KEYNOTE PAPER

Supply Chain and Logistics Challenges and Opportunities in Asia: Innovative Urban Logistics Concept

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Abstract

Rapid urban population growth in Singapore poses interesting challenges to resource capacity such as land, transportation and labour. With limited resources and the rapid growth of customer demand and expectations, an efficient plan of urban logistics activities that maintains a sustainable urban environment holistically is a prerogative. We propose an innovative urban logistics framework for efficient land, transportation and labour use. The proposed concept aims to reduce industrial land use by consolidating warehouses, reduce road congestion through a collaborative synchronized last mile and automated systems and processes for warehousing.

Keywords
Urban logistics, Singapore, resource scarcity, consolidation warehouse, synchronized last mile

1. Introduction

As urban populations worlwide grow rapidly, urban logistics is emerging as a field of research. Urban logistics undertakes the local distribution of goods within and through urban areas (Bajdor 2012). It mainly involves road freight transportation systems that are essential for the economic development of a city and the supply of its residents, but also harmful to the environment and human health (Anderson et al. 2005). Urban logistics involves many stakeholders with different and often conflicting interests, such as: industry stakeholders in supply, manufacturing, transportation and retail in the urban space; different layers of government; road traffic participants, retail consumers, and communities in broader urban society (Russo and Comi 2010).

In Singapore, urban population is growing at a fast rate. As a small island of approximately 710 sq km (Singapore Department of Statistics 2013a) and a growing population, Singapore is a densely inhabited urban city that exerts great challenges in dealing with higher customer demands and expectations.

Lying in the heart of the Singapore's challenge is a resource scarcity problem – including land, transportation and labour. Different kinds of social needs – such as business, industries, utilities, residences, schools – compete for the limited land resource available. As the city grows, demands on land resource will be inevitably greater. Industrial land use, which accounts for more than 15% of the total land use (NUS-JTC I3 Center 2012) is a major area where governments and researchers are looking for land use intensification opportunities.

Rising transportation demands (goods or people) may produce uncontrolled growth in the number of vehicles, which result in traffic congestions. Singapore has one of the highest ratios of vehicles per kilometer of road at 281, which is seven times that of the US and four times that of Japan (Gibb 2013). The traditional solution for traffic congestion is to build more and wider roads, but this is not a sustainable long-term solution especially for small islands like Singapore (STPP 2011). In contrast to the growing number of vehicles, the utilization of those vehicles, especially commodity vehicles, most of the time is not optimal (van de Klundert and Otten, 2011). Most logistics service providers are missing the benefits of loading trucks to their most efficient weight and volume capacity.

Besides land and transportation, labour has been yet another limited resource for Singapore. The logistics sector in many industries is often observed with a fairly uneven level of automation, and a continued reliance on non-skilled/semi-skilled labour. Although the city has an increasingly well-educated workforce (Singapore Ministry of Manpower 2013) that makes up the bulk of a growing population, the importing of supplementary labour from neighboring regions is unsustainable.

To manage the resource scarcity problem in Singapore, we, together with our contributors and industry partners, propose an innovative urban logistics concept that tackles inefficient utilization of land, transportation and labour through collaboration and resource sharing mechanism. We introduce an integrated concept of a consolidation warehouse and synchronized last mile. It is conceived out of two considerations: (1) the need to revolutionize the supply chain practice and the desire to further optimize current freights/goods transportation and handling processes and (2) the need to balance a livable, urban environment while continuing to grow a mature national economy. The consolidation warehouse offers storage, sorting, consolidation and deconsolidation facilities equipped with automated processing and handling system to sort and distribute goods. It is also equipped with underground and above ground transportation systems to and from Singapore's ports and airports. The synchronized last mile serves as a comprehensive last-mile delivery mechanism from the consolidation warehouse to the customers. As presented in de Souza et al. (2013), the synchronized last mile provides analysis tool to visualize, control and manage demand as well as freight transportation.

The remainder is structured as follows: Section 2 provides challenges of urban logistics in Singapore. We categorize these challenges into four groups: land use limitation, transportation use limitation, labour use limitation and externalities of urban logistics. In Section 3, we discuss our innovative urban logistics concepts in more detail. Section 4 presents key dimensions of the innovative urban logistics concepts and section 5 concludes this paper by presenting summaries of innovative urban logistics concepts.

2. Challenges

Singapore, as one of the most densely populated countries in the world with more than 5.4 million residents (Singapore Department of Statistics 2013b), needs to deal with several resource scarcity problems. On top of the list is land scarcity, paired with increasing land cost, that is becoming an acute concern for industrial land users (Zhu 2000). In an urban zero sum game, factories, warehouses, highways and local roads cannot expand without taking away land to be potentially used for housing precincts, parks, and other public amenities (Sapuan 2007). To balance the increasing number of vehicles and road availability, the government tightly controls and regulates vehicle ownership which increases the total cost of ownership. Insufficient supply of non-skilled/semi-skilled labour to fill the industry's needs is another source of scarcity. Industries, including the logistics sector, with less automated processes suffer from a labour shortage which decreases their productivity.

It is common practice for companies involved in urban logistics to pursue their individual strategies to handle these challenges by optimizing travel time and load capacity usage. Unfortunately, these efforts may result in lose-lose situations, where short-term efficiencies of individual companies are achieved at the expense of the other stakeholders.

2.1 Land Use Limitation

Rooted in the small island of Singapore with a growing population, different kinds of needs never cease to compete against each other for land use: business, industry, housing, education, green land, defense, and all other needs have to be carefully addressed with wise land allocation decisions. Currently 18% of the land mass is used for industrial use, and it is set to account 20% by 2050 (NUS-JTC I3 Center 2012). A land use allocation plan is illustrated in Figure 1 (Singapore Urban Redevelopment Authority 2013). Providing services to other booming industries in Singapore- an Asia-leading logistics hub- the logistics industry will expect expansion in the future (the current development of Singapore's logistics service is shown in Figure 2) (Singapore Department of Statistics 2013c). However, the growth of the logistics sector has to be constrained within the allocated land quota.

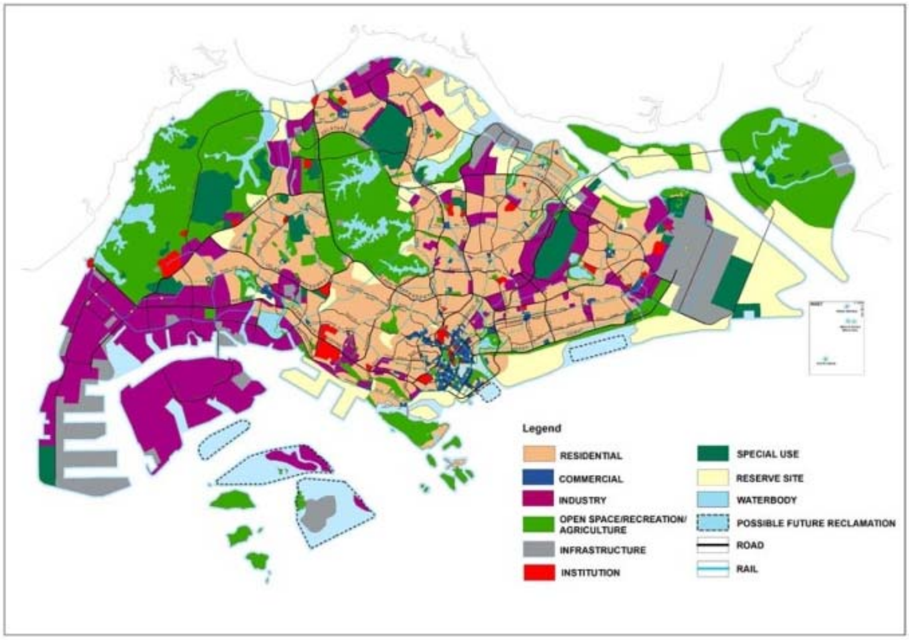


Figure 1: Land use allocation propfile beyond 2030
Adapted from (Singapore Urban Redevelopment Authority 2013).

There are some problems with the land use in the logistics sector. First, many industries operate their own warehouses at less-than-full capacity, which results in a portion of idle land that could have been saved for other more value-added activities such as manufacturing and R&D. Second, there are some warehouses remaining vacant every year, which accounts for on average 8% of the total available warehouse space (as is shown in Figure 3) (Singapore Department of Statistics 2013c). Through better planning, this portion of land could also be saved for better uses.

2.2 Transportation Use Limitation

Due to intensive urbanization and rapid economic growth, transportation demands (for goods and people) have tremendously increased, but in a small island like Singapore, there are no vast amounts of land available to be dedicated as roads (Yap 2005). Road length increases at a slower rate as illustrated in Table 1 (Singapore Land Transport Authority 2012a and 2013). Road building can never keep up with the annual increment of vehicles as illustrated in Figure 4 (Singapore Land Transport Authority 2012).

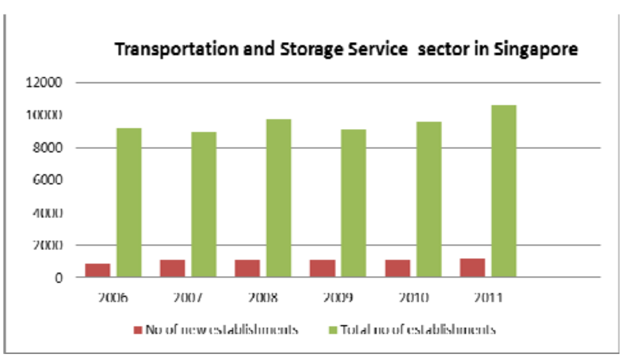


Figure 2: Establishments of transportation and storage service sector in Singapore 2006-2011
Adapted from (Singapore Department of Statistics 2013c).

Figure 3: Warehouses space in Singapore 2006-2012
Adapted from (Singapore Department of Statistics 2013c).

Table 1: Road Length and Traffic Condition in Singapore

		2010	2011	2012
Road Length (km)	Expressways	161	161	161
	Arterial Roads	634	645	652
	Collector Roads	535	557	561
	Local Access Road	2,047	2,048	2,051
Average Speed during Peak Hours (km/hour)	Expressways	62.3	62.5	63.1
	Arterial Roads	28.0	28.5	28.6

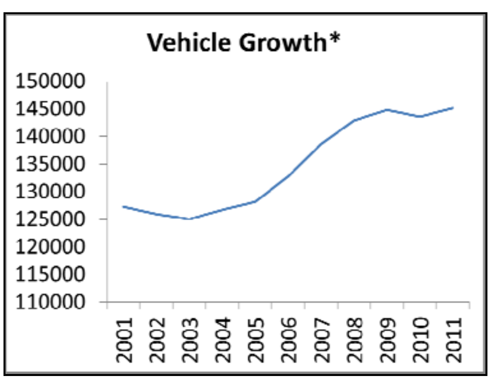
Adapted from Singapore Land Transport Authority “Statistics in Brief 2012” and “Statistics in Brief 2013”.

However, vehicle growth is not a guarantee that truckloads are fully utilized. As reported by van de Klundert and Otten (2011), in Europe, truck utilization average is below 50%, while in the US, the empty line haul miles account for a large percentage of the 80 billion dollar wasted in transportation sector, which is more than 10% of the sector’s total revenue.

An increasing number of vehicles within limited city space leads to negative effects in terms of congestion and emission. Road congestion has become one of the inconveniences of modern life that escalates travel time not only for logistics service providers but also for urban society as a whole. With increasing number of vehicles (as shown in Figure 4), the congestion level is escalating. Congestion, in turn, also increases CO_2 emission. According to Singapore National Environment Agency, Singapore emits about 38,000 kilotons of CO_2 each year, 15% of which is from transportation (Singapore National Environment Agency 2000).

2.3 Labour Use Limitation

Many industries in Singapore rely on non-skilled/semi-skilled labour to conduct their business. At the sam time the non-skilled/semi-skilled labour resource is not increasing. With an increasingly well-educated workforce that makes up the bulk of a growing population, Singapore needs to import the supplementary labour from neighboring regions, which may not be sustainable. Due to the increment of the non-skilled/semi-skilled labour demands, the unit cost of labour is also increasing (as illustrated in Figure 5).



*: for Goods and Other Vehicles

Figure 4: Vehicle Growth
Adapted from (Singapore Land Transport Authority 2012).

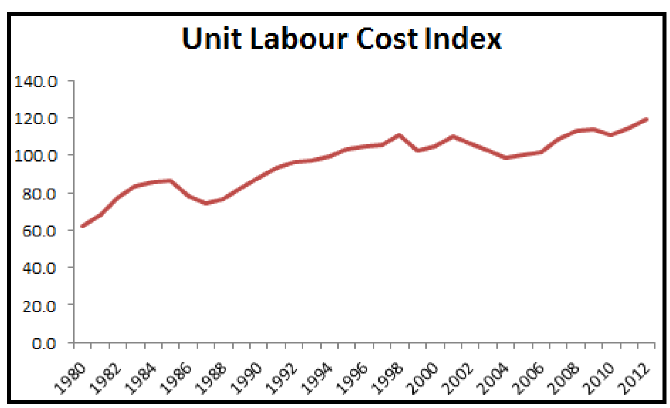


Figure 5: Unit Labour Cost in Singapore 1980-2012
Adapted from (Singapore Department of Statistics 2013c).

2.4 Externality Problem in Urban Logistics

In economics, the situation where the activity of one or more stakeholder impacts the ‘welfare’ of other stakeholders outside the market mechanism is termed an ‘externality’ (Ranaiefar and Regan, 2011). Increasing efficiencies of individual companies are achieved at the expense of the long-term sustainability of the urban logistics systems. This generates negative externalities that will end in ‘market failure’ – a situation where urban logistics fail to attain a socially acceptable optimal level, i.e. result in inefficiency and inequality of allocation of resources. A brief summary of externalities in the urban logistics transportation cost and benefit context is presented in Table 2.

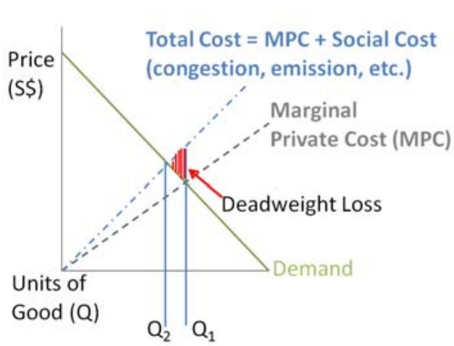
Table 2: Externalities in General urban logistics transportation cost and benefit specification

Cost	Description	E/I	V/F	M/NM
Vehicle ownership	Vehicle expenses not proportional to distance	I	F	M
Vehicle operation	User expenses proportional to distance	I	V	M
Vehicle coordination	Expenses for planning and managing vehicle fleets	I	F	M
Operating subsidies	Vehicle expense not paid by user	E	V	M
Reliability risk	The cost associated with likelihood of delay	E	V	M
Congestion	Increased delay, costs, stress	E	V	NM
Benefit	**Description**	**E/I**	**V/F**	**M/NM**
Income	As provided to firms and their employees	I	V	M
Reputation	In terms of reliability, also social responsibility	I	F	NM
Access to goods	Reliable access to a variety of goods	E	V	NM
Supply Chain Effectiveness	Last mile reliability benefits entire chains	I	F	M
E = external cost; I = internal cost; F = fixed cost; V = variable cost; M = market cost; NM =nonmarket cost				

Adapted from Ranaiefar and Regan (2011).

A graphical representation of the externality problem in freight transportation using a cost-demand graph is drawn in Figure 6. Marginal Private Cost (MPC) is the cost to a stakeholder of delivering a given product or service. Each stakeholder is trying to minimize its MPC by improving its individual efficiency which unfortunately may result in negative externalities. These negative externalities such as pollution or congestion, create industry inefficiencies (‘deadweight loss’) that shift the MPC to its true total cost: that is the sum of MPC and Social Cost.

In addition to freight transportation, the externality problem also exists in freight storage. The low-level of supply chain integration and cooperation across different stakeholders results in many companies running individual logistics operations. This not only brings about a complex transportation network overall, but also brings forth a large number of individual warehouses that normally run at less-than-capacity. The idle land in those less-than-full warehouses could have been used for other purposes, such as building public parks for the community, developing reservoirs for more secure water supply, and constructing shopping malls for more business opportunities. In consequence, this land opportunity cost adds up to the marginal private cost, leading to a higher marginal social cost to the whole society (as illustrated in Figure 7).



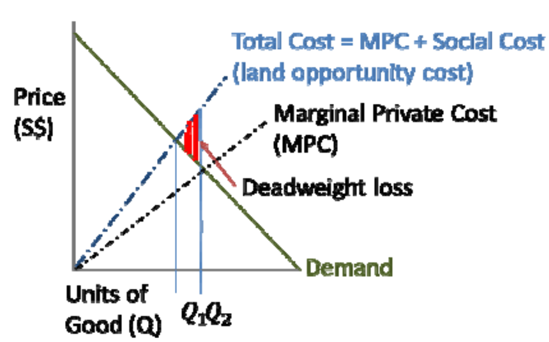


Figure 6: Externality Problem for Freight Transportation   Figure 7: Externality Problem for Freight Storage

3. Solution Concepts

Our urban logistics concept consists of two major elements: a consolidation warehouse and the synchronized last mile. A consolidation warehouse is used by collaborating companies to receive, store and distribute all industrial goods. Transportation of goods to and from ports and airports is done using fully automated underground and above ground transportation systems which not only reduce the amount of land used, but also reduce the labour requirements. To connect the consolidation warehouse with customers, the synchronized last mile concept is introduced to encourage customers, suppliers, and service providers to interact and collaborate in a fair environment through an electronic marketplace.

3.1 Consolidation Warehouse

A consolidation warehouse serves a group of interrelated companies closely located within an industrial estate. It handles the inbound flow of raw materials from ports/airports to the estate, distributes raw materials to individual companies for production, and deals with the outbound flow of finished products from the estate to ports/airports for export, or from the estate to domestic demand points via synchronized last mile services. The consolidation warehouse could be operated by a 3PL service provider. The concept is illustrated in Figure 8.

The consolidation warehouse is connected with companies in the estate via an automated goods moving system. This automated system, in the form of conveyer belt or automated guided vehicles (AGVs), ensures the smooth and fast flow of goods. An advanced warehouse management system (WMS) or an enterprise resource planning (ERP) is advantageous to manage customer orders.

To further intensify land use, the goods moving process can be performed either underground using tunnels or above ground using overhead infrastructure. Consequently, land could be saved from constructing driveways and docks in the estate area. Moreover, the high level of automation may significantly reduce labour needs.

Consolidating their storage and transportation operations into the shared warehouse, each company only needs to pay service subscription fees according to the capacity they lease.

3.2 Synchronized Last Mile

The synchronized last mile is envisioned as a holistic and comprehensive analysis tool with real-time solutions that can be readily adapted and applied with features to: (1) visualize the demands, (2) manage coordination and collaboration, (3) provide a dynamic delivery schedule, and (4) establish an interactive space for all stakeholders. Having this in mind, we, together with our contributing organizations, outline four interdependent areas of cooperative study between research institutes, university departments, government agencies and businesses. Using Singapore as a living laboratory for experimentation, the synchronized last mile is illustrated in Figure 9 (de Souza et al. 2013). An overview of each contributing area is as follows.

3.2.1 Data Harmonization and Analytics

To improve the efficiency and effectiveness of last-mile, there is a compelling need for a basic and holistic framework which integrates and harmonizes all the components in urban logistics. Based on that, urban logistics models can be intuitively visualized using a geographical visualization tool that allows stakeholders to visualize key information (such as demand) to provide (operational) insight to industry stakeholders (e.g. retailers, LSPs and authorities). The main purposes of visualization are:

1. To map demands based on user categories (such as: regions and type of goods).
2. To analyze supply chain network flows to provide a better insight and deliver opportunities to craft an efficient and responsive strategy for improvement of the overall last-mile logistics process.

Data Analytics provides companies with the ability to exploit real-time information for dynamic supply and demand coordination, management, unnecessary hidden opportunities, dash boarding key performance indicators and the synchronization. Alternatively, data analytics is employed in generating and interpreting business intelligence reports to monitor the operational status.

3.2.2 Synchronization and Multi-objective Planning

Last-mile logistics, especially in the collaboration context, considers several potential trade-offs between competing objectives, such as to meet demands and service level and to reduce both operational costs and environmental impact costs. In synchronization and multi-objective planning, these often conflicting objectives are managed using three main functions:

1. Multi-objective resource scheduling that aims to provide resources scheduling and demand allocation with regard to each stakeholder's objective.
2. Service level and contract performance management and analysis that aims to design a formalized service level contract that standardize the expectation and information sharing between stakeholders.
3. Simulation and interaction with the urban freight system that aims to model the sensitivities of dynamic elements in last-mile logistics content to provide a better understanding of their service level.

3.2.3 Eco-Friendly Collaborative Delivery

The distribution of goods can, in turn, be defined as a task of servicing a set of customers with a fleet of capacity-constrained vehicles located at single or multiple depot(s) and has been established as the Vehicle Routing Problem (VRP). The significance of solving VRP is increasingly apparent not only to the organizations involved, but also poses significant national and international implications due to the escalation of traffic congestion and air pollution experienced by many urban cities worldwide. Our objectives in eco-friendly collaborative delivery are: (1) reduce operating costs, (2) increase customer service levels, and (3) reduce or minimize traffic congestions and CO_2 emissions.

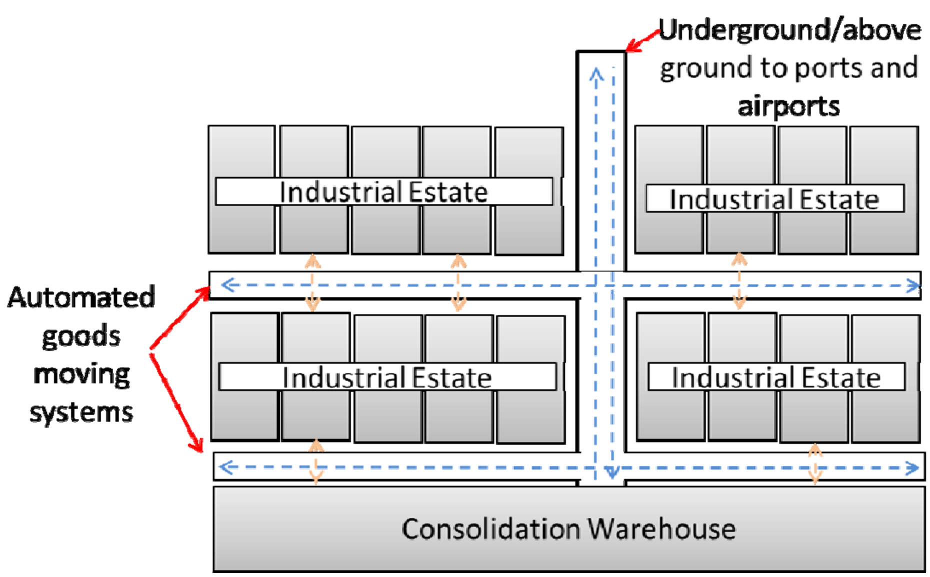


Figure 8: Consolidation Warehouse

3.2.4 Multi-Party Coordination

A multi-party coordination is meant to encourage stakeholders with varying interests to interact and share their business requirements via an electronic marketplace mechanism. The purpose of the market mechanism is to negotiate the fair allocation of tasks, cost and benefit among stakeholders to reduce negative externalities and gain maximum industry efficiency.

We propose an iterated combinatorial auction mechanism in which bid generation is performed within each agent, while a centralized auctioneer performs a price adjustment procedure. While this approach is fairly well-studied in the literature, our primary innovation is in an adaptive price adjustment procedure, utilizing variable step-size inspired by adaptive PID-control theory coupled with utility pricing inspired by classical microeconomics.

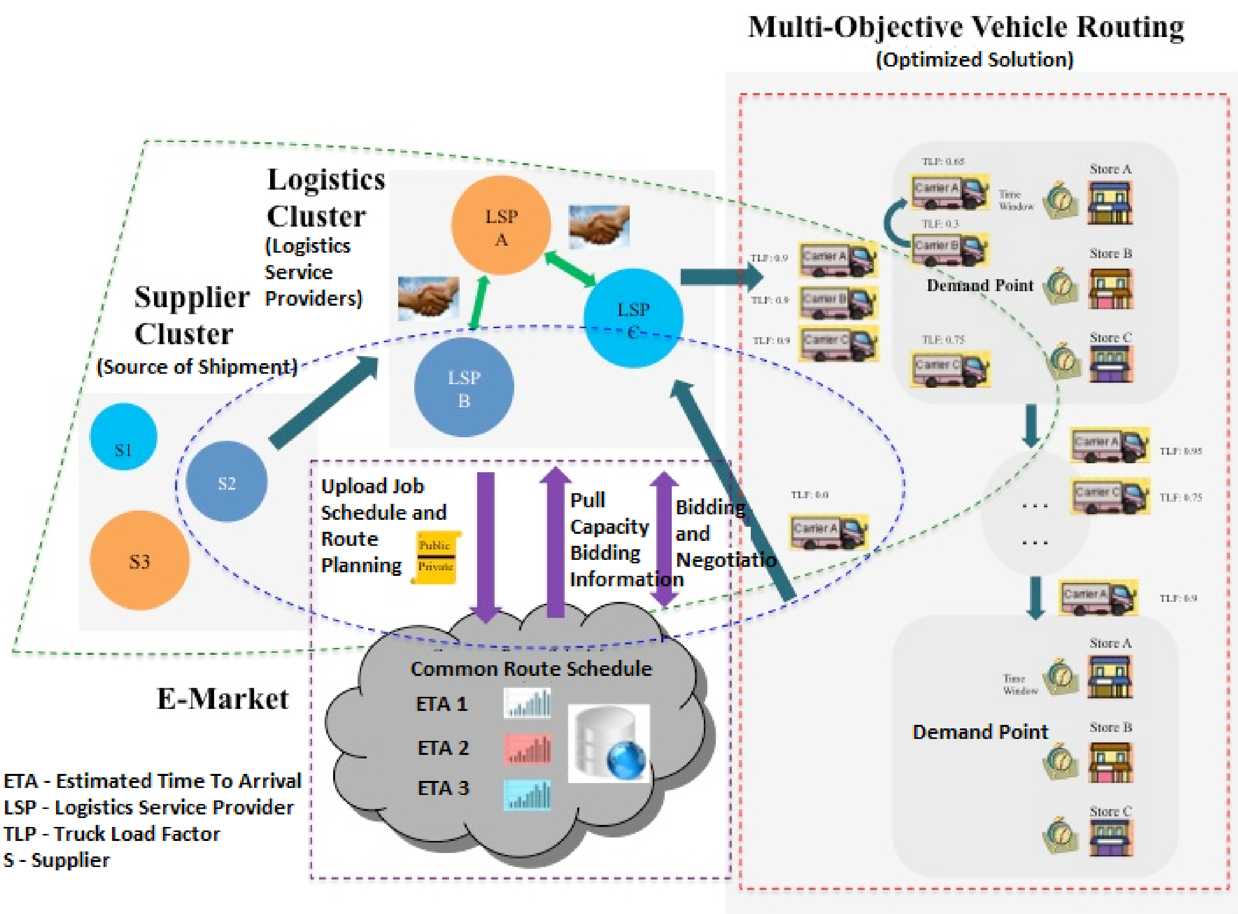


Figure 9: Collaborative Urban Logistics – Synchronizing Last Mile in de Souza et al. (2013)

4. Key Dimensions in Innovative Urban Logistics Concept

To further understand the innovative urban logistics concept, we identify the key dimensions of the concept using a methodology designed by Quak (2011) as illustrated in Figure 10. This methodology is simple yet comprehensive in highlighting the importance of each dimension, and the relationship between these dimensions. Each of the initiatives is framed on five key dimensions: main objectives, main players, the reason for players' involvement, geographical planning options and logistics characteristics.

5. Conclusion

In conclusion, this paper has outlined the scarcity resource problem - including land, transportation and labour - and innovative urban logistics concept to tackle this problem. Our concept encourages customers, suppliers, and service providers to interact and collaborate through an electronic marketplace mechanism. Using Singapore as a living laboratory for experimentation, this innovative concept and paradigm may be translated into business practice with selected pioneering companies.

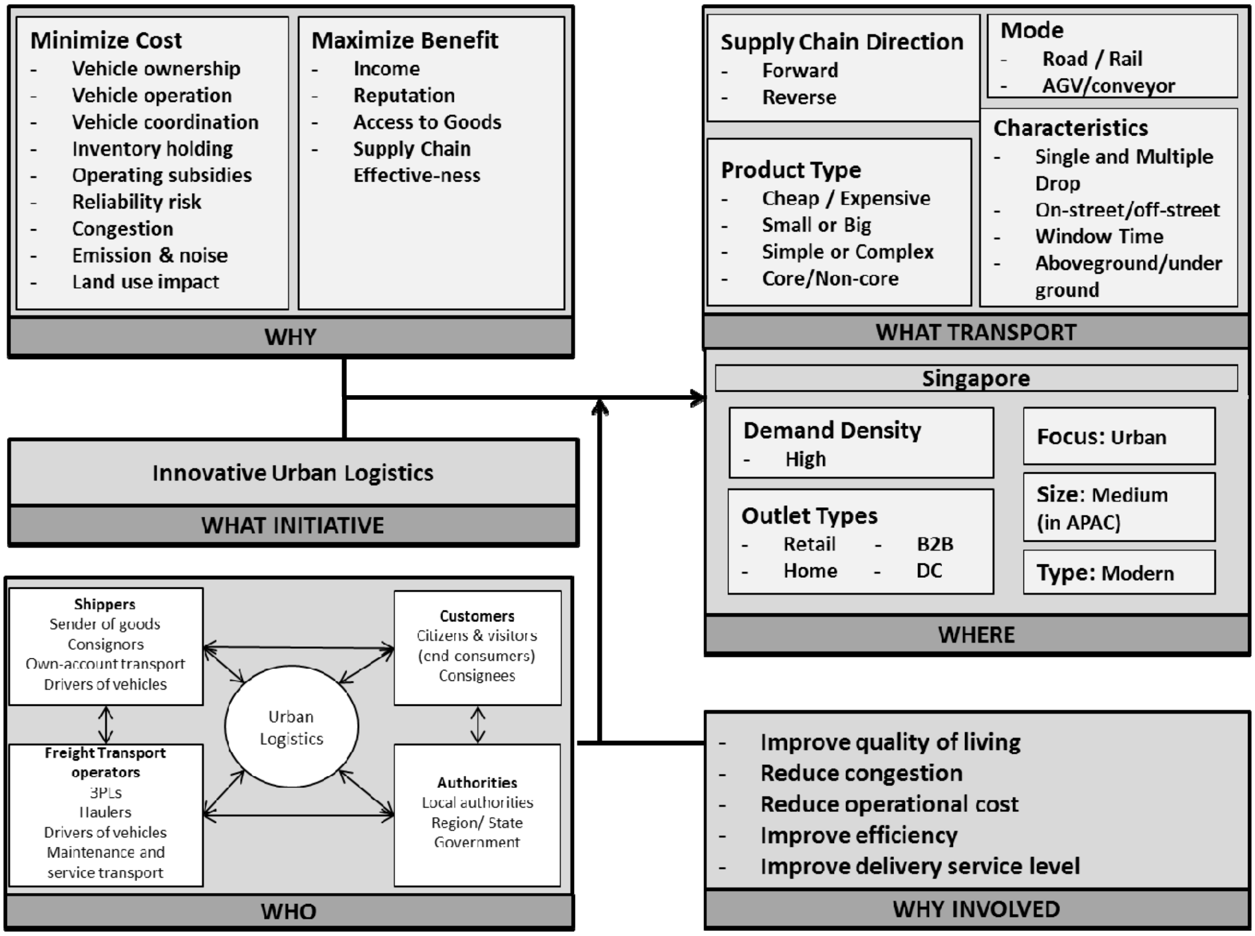


Figure 10: Key Dimensions of Innovative Urban Logistics

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