HIGH PRODUCTIVITY FREIGHT VEHICLES FOR THE PHYSICAL INTERNET

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Abstract

There are enormous challenges associated with achieving net zero emissions from freight systems due to the growth in demand for smaller and more frequent deliveries. The Physical Internet (PI) is an emerging concept that has the potential for dramatically reducing emissions by transforming independent own account networks to increase vehicle consolidation levels and reduce distances travelled.

This paper illustrates how shared multi-modal networks for improving vehicle consolidation levels can dramatically reduce distances travelled by freight vehicles and improve social and environmental outcomes. A case study involving general freight between major freight areas in metropolitan regions is used to illustrate the potential of collaborative and more integrated freight networks.

Shared freight networks can achieve a high degree of consolidation. This paper illustrates the substantial benefits of operating a shared freight network for transporting goods between KFAs in Melbourne using high productivity freight vehicles based on direct movements between all KFA in Melbourne.

Keywords: Physical Internet, City Logistics, Collaborative Freight Systems

1. Introduction

The Physical Internet (PI) is an emerging paradigm for planning and managing freight and logistics networks (Montreuil, 2010). It aims to transform the way physical objects are moved, stored, realized, supplied and used in the pursuit of global logistics efficiency and sustainability. Key elements of the PI are, open and shared networks, standardised and modular load carriers, track and trace protocols and certificates. The PI requires new business models for sharing assets. Supply network coordination, synchromodality and information technology are employed for improving the safety and sustainability of supply chains. PI aims to achieve the right modes and load factors for the right loads that requires compatible load units and coordinated transfers between modes. This involves integrating vehicles, loads and transhipment facilities.

Hyperconnected City Logistics (HCL) combines concepts from the Physical Internet and City Logistics (Crainic and Montrieul, 2016). The aim of HCL is to create more collaborative and integrated distribution networks to address sustainability issues. Sharing vehicles and warehouses can reduce the distance travelled by freight vehicles that can reduce operating costs, emissions and energy consumption as well as noise and congestion. However, exchanging goods involves additional costs such as unloading and unloading goods as well as storage and vehicle wait times. There is a need to understand more about the trade-offs between transport and transfer/storage costs to assist in promoting HCL.

Major cities in Australia generate a substantial volume of freight movement and are characterised by some of the largest metropolitan areas in the world, with low population densities and limited transport infrastructure. Increasing urban congestion, coupled with increased levels of home deliveries from eCommerce, has created significant sustainability challenges for Australian urban freight systems. This worsening congestion is expected to cost Australian cities $37.3 billion by 2030 (Bureau of Infrastructure, 2015), while Australia's urban freight volumes are predicted to increase by up to 60% before 2040 (Transport and Infrastructure Council, 2021).

Australian governments are committed to reducing emissions with the aim of achieving net zero emissions. However, to attain environmental goals, new initiatives for transforming urban freight movement towards the use of more shared vehicles and storage facilities is required. This will require a radical transformation of existing urban freight systems into real-time based collaborative networks, which will subsequently reduce vehicle emissions, noise levels, and increase system efficiency.

Significant benefits in terms of productivity gains, safety and emissions from operating PBS vehicles instead of conventional in urban areas have been estimated (Hassall and Thompson, 2011; Thompson and Hassall, 2014). This can lead to a lowering of several key freight exposure metrics, such as kilometres travelled, trips, task travel times and vehicle numbers. B-doubles have also been found to have a greater advantage in reducing pavement damage than semi-trailers at higher load levels (Ren et al., 2019).

When redesigning urban freight networks, there is a need to identify appropriate performance measures for urban freight networks considering a range of stakeholders and to combine them to provide measurable goals for designing more open and collaborative urban distribution systems. This paper describes a range of performance that can be used to assess the sustainability of urban distribution networks. Case studies involving retail swaps and retail distribution networks are presented.

Urban Consolidation Centres (UCC) have been established near city centres in a number of cities in Europe and Japan to reduce the number of freight vehicles (van Duin, 2015). More recently since COVID, the need for small hubs within the metropolitan areas to be created to reduce distances travelled and distribution costs by trucks and vans in response to rising levels of eCommerce has been more urgent.

2. Measuring Network Performance

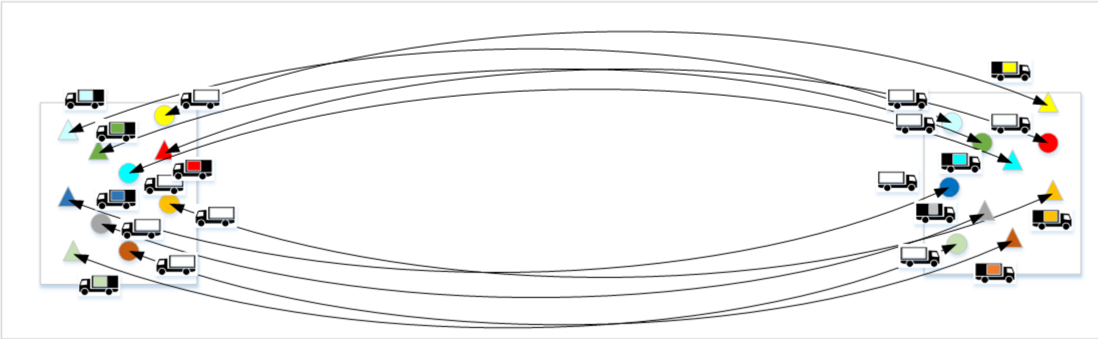
There are a number of common measures of performance for urban distribution networks, including number of vehicles used by type and vehicles kilometres travelled by vehicles (VKT). However other network measures can provide useful information for addressing sustainability issues, including:

(i) Efficiency (TKM/VKT) (ITF, 2018)
(ii) Load Factors (proportion of capacity of vehicles: weight or volume used over all legs on routes)(McKinnon, 2000)
(iii) Work (product of load carried by distance travelled for all legs on routes)
(iv) Laden (percentage of distance travelled with goods in vehicles on routes) (McKinnon, 2000)
(v) MNAD (average number of arrivals and departures at receivers)

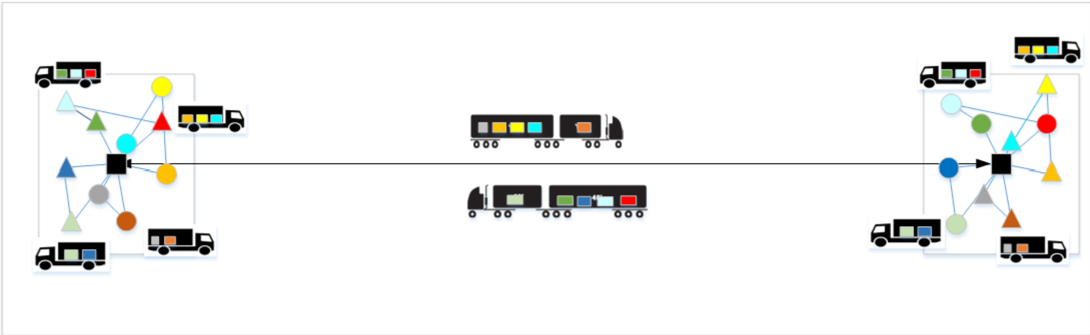
These network performance measures can be used to aid the design new freight networks based on PI principles by assisting with identifying improvement goals. Such measures can also be used to compare the predicted performance of collaborative networks with existing ones.

3. Metropolitan Freight Shuttle Networks

Large metropolitan areas typically have designated areas of high intensity production that generate a large number of freight trips between them. Shippers who are own account carriers often generate consignments of freight to consumers in other areas that are a considerable distance from them. This is generally undertaken using small to medium sized trucks that are often empty on the return trip. A shared freight network based on utilising high capacity freight vehicles operating between Key Freight Areas (KFA) via transhipment hubs with smaller trucks being used to pick-up and delivery goods within KFA (Figures 1 and 2) can lead to lower emissions from reduced distances travelled by freight vehicles. Separate pick-up and delivery routes within freight areas are undertaken using medium sized trucks. Goods are consolidated at hubs within each KFA. High capacity (multi-combination) freight vehicles are used as shuttles to transfer consignment between freight areas (Thompson et al., 2020).



(A)



(B)

Figure 1 (A) Existing freight movement patterns between 2 Freight Areas, (B) a Transshipment Hub (TH) with HPVs

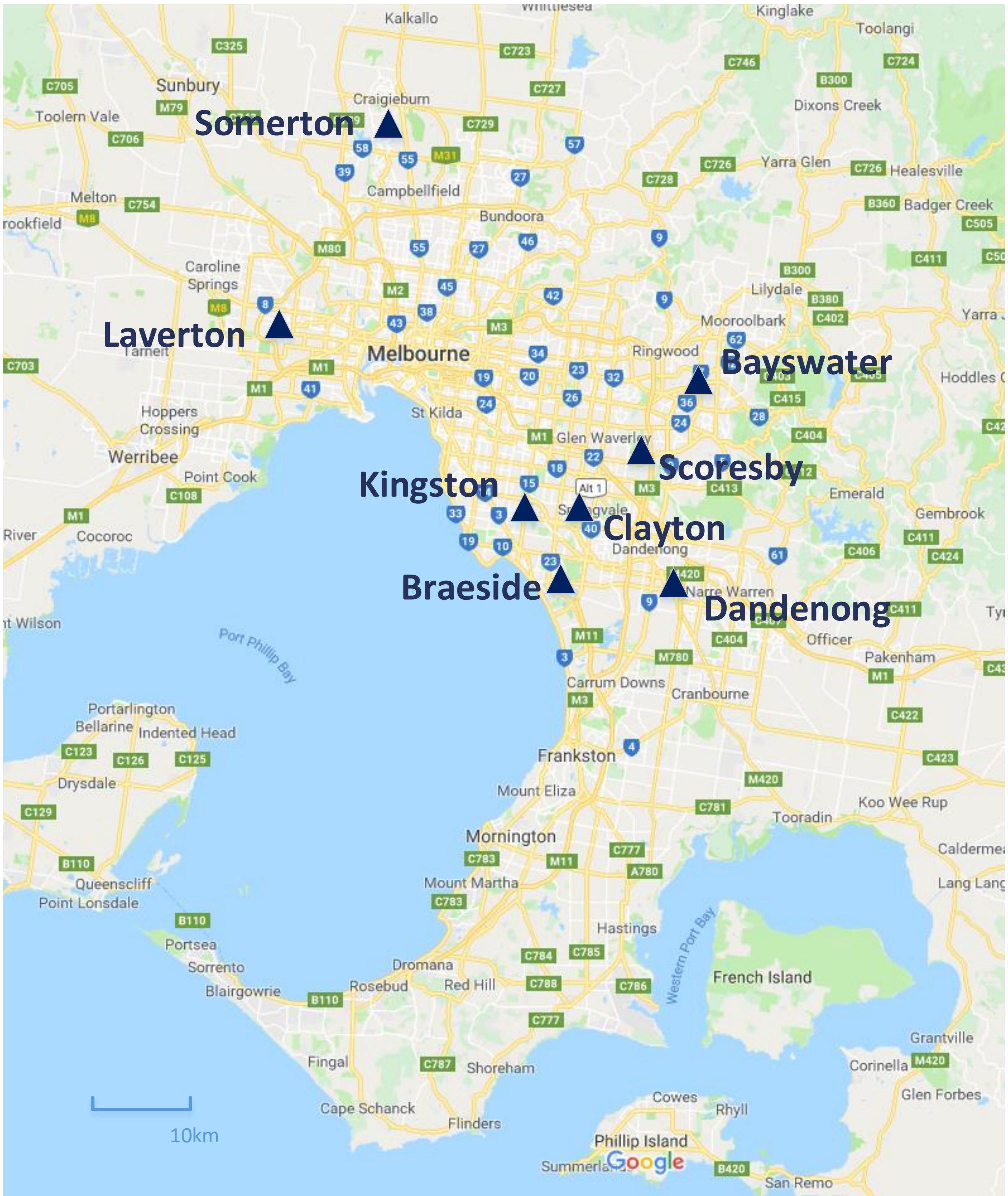


Figure 2 Key Freight Areas in Melbourne

The shared freight network operating in the Melbourne metropolitan area can achieve a high degree of consolidation. Network efficiency was estimated to rise to 17.2 from currently 2.5. Whilst the majority of costs were associate with operating the shuttles between KFAs, a substantial proportion (around 1/3) of the total costs were relating to transfer costs (Figure 3 and Table 1).

The benefits of operating a shared freight network for KFAs in Melbourne based on direct movements between all KFA in Melbourne was shown to reduce distances travelled by freight vehicles from around 190,000 kms to 27,500.

A higher reduction in emissions would be expected to be achieved using the shared freight network since high productivity freight vehicles are more fuel efficient and generate less emissions than conventional trucks (Hassall and Thompson, 2011).

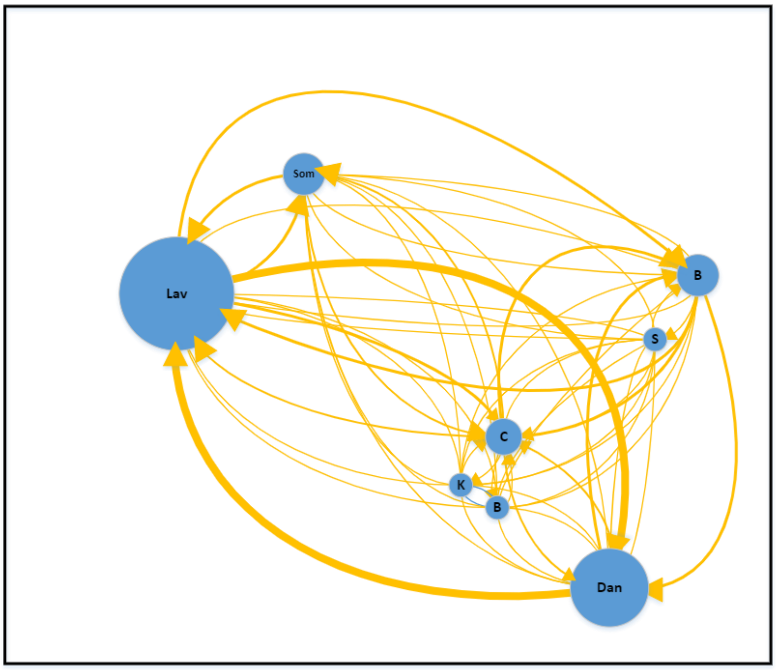


Figure 3 Complete Shared Network for Melbourne

Table 1

	($/day)	%
Shuttle	108,000	55.3
Transfers & Transhipments	55,836	28.6
Local Routes	31,500	16.1
Total	195,336	100.0

Personnel and administration costs consisting of management expenses as well as operational staff costs were found to account for the majority of expenses at an urban consolidation centre (Aljohani and Thompson, 2021). Equipment and facility costs were shown to be significant. However, Sydney's Courier Hub has minimal personnel and administration costs (Stokoe, 2017). Forklift and hub lease costs should also be considered (Thompson et al., 2020).

4. Implementing Hyperconnected City Logistics

There are a number of initiatives that will need to be undertaken to facilitate the implementation of more sustainable urban freight networks based on Hyperconnected City Logistics to achieve net zero emissions from freight transport in cities.

4.1 On-line Platforms

On-line platforms will be required to effectively plan, design and operate Hyperconnected City Logistics initiatives. On-line platforms are required to connect shippers and carriers as well as carriers and carriers. This allows exchange of goods to be arranged and pricing to be negotiated as well as level of service agreements to be made. Without on-line platforms, shippers and carriers cannot exchange information to allow effective sharing of transport and logistics resources. On-line auctions and systems for allocating freight vehicles to loads will provide an effective means of formalising the transfer of consignments between carriers.

4.2 Hyperconnected City Logistics Organisations

New organisations will need to be established for planning and managing the transfer facilities or hubs associated with open multimodal networks. These organisations will have a broader role than that of logistics service providers.

Open and shared hubs are new types of facilities that require innovative organisations to operate and manage them effectively. This is due to the complexity of coordinating a number of independent shippers and carriers and organising loading and unloading docks as well as temporary storage areas.

Organisation the operation of Hyperconnected City Logistics hubs will involve the management of the resources available at these facilities and controlling the costs and revenue streams that are similar to those associated with operating urban consolidation centres (Aljohani and Thompson, 2021).

4.3 Network Optimisation Software

Specialised software procedures for coordinating activities at transfer points to ensure high levels of reliability and efficiency will be required to implement Hyperconnected City Logistics. Advanced loading dock booking and allocation systems will allow a high degree of coordination between carriers and hub operators. On-line loading dock booking systems are an example of the type of systems that will be required to effectively manage hubs to avoid delays to carriers (Sanders et al, 2016).

Currently urban freight transport is typically undertaken using a single vehicle such as a medium rigid truck that transports goods between producers and suppliers to consumers and receivers. This leads to low levels of consolidation and network efficiency. To reduce distances travelled and emissions by freight vehicles in urban areas, new optimisation procedures for designing collaborative networks based on multiple modes will need to be developed. Advanced software systems will be necessary to determine which hubs or transfer facilities should be used as well as what new modes (including electric trucks) are available to minimise emissions, financial costs and satisfy service delivery requirements.

5. Conclusions and Future Work

Hyperconnected City Logistics based on open and shared networks provides a framework for transforming current urban distribution system to reduce transport costs, congestion and achieve net zero emissions. Such networks will have increased vehicle consolidation levels, shorter distances travelled that will render high capacity freight vehicles more practical and viable. However, to facilitate the implementation of hyperconnected city logistics new on-line platforms, organisations and network planning software will be required.

A set of network performance measures relating to various stakeholders were defined. The relative performance of traditional and PI networks was illustrated. The need to consider transfer and storage costs in transformed networks was demonstrated. Sharing warehouses and storage space within retail stores would require additional resources to manage facilities and would be more disruptive to shippers and receivers.

There are a number of areas where the model could be extended in future work. This could include considering how service levels such as same day or next day delivery would affect costs. Incorporate the management of loading docks and reliability issues associated with transfer between shuttles and local routes would also be necessary to estimate delay and short term storage costs. Also, determining which KFA hubs will have a transhipment function would be good to investigate as this may substantially affect the management costs of hubs and network flows.

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