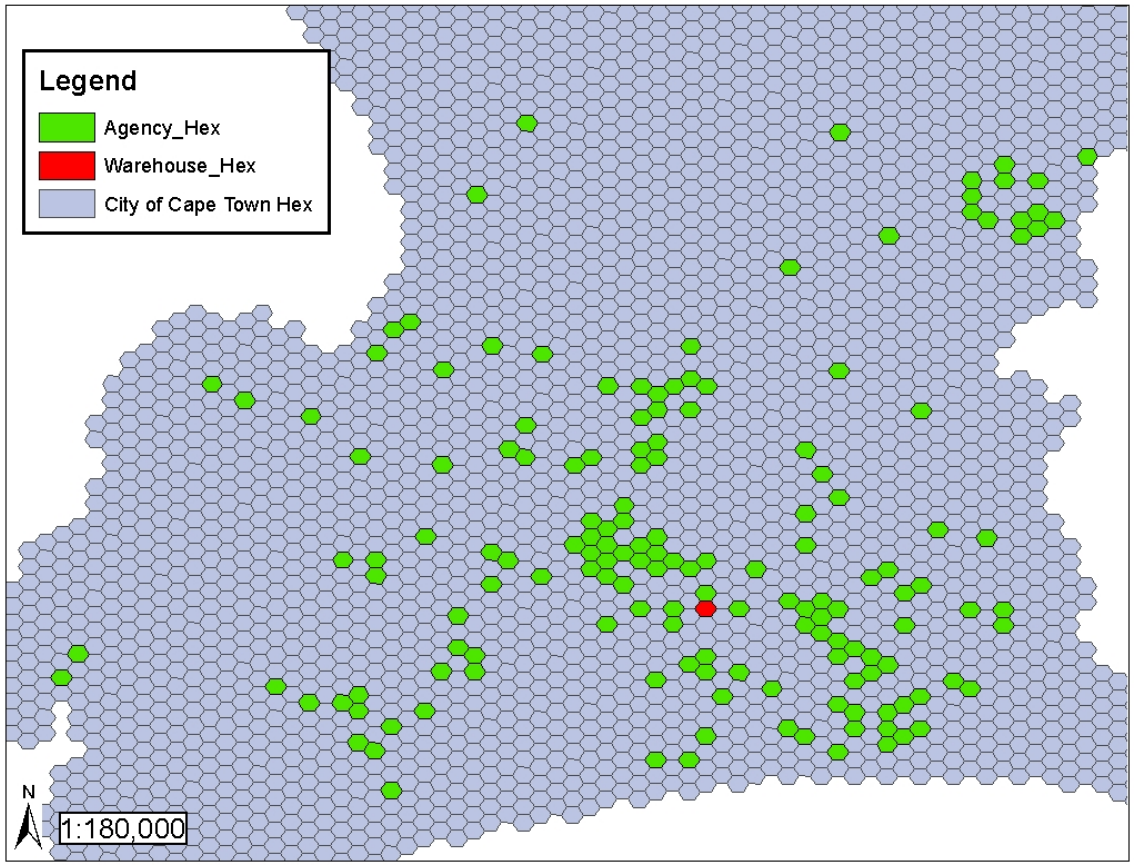

Figure: ArcMap: 157 Demand hexagons

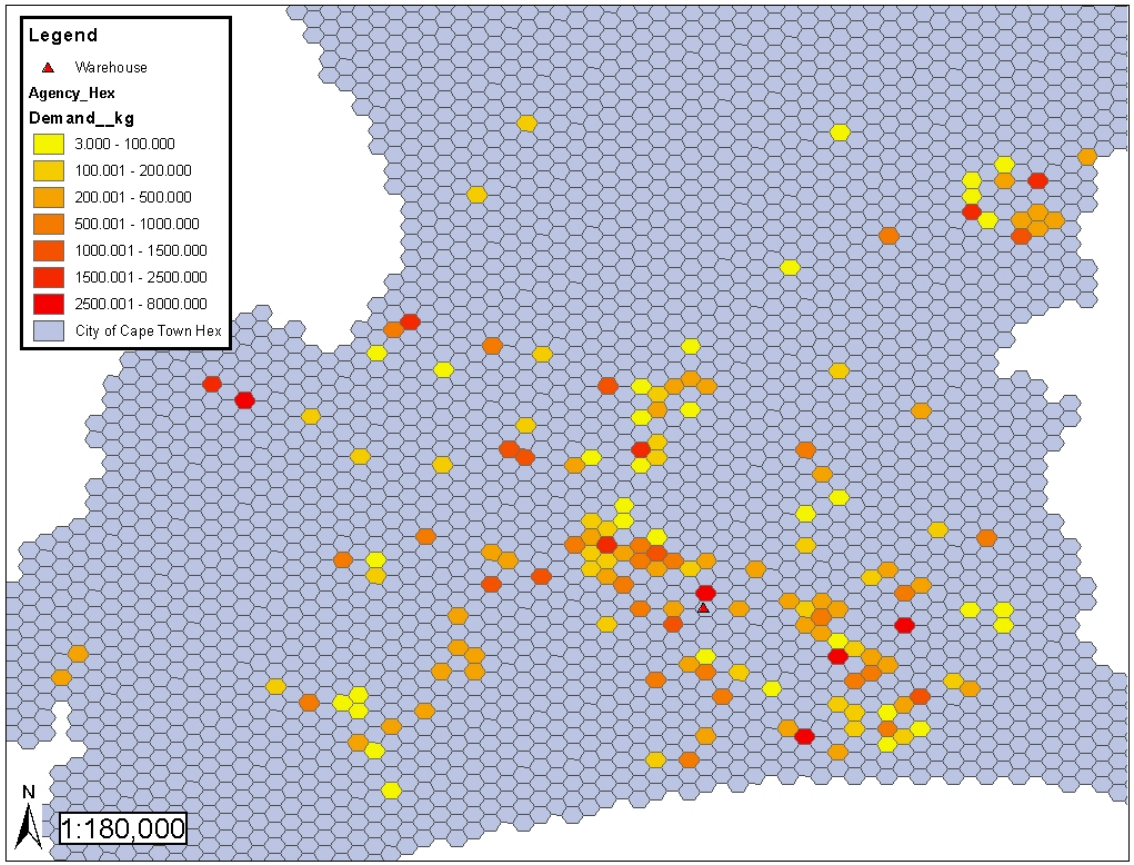

Figure: ArcMap: Demand hexagons demand (kg)

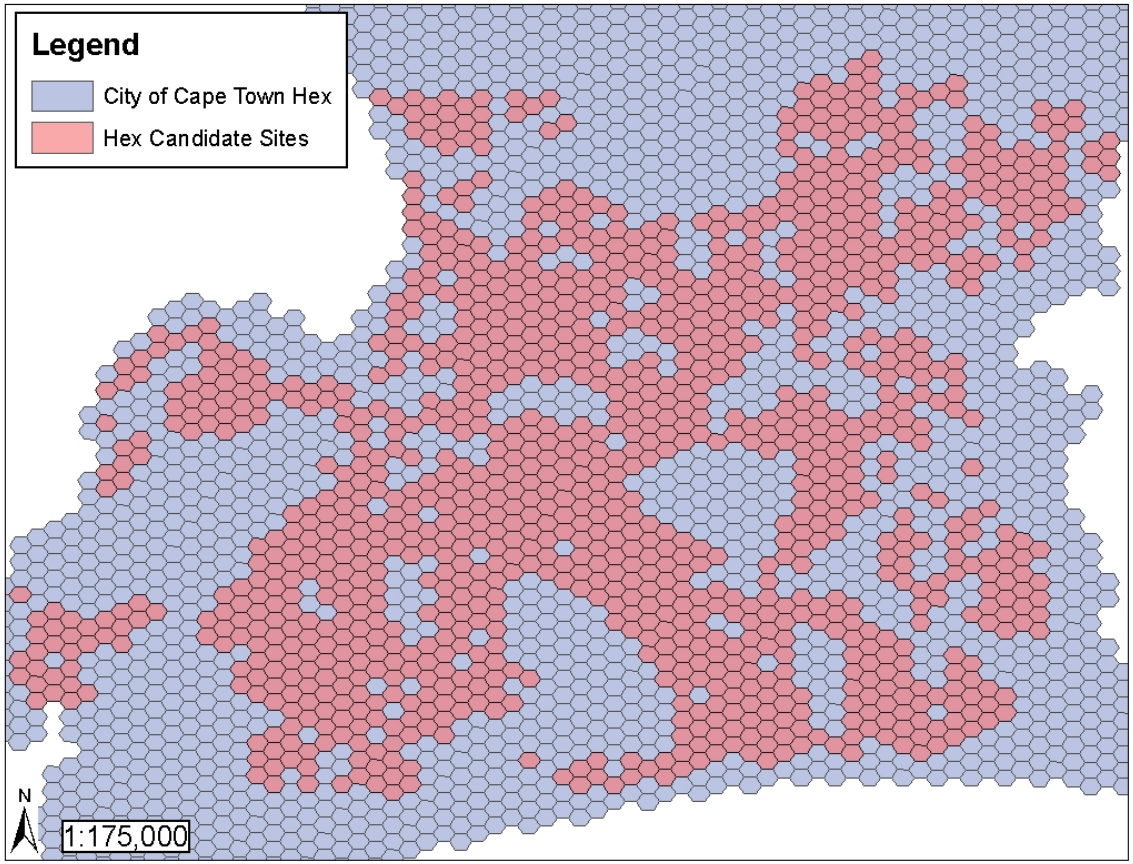

Figure: ArcMap: 1169 Candidate Sites

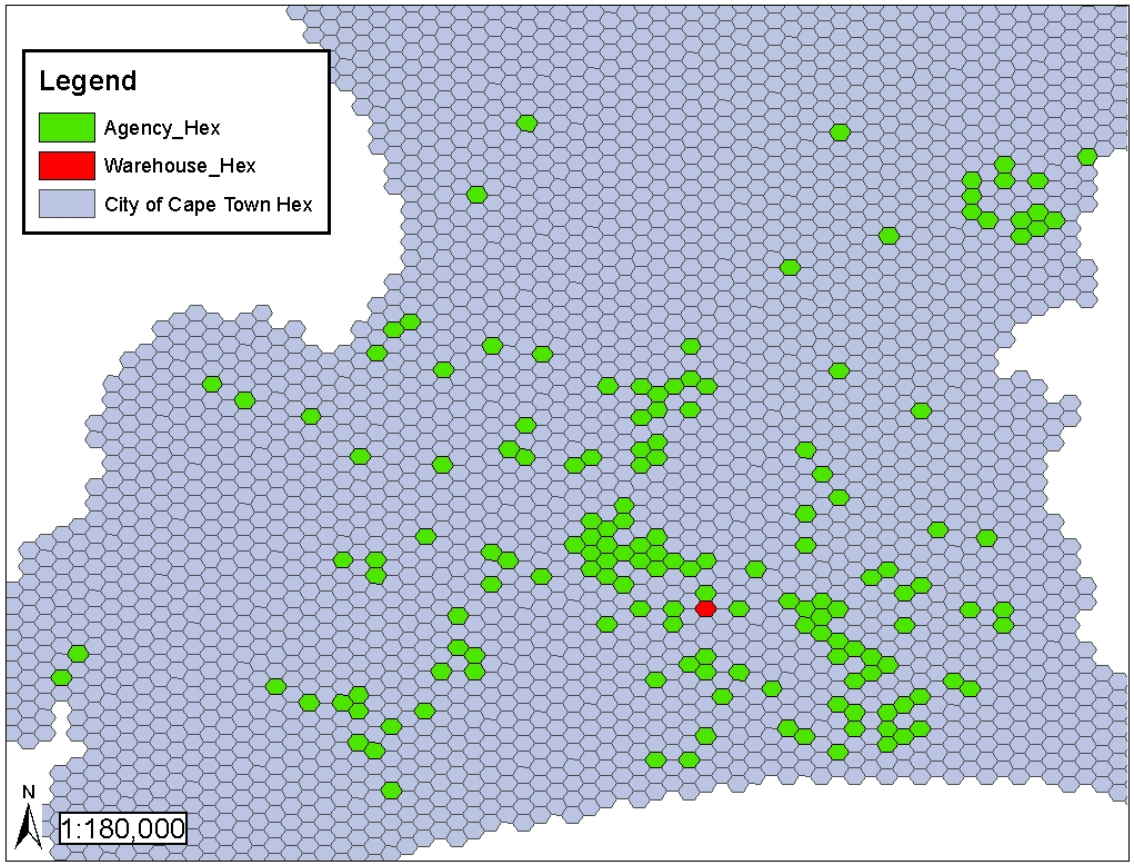

Figure: ArcMap: 157 Candidate Sites

Facility Location

- Set of demand points $I \in \{u_1, ..., u_n\}$
- Set of candidate facility sites $J \in \{x_1, ..., x_m\}$
- Demand point demand h_i
- Facility fixed charge f_j
- Facility capacity C_j
- Distance (d_{ij}) or cost (c_{ij})

Literature Review: K-Centre

$$\text{Minimise } g = \max_{i \in I; j \in J} \{h_i d_{ij} y_{ij}\} \tag{1}$$

subject to

$$\sum_{j \in J} x_j = K, \qquad j = 1, \ldots, m \tag{2}$$

$$\sum_{j \in J} y_{ij} = 1, \qquad i = 1, \ldots, n \tag{3}$$

$$y_{ij} \leq x_j, \qquad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{4}$$

$$x_j, y_{ij} \in \{1, 0\}, \qquad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{5}$$

Literature Review: K-Median

$$\text{Minimise } g = \sum_{i=1}^{n}\sum_{j=1}^{m} h_i y_{ij} d_{ij} \tag{6}$$

subject to

$$\sum_{j\in J} x_j = K, \qquad j = 1,\ldots,m \tag{7}$$

$$\sum_{j\in J} y_{ij} = 1, \qquad i = 1,\ldots,n \tag{8}$$

$$y_{ij} \leq x_j, \qquad i = 1,\ldots,n,\quad j = 1,\ldots,m \tag{9}$$

$$x_j, y_{ij} \in \{1,0\}, \qquad i = 1,\ldots,n,\quad j = 1,\ldots,m \tag{10}$$

Literature Review: Fixed Charge Location Model

$$\text{Minimise } g = \sum_{j=1}^{m} f_j x_j + c \sum_{i=1}^{n} \sum_{j=1}^{m} h_i y_{ij} d_{ij} \tag{11}$$

subject to

$$\sum_{j \in J} x_j = K, \qquad j = 1, \ldots, m \tag{12}$$

$$\sum_{j \in J} y_{ij} = 1, \qquad i = 1, \ldots, n \tag{13}$$

$$y_{ij} \leq x_j, \qquad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{14}$$

$$x_j, y_{ij} \in \{1, 0\}, \qquad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{15}$$

$$\sum_{i \in I} h_i y_{ij} \leq C_j x_j, \qquad j = 1, \ldots, m \tag{16}$$

Formulation of Facility Location Model

- Adapted from K-Median & Fixed Charge Location Model
- Fixed charge is the cost or distance from warehouse to local depot
- Formulated as mixed integer linear programming problem

Facility Location Model

$$\text{Minimise } g = \sum_{j=1}^{m} f_j x_j + \sum_{i=1}^{n}\sum_{j=1}^{m} y_{ij} d_{ij} \tag{17}$$

subject to

$$\sum_{j \in J} x_j = K, \qquad j = 1, \ldots, m \tag{18}$$

$$\sum_{j \in J} y_{ij} = 1, \qquad i = 1, \ldots, n \tag{19}$$

$$y_{ij} \leq x_j, \qquad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{20}$$

$$x_j, y_{ij} \in \{1, 0\}, \qquad i = 1, \ldots, n, \quad j = 1, \ldots, m \tag{21}$$

$$\sum_{i \in I} h_i y_{ij} \leq C_j x_j, \qquad j = 1, \ldots, m \tag{22}$$

Facility Location Model

- Solved using LINGO 11.0 or Adaptive Tabu Search (ATS).
- Tightness factor (τ) determines how highly constrained the problem is.

  $\tau = \sum_{i \in I} h_i/(K.C)$

  - $\tau < 0.7$, LINGO - exact solution $<$ 1 hour
  - $\tau \geq 0.7$, LINGO - exact solution $>$ 1 hour
  - $0.82 \leq \tau \leq 0.96$, ATS - good solution in 2.5 minutes
- Adaptive tabu search used for $K = 18, 19, 20$
- LINGO used for $K \geq 25$

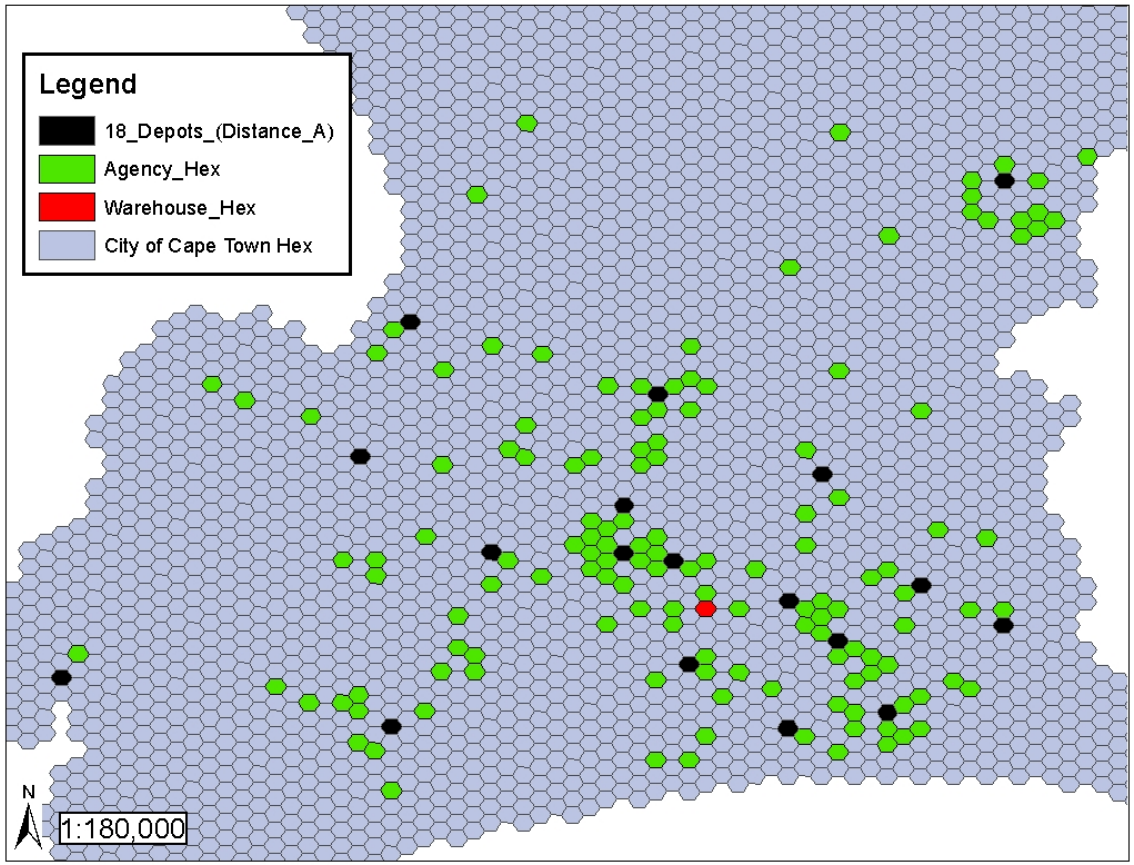

Figure: ArcMap: 18 Depots - Agency distance

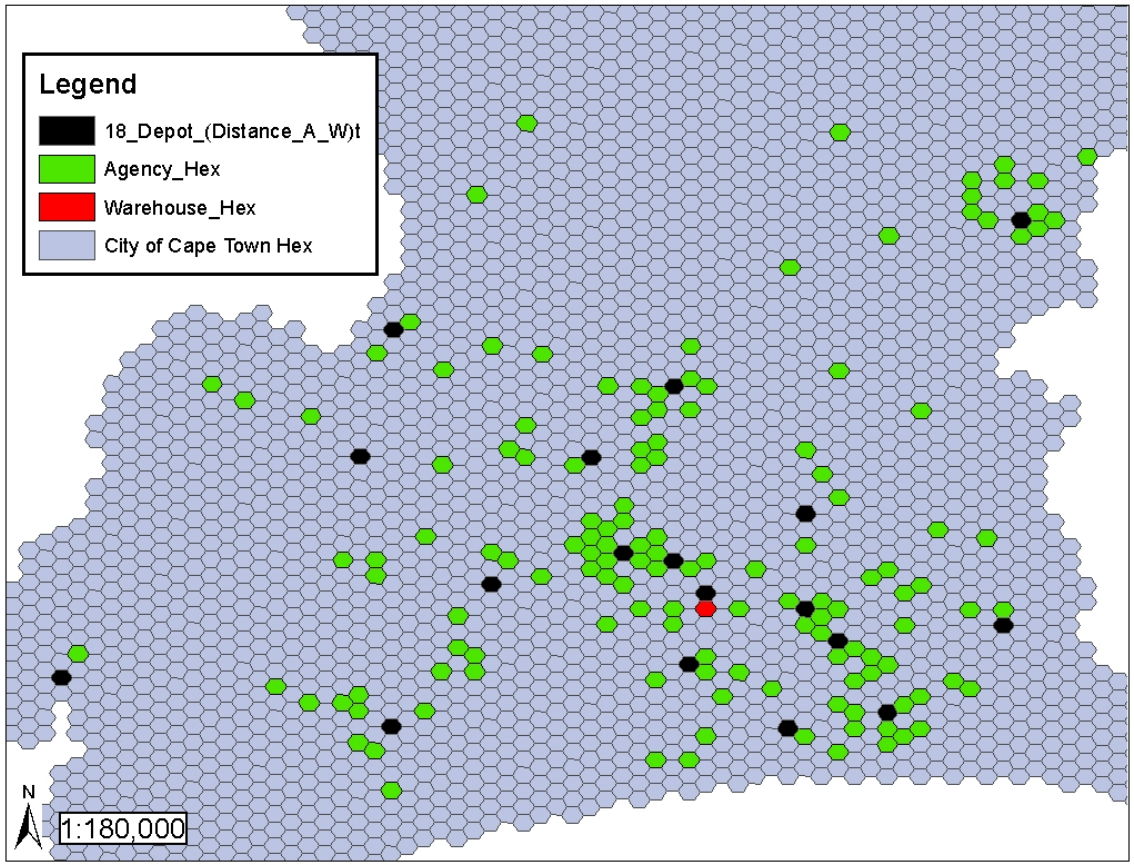

Figure: ArcMap: 18 Depots - Agency & Warehouse distance

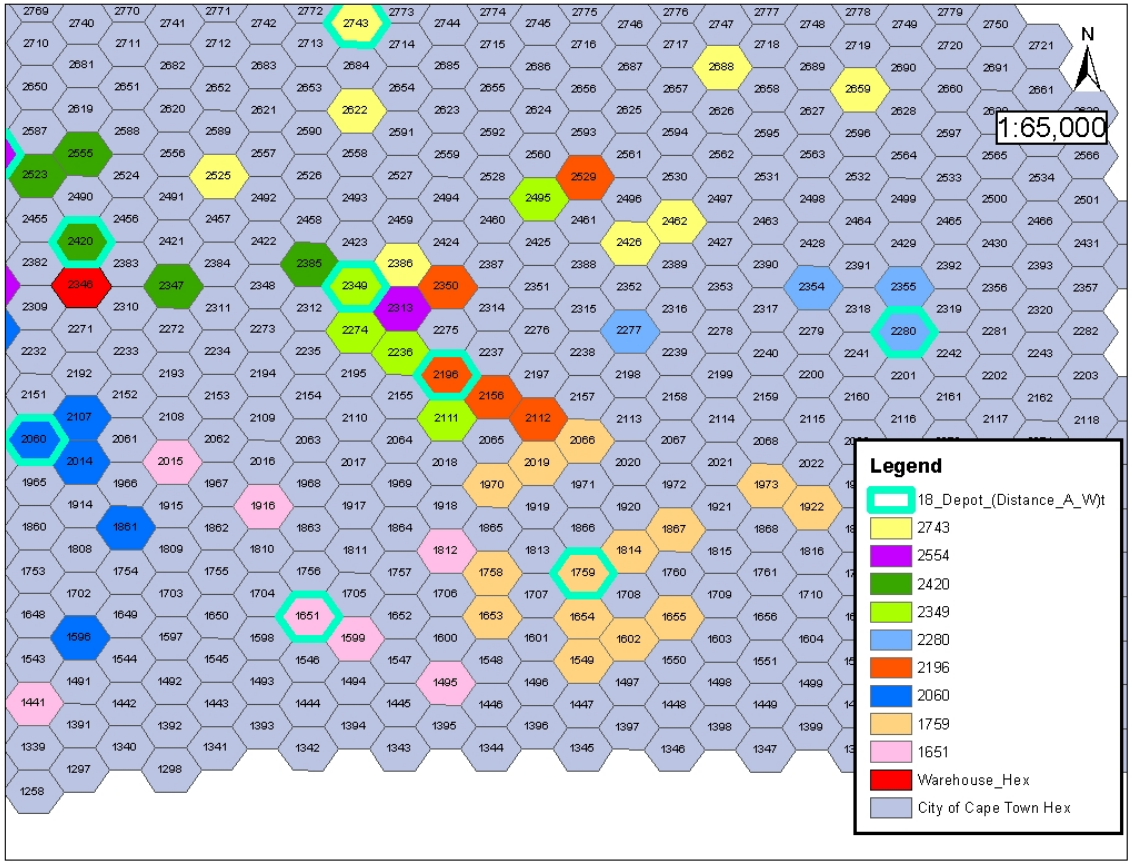

Figure: ArcMap: Assignment of Agencies

Vehicle Fleet Composition

- Clarke-Wright Savings Algorithm used to create routes
- Create daily trips for available vehicles
  - 8 hour day
  - Travel time
  - Loading & Offloading time
- Distribution costs calculated
  - Fixed Cost per day
    - Finance Cost
    - Staff Cost
  - Variable Cost per kilometre
    - Fuel & Lubricants
    - Tyres
    - Maintenance

18 Depots (K-Median - Distance) Fleet Distribution Cost

Vehicle Fleet Composition	Agency Distance (km)	Agency Cost (R)	FB Distance (km)	FB Cost (R)	Total Cost (R)	FB % Total Cost
5 Ton x 2	995	10,382	416	14,367	24,749	58
5 Ton, 2.5 Ton	995	10,382	454	13,928	24,310	57
5 Ton, 1.5 Ton	995	10,382	507	11,285	21,667	52
2.5 Ton x 2	995	10,382	595	13,480	23,862	56
2.5 Ton, 1.5 Ton x 2	995	10,382	755	14,316	24,698	58
1.5 Ton x 3	995	10,382	774	11,358	21,740	52

18 Depots (Fixed Charge Location - Distance) Fleet Distribution Cost

Vehicle Fleet Composition	Agency Distance (km)	Agency Cost (R)	FB Distance (km)	FB Cost (R)	Total Cost (R)	FB % of Total Cost
5 Ton x 2	1001	10,446	398	14,303	24,750	58
5 Ton, 2.5 Ton	1001	10,446	428	13,860	24,306	57
5 Ton, 1.5 Ton	1001	10,446	462	11,205	21,651	52
2.5 Ton x 2	1001	10,446	568	13,412	23,858	56
2.5 Ton, 1.5 Ton	1001	10,446	717	10,923	21,369	51
1.5 Ton x 3	1001	10,446	737	11,292	21,739	52

Current & Future Work

- Calculate distribution costs when replacing distance between points with cost between points, then feedback into Facility Location Problem.
- Compare distribution costs for different values of K.
- Compare distribution costs when the Agency costs are weighted.

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