# Sustainable freight transport systems for Melbourne – how many freight terminals?

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## 1 Introduction

For a city to exist as an entity it must draw on a hinterland for its resources and it generates wealth by exporting what it produces. In order to achieve this it must be able to move products in various stages of production within the city. So the freight distribution system in a city is vital to the economic success of the city and is of concern to planners and decision makers if it fails deliver through congestion and delay. This paper uses Melbourne as a case study of a typical medium size metropolis that until recently did deliver an efficient freight distribution system. The road system, coupled with a limited radial rail system allowed the city to expand efficiently in terms of the provision of freight over the last century. The Port of Melbourne is still the largest container freight port in Australia due largely to the historical importance of the city's manufacturing base. But this has changed as the manufacturing base has declined. Economic growth has generated freight at a faster rate than has been expected and transport infrastructure has not kept pace. The result has been growing congestion on both the road and rail system for both freight and passengers but in this paper we will focus on freight.

This paper models the optimal location of freight terminals or hubs for Melbourne. The objective is to determine the number and location of these terminals. The advantage of developing inland freight terminals with a rail road interchange system is two-fold. First, putting freight on rail will reduce the number of trucks on urban freeways and roads. Second, it will allow the consolidation of freight into fewer high capacity vehicles dedicated to the delivery task within the metropolitan area. The terminals being modelled in this paper are not international or interstate intermodal terminals such as Dynon (rail/road) or the Port of Melbourne rather they are consolidation and distribution facilities with limited storage, handling time critical freight involving parcels or pallets for immediate delivery to retail stores and offices rather than shipping containers or the larger loads associated with national or international transport movements. The terminals are local intra-urban freight facilities.

In Melbourne it is estimated that there are about 174,000 freight trips each day circulating within the metropolitan area (Spiridonos, 2008). The majority of these trips (about 60%) are truck based and related to a retailing function. Many of these trips would involve movements from factories and warehouses to other warehouses or distribution centres and retail stores. It is also highly likely that many of these trips are carried out by in-house fleets using small vans or trucks that are not fully loaded. Shopping centres, for example, generate a large number of trips from a broad supplier base that contribute significantly to freight traffic in and about regional shopping centres. The idea proposed in this paper is to develop freight consolidation centres so that loads could be rationalised and instead of 80 or 100 small light commercial vehicles or trucks unloading each day at these centres a few larger special purpose designed freight vehicles could do the task resulting in less freight traffic and the consequential various negative social and environmental impacts. The terminals are effectively public cross-docking facilities but they could also incorporate other value adding functions such as breaking bulk, mixing and matching orders for customers, ticketing and tagging product or handling reverse logistic processes such as returns, repairs and waste recovery. The saving in transport costs is the reason for warehouses in a logistic system. Figure 1, from "logistics 101" (see Stock and Lambert, 2001), shows the idea.

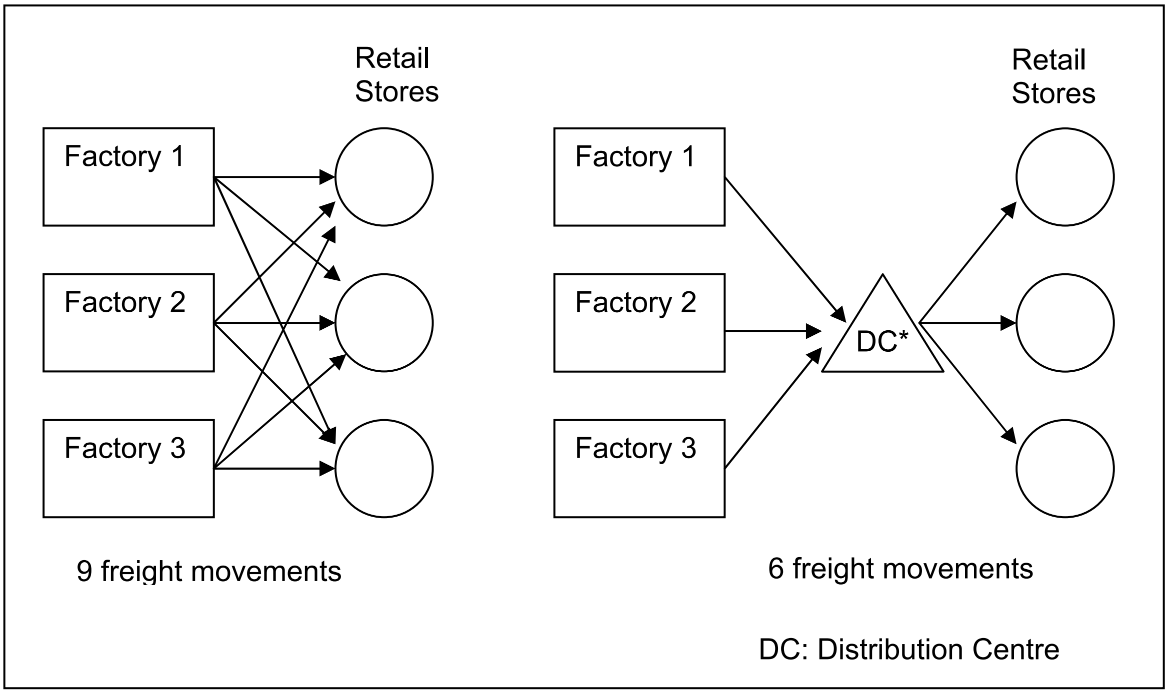


**Figure 1 – A warehouse or DC in a supply chain reduces freight movements**

The impact of warehouses or distribution centres on freight movements can be more substantial if appropriate freight vehicles are used so that tours can be developed that optimise the transport task, for example as in Figure 2.

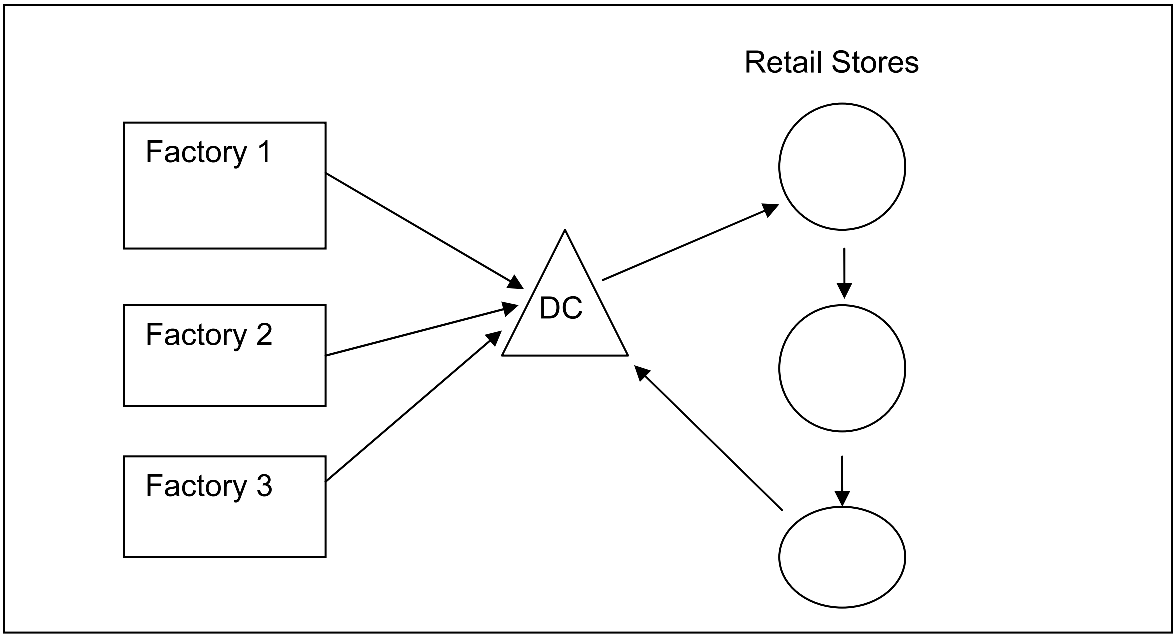


**Figure 2 – A freight tour – optimising the transport task**

In systems such as that illustrated in Figure 1, not only do many freight vehicles leave factories without a full load, they invariably return empty with many dead kilometres of travel resulting in substantial transport inefficiency. So there are significant benefits in coordination and consolidation of freight collecting and delivery systems.

## 2 Structure of Melbourne's Freight System

Before briefly reviewing the literature in this area, the structure of the freight system in Melbourne is described in order to provide the background for the freight hub modelling that is the purpose of the paper. Figure 3 shows the centroids of the local government areas (LGAs) in Melbourne and the change in manufacturing, transport and storage jobs between 1981 and 1996 for each area. The manufacturing, transport and storage sector generates much of the freight traffic in the city. It can be seen that the inner local government areas lost jobs in this sector and that the outer local government areas gained jobs. In most cases these were different jobs, not relocation from inner suburbs to outer suburbs of factories. The symbols are located at the centroids of each local government area so they are also a proxy for the distribution of the population in the Melbourne region. In turn they are geographically related to the location of shopping centres since each local government area has at least one regional retail centre that attracts freight traffic. What this shows is that over time, centrally located manufacturing has decentralised to outer suburban locations resulting in longer freight movements. For example, the dominant retail centre (CBD) now is serviced by suppliers located on the fringe of the urban area. The congestion of freight moving into the CBD is legendary among transport providers and is sometimes given as one of the contributing factors to the growth of large regional shopping centres such as Chadstone. These mega shopping centres are located in the middle of large catchment areas at the expense of the retail function of the CBD and are supposed to be easier to supply.

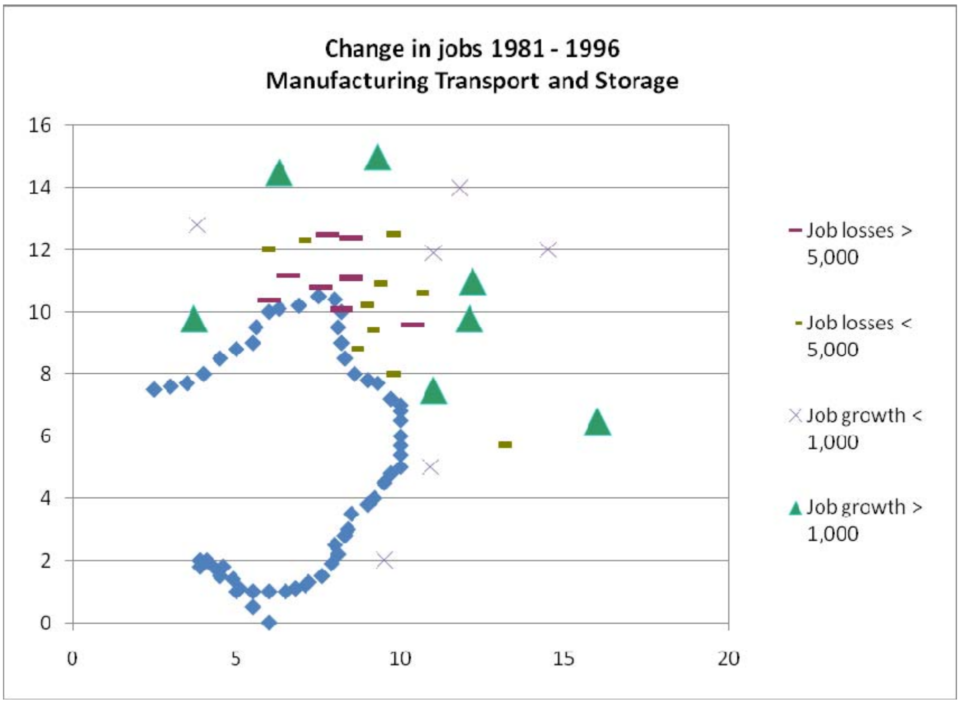


**Figure 3 – Change in jobs in manufacturing, transport and storage by Local Government Area 1981 – 1996**

*Source: Table 2*

The major manufacturing, transport and distribution locations have moved from inner local government areas such as Footscray and Collingwood to the southeast of the city (Dandenong) to the north (Somerton) and in the west along the Geelong/Melbourne corridor. It could be called a doughnut model of manufacturing, transport and storage job changes, with the hole focusing on the CBD and inner suburbs. Between 1981 and 1996 Melbourne lost a net 90,000 manufacturing, transport and storage jobs. The largest loss occurred in the Melbourne local government area. The two local government areas gaining the most jobs in the sector (about 5,000 jobs each) in the time period were Hume and Knox.

## 3 Literature Review

There is an expanding literature on the subject of urban freight in a new discipline known as City Logistics. This has been defined by Tanaguchi as:

> *"..the process of totally optimizing the logistics and transport activities by private companies in urban areas considering the traffic environment, the traffic congestion and the energy savings within a framework of a market economy"*
>
> *Tanaguchi et al. (1999).*

Over the space of the last five years the City Logistics movement has generated research into understanding the movement of freight and its economic, environmental and social impacts on cities. Many of the case studies have been drawn from Japanese and European cities that have experienced severe traffic congestion in their downtown areas. Before discussing more recent studies it is worthwhile briefly discussing the earlier work of Ken Ogden whose text on urban freight is a thorough review of the state of the art at that time.

Ogden (1992) reviewed urban freight in Australia. He showed that more freight activity is generated within cities in Australia than between cities, hence the management of urban freight is of particular significance for freight planning in general. He also discussed the role freight consolidation centres in cities and this may be one of the first such studies focussing on the importance of urban freight. Some of his suggestions for improving urban freight distribution productivity have been taken up by the more recent work on urban freight distribution in European and Japanese cities.

In the recent literature, one of the key findings is the use of public freight terminals on the fringes of downtown areas. Urban freight planners have shown that these terminals can act as freight consolidation points (Castro *et al*. 1999) to minimise the unnecessary movement of small trucks. For example Ieda *et al*. (2001) described a pilot project in Fukuoka Japan (Fukuoka is in northern Kyushu, population about 2.5 million) that began in 1977. It involved the creation of a public company, MCJDS, (Multi-Carrier Joint Delivery Services) that provided a consolidation point for parcel deliveries in Fukuoka to minimise inner city congestion by reducing the number of delivery trucks. The concept was that parcel companies could use the MCJDS company as the delivery system instead of their own vehicles for the final leg of the parcel delivery task to customers. It was a small scale operation for a congested downtown region. Although the company has been enlarged and recently privatised Ieda reported that it has captured less than one third of the market and struggled to remain financially viable. Similar cases have been reported in the European literature in City Logistics and one of the best resources is known as "Bestufs".

"Bestufs" is an acronym for Best Urban Freight Solutions and was created by the European Union in 2000 to address issues of traffic congestion in European cities and the movement of freight in general across Europe. It is a collaborative venture aimed at creating networks of people and organisations that work in any aspect of the freight industry. Consequently it is an amalgam of city planners, transport and freight operators, private and public organisations that are interested in optimising freight solutions. It is also an example of a virtual organisation that uses the networking capacity of the internet to organise collaborative projects across the continent.

Bestufs provides many practical examples of innovative freight distribution strategies involving a range of techniques; intelligent transport systems and high productivity vehicles (see Figure 4 below) optimised for the particular delivery task.

**Figure 4 – Downtown distribution vehicle.**

*Source: <http://www.bestufs.net/download/Workshops/BESTUFS_I/La_Rochelle_Apr02/BESTUFS_La Rochelle_Apr02_Waibel_Nuremberg.pdf>*

Spiridonos (2008) has developed a freight model for Victoria with a focus on Melbourne. Figure 5 shows a possible freight hub system based on a model of freight flows in Melbourne. The freight model incorporates a highly detailed commodity flow data base linked with a freight distribution model. Figure 5 shows the location of three proposed freight hubs; a northern industrial hub which would be centred on Somerton and its standard gauge rail terminal, a South East hub located in the vicinity of Dandenong and a South West hub.


**Figure 5 – A proposed freight hub system for Melbourne (Spiridonos, 2008)**

Castro *et al*. (1999) used a logistics modelling approach based on the fundamental theories of the relationship between warehouses, factories and customers outlined in Figure 1 (Stock and Lambert, 2001) to determine the location and number of distribution centres for Tokyo, Japan. Their results are reproduced in Figure 6. Essentially their model trades off transport costs with facility costs using a linear programming optimisation approach. An exchange rate of 80 Yen to the Australian dollar was used to convert their cost data.

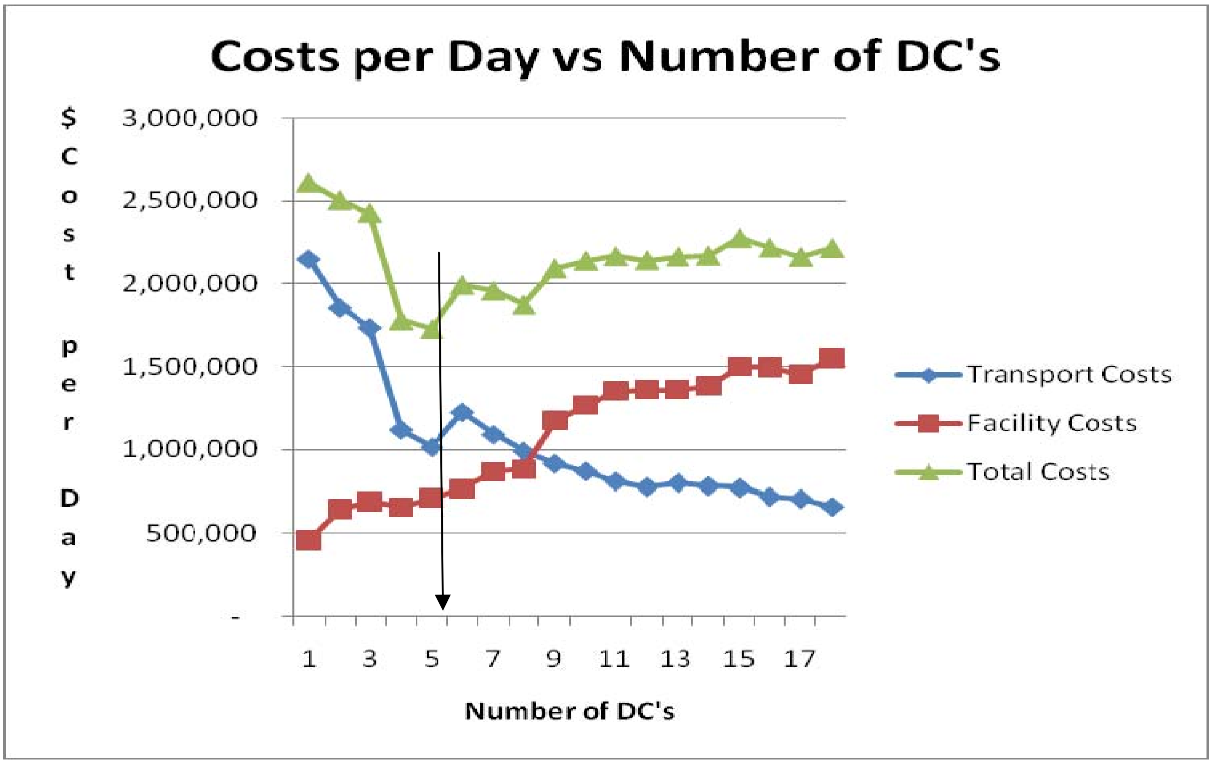


**Figure 6 – Costs vs Number of DC's for Tokyo (from Castro *et al*. 1999)**

Their model was developed for the greater Tokyo metropolitan area and shows that 5 distribution facilities resulted in the lowest total logistic cost. It was based on 56 traffic zones and used the 1994 Goods Movement Survey for the city. Greater Tokyo is of course much larger than Melbourne, with about 30 million people in 15,000 $km^2$ compared with 3.6 million in an area of about 9,000 $km^2$.

Although much theoretical work has been done on urban freight consolidation and distribution terminals throughout the world, it would appear that with the exception of a few European cities, little in the way of implementation has occurred in countries such as Japan despite trials in cities such as Fukuoka. Tokyo for example does not appear to have such freight terminals (Shimizu *et al*. 2007).

In this paper, rather than using a transportation optimisation model we have used an alternative optimisation methodology.

## 4 Location of Intermodal Freight Hubs.

A set covering model was used to identify how many intermodal terminals (hubs) were required for the Melbourne region. These models use integer programming to identify the number and location of the hubs. The mathematical model is developed following Winston (1994) and Albright *et al*. (1999):

Minimise $\sum X_i$ i= 1 to 31 [31 local government areas (LGA)]

Subject to:
$X_i \leq K$ [a hub must be less than K kilometres from an LGA]
$X_i \geq 1$ [there must be at least 1 hub K minutes away]

A 31 × 31 distance matrix was developed using straight line distances between the centroids of the LGAs. From this a set of LGAs ($X_i$'s) were identified that were within K kilometres of each LGA. Microsoft Excel's Solver function was then used to identify the optimal number of hubs required.

A series of solutions were explored with K varying from 80 kilometres down to 10 kilometres. The results are given in Table 1:

**Table 1 – Hub locations using set covering method**

| *K=km's* | | *K=40* | *K=30* | *K=20* | *K=10* |
|---|---|---|---|---|---|
| 80 | Moonee Valley | Bayside | Darebin | Maribyrnong | Brimbank |
| 70 | Brimbank | Cardinia | Frankston | Manningham | Yarra |
| 60 | Hobsons Bay | | Mornington Peninsula | Frankston | Kingston |
| 50 | Port Philip | | | Cardinia | Maroondah |
| | | | | | Frankston |
| | | | | | Mornington Peninsula |
| | | | | | Casey |
| | | | | | Cardinia |
| | | | | | Yarra Ranges |
| | | | | | Nillumbik |
| | | | | | Whittlesea |
| | | | | | Hume |
| | | | | | Melton |
| | | | | | Wyndham |
| **Number of hubs** | **1** | **2** | **3** | **4** | **14** |

The data for the model is given in Table 2. From this the distance matrix was used to develop the set covering integer linear programming model of hub locations.

**Table 2 – Local Government Area centroids, manufacturing, transport and storage jobs (1981 – 1996).**

*Source: Dr. J. Wolinski, personal communication.*

| | *LGA* | *X* | *Y* | *1981* | *1986* | *1991* | *1996* | *Change 1981-96* |
|---|---|---|---|---|---|---|---|---|
| 1 | Brimbank | 5.8 | 12 | 10780 | 8648 | 11054 | 10213 | -567 |
| 2 | Hobsons Bay | 6 | 10.4 | 17286 | 11584 | 9075 | 11820 | -5466 |
| 3 | Port Philip | 8.2 | 10.1 | 12735 | 8148 | 5685 | 7016 | -5719 |
| 4 | Melbourne | 7.6 | 10.8 | 66010 | 52414 | 33319 | 29121 | -36889 |
| 5 | Yarra | 8.5 | 11.1 | 26092 | 19724 | 13212 | 12057 | -14035 |
| 6 | Maribyrnong | 6.6 | 11.2 | 19324 | 14518 | 12125 | 9733 | -9591 |
| 7 | Bayside | 8.5 | 8.8 | 4980 | 3817 | 3385 | 3326 | -1654 |
| 8 | Kingston | 9.6 | 8 | 28352 | 27055 | 24008 | 25301 | -3051 |
| 9 | G Dandenong | 11 | 7.5 | 17986 | 17458 | 19268 | 22978 | 4992 |
| 10 | Stonnington | 8.8 | 10.2 | 7311 | 5457 | 3929 | 3321 | -3990 |
| 11 | Glen Eira | 9 | 9.4 | 9272 | 6942 | 6047 | 7098 | -2174 |
| 12 | Monash | 10.4 | 9.6 | 27283 | 24897 | 21342 | 21495 | -5788 |
| 13 | Whitehorse | 10.5 | 10.6 | 10372 | 9391 | 7416 | 7700 | -2672 |
| 14 | Knox | 12.1 | 9.8 | 9036 | 9049 | 12672 | 15002 | 5966 |
| 15 | Maroondah | 12.2 | 11 | 6977 | 9236 | 6702 | 8885 | 1908 |
| 16 | Manningham | 11 | 11.9 | 1129 | 1291 | 972 | 1286 | 157 |
| 17 | Banyule | 9.6 | 12.5 | 5021 | 5353 | 4183 | 4561 | -460 |
| 18 | Boroondara | 9.2 | 10.9 | 5925 | 5153 | 4374 | 4350 | -1575 |
| 19 | Darebin | 8.5 | 12.4 | 17998 | 14896 | 10154 | 9375 | -8623 |
| 20 | Morebank | 7.8 | 12.5 | 20822 | 17375 | 19229 | 10367 | -10455 |
| 21 | Moonee Valley | 6.9 | 12.3 | 9141 | 6957 | 4425 | 4515 | -4626 |
| 22 | Frankston | 10.9 | 5 | 3198 | 4029 | 3324 | 3715 | 517 |
| 23 | Mornington Peninsula | 9.5 | 2 | 4102 | 4126 | 4021 | 4460 | 358 |
| 24 | Casey | 13 | 5.7 | 4211 | 2439 | 2151 | 3443 | -768 |
| 25 | Cardinia | 16 | 6.5 | 241 | 554 | 1370 | 1970 | 1729 |
| 26 | Yarra Ranges | 14.5 | 12 | 3461 | 3660 | 3411 | 4202 | 741 |
| 27 | Nillumbik | 11.8 | 14 | 667 | 1037 | 771 | 910 | 243 |
| 28 | Whittlesea | 9.3 | 15 | 6689 | 6376 | 6752 | 8615 | 1926 |
| 29 | Hume | 6.3 | 14.5 | 21908 | 21137 | 21405 | 27866 | 5958 |
| 30 | Melton | 3.8 | 12.8 | 302 | 625 | 499 | 477 | 175 |
| 31 | Wyndham | 3.7 | 9.8 | 2193 | 2293 | 3341 | 4849 | 2656 |
| | **Total** | | | **382785** | **327625** | **281613.3** | **292023** | **-90762** |

If hubs can be between 50 to 80 kilometres from any LGA then only one hub is required. Depending on the distance constraint, the location varies from Moonee Valley (a hub can be 80 kilometres from any LGA) to Port Philip (a hub can be no more than 50 kilometres from an LGA). If hubs need to be closer than 50 kilometres then more hubs are required. Table 1 shows that for distances up to 40 kilometres 2 hubs are needed and this grows to 4 hubs if LGAs must be within 20 kilometres. If hubs are required to be at most 10 kilometres away then the number of hubs required jumps to 14. Castro *et al*. (1999) using an alternative methodology found a similar result for Tokyo.

From this analysis it would seem that a service distance of 20 kilometres would result in the best coverage. Each hub or terminal is expensive in terms of land and equipment. So a balance is required between cost of hubs and access to LGAs. The set covering analysis conducted seems to suggest that 4 hubs or terminals would provide Melbourne LGAs services within 20 kilometres of a hub. This translates to about an hour travel time in peak periods and less in the off-peak. It would provide a high level of access to all LGAs.

The Melbourne region could be served with 4 regional freight hubs located in the LGAs of Maribyrnong, Manningham, Frankston and Cardinia. Figure 7 shows the location of the hubs superimposed on the LGA centroids. Two of the hubs are located in regions that have lost manufacturing transport and storage jobs (Frankston and Maribyrnong) and two are located in outer areas that have gained jobs (Manningham and Cardinia). This would provide Melbourne with four freight hubs which could provide consolidation points for manufacturers and suppliers distributing to the 31 LGAs of Melbourne.

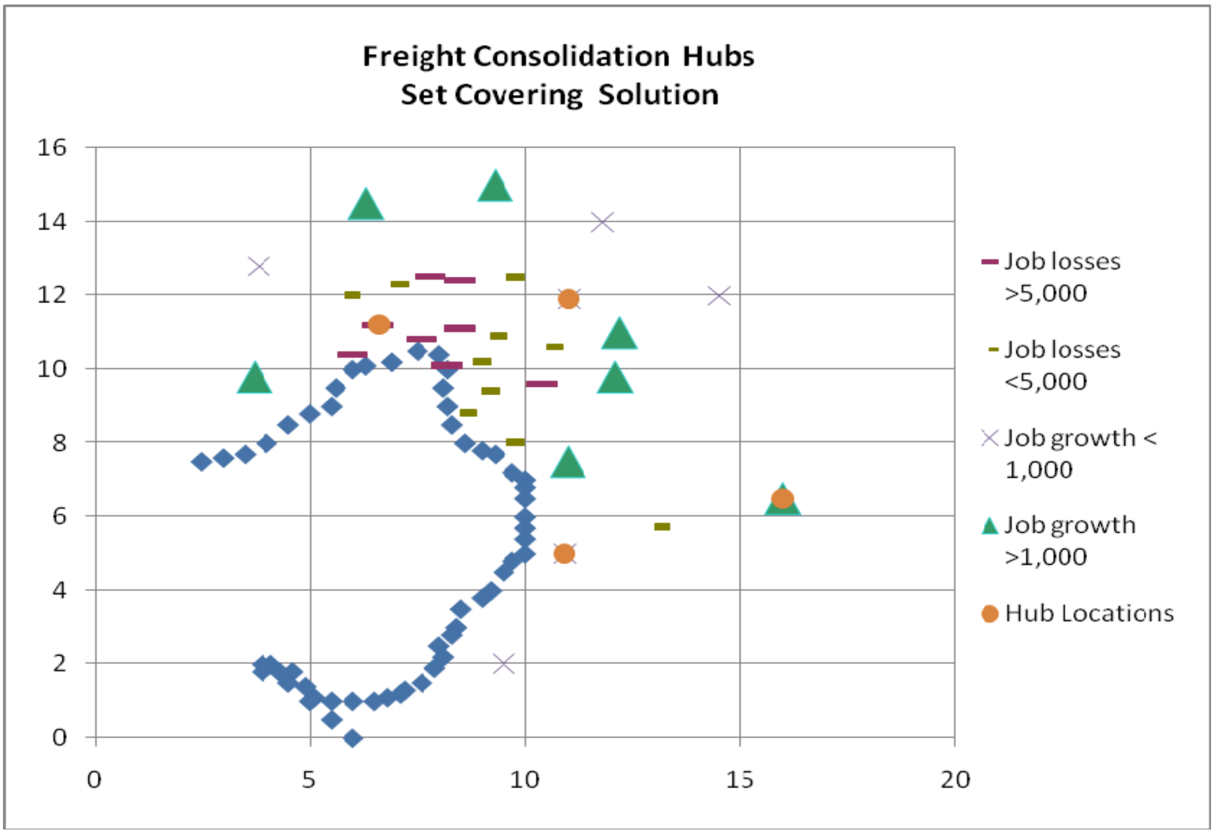


**Figure 7 – Location of hubs**

It is important to note that this is not necessarily a unique solution, because there are other locations that could also provide this level of coverage. But what it does show is that about three or four hubs are required for Melbourne. Depending on the solution procedure the locations will change. For example, using a quadratic programming approach, four locations identified for hubs were Brimbank, Darebin, Casey and Monash/Whitehorse. Both the set covering approach and the quadratic programming approach seek to minimise distance from the hubs to the LGAs.

It is interesting to note that at present Melbourne does seem to be developing 3 intermodal freight hubs located at Somerton in the North, Dandenong in the South and Altona in the West (see Figure 5) which is consistent with the theoretical results in this research – though the locations are different.

## 5 Discussion and Conclusions

Many European and Japanese cities have freight consolidation hubs located on the outskirts of downtown areas. These have been developed to reduce freight traffic congestion in their inner cities. Similar strategies could be used in Melbourne but at a larger scale.

The analysis conducted for this paper suggests that 4 hubs located strategically in the metropolitan area could provide coverage to all LGAs. It is proposed that these hubs be multi-modal, so that rail/road interchanges could take place. The hubs could provide a consolidation function reducing the number of vehicles required to deliver to offices, retail outlets and households in a hub's catchment area.

Movement between hubs could use purpose built standard gauge rail for bulk volumes or alternatively light freight rail. The hubs in turn would be connected to the port of Melbourne and the airport with high capacity rail links.

Decision makers and planners in Melbourne seem to have a much lower level of concern about the freight system than the passenger system. Freight is in the background, largely ignored as centre stage is taken with new freeways, debates on tolls, tunnels or public transport ticketing systems. But it is quite clear that much of the congestion of Melbourne's roads and freeways is due to truck freight traffic. Inner city congestion has a substantial component of smaller delivery vehicles providing goods to a wide variety of retail and office functions. Therefore if the freight vehicles could be reduced by consolidating shipments into higher productivity vehicles and onto cross city rail freight lines there would be a considerable reduction in road congestion and the associated negative environmental externalities.

This paper proposes that the approaches to freight planning in Europe and Japan provide good models for Melbourne to adopt and adapt. City Logistics and Bestufs provide a framework and strategy that needs to be carefully considered because it may well provide the most economical and environmentally sustainable transport strategy for the city. To begin, four intermodal freight hubs with dedicated high capacity freight delivery vehicles might just be the way forward to solving our transport congestion problems.

## Acknowledgements

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