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Collaborative Urban Logistics – Synchronizing the Last Mile

A Singapore Research Perspective

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Abstract

The synchronized last mile logistics concept seeks to address, through coordinated collaboration, several challenges that hinder reliability, cost efficiency, effective resource planning, scheduling and utilization; and increasingly, sustainability objectives. Subsequently, the meeting of service level and contractual commitments are competitively impacted with any loss of efficiency. These challenges, against a backdrop of Singapore, can essentially be addressed in selected industry sectors through a better understanding of logistics structures; innovative supply chain designs and coordination of services, operations and processes coupled with concerted policies and supply chain strategies.

Keywords: Collaborative; urban; synchronisation; Singapore; last mile; coordination

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1. Introduction

The pragmatic coordination of the "Last Mile" (or Last Kilometre" or "First Mile" in the case of collections and/or returns is a little addressed but is a common logistics collection/distribution problem in built-up (urban) environments, particularly in Asia (or more specifically ASEAN or even for that matter in Singapore). The nearer to the aggregated or single demand (or origin in B2B) point the higher is the apparent loss in capacity and efficiency. This last leg of the supply chain may face significant fulfilment constraints, higher social, environmental and economic costs and increased complexity in maintaining its designed-in economies of scale and expected service levels.

Last Mile challenges may be attributed to several dynamically interacting but poorly understood causes, not least of which is that the demand points (source points in B2B or reverse supply chains) are often located in highly access-restricted areas away from larger distribution centres, spread into disparate demand or supply clusters and subject to regulated access (e.g. time windows), congestion, fleet/load use limits, and dynamic interaction amongst many competing interests and services, policies and interventions.

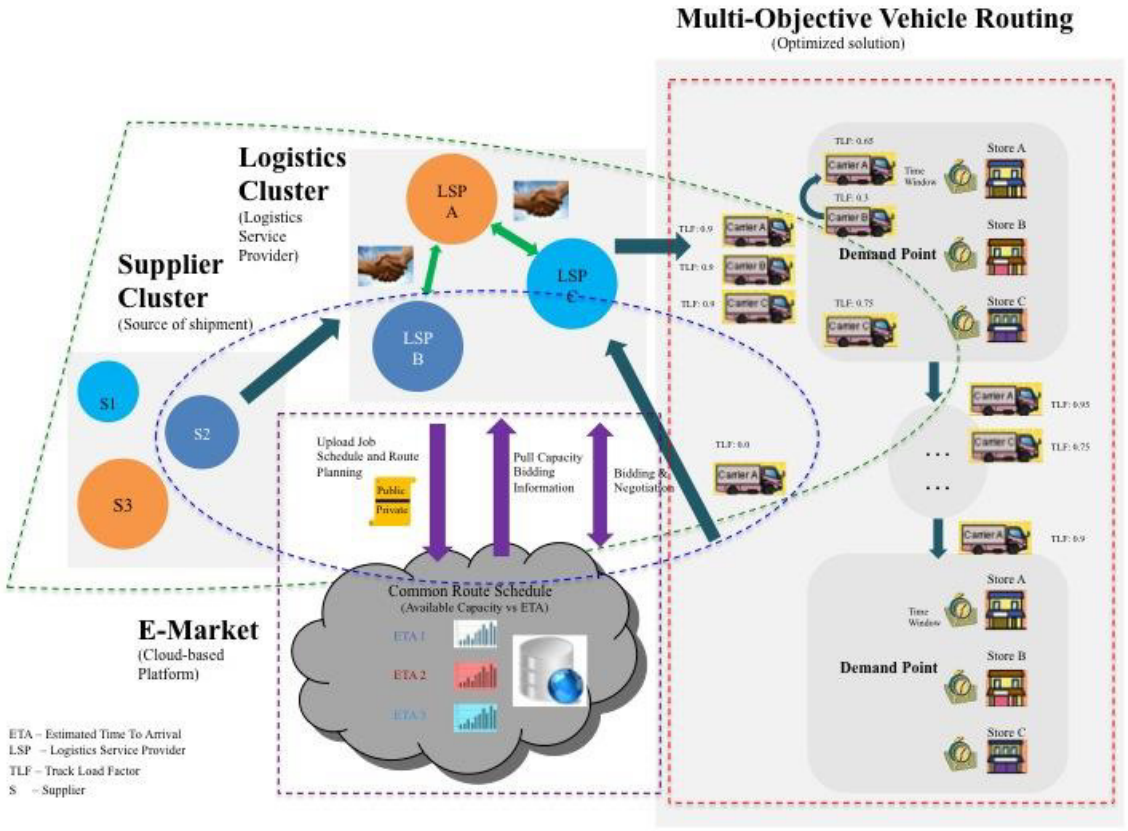

Fig. 1. Collaborative urban logistics concept.

This paper addresses industry alignment through a (simplified) synchronized last mile concept as is illustrated in Fig. 1. This is a variation (or an embellishment) of the current practice (in single company managed supply chains only). The scenario includes clusters of customers, suppliers and service providers collaborating through a suggested coordinating marketplace (that could either be virtual, company-specific or industry focused). Our work addresses the challenge in all three scenarios. It is postulated that the Logistics Service Providers or LSPs may exchange supply chain transfer requests from manufacturer/shipper or supplier clusters (between themselves), or each LSP may have its own independent supply chain request bank. Each LSP may up/down load its job schedule and route planning to the electronic market which plays an intermediary role between coordinating the clients' upstream and downstream and at the same time trade-off between multi-objectives aligned to their respective competitive interests.

The "e-market" pools the requests to, and in turn, generate feasible (efficient and sustainable) vehicle routing options for (respective) LSPs within probable time window and other constraints. The LSPs may pull capacity bidding information, for example, from the E-market and either schedule self-fulfilment or collaborate with other LSPs through load consolidation, open bidding and negotiation. Information is exchanged and protected in public/private formats for the "subscribing" actors to leverage common planning efficiencies without loss of competitive advantage. Data encryption, harmonisation and analytics methodologies are deployed for such transaction processing.

The generated final vehicle routing plan, it is anticipated, optimizes truckload factor and information for estimated time to arrival – this is depicted for a hypothetical scenario in Fig. 1. Benefits such as a higher truckload factor, lower transportation cost, and a more environmental friendly solution through less congestion may result from such total system coordination and multi-goal alignment. This, it is believed, is possible in a country like Singapore that has a long history of cutting edge technology adoption and inter/intra collaborative ventures between regulatory agencies and business – in public/private partnerships.

2. Relevance to (Urban) Singapore

Singapore as a (small closely knit) city-state is unique and has generally handled the synchronized last mile effectively but as the city-state urbanizes at a faster rate (as is common in fast growing cities in Asia) across limited space, several auxiliary influencing factors need to be considered, that include: population (demand) density and intensity; higher demands and expectations as e-commerce gains traction; environmental solutions as sustainability ranks higher in public and corporate consciousness; productivity as costs escalate and service levels become more acute; and, leveraging analytics as "big data" proliferates. All of this and time, itself, now becomes a competitive advantage and hence, companies need to seriously revisit the existing basis of their collaborative arrangements, resource allocation, delivery modes, patterns and asset utilization and ownership – through collaborative urban logistics.

Fig. 2. The Singapore skyline.

Secondly, Singapore provides a living laboratory for experimentation with innovative synchronized last mile urban concepts and paradigms that could be readily translated into business practice with selected pioneering companies. Collaboration between business, agencies and academics provides an essential backdrop for such experimentation and fine-tuning. The Urban Solutions Logistics program (on which this paper is premised) is such an initiative to explore the alignment of theories and "solutions" with practice. The lessons learnt and catalysts documented in the extant literature base can then also be applied to the greater region with multiple (tiered and possibly planned) cities (with probably clustered industries). This is a natural progression and an opportunity for significant visibility and knowledge transfer, as work in this area of the synchronized last mile, still lags in our region but is relatively prevalent elsewhere albeit with varying degrees of success. The image below shows the Singapore skyline depicting a rich vibrancy with planned urban infrastructure. This leading city itself is segmenting further via many new urban initiatives that make the research perspectives discussed in this paper on urban logistics highly relevant and very timely.

3. Key Industry Challenges

The work discussed here is as a result of discussion with manufacturers, their suppliers and logistics service providers, agencies and academics and based on extant literature review. A focus group meeting of senior industrialists also met at the end of March 2013 to discuss a whitepaper presented by the authors on the core concepts discussed in this paper. The meeting endorsed the viability of the ideas presented herein and further included many new suggestions in revisiting design blue prints of buildings especially in high traffic clusters, utilizing the public transport infrastructure and also the development of new business models and practices. Much of the latter is outside the scope of this paper but the increasing trends of emerging depth and breadth of collaboration and synchronization (not only in the last mile) were very evident and support our thesis. In summary, the relevant key challenges include:

- Exploring effective sustainable time managed solutions to freight traffic congestion in commercial zones,
- Addressing the implicit and explicit complexity of last mile logistics and the associated system level dynamics amongst cooperating agents – suppliers, service providers and customers,
- Coordinating multiple parties (agents) for overall system efficiency and cost effectiveness for the larger perceived benefits with the objective of higher productivity and greater resource utilization,
- Harnessing and harmonizing data and dynamic analytics for real-time decision support, efficient practices and fine-tuning business strategies for competitive advantage,
- Rationalizing urban freight movements in the context of emerging urban developments and planning in cities that are developing at fast paces, and
- Integrative synchronization through a public/private market for auctioning and exchange of traded information that leads to the satisfaction of multi-objectives.

4. Collaborative Logistics

Our concept of the synchronized last mile emphasizes multi-party collaboration to extend and optimize the respective parties resource portfolios and to reinforce their own market position. In this collaborative synchronized last mile scenario resources are directly connected and coordinated, and relevant data are harmonized and exchanged in order to create a common and mutually accessible plan. Manufacturers and service providers can improve operational efficiency and effectiveness and reduce costs through collaboration due to higher utilization of their less-than-truckload capacity and asset repositioning capabilities.

Corporations are exposed to a variety of challenges resulting from the future development of markets, increasing environmental requirements, new technologies, and evolution of complex supply chains, requiring the fulfilment of demanding customer promises such as tight delivery time windows in the environment of congested urban areas. The main objective of the synchronized last mile collaborative urban logistics pardigm is for shippers, manufacturers and logistics service providers to individually and/or collectively improve their economies of scale/scope in terms of value chain efficiency (total end-to-end logistics cost), overall system productivity and effectiveness (of asset utilization and customer service levels), harmonized data analysis and environmental sustainability (minimize the overall carbon footprint) without compromising their competitive advantage.

To this end, we can outline four inter-dependent areas of cooperative study between research institutes, university departments, government agencies and businesses, in Singapore, to further the concept of collaborative urban logistics. These areas are shown in Fig. 3. For ease of comparison, dotted line "boxes" in Fig. 1, demarcate respective areas of inter-related research and the same colour code of the boxes are shown in Fig. 3. Each area is led by one of the authors (the project Principal Investigators), who in turn lead a team of researchers with a track record of domain work in the area. Identified industry collaborators are envisaged to participate as a consortium - these include participants in retail, hospitality, pharmaceutical manufacturers and their respective suppliers and (competing) logistics service providers – in a proof of concept over the next two years. The expectation is usable decision support tools in one or more areas. An overview of each contributing area is now presented.

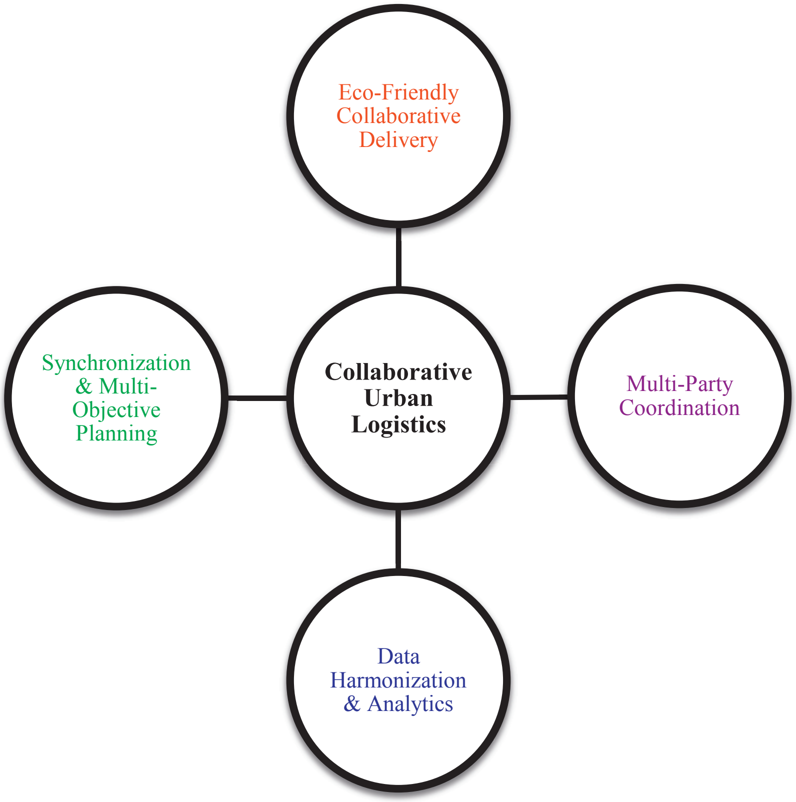

Fig. 3. Areas of study in collaborative urban logistics.

4.1. Eco-friendly collaborative delivery

Last mile delivery is defined as the last leg in a supply chain whereby the consignment is delivered to the (final) recipient. The distribution of consignments 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. This is mainly due to cost escalation with soaring fuel prices, inflation and on the flip side, downward cost pressures from customers. Therefore, it is not surprising that there is a growing demand for planning systems capable of producing sustainable, economic and efficient delivery routes.

To date, a plethora and variant of VRPs have been established and investigated, both in academia and the industry, see Fig. 4. These, however, do not adequately represent (inter company) collaborative and optimal delivery in many to many types of problems with sufficient relevance to Singapore. The Vehicle Routing Problem (VRP) solution that is a representation of the less-than-truckload pickup or delivery problem incurred by many logistics service providers (LSPs) simultaneously and at speed is sought. This VRP can be described as the problem of designing coordinated and cooperative optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to defined (real-time) constraints. VRP does represent the cornerstone of optimization for collaborative urban logistics. However, being one of the most important practical problems of operation research, VRP is considered as one of the most difficult problems due to its complex combinatorial nature.

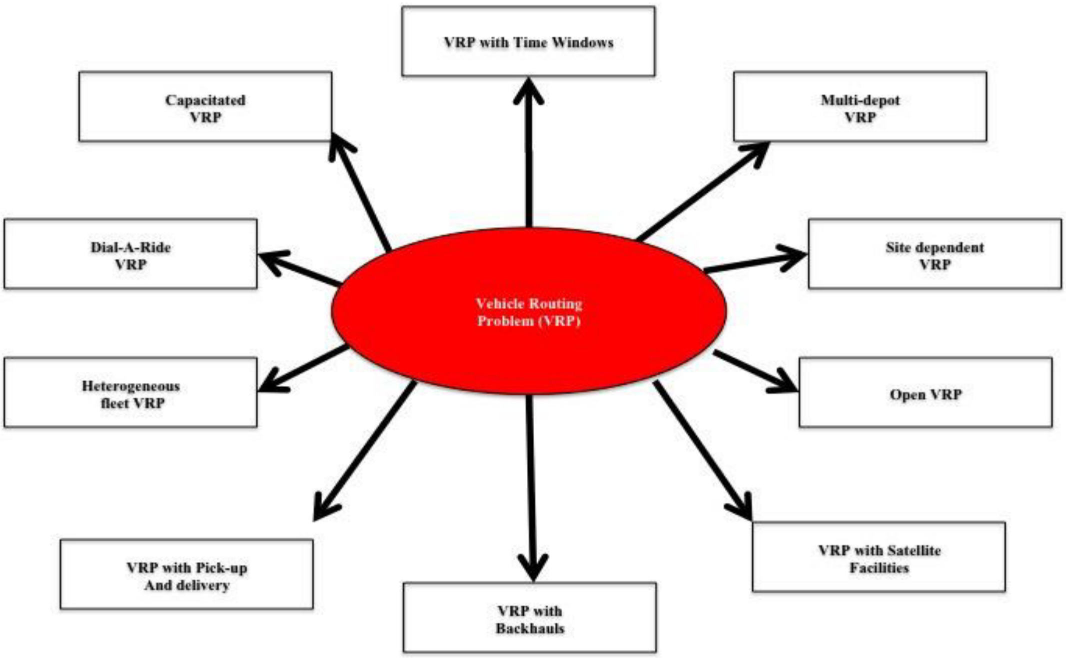

Fig. 4. Types of vehicles routing solutions.

Further, as last mile logistics is one of the most (felt) polluting legs of the entire logistics chain, sustainability and efficiency need to be addressed concurrently. Thus, conventional VRP should be extended with these additional objectives and constraints of environmental factors to improve the efficiency and reduce environmental impacts for last mile logistics in an urban environment. An emission estimation model needs to be established to convert the fuel combusted data to the estimations of the vehicle's emissions. It is the view that this should help:

- LSPs plan and optimise their logistics services provided for common routes with multiple pickup and delivery points according to the schedules, which define time windows with consideration of environmental impacts,

- An LSP to do dynamic routing and scheduling for a vehicle based on real-time traffic conditions for a common route with multiple pickup and delivery points and to repair the route in response to any change of environment/traffic conditions;, and
- The designs of new models and algorithms for Quantification of Eco-Indicators (QEI) based on multi-factors such as relationships between vehicle types, tonnage/loading, road conditions, traffic conditions, fuel consumptions and emissions, etc. – providing a measure of the environmental impact.

4.2. Multi-party coordination

Last mile delivery of goods into the city centre represents a significant proportion of traffic volume. In most cities including Singapore, last mile freight logistics is largely fragmented and hence uncoordinated. Shippers engage different logistics service providers (LSPs) and carriers for deliveries to the retailers in the cities. This model is inefficient and unproductive, resulting in:

- Low utilisation of trucks,
- Excessive truck movements,
- Higher system-wide costs, and
- Negative environmental impacts.

The concept of Consolidation Centres (CCs) has been proposed as a solution to address this challenge. Goods to be delivered are first consolidated in a CC before delivery to the individual retailers. In this case, the operator of a CC could take advantage of the consolidation in order to arrive at a more optimal delivery plan to the city centre. The benefits generated include:

- An increase in load factor,
- A decrease in the commercial vehicular traffic,
- Reduction in CO_2, NO_X and PM10 emissions, and
- An increase in overall service levels.

However traditional CCs have been successful only due to the facilitation and support of a governing authority. In a purely voluntary model (i.e. without facilitation and support) financially viable operation requires a high level of participation from the ecosystem of end receivers (retailers for the case of the retail sector) and LSPs.

To rely less on the governing authority such as the city municipality, a flexible and dynamic model focusing on collaboration across different parties on a common platform – the market - is necessary. This departs from the traditional model in that it aims to create an environment where the consolidation centre is established as a (virtual) market. Different parties and stakeholders, including shippers, LSPs, retailers, consumers, city municipalities, will all have important roles to play in determining how the last mile deliveries are coordinated and eventually executed.

Market mechanisms such as auctions have their roots in Economics, and have been widely used in allocation of scarce resources (such as the Singapore COE system). On the management front, market mechanisms have been successfully used in sourcing, procurement and transportation. 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. Against a classical integer programming model as well as conventional price adjustment schemes, our initial proposition anticipates significant run time opportunities with insignificant loss of global optimality.

This market mechanism allows multiple shippers, LSPs, carriers and customers to collaborate, to efficiently and effectively fulfil last-mile delivery in an urban city enabling these multiple parties to bid/negotiate on delivery jobs and to coordinate timings of deliveries while respecting their individual constraints and the statutory requirements of the city authorities. In this way, we minimize the logistics footprint. Thus, a well-designed market to facilitate the auction mechanism, integrated with the other areas, ensures that these different criteria are appropriately taken into consideration, leading eventually to the different parties coordinating together in a fair manner, to achieve system-wide optimality.

4.3. Data harmonization & analytics

To improve the efficiency and effectiveness of last-mile logistics, there is a compelling need for a basic and holistic framework that integrates and clearly organizes all the related roles, components and factors – this also integrates all the other areas. Based on such a framework, last-mile urban logistics models can be intuitively visualised, the performance of each cluster can be analysed, the overall effectiveness can be evaluated, optimizations and improvements can be targeted, and resources and information can be shared among the different actors in the ecosystem.

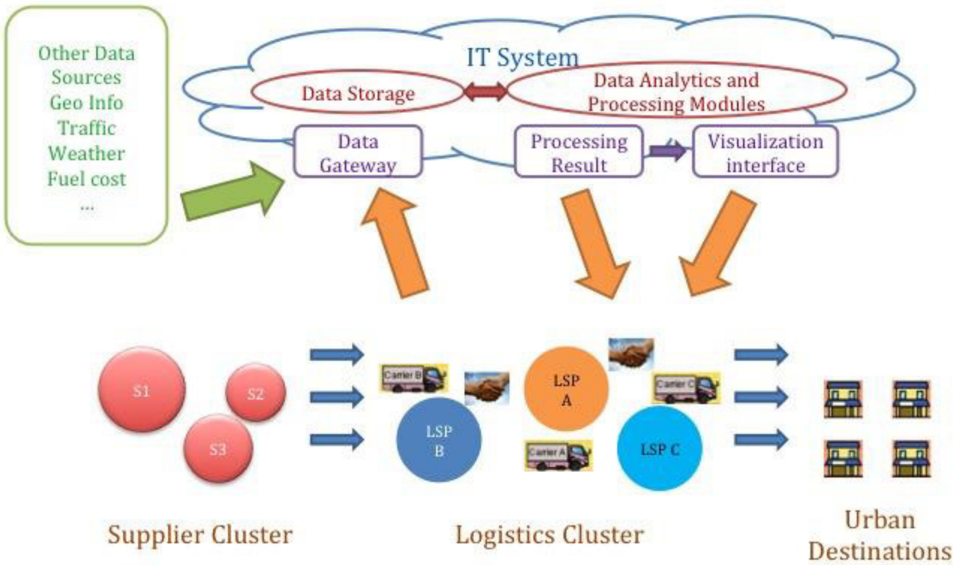

Fig. 5. Information Framework.

This representative framework for last-mile urban logistics, should be simple enough for common understanding among different industries and stakeholders but flexible enough to be carved out for a specific party. Furthermore, based on the understanding of this relationship among different last-mile logistics components in the framework, a data-centric system is necessary beyond that which collects, harmonizes and analyses data from those components and offers essential functions such as visualization, analytics and transaction generation.

The parallel and rapid development of info-communications and computer science technologies has brought forth data analytics at the enterprise and supply chain levels. This business analytics has captured attention with a value placed on "learning from data". The ability to exploit real-time information for dynamic supply and demand coordination, management and synchronisation is critical for the overall effectiveness of collaborative logistics. Application of efficient data mining techniques on historical data, needs to consider dynamic real-time data from different aspects, e.g., changing seasons, traffic conditions, etc., and holistically come out with prediction and analysis models for the synchronised last mile, leveraging on integrating, maintaining and analysing static and dynamic data from different sources, e.g., past purchase orders, historical delivery activities, current customer demands, current season, real-time traffic conditions, etc., to provide interfaces and decision support modules to Logistics Service Providers allowing them predictive capabilities and decision support for last-mile logistics. It is, thus necessary to include:

- A framework for last-mile urban logistics to analyse the efficiency and effectiveness of the system by framing into the Asian context last-mile logistics models,
- Visualization of the last-mile urban logistics scenario through "geographical situational analysis" as a prelude to deeper analysis, insights and generating key performance criteria,
- Capturing of historical and real-time data from heterogeneous data sources then providing a uniform interface over which urban logistics' end users may access these multiple autonomous and heterogeneous data sources hence eliminating data uncertainty and ambiguity, and
- Holistic analysis of both historical and real-time data from heterogeneous sources using efficient and reliable data analytics algorithms.

4.4. Synchronization through multi-objective planning

Synchronizing last mile logistics for suppliers, logistics service providers, shippers, and urban consumers is important for Singapore, where the aforementioned population density is high, and congestion and environmental concerns are a problem. What is missing, in the extant literature is the recognition of multi-objectives, multi-criteria, complex constraints, integrating resource scheduling with shared service contracts, and involving congestion in an urban context as the new norm for concerted urban freight delivery.

A second issue concerns the ability to efficiently compute large-scale multi-objective resource allocation problems under uncertainty. The last mile decision space includes multi-objective optimization, last mile delivery, urban logistics, competitive resource allocation, less than truckload factors and full truckload shipping, backhaul trucking, packing and unpacking optimisation and of course, sustainability.

Collaborative Urban Logistics also must necessarily focus on service level achievements and contract performance analysis. Information sharing and service contract design help to enhance collaboration and coordination. However, it is also a perceived vulnerability to share business intelligence (analytics) that may compromise competitive advantage. Service contracts have been proven to be an effective tool to motivate logistics service providers (LSPs) to enhance their service quality through selecting a proper benefit-allotting ratio. To better serve the purpose of a collaborative logistics service system for urban level delivery, a framework to share information and a guideline for the service contract, itself is required to ensure effective coordination between customers and suppliers.

An understanding of system level interaction (dynamics) is also essential to the success of such collaboration initiatives, particularly to address the complexities specific to Singapore. The system dynamics approach addresses system-level problems and considers the nonlinear interactions among the already complex related sub-systems in Singapore. A system dynamics model allows for the many factors that contribute to traffic congestion to be identified and simulated. This is particularly valuable in practice, as the stakeholders of the last mile have to be active participants in understanding and managing congestion better. Further, the interactional relationship among the various variables on the one hand can be analysed quickly and visually, and then the most relevant factors (sub-systems) are determined to provide richer insights for better decision making, taking into account the impact of the causal loops in a temporal sense. This helps to reinforce the "what-if" scenario analysis with easy to use parametric levers such that:

- LSPs may adopt multi-objective planning mechanisms to improve efficiency in urban freight delivery,

- Suppliers, end customers and LSPs have better visibility of the delivery performance of the contract, and
- A deeper understanding leads to more robust strategies for last mile synchronization that could improve the delivery process efficiency while reducing cost and in managing the inherent trade-offs in a structured manner.

5. Conclusion

In conclusion, this paper has outlined key areas of collaborative urban logistics for synchronisation of the last mile problem. However, in summary, it can be stated that particular problem statements addressed are:

- How do companies face up to the challenges and respond with innovative solutions for freight planning and scheduling for last mile logistics in urban environments? Specifically, how should commercial traffic servicing retailers and other business users at downtown locations be optimised to increase the quality of urban life? How could the amount of heavy goods commercial delivery vehicles be managed to reduce congestion and improve air quality?
- Is there a market mechanism that allows multiple shippers, LSPs, carriers and customers to collaborate across a platform to bid/negotiate on delivery jobs and coordinate timings of deliveries while respecting their individual constraints and the statutory requirements of the city authorities?
- Is good resource scheduling under multiple objectives and complex constraints a possibility? How could contracts be crafted to increase cooperation among vendors and service providers, and how is it best to analyse service contract performance? How is it best to simulate and understand issues in urban congestion through system dynamics studies?
- Last-mile urban logistics has many structures and serves varied sectors. Is there a framework that best represents these in a comprehensive manner? Can such problems be visualised easily with geographical situational analysis based on available data? Can a unified view be presented of (real time) data residing at different sources in an unambiguous manner? Can this be exploited for dynamic supply-demand forecasts that are critical for the synchronized last mile?

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Many authors have contributed ideas to this paper and are co-investigators in the teams led by the area Principal Investigator co-authors.

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There is a great body of literature in the field of urban (city) logistics that can be drawn upon to support the ideas in the paper, however space does not permit us, nor is it our intent to list the body of works here. We do, however, wish to draw attention to some of the key works that have somewhat influenced our thinking. These include:

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