# Location Modeling in Logistics; A Decision Maker Defined Approach.

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By

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Abstract:
The location of factories and warehouses has always been considered an important part of many disciplines (geography, regional science, transport studies, operations management, industrial economics and, more recently, logistics. Logistics texts usually treat this as a transhipment problem or transportation problem where there are fixed locations of supplies and customers and it is desired to optimally locate a facility to minimise some combination of production and transport costs between the origins and destinations. More recently interest in location studies have been re-awakened with the attention of business executives on supply chains. This paper uses a more general heuristic framework of distance minimization combined with a doubly constrained gravity model. The model developed is spreadsheet based and allows the user to set customer service level requirements to determine optimal locations.

## Introduction

The location of factories and warehouses is an important part of logistics. Location studies in general owe their origins to work in geography and their further development in the economics related discipline of regional science and land economics. Fundamental logistics texts such as Bowersox (1974), Coyle, Bardi (1984), Ballou (1999) discuss how to locate facilities such as factories and warehouses. They begin with simple centre of gravity models to locate single facilities and then progress to more complex linear programming approaches for location, allocation and transshipment problems. More recently, with supply chain focus, managers are asking their logistics and technical staff to redesign their networks with applications such as CAPS, CAST or SAILS. These are a few of the many (and growing) commercial information systems that logistics managers use to design their supply chains.

Notwithstanding the usefulness and industrial strength of these systems, invariably, they work with fixed supply and demand locations. These are usually given and known and the problem becomes one of locating intermediate facilities or allocation of production to a network to minimise some generalised costs. In this paper we use a centre of gravity heuristic and a doubly constrained gravity model to optimise warehouse locations using the largest one hundred Australia cities as an example.

## Problem Formulation

The simple gravity model is usually presented as a set of demand points located on a map with the problem of finding the least cost site for a warehouse or distribution centre. Figure 1 below illustrates the problem:

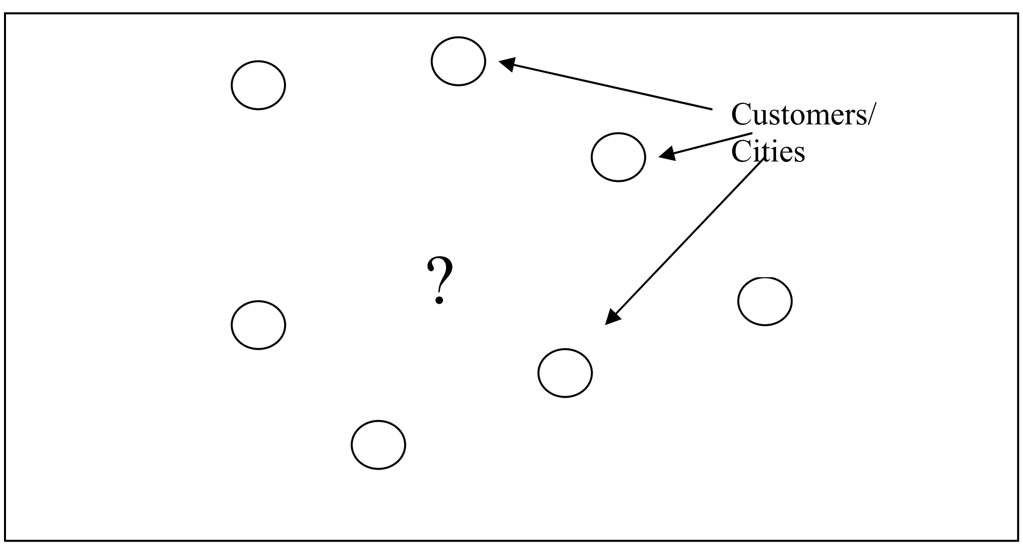


Figure 1: Location of customers / markets (O) and warehouse (?)

In this paper we are interested in exploring optimal warehouse locations using Australian city data as an illustration. For example, where are the best locations for warehouses serving the Australian market? What happens when managers add constraints such as delivery times in less than 5 hours or within one day?

Chicago Consulting (2003) has identified Bloomington, Indiana as the best single location for a warehouse in the USA that minimizes total transport time to population. In their work they have modeled locations between one and ten warehouses with each extra warehouse reducing the transit time to customers. There are trade-offs involved as shown in figure 2 based on Chicago Consulting results. This paper asks the same question for Australia.


Figure 2: Optimal Warehouse Locations USA. Source: Chicago Consulting (2003)

In figure 2 the trade-off between number of warehouses and time to customer is quite clear. The marginal gain in access beyond 3 warehouses is quite clear in the case of the USA. Logistics managers need to make trade-offs in order to optimize their supply chains in the current highly competitive market situation.

# Methodology

For this paper we have used the 100 largest Australian cities. Their locations are given in figure 3 below.

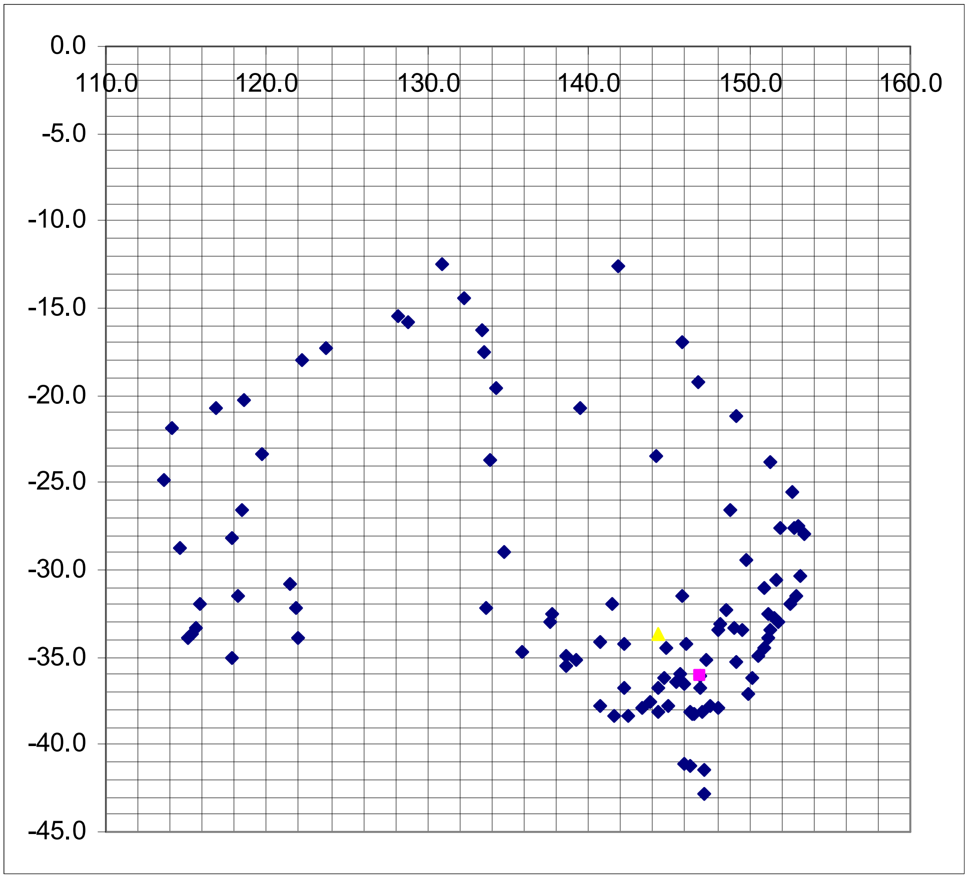


Figure 3: Location of 100 largest cities in Australia.

The 100 largest cities in Australia represent nearly 80% (15.9 million people) of the Australian population of 20 million. The city population figures were obtained from searching the internet (using Google) filtered for Australia and using each city's web site or description. The latitude and longitude were obtained from an atlas.

Distances were calculated using the standard Euclidean metric and so do not represent actual airline distances (curvature of earth and scaling factors not taken into account).

Location modeling began using the standard weighted centre of gravity method. From this another location was added on a systematic but effectively "trial and error" basis in order to work out the best location for two warehouses serving the Australian population.

The constraint of within 5 hours was used. This approach is easily performed on a spreadsheet.

Next, a doubly constrained gravity model Wilson, 1974) was used to simulate the pattern of freight between the capital cities and all of the other cities. This model is:

$$Tij = AiBjOiDj\ f(Cij)$$

$$Ai = 1/ \sum Bj\ Dj\ f(Cij) \quad \text{[summed over j's]}$$

$$Bj = 1/ \sum Ai\ Oi\ f(Cij) \quad \text{[ summed over i's]}$$

$$F(Cij) = e^{\alpha\,(dij)} \quad , \alpha < 0$$

One of the benefits of using a doubly constrained gravity model is that as $\alpha$ becomes smaller and smaller the Tij solution approximates a linear programming solution. Hence the model provides the optimal set of movements of freight from capital cities to all other cities in Australia. Since much of the road freight is generated in cities in Australia this provides a useful result in helping identify optimal shipping patterns.

## Results

A weighted centre of gravity model indicates that a location near Hay New South Wales (latitude 33.63 South and 144.803 East) will be optimal for a single warehouse. Figure 4 below shows the percentage of population that can be accessed within a defined number of hours by road.

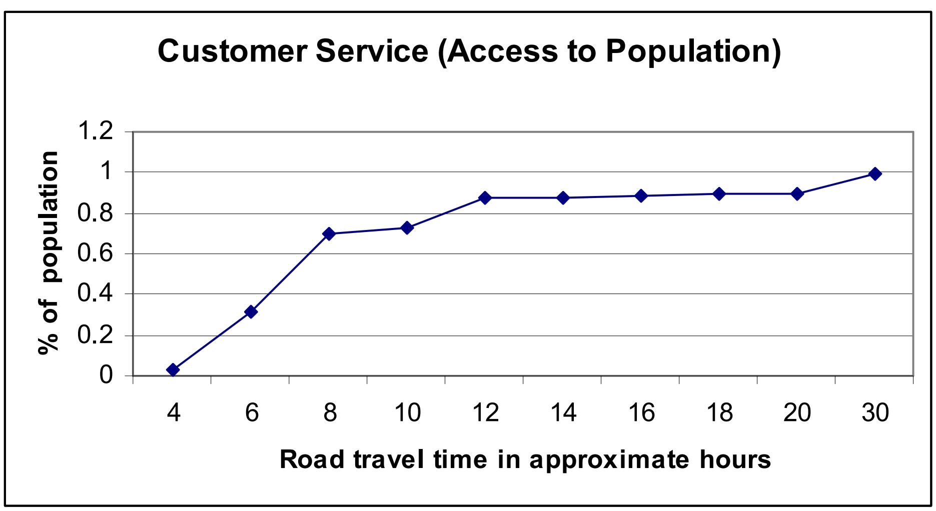


Figure 4: Single site warehouse Australia

The figure shows that within approximately one day's drive, about 70% of the Australian population may be accessed. Within half a day, about 30% is possible.

In order to test two sites a set of cities were selected (Table 1) and the population and distance accessed from each of the 10 sites to every other city (100) were calculated. The results of the single warehouse location were used to inform the location of one of the warehouses and a set of cities about that location, plus Brisbane, Sydney, Adelaide and Perth were also included.

Table 1 shows the percentage of the population that is within 5 hours drive for each warehouse location. For example 40% of the Australian population is accessed if warehouses were located at Perth and Hay, New South Wales. Table 2 shows a similar table using "distance" travelled without taking population into account. Effectively table 2 is a proxy for travel distance.

Table 1: Percent of Population accessed with 2 warehouses < 5hours road travel

| | Hay | Sydney | Parkes | Orange | Griffith | Dubbo | Albury | Melbourne | Shepparton | Brisbane |
|---|---|---|---|---|---|---|---|---|---|---|
| Perth | 0.4 | 0.36 | 0.36 | 0.36 | 0.32 | 0.36 | 0.58 | 0.3 | 0.3 | 0.26 |
| Adelaide | 0.38 | 0.44 | 0.44 | 0.44 | 0.39 | 0.44 | 0.66 | 0.38 | 0.38 | 0.23 |
| Hay | 0.3 | 0.62 | 0.62 | 0.62 | 0.32 | 0.62 | 0.58 | 0.31 | 0.31 | 0.46 |
| Sydney | 0.62 | 0.36 | 0.36 | 0.36 | 0.62 | 0.36 | 0.62 | 0.63 | 0.63 | 0.51 |
| Parkes | 0.62 | 0.36 | 0.36 | 0.36 | 0.62 | 0.36 | 0.62 | 0.63 | 0.62 | 0.51 |
| Orange | 0.62 | 0.36 | 0.36 | 0.36 | 0.62 | 0.36 | 0.62 | 0.63 | 0.63 | 0.51 |
| Griffith | 0.32 | 0.62 | 0.62 | 0.62 | 0.31 | 0.62 | 0.58 | 0.33 | 0.32 | 0.47 |
| Dubbo | 0.62 | 0.36 | 0.37 | 0.36 | 0.62 | 0.36 | 0.62 | 0.63 | 0.63 | 0.51 |
| Albury | 0.58 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.58 | 0.59 | 0.58 | 0.73 |
| Melbourne | 0.31 | 0.63 | 0.63 | 0.63 | 0.33 | 0.63 | 0.59 | 0.3 | 0.31 | 0.46 |
| Shepparton | 0.31 | 0.63 | 0.62 | 0.63 | 0.32 | 0.63 | 0.58 | 0.31 | 0.3 | 0.46 |
| Brisbane | 0.46 | 0.51 | 0.51 | 0.51 | 0.47 | 0.63 | 0.73 | 0.46 | 0.46 | 0.16 |

Table 2: "Distances" to 100 cities

| | Hay | Sydney | Parkes | Orange | Griffith | Dubbo | Albury | Melbourne | Shepparton | Brisbane |
|---|---|---|---|---|---|---|---|---|---|---|
| Perth | 783 | 813 | 754 | 763 | 746 | 770 | 752 | 806 | 763 | 1059 |
| Adelaide | 1018 | 985 | 966 | 962 | 991 | 972 | 981 | 1042 | 1009 | 1048 |
| Hay | 1198 | 1093 | 1104 | 1094 | 1163 | 1092 | 1145 | 1152 | 1158 | 1084 |
| Sydney | 1093 | 1409 | 1229 | 1275 | 1129 | 1251 | 1166 | 1120 | 1110 | 1323 |
| Parkes | 1104 | 1229 | 1258 | 1243 | 1143 | 1239 | 1158 | 1107 | 1109 | 1195 |
| Orange | 1094 | 1275 | 1243 | 1292 | 1133 | 1252 | 1158 | 1106 | 1105 | 1228 |
| Griffith | 1163 | 1129 | 1143 | 1133 | 1207 | 1131 | 1172 | 1150 | 1159 | 1110 |
| Dubbo | 1092 | 1251 | 1239 | 1252 | 1131 | 1277 | 1142 | 1095 | 1095 | 1227 |
| Albury | 1145 | 1158 | 1158 | 1158 | 1142 | 1142 | 1255 | 1193 | 1192 | 1131 |
| Melbourne | 1152 | 1120 | 1107 | 1106 | 1150 | 1095 | 1193 | 1286 | 1219 | 1108 |
| Shepparton | 1158 | 1110 | 1109 | 1105 | 1159 | 1095 | 1192 | 1219 | 1234 | 1093 |
| Brisbane | 1084 | 1323 | 1195 | 1228 | 1110 | 1227 | 1131 | 1108 | 1093 | 1625 |

If access to population within 5 hours and distances to the 100 cities are plotted, the result is a trade-off graph between population access and distance. Both are important in factoring in customer service and transport costs. Figure 5 presents the trade-off results for two warehouse locations.

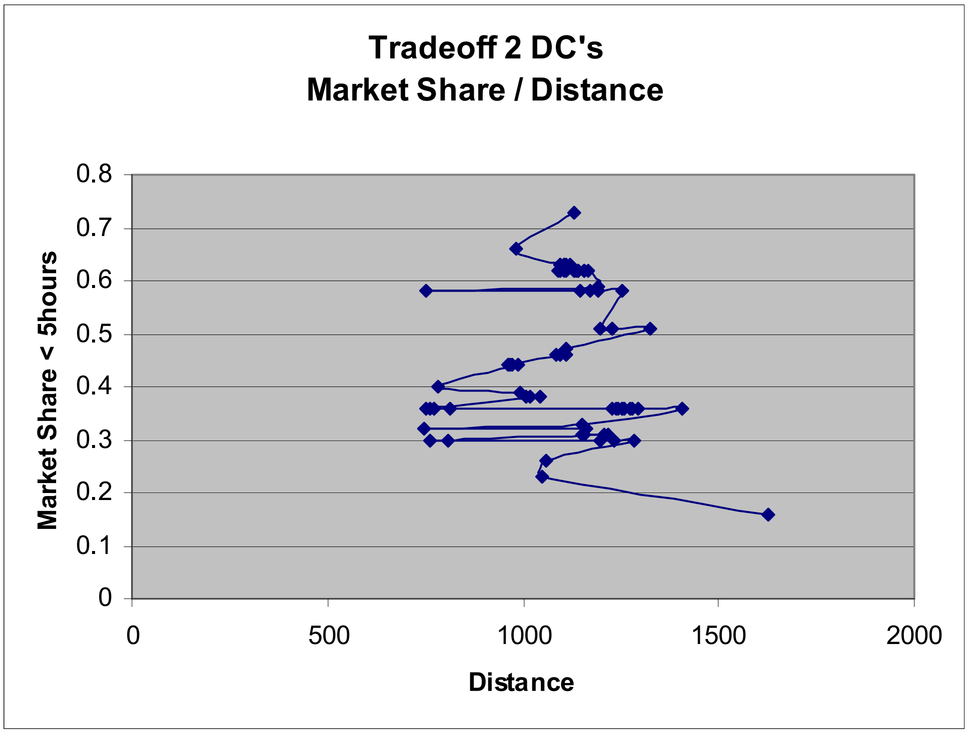


Figure 5: Trade-Off 2 Warehouses % Population < 5hours and Distance Travelled

Each point on the trade-off curve represents a city pair. The city pair with the greatest access to population is Albury, Brisbane with about 75% population access within 5 hours. However, because of the long distances to service cities in Western Australia, it has a larger travel distance (>1200 ). If a decision maker wanted to combine population access and minimise distance travelled then a location in Albury and Perth, Western Australia would be best (access to population 60% and distance travelled (about 700 distance units).

The optimal location of warehouses is important from a supply chain perspective. But what would be useful is to place these sites in the context of the Australian freight flow system. In this paper the doubly constrained gravity model has been used to develop a transport matrix of capital city origins (7) and 100 city destinations. The populations were used as proxies for the freight demand. The resulting matrix ($\alpha = -1$) gives the simulated pattern of freight flows (figure 6).

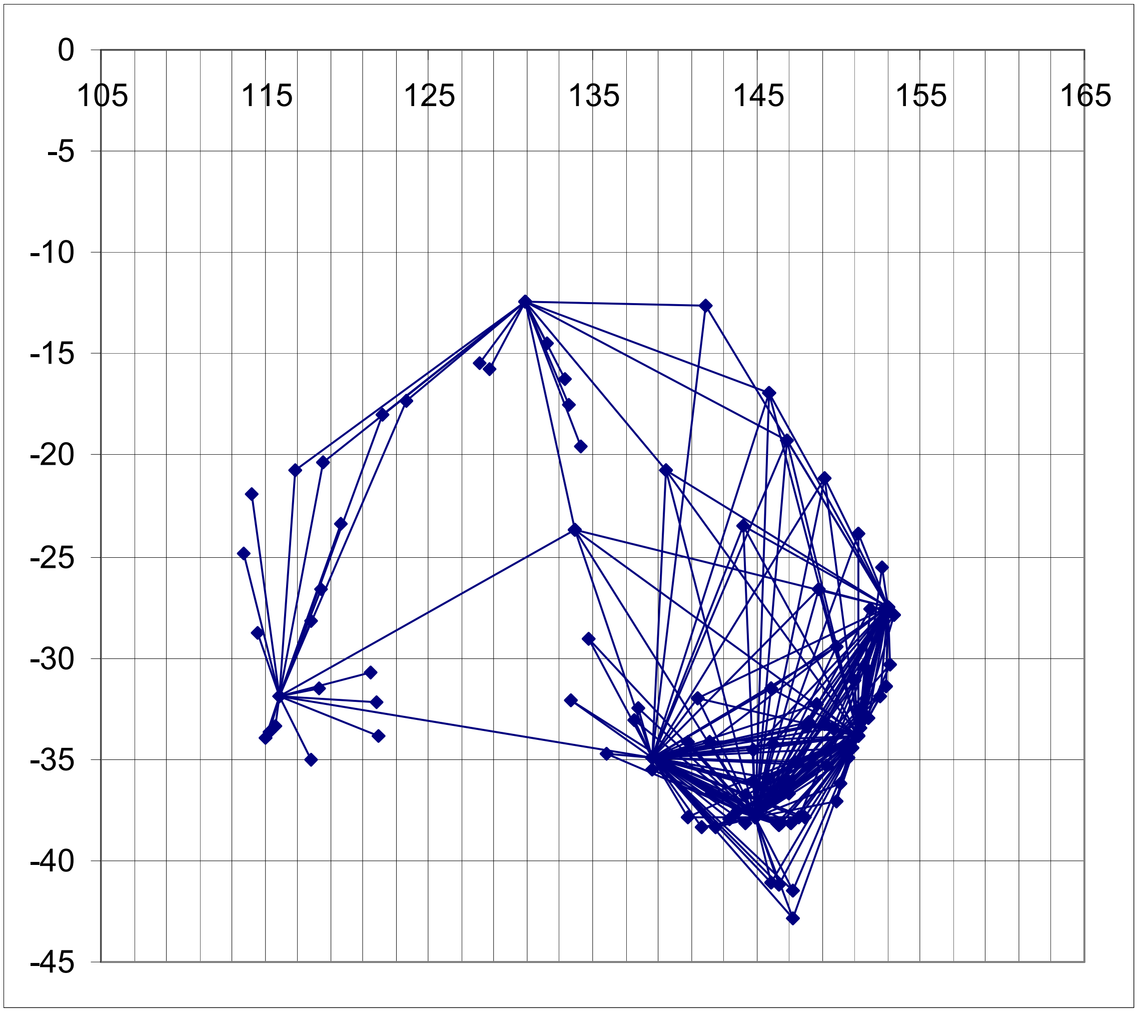


Figure 6: Gravity Model Simulation of Freight Flows

Using the resultant simulation of freight flows as a beginning, the alpha value was decreased ($\alpha = -3$) which begins to approximate a linear programming solution of optimal flows. Figure 7 shows the results of the optimal distribution pattern. The lines represent the flows without volume but the pattern is quite clear. The optimal distribution pattern is very much along the lines of State boundaries for Western Australia and the Northern Territory. However, the pattern becomes more complex and less obvious in the South East. Figure 8 focuses on the south east corner of Australia which is not quite clear in figure 7.

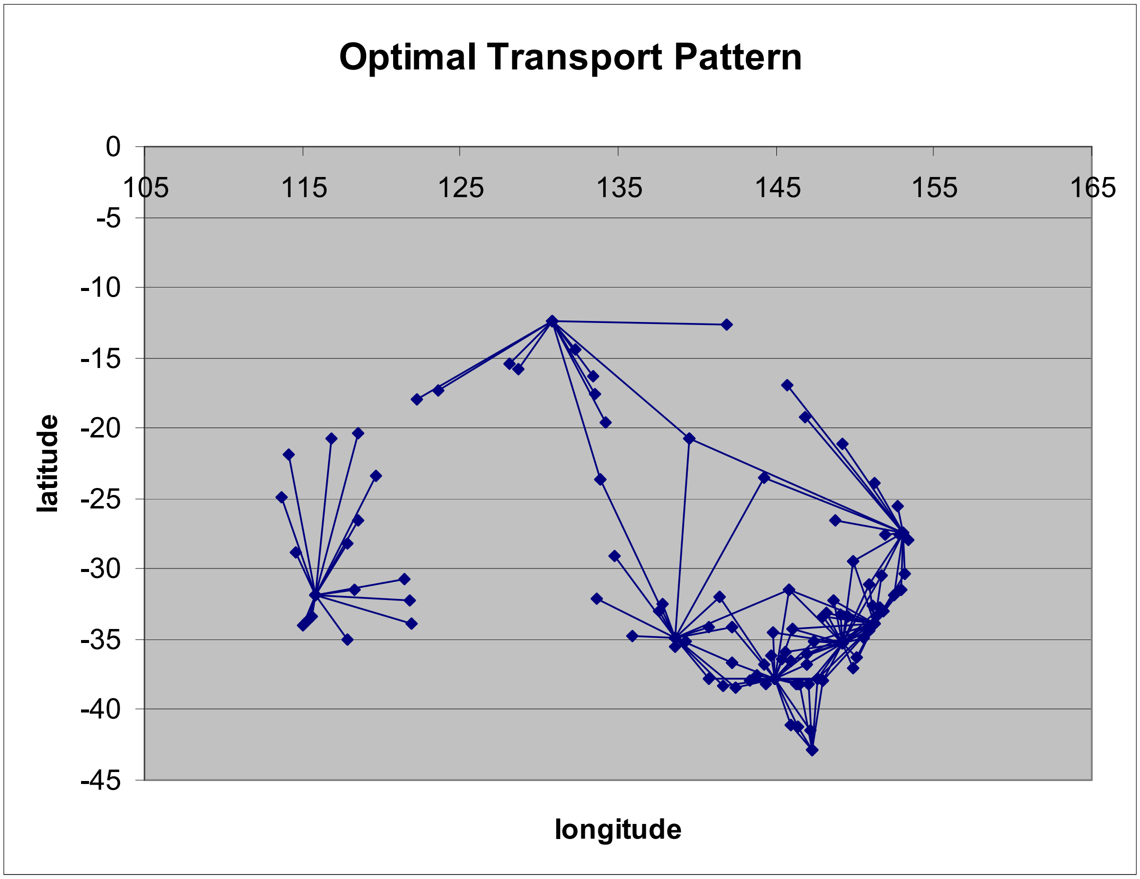


Figure 7: Optimal Transport Distribution Pattern.

Figure 8 shows that Canberra becomes an important origin hub for freight. Tasmania is served not only by Hobart but also by Melbourne, pretty much reflecting current distribution patterns.

## Discussion

So what has been shown? First from a technical point of view, all the modelling has been done using simple, non-macro driven spreadsheets. It is ideal for logistics managers because it is readily available and easy to use. The customer service level of “5 hours” delivery is straightforward and can be changed to reflect any desired service level.

The analysis has shown that Perth and Albury are two sites that combine access to population and fewer travel kilometres than the other locations tested. Combined with the optimal freight flow results they seem to confirm that they may function as ideal transhipment points but this hasn’t been proven.

The next steps in this research are to use the transhipment model to test these solutions (Albury and Perth). Further, we need to use more rigorous methods to test multiple locations beyond two warehouse sites.

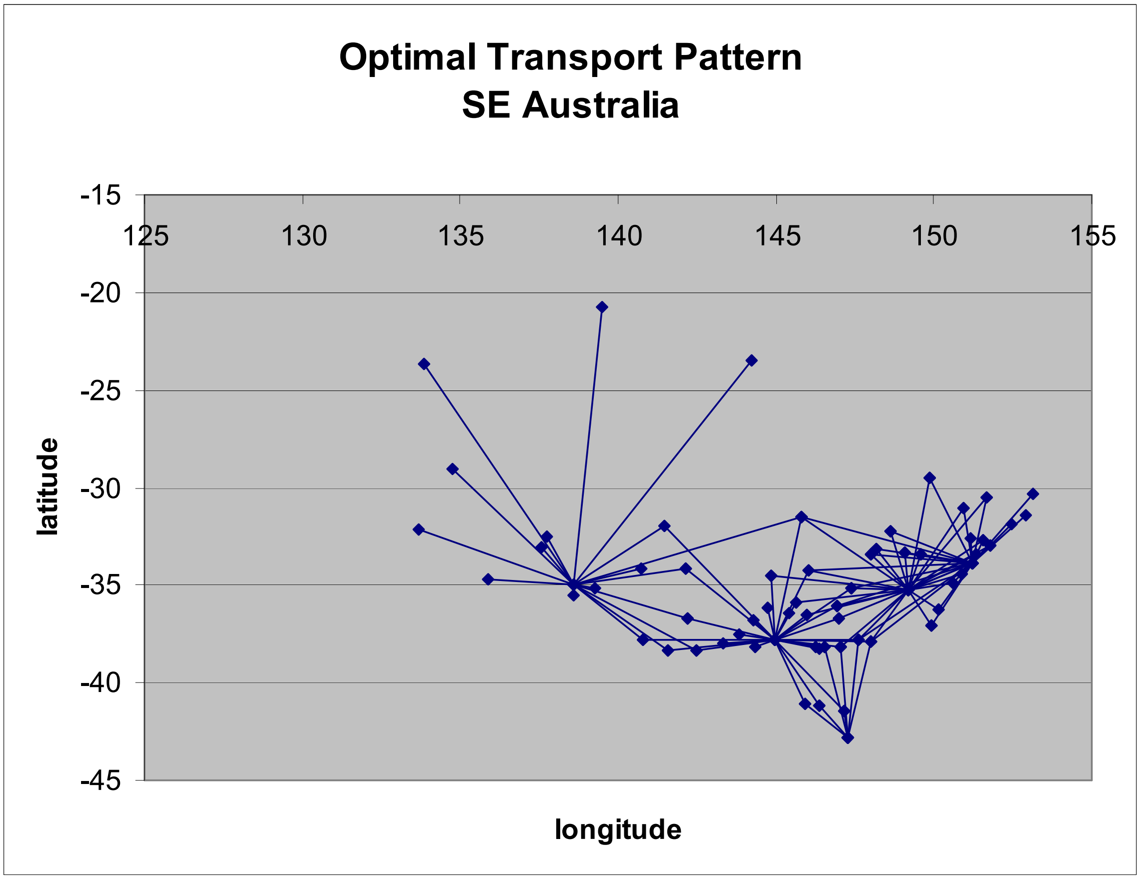


Figure 8: Optimal Freight Flow Pattern for SE Australia

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