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Developing A Strategic Framework to Build Future Last Mile Delivery Scenarios: A Scenario Thinking Approach

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ABSTRACT

Last mile delivery (LMD) logistics research has drawn attention due to increased urban compactness and environmental concerns arising from freight traffic congestion. This has affected the cost-effectiveness and on-time delivery of urban freight. This study aims to develop a strategic framework to formulate future LMD scenarios based on transport and urban planning constraints using a scenario thinking approach. A scenario thinking stakeholder workshop was conducted to collect data on last mile delivery constraints in Metropolitan Melbourne. The research develops five abridge scenario thinking stages that researchers can adopt in scenario thinking methodology. Using brainstorming and storytelling of scenario thinking approach, participants identified 34 transportation and planning constraints clustered into six urban built-environment dimensions that formed the basis of the development of LMD future scenarios. The six clustered dimensions include Freight Infrastructure, Infrastructure Supply, Land use Intensity, Infrastructure Sharing, Intersection Controls and Human Behaviour. Infrastructure Supply and Land use Intensity were found to represent higher uncertainty and higher impact on city logistics provisions. The proposed regulatory-informed and efficiency-responsive strategies are the key to manage LMD. These strategies will help city logistics providers and planners in development of operational plans in making investment decision on LMD challenges.

Keywords: *city logistics, last mile delivery, scenario thinking, urban freight*

1. INTRODUCTION

The last leg of supply chain process, referred as ‘Last Mile Delivery (LMD), has become highly susceptible to supply chain disruptions and demand uncertainty. Growing pressure for urban compactness and burgeoning demand for e-commerce in large urban agglomerations have made LMD more complex, inefficient, costly, and labour-intensive (Ewedairo, Chhetri, & Jie, 2018; Lemardelé, Estrada, Pagès, & Bachofner, 2021; Perboli & Rosano, 2019). As the demand for LMD is expected to grow by 78% over the next decade (Rode, Heeckt, Huerta Melchor, Flynn, & Liebenau, 2021), the evolving urban development and planning on city compactness model, increased dwelling density in Transit-Oriented Development (TOD) nodes and vertical urban growth continues to shape the future of LMD (Huang, Lieske, & Liu, 2022; Limb, Grodach, Mayere, & Donehue, 2020). During the recent COVID-19 pandemic, e-retailers and parcel logistics operators were compelled to adopt a variety of delivery models to enhance operational efficiency of last mile distribution (Winkenbach & Janjevic, 2018) to maintain financial viability and short-term business sustainability. Yet, the cost-effectiveness and operational efficiency of LMD logistics have remained challenging to cope with the growing global trade volatility with increased restructuring of cities. To retain cost-effectiveness and on-time delivery of urban freight, future LMD logistics needs further investigation, given the evolving uncertainties and complexities associated with the creation of compact cities

(Huang *et al.*, 2022; Randolph, 2006).

The provision of LMD logistics is not only an operational problem but also a policy challenge. The growing built and regulatory environment controls to contain and manage urban growth and freight traffic continues to impact cost-effectiveness of LMD (Chhetri, Han, Chandra, & Corcoran, 2013; Huang *et al.*, 2022; Limb *et al.*, 2020). Controlling the land use also increases the city compactness in strategic nodes/hubs, and is more likely to deter the movement of urban freight around TOD nodes and thus create further challenges to LMD (Cardenas *et al.*, 2017; Ewedairo *et al.*, 2018; Morris, Kornhauser & Kay, 1999). Aized and Srai (2014) consider the LMD as the final step in business to customer (B2C) logistics where delivery efficiency is viewed as playing a critical role in supply chain performance (cited in Amellal, *et al.*, 2023). Mangiaracina *et al.* (2019) reviewed literature to explore innovative solutions for higher LMD efficiency in B2C context where they identified some factors (failed deliveries, customer density and the degree of automation) affecting the LMD cost. Balancing the aspirational goals of the compact city model and LMD challenges needs stakeholder engagement to help generate potential solutions to plausible future LMD scenarios in B2B context. Engaging and brainstorming is unique to a scenario thinking approach to formulate the likely outcomes under different sets of future scenarios.

There have been many attempts to identify challenges and predict the future of LMD in the extant literature. For example, Peppel, Ringbeck, and Spinler (2022) utilised Dephi-based approach to project future consumer behaviour, delivery technologies, delivery services, and regulation in last mile. These authors reported the certainty about the future use of delivery technologies and changing consumer preferences, but they were uncertain about future design of delivery services. These challenges have been further addressed to some extent in extant literature (Allen, Browne, & Cherrett, 2012; Crainic, Gendreau, & Potvin, 2009; Ehmke, 2012; Fikar, Hirsch, & Nolz, 2018), but mostly focussing on operational and management aspects of LMD. Hayel, Quadri, Jiménez, and Brotcorne (2016) used optimisation model for the LMD services in which consumers played as competitors for the same supplier. Wang, Zhang, Liu, Shen, and Lee (2016) propose a large-scale mobile crowd-tasking model to perform LMD services for the mobile consumers. Frehe, Mehmann, and Teuteberg (2017) evaluated the concept of crowd sourcing logistics model for the end users. Ewedairo *et al.* (2018) presented LMD as a geographic phenomenon which involves spatial distribution of goods to retailers largely via road networks within the urban context.

Despite the growing literature on LMD, the complex relationships, interactions, and interdependencies between the constraints of the urban environment with last mile logistics and the way they shape the future of LMD services in large metropolitan cities are yet to be empirically investigated and needs further probing. In other words, the identification of the urban constraints through scenario thinking story telling methodology and development of a matrix-based strategic framework that incorporates regulatory-informed and efficiency-responsive operational strategies to manage the LMD have not been considered in extant literature. One way to understand the uncertainty of the future is to build scenarios based on a plausibility-based approach (Goodwin & Wright, 2014) to create sets of distinct LMD future outcomes based on the built and regulatory environment controls. This study therefore aims to formulate the future LMD using the scenario thinking methods based on transport infrastructure and planning (urban) constraints of the built and regulatory environment and proposes a strategic framework to mitigate the likely LMD challenges. While the strategies might not be applicable in developing economy, the metropolitan Melbourne experience discussed in this paper can be applied to other cities of similar context.

The paper continues with literature review on last mile logistics and methods applied for building LMD scenarios. Section 3 presents the research methodology with a particular focus on scenario thinking method; whilst section 4 presents the results and analysis of the research. The strategic framework proposed to mitigate LMD challenges is presented in section 5. The conclusion in section 6 summarises the key findings, identifies the limitations as well as highlights the major contributions of this study.

2. LITERATURE REVIEW

2.1 Last Mile Delivery and Compact City

The LMD focuses on the provision that links end-users and logistics systems including freight distribution, and urban logistics process and policies (Janjevic, Knoppen, & Winkenbach, 2019). While LMD may not be a major issue in rural environment, it is often faced with various challenges within the urban built environment which is yet to be fully understood (Ballantyne, Lindholm, & Whiteing, 2013). Particularly, local authorities' policy initiative on compact city aspiration continue to hinder LMD by placing restrictions on city logistics (Anderson, 2000; Dablanc, 2007). Many of these restrictions, if not all, create impedance to LMD.

The LMD within the city can be conceptualised in a hierarchical structure (Cardenas *et al.*, 2017), consisting of macro level (city logistics); meso level (urban goods distribution), and micro level (last mile logistics). City logistics at a macro level relates to vehicle and freight flows and goods characteristics, while at the meso level, urban goods distribution focuses on how goods are distributed within urban areas (Cardenas *et al.*, 2017; Fernandez-Barcelo & Campos-Cacheda, 2012). The meso level also includes freight inflow into city (Goel, 2010), freight de-bundling and consolidation (Giampoldaki, Madas, Zeimpekis, & Vlachopoulou, 2021), urban freight transport (Ewedairo *et al.*, 2018) and the impact of freight on traffic flows and urban liveability (Crainic *et al.*, 2009). LMD occurs at the micro level and is the last leg of urban freight, linking distribution networks with end consumers (Cardenas *et al.*, 2017) including the delivery via the road network. It is at this level that the urban planning policies (i.e., policy on built environment and transport infrastructure) greatly impact the operational efficiency of LMD (Cortes & Suzuki, 2022). Freight transport efficiency in relation to LMD refers to the ability to deliver goods to end users without wasting materials, time, or energy. Driving efficiency, delivery reliability, energy efficiency and service efficiency are the four dimension within it (Fu & Jenelius, 2018).

LMD appears to be the most inefficient and costly part of supply chain (Aized & Srai, 2014; Giuliano, O'Brien, Dablanc, & Holliday, 2013), because of the de-bundling of the goods into smaller deliveries and distribution to many destinations through complex scheduling, storing and routing in a large urban setting (Cattaruzza, Absi, Feillet, & González-Feliu, 2017). One key factor that can contribute to the severity of LMD problems in urban areas is the level of impedance imposed by transportation and planning restrictions due to the changing city structure. These urban planning affects and regulates the distribution of urban freight (Ewedairo *et al.*, 2018).

The dynamics of the LMD will continue to change given the increased e-commerce, globalisation, technological improvements, reduction in brick and mortar space (warehousing) through e-commerce (Hübner, Wollenburg, & Holzapfel, 2016; Peppel *et al.*, 2022); the changing urban environment, implementation of city compactness (Cardenas *et al.*, 2017; Ewedairo *et al.*, 2018); as well as varying and often conflicting interest of stakeholders in respective business operations (Ballantyne *et al.*, 2013; Yannis, Golias, & Antoniou, 2006; Multaharju, 2016). While, on one hand, the end-users' delivery expectations are growing (i.e., within two hours to same day delivery) through booming e-commerce (Allen *et al.*, 2018); on the other hand, the growing built environment and transport infrastructure requirements impede the LMD operations. This has been challenging for the logistics service providers (LSPs) to timely deliver to inner city end-users resulting in wasted transport capacity alongside multiple stops and starts (Aljohani & Thompson, 2020; Gurrala & Hariga, 2022).

The future is uncertain, and no single policy will remedy these challenges. As the urban environment changes, the LMD is likely to be changed. The transport networks are part of the continued incremental change in built environment. Planning and transport control impedance on LMD can therefore be considered in an incremental way. Fainstein (2013) view this incremental approach as a non-planning approach, based on laissez-faire premises. However, even though incrementalism may be regarded as the opposite of planning, it has gained much attention within the planning theory, as "it produces the fruits of planning in its results" (Carmon & Fainstein, 2013, p. 272). For a sustainable LMD operations (Kiba-Janiak, Marcinkowski, Jagoda, & Skowrońska, 2021), LSPs' cost-effective order fulfilment objectives must be attained while meeting the end-users' requirement.

The need to know the future of LMD in large cities to cope with the rising demand for home delivery sets the ground for the need to formulate the future scenarios of LMD. Policies on built environment, planning and transport systems drive the cost-effectiveness of LMD. The drivers within the systems are, what Ewedairo *et al.* (2018) identify as, the transport network attributes. These drivers are planning policy issues and have potential to directly/indirectly, positively/negatively affect the efficiency and effectiveness of LMD operations. These drivers include population density, proximity to activity centres, speed limit, toll payment, number of traffic lights, different planning zones, railway boom gates, tram lanes proximity, number of traffic contesting with LMD vehicles, number of intersection and availability of bicycle lanes (**Table 1**). These drivers form the basis of the LMD discussion in the scenario thinking workshop in this study.

Table 1 LMD drivers within built environment

Constraints	Impact on LMD	Key Studies
Population Density	+	Chhetri *et al.* (2013); Jenks, Kozak, and Takkanon (2008)
Proximity to Activity Centres	+	Jenks *et al.* (2008)
Speed limit	-	International Road Assessment Programme (2022)
Toll	+/-	He and Zhao (2014)
Traffic lights	+	Luo, Wang, Xiang, and Wang (2015) He and Zhao (2014)
Tram lanes	+	National Transport Commission Regulations (2022)
Planning Zones	+/-	Victoria Planning Provisions (2022)
Railway Gates	-	National Transport Commission Regulations (2022)
No of Lanes	+/-	International Road Assessment Programme (2022)
Traffic Count	+/_	International Road Assessment Programme (2022)
Intersection	+/-	Luo *et al.* (2015); He and Zhao (2014)
Bicycle lane	+/-	National Transport Commission Regulations (2022)

Source: Ewedairo et al. (2018)

2.2 Current Approaches and Methods of Building Future LMD Scenarios

Scenario is a description of possible happenings in the future given certain circumstances of events (Schwartz, 2012). It is an illustration of how the future can eventuate; hence it is the state of the future representing 'alternative plausible conditions under different assumptions' (Mahmoud *et al.*, 2009, p. 798). Scenarios, generally, allows decision-makers to anticipate coming changes and plan timely responses to help adapt for the change (Schwartz, 2012). The use of scenarios has the ability to contest orthodox thinking and challenge previously accepted norms for the future (Kahn & Wiener, 1967) with the objective of producing a small number of scenarios with plausible explanations of system factors that can be possibly different in each scenario (Mahmoud *et al.*, 2009).

Scenario thinking has variously been studied from qualitative, quantitative, and mixed method perspectives (Chermack *et al.*, 2001). Qualitative scenario method is rooted in futurology resulting from judgement and intuition (Khan and Weiner, 1967), while quantitative method utilises mathematical modelling and algorithms using computer. The third method blends the judgement and intuition in qualitative approach and algorithms/modelling in quantitative approach to establish a blend of the two methods (i.e., mixed methods).

There are three basic schools of thought which were identified in Scenario Thinking research (Schnaars 1987; Postma & Liebl 2005; Ramirez *et al.*, 2015). They are intuitive logic, the probability modified trend and the French-Origin La Prospective (Boyonas *et al.*, 2020). These approaches and methods can be associated with the Delphi method, Horizon Scanning, Trend Impact Analysis and Scenario Thinking. **Table 2** provides a matrix of these approaches and their suitability of techniques in future LMD.

Table 2 A comparison of different scenario methods and techniques

	Quantitative	Qualitative	Normative	Exploratory	Engagement	Spotting Unexpected
Scenario Thinking Method	X	X	X	X	X	X
Delphi Method		X	X	X	X	X
Horizon Scanning	X			X		X
Trend Analysis	X	X		X		

LMD provides the context which necessitates innovative foresight to unfold continuous urban changes, higher uncertainty of physical environment and countless intricacies of logistics operations drawn through internal and external business processes (Wack, 1985). In this study, a Scenario Thinking (ST) approach is adopted for three key reasons. First, the ST helps understand and analyse problems that are apparently intractable, especially, where there are ‘critical uncertainties’ that span a range of subject areas or boundaries across functions (Wright & Cairns, 2011). Second, the ST is well suited to generate flexible long-term plans (Boyonas *et al.*, 2020), especially in considering the uncertainty that clouds LMD in an emerging compact city. Third, this study is not intending to seek an answer or predict into the future (Miller, 2007). Thus ST approach is more appropriate to appraise the current situation and provide a better understanding of the future uncertainty, ambiguity and complex interplay (Crainic & Montreuil, 2016). Given the complexity of the built environment, planning and transport controls, uncertain LMD future, a ST approach will help develop a collaborative and co-design-led strategic framework to help urban freight to be delivered faster, efficiently and more effectively with reduced environmental impact (Fu & Jenelius, 2018; Kiba-Janiak *et al.*, 2021).

3. RESEARCH METHODOLOGY

3.1 Sampling and Process of Data Collection

A scenario thinking workshop was conducted to identify, cluster, and build last mile scenarios including stakeholder analysis with 14 participants. The purposive sampling technique helped select these participants for the workshop. The use of smaller number of participants offers opportunity to discuss and debate the focal issue in depth (Saunders & Townsend, 2016). Participants are drawn from local council, state government agency and last mile operators including retailers.

The participants were sourced to represent three major stakeholders identified in the LMD (Ehmke, 2012; Russo & Comi, 2011). These include administrators, operators, and end-users. The administrators include the officials from state government agency (VicRoads) and local government council officers within the transport departments in the Metropolitan Melbourne. Drivers and logistics managers represent the operators while the retailers represent the end-users. The research focuses on business to business (B2B) LMD. Participants were selected based on their understanding of the issue of LMD and have been involved in LMD for the past five years either as a transport/strategic planner, driver, logistic manager, or retailer.

3.2 Research Design

The Scenario Thinking workshop, through intuitive reasoning, can generate and cluster the constraints into dimensions of future LMD scenarios. The future scenarios are based on a generally accepted ten-year planning horizon (Bradfield, Wright, Burt, Cairns, & Van Der Heijden, 2005). A stakeholder analysis was also carried out based on the power and interest of LMD stakeholders who could influence changes (Mendelow, 1981).

A five-stage procedure is followed in this scenario thinking workshop. This is a balanced approach that commonly uses three steps or eight steps approach (Thord 1993; Miller 2007; Wright & Cairns 2011). The three steps approach (Thord, 1993 and Miller 2007) limits the opportunity for important discussion, for example, stakeholders’ analysis; while the eight steps approach (Wright & Cairns, 2011) duplicates some steps. **Figure 1** shows the process adopted to derive the five-stage approach followed in the workshop.

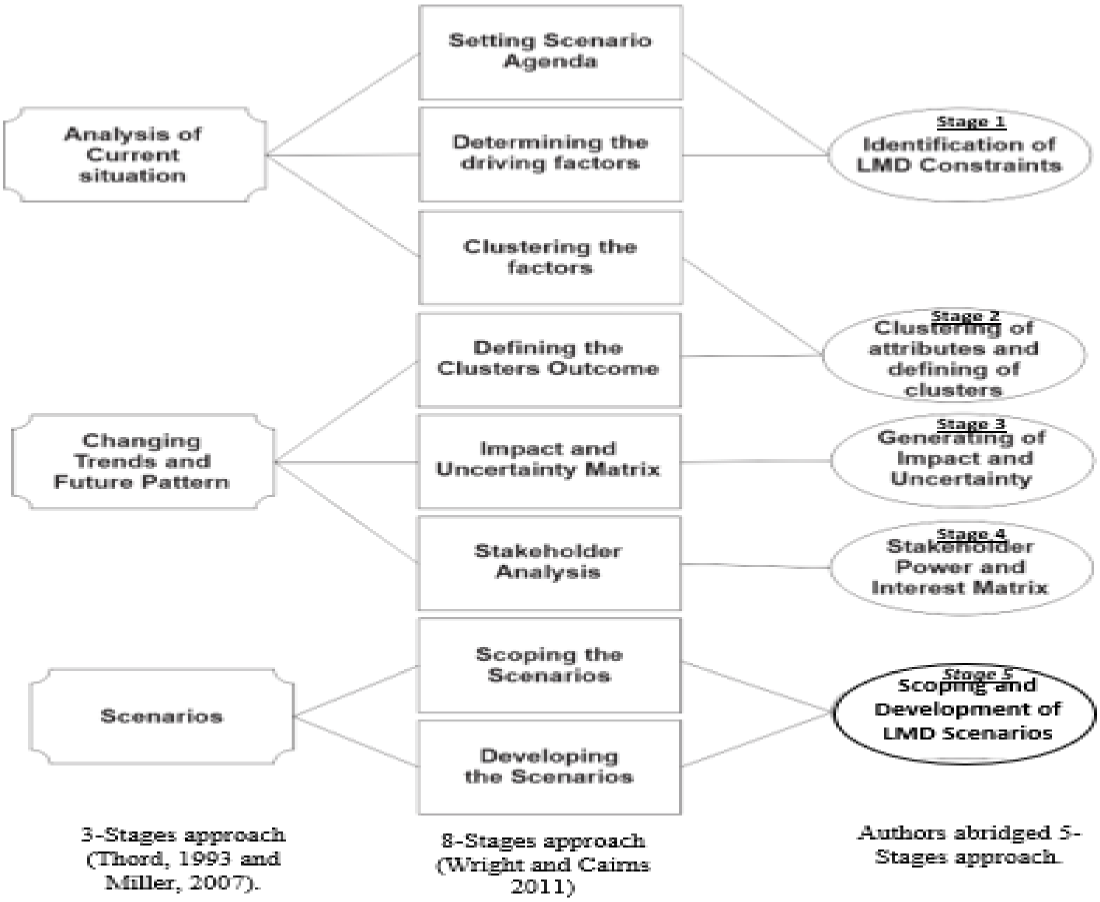

Figure 1 5-Stage approach (developed by authors)

Figure 2 shows these five stages with the integration of the first principle of the Theory of Constraints on what to change, what to change to, and how to cause the change (Goldratt, 1990; Rahman, 1998). Through the scenario thinking process, Stages 1-3, that is, identification of LMD constraints; clustering of the constraints and definition of the clusters; and generation of impact and level of uncertainty represent 'what to change' in the logistics paradigm. These constraints resulting from the built urban systems and environment cause impedances to LMD. The availability and non-availability of these attributes need change for efficient LMD. For instance, railway boom gates as a constraint need to be removed (i.e., what to change).

The realm of 'what to change to' in the logistics paradigm is derived through the Stakeholder Power and Interest Matrix analysis (Stage 4) and Scoping and Development of LMD scenarios in stage 5. Hence the discussion is on the development of the strategies to change to an efficient LMD within the urban system. Stakeholders has the power to control 'what to cause change', through implementation of these strategies The analysis of Stakeholder Power and Interest assist in determining "how to cause change".

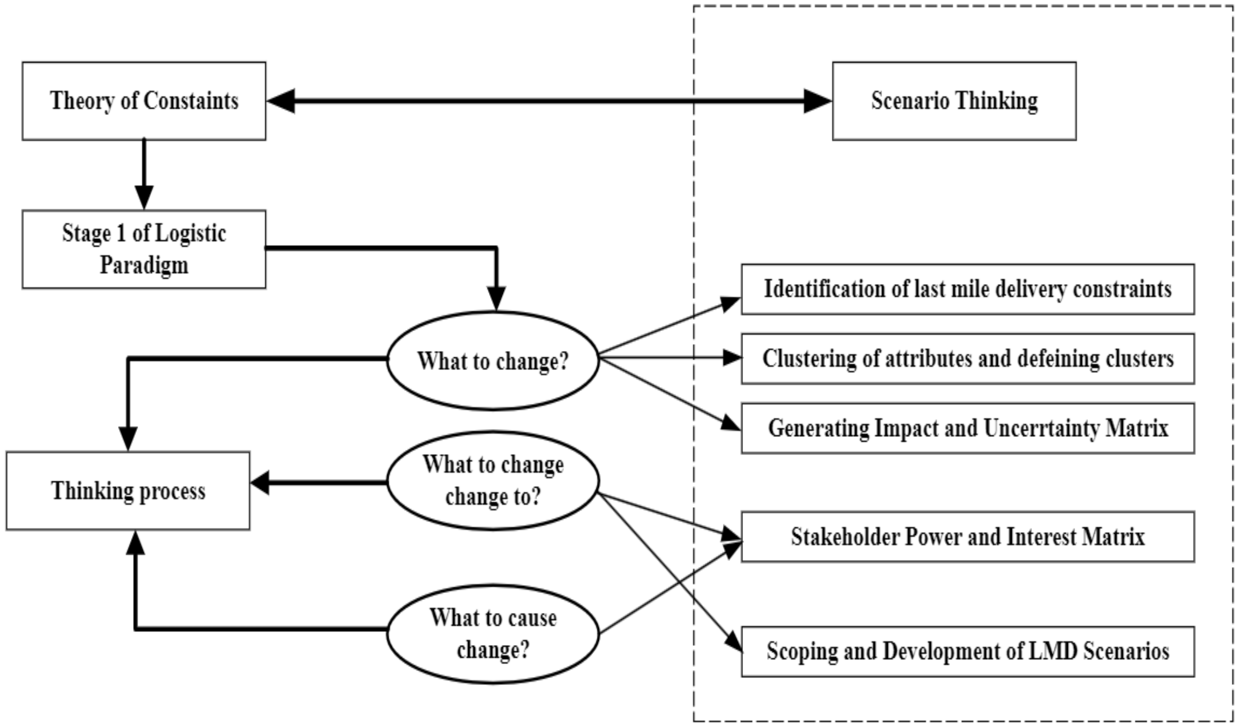

Figure 2 Integration of principles of theory of constraints and scenario thinking

For instance, in Metropolitan Melbourne, railway boom gates (what to change) as a constraint are being removed (what to change to) by the Victorian Government stakeholders with power to carry out such removal (what to cause change).

Each one, as represented in scenario thinking stages, is discussed in the next section.

4. RESULTS AND ANALYSIS

The section presents the results and analysis of the five Scenario Thinking stages followed in the workshop.

4.1 Stage 1: Identification of LMD Constraints

Participants identified 34 constraints (**Table 3**) perceived as built environment, planning and transportation systems constraints that impede LMD within Metropolitan Melbourne. The identified constraints reflect the diversity of views of participants and reveal how important the constraints are to each of the participants.

Table 3 List of identified constraints by participants

1. Loading and unloading area.	18. Road width
2. Number of available loading and unloading area.	19. Number of lanes
3. Parking restrictions	20. Abrupt change in number of lanes
4. Surrounding area and vehicle ownership	21. Proximity to freeway interchange
5. Traffic counts	22. Distance from freight network
6. Population density	23. Location of adjacent arterial road
7. Year of land subdivision	24. Road network design and alignment (road geometry)
8. Zoning	25. Road hierarchy
9. Size of shopping centres	26. Presence of toll
10. Number of shops (traffic generation and parking spaces)	27. Presence of railway boom gate
11. Activity centres	28. Traffic lights
12. Intersection constraint	29. Road design afterthought
13. Speed limit	30. Bicycle lanes
14. Road network capacity	31. Trams
15. Change in road hierarchy and change in no. of lanes	32. Proximity to other transport modes (Railway, Tram)
16. Road closure.	33. Lack of drivers understating of road merge
17. Speed limit and change in speed limit	34. Road wok restrictions when there is no road works

For example, intersection constraints (12); road toll payment identified by the drivers (26); lack of drivers' knowledge on how to merge (33); and roadwork restrictions when there is no road works (34) are not considered as significant impedance by the administrators and the retailers. Specifically, drivers are frustrated when traffic restrictions are still on the road post-construction stage. While this is not likely to be applicable to large operators, small scale operators identified it as a major impedance and drivers tend to avoid toll as much as possible given the high cost of it.

On the other hand, participants representing the administrators identified few other LMD constraints such as surrounding area and vehicle ownership rate; dwelling density; the year of land subdivision; change in road hierarchy and change in number of lanes; proximity to freeway interchange; and distance from freight network.

4.2 Stage 2: Clustering of Attributes and Defining the Clusters

The identified constraints are clustered through a group process of action discussion and consensus building. Clustering of LMD identifies a six higher-order dimensions from 34 built environment, planning and transport systems. Constraints are clustered by ensuring coherence within each cluster. Constraints in each cluster can have either a positive or negative effect on LMD. Hence constraints can aid or impede the LMD. For example, lower speed limits hinder (negative) the movement of freight vehicles, while higher speed limits reduce lead time (positive) by expediting vehicle movement.

4.2.1 Freight Infrastructure

The constraints clustered into the Freight Infrastructure dimension relates to the basic physical infrastructure and facilities required for provision of last mile logistics. Three constraints are clustered into this dimension. These constraints include loading and unloading areas, number of available loading and unloading areas and parking restrictions. These constraints are associated with logistics infrastructure in cities that enables pickup and drop off of goods. The loading and unloading can be on-street or off-street. Specifically, availability of loading and unloading areas will assist in quick loading and unloading turnaround, reduced lead-time and cost associated from delays. Parking restrictions on the other hand limit availability of spaces for loading and unloading of freight vehicles. Where parking restrictions are not available, it can result into illegal parking and infringement notice, which in turn adds to the cost of LMD.

Loading and unloading areas are restricted space for use by delivery vehicles and are often designated with a sign to indicate the exclusiveness for loading and unloading functions. While other vehicles can possibly use an on-street loading zone, delivery vehicles are proscribed from accessing taxi ranks and bus stops. In addition, private cars deprive the LMD vehicles opportunities to park in designated loading zones. A delivery vehicle is, therefore, deprived of a designated loading zone parked on by other vehicles. Prior to 18 January 2018, the Victoria Planning Provision prescribed the requirements of a loading area as a part of an industrial development, but it appears to be a missed opportunity for statutory provision of appropriate loading area for development.

When provided off-street loading facility, manoeuvring of vehicles in and out of the loading zone from the street is often frustrating especially if a vehicle is parked at the entry of the loading zone.

4.2.2 Land Use Intensity

Land use intensity is the magnitude to which a portion of land is being used or developed in conformity with zoning ordinances. In economic terms, the interaction between the values determined by location based on land use and rent payable on the used land determines the intensity of the land. The classical concentric model of Von Thunen (O'Kelly & Bryan, 1996) applies in the level of land use intensity and value from the city centre to the hinterland.

Eight constraints relating to urban planning and zoning on LMD are clustered into this dimension. The dimension includes surrounding area and vehicle ownership, traffic count, dwelling density, size of shopping centres, traffic generation and activity centres. This dimension is largely associated with population density and vehicle ownership as well as the status of shopping centres and their locations. Larger regional shopping centres are more likely to attract more consumers and thus require larger number of freight vehicles. The size of the shopping centres is also a function of the applicable zoning that dictates their sizes and functions.

4.2.3 Infrastructure Supply

Infrastructure supply relates to both physical and material services required by a logistics system to function properly. The adequacy or inadequacy of such Infrastructure Supply can promote or hinder the LMD. In a transportation network, the road pavement, and associated services, for instance, must be adequate to enhance the LMD due to the size and shape of freight vehicles used in LMD.

The constraints loaded on this dimension are made up of intersection constraints, speed limit and change in speed limit, road network capacity, change in road hierarchy and change in number of lanes, road closure. Others are road width, number of lanes, distance from freight network, road network design and alignment (road geometry), road hierarchy and toll. The speed limit on a road is a function of the hierarchy of such roads. While speed on arterial roads can be up to 80 – 100km/h, street and collector roads vary between 40 and 60km/h. The controls on each intersection can be signalised or un-signalised. Each form of same grade intersection whether signalised or non-signalised has varying impedance levels on movement of freight fleet. The association of intersection with road capacity, traffic lights, road hierarchy and alignment are important consideration, which participants considered as important in LMD.

Also considered important are constraints on LMD through road closure or prohibition of using some local roads even when such roads are the best connection to pick up or drop off location. Abrupt changes in the hierarchy of road and subsequent speed limit changes also restrict the use of road infrastructure by LMD vehicles.

4.2.4 Intersection Control

Where a grade separation is not available, intersection controls are often adopted to control traffic to limit conflicts and crashes within the transport network. Participants acknowledged the advantage of roundabout as a better intersection control compared to traffic lights. Three constraints are clustered into this dimension, which includes railway boom gate, traffic lights and road design afterthought. The intervals between traffic lights and associated timing along a stretch of road can have either positive or negative effect on the efficiency of LMD vehicles. Shorter timing of traffic lights and closer intervals will result in delays and loss of valuable time.

Traffic light is found to be one of the intersection controls that influence LMD. The constraint of traffic lights at an intersection astronomically increases with the number of conflict points at intersection. While traffic conflict points can be as low as six in a three-leg intersection, it increases to 24 and 120 in a four leg and five leg intersections. Delays therefore increase with the number of legs and conflicts points at intersection.

The issue with road design afterthought is associated with delays during the construction as well as the geometry and alignment resulting from such afterthought design. An introduction of a roundabout on a road as afterthought can greatly alter the road usage. Cutting out of bicycle lanes and bus lanes also reduces number of lanes on a road and can affect manoeuvring along the road segment.

4.2.5 Infrastructure Sharing

The constraints in this dimension are bicycle lanes, trams, and proximity to other transport modes (Railway/Tram). Infrastructure sharing dimension relates to other modes of transport that share the road with LMD vehicles especially when at the same grade level. For example, bicycle lanes carved out of the road as an afterthought are considered as limiting manoeuvring and slowing down the LMD vehicles. Compulsory stoppage behind trams at tram stop is recognised as a major constraint on the LMD vehicles. There are often no or limited opportunity for parking for loading and unloading on shared roads, which result in considerable walking distance for pickup or delivery.

Land transport generally includes road and rail transportation, hence sharing the road with other modes of transportation is therefore inevitable. The road is often shared with same grade rail for tram and bicycles.

4.2.6 Human Behaviour

Lack of understanding of road rules, and road work restrictions are the constraints in this dimension. The constraints in this dimension are of high importance to drivers because of the size of their vehicles and frustration experienced by drivers when other road users take advantage of low take off speed of LMD vehicles. Speeding to merge in front of LMD vehicles is acknowledged by participants as constraint which results in accidents and road rage in many occasions.

4.3 Stage 3: Generating an Impact and Uncertainty Matrix

The purpose of generating the matrix is to understand the impacts of the underlying dimensions on LMD and uncertainty associated with those impacts. Impact refers to the likely effect (i.e., high-low) of the identified dimensions on the efficiency and performance of the LMD in cities: whilst certainty is the levels of confidence on the likelihood of the outcomes.

The participants identified two-dimensional framework driven by Infrastructure Supply and Land use Intensity based on high impact on LMD and high uncertainty of the potential outcomes in the future were developed to develop the future scenarios of LMD. **Figure 3** shows the positioning of all dimensions on their respective level of certainty and impact.

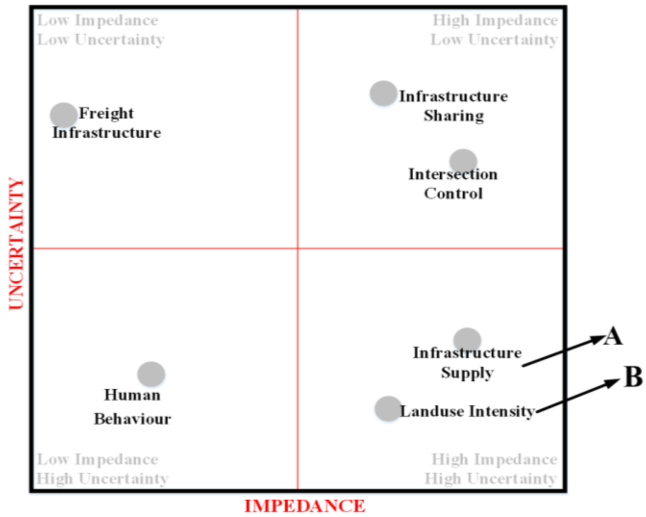

Figure 3 Impedance – uncertainty matrix (higher order factor)

Freight Infrastructure is identified to be of low impact and medium impedance and located within the Quadrant 1 of low impedance and high certainty. Two dimensions, Infrastructure Sharing and Intersection Controls are of moderately rated on impact and certainty and positioned within Quadrant 2. Human Behaviour is considered to be of low impedance and low certainty and positioned within Quadrant 3. Infrastructure Supply (A) and Land use Intensity (B) are rated to be of high impact and of high uncertainty and positioned within Quadrant 4.

The dimensions within Quadrant 4 are of high impact and high/medium uncertainty as the participants are not sure of the likely outcomes. Hence, they are of high impact of the constraints identified by the stakeholders and high/medium uncertainty of the potential outcomes. These constraints are considered by participants as independent of each other and are used to form the LMD impedance scenario dimensions. The dimensions are identified as A and B to be used further for building of future scenarios.

4.4 Stage 4: Scoping and Developing the LMD Scenarios

Stage 4 purports to scope and develop LMD scenarios using the two key dimensions (i.e., A and B) that reflect higher impact and higher uncertainty. This stage aligns with the first principle of Theory of constraint by answering the question: what to change to? Efficient delivery and reduction in cost of last mile logistics, despite the constraints of the built and regulatory environment, are the goals. This is where different scenarios are attempted. These two dimensions of Infrastructure Supply and Land use Intensity are used to portray the future of last mile logistics.

Scoping of the future outcomes for the LMD is conducted through an in-depth discussion of the two dimensions towards answering the "what if" question. What if the constraints in Land use Intensity are at the worst or at their best and Infrastructure Supply at their worst or best? A consideration of the positive and negative aspects of the constraints is the focus of the scoping and building of the scenarios. The participants identified a growing complexity of LMD that results from the compact city model and discussed the following what-if situations prior to the development of LMD scenarios.

(i) increased/decreased vehicle ownerships resulting from higher density living without increased road capacity, or use of other transportation modes like increased public transportation.
(ii) more restrictive zoning with imposition of lower speed limits in inner city suburbs.
(iii) a reduction or more loading opportunity for LMD vehicles resulting from the removal of the provision of loading and unloading provisions from the Victoria Planning Provisions (VPP).
(iv) decreased or increased speed limits; number of lanes/lane width.
(v) increased or decreased distance from freight network; and
(vi) increased or decreased or no tollway etc.

Using the two selected dimensions in building the LMD scenarios, participants considered the future of LMD over the next 10 years within Metropolitan Melbourne. A 10-year period is selected based on the planning horizon and projected urban development plans in Melbourne. While urban planning often uses a 10-year planning horizon (Bradfield *et al.*, 2005), 72% of Scenario Thinking operators have used 10-year planning horizon (Boyonas *et al.*, 2020).

The reflections by the participants are represented in terms of best/worst, best/best, worst/worst, and worst/best scenarios, which were constructed using these two dimensions The best/best outcomes describe an 'ideal world', where the dimensions favour the LMD. However, the last mile impedance issues arise by consideration of the best/worst outcomes of the dimensions. This is a scenario in which one set of positive descriptors was moderated by a set of largely negative descriptors. For example, moderating the best of infrastructure by worst land use intensity.

The four key scenarios developed are interpreted in four quadrants to provide the basis for the development of LMD scenarios on a best/worst interaction of the dimensions. The quadrants represent a set of well-defined four possible LMD outcomes in terms of best and worst of the selected dimensions as represented in each quadrant.

The four scenarios formulated in the framework are not a prediction of the future, rather, an indication of the range of possible and plausible future outcomes under certain well-conceived conditions (**Figure 4**).

4.4.1 Best/Worst Scenario

Quadrant 1 indicates an improvement in the Infrastructure Supply and a worst case for Land use Intensity that is unfavourable land use to LMD. Participants agreed that in these circumstances, there is a possibility of an efficient and cost-effective delivery as a result of the best outcomes of the larger infrastructure capacity.

The best of Infrastructure Supply conditions includes lower constraint on LMD vehicles in terms of reduced road closure, improved road alignment, increased number of lanes and reduced or no cost for using toll roads for LMD vehicles. Best of Land use Intensity includes a reduction in traffic competing with LMD vehicles, especially within inner city suburbs, commercial areas, Activity Centre Zones, and shopping precincts. On the contrary, the worst of Infrastructure Supply and Land use Intensity includes continued closure and restriction on LMD vehicles, increased toll, reduced number of lanes and more intensity land use with increased private vehicles competing with LMD vehicles within activity centres and shopping stripes.

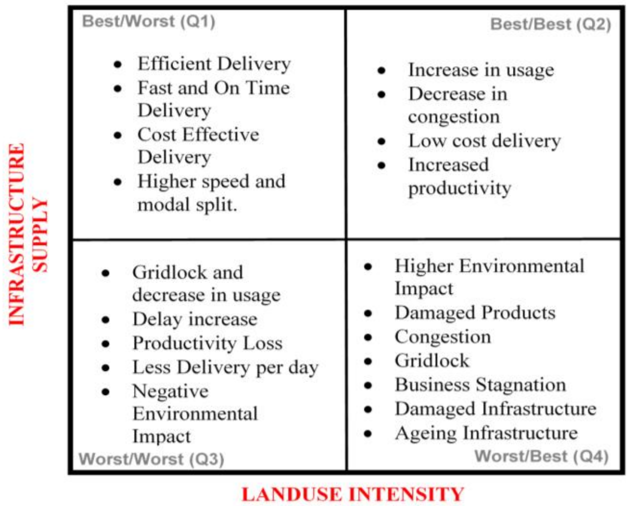

Figure 4 Scenario outcomes scoping broad descriptions of future scenarios

4.4.2 Best/Best Scenario

Quadrant 2 indicates the best of both dimensions. With this scenario, there will be more certainty of speed limits. For instance, on Melbourne roads, speed limits can be reduced from 100km/h to 60km//h or even to 40km/h within sort distance on a road segment. Increase number of lanes, minimum disruption from road closures, and increased width of lanes to conveniently accommodate LMD trucks are part of the best/best scenario. This will result into increased usage of the available infrastructure, decreased congestion due to better infrastructure, low-cost delivery resulting from lower impedance and increased productivity.

4.4.3 Worst/Worst Scenario

Quadrant 3 represents a worst/worst situation of the two dimensions. This will result in a likely collapse of LMD infrastructure and congested transport network due to increased Land use Intensity. The projected outcomes are opposite to the scenario in Quadrant 2 resulting from gridlock and decrease in usage, delay increase, increased and higher cost, productivity loss, lesser number of deliveries per day and negative environmental impacts such as poor air quality, increased greenhouse gas emissions, increased noise from LMD vehicles, public safety, and unsustainable delivery system.

4.4.4 Worst/Best Scenario

Quadrant 4 represents the best of dimension B and the worst of dimension A. Within this scenario, Infrastructure Supply will be at its worst with reduced speed limit for LMD vehicles, more road closures and reduced number of lanes including reduced lane width associated with increased traffic competing with last-mile delivery vehicles, considerable increase in dwelling and population density within the CBD and activity centres as well as surrounding land and longer travel distance from main arterial roads passing through restricted planning zones or through to the CBD to shopping centres. Participants largely agreed to the following possible and plausible outcomes of an ageing and damaged transport infrastructure, which results in deleterious impact on environment, damaged products, higher congestion, frequent gridlock, and business stagnation.

4.5 Stage 5: Stakeholder Analysis – Power and Interest Matrix.

Stakeholder analysis identified the actors who have power and interest to cause change. Interest represents the level of concern by the stakeholder who has a stake, while power represents the level of authority to influence or implement change in LMD. Power is also the capacity to influence behaviour, cause change or ability to restructure situations (Mendelow, 1981).

A matrix with two axes is categorised into four quadrants characterised and labelled as Context Setters (unaffected), Players (actors), Crowds (unaffected bystanders) and Subjects (bystanders affected by decisions) in LMD (Wright & Cairns, 2011).

Overall, the Federal, State and Local Governments, Truck Association, NGO, Road Users, VicRoads, Lobbyist, Traders Association, Port Authority, Business Owners, Local Community and Drivers are identified as stakeholders in the LMD with different levels of power and interest and positioned relatively within the 4 quadrants (**Figure 5**). Power over the focal issue and interest in the matter can change over time. For instance, the interest of a particular person in the local community, for example, a customer expecting a delivery can change from crowds to players if that delivery is linked to the performance of his/her business. Also depending on the situation, a context setter can become a crowd or player.

4.5.1 Quadrant 1 – High Power-Low Interest

From the analysis, Administrators (i.e., Federal, State and Local Governments), Transurban and Trucks Association fall within Quadrant 1. They are context setters because they set the policies and regulations that affect LMD. Stakeholders in this quadrant have high power, but with low interest in the functioning of LMD. These agencies are responsible for regulations and policies to plan transport infrastructure and control city logistics provisions. The federal government sets general road rules at the national level; whilst they are implemented by state and local government.

Strategically, government as administrator can introduce land use zoning and corridors to facilitate faster LMD vehicles movement and incorporate such into the relevant planning statutory documents. In addition, greater importance to loading and unloading especially in areas with close proximity to activity centres and apartment building in statutory planning assessment is important. Such provision lies in the powers of state and local councils.

Toll is considered as additional cost to operators. Issues relating to toll lies within the power of Transurban positioned as having the lowest interest among all stakeholders. The reduction in toll payment by the LMD vehicle will encourage private operator to use it and further reduce congestion on local roads. However, Transurban will not be interested in mitigating the LMD issues.

The Australia Truck Association includes major logistics companies and transport industry associations in Australia. One key task of the association is to develop national policies in conjunction with its member and lobby government to put such policies into effect. The Association is considered as having high power, but with low interest in the LMD. None of the drivers and logistic managers at the Scenario Thinking workshop identified any important role played by the Truck Association that could cause any positive change in the LMD.

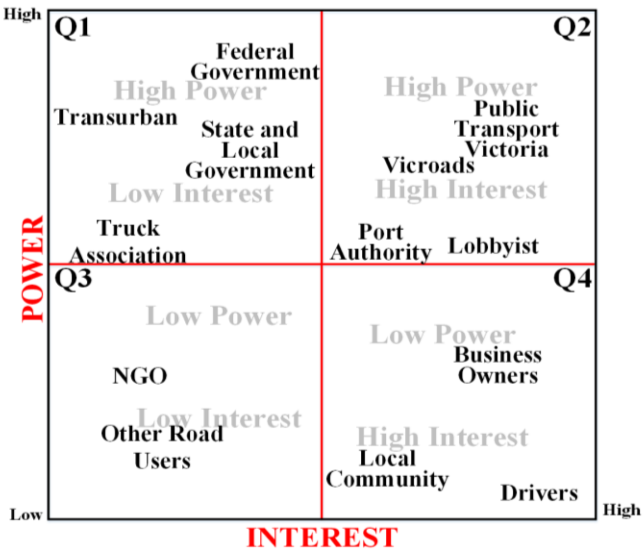

Figure 5 Stakeholder matrix – stakeholder to cause change in LMD

4.5.2 Quadrant 2 – High Power-High Interest

This quadrant represents the stakeholders with high power and high interest. These are actors who have the potential to cause change in last mile logistics. This quadrant represented by Public Transport Victoria (PTV), VicRoads, Traders Association and Port Authority.

While PTV is a statutory public transportation agency, participants considered it to have high interest and power which can positively influence last mile logistics. Also, VicRoads has the key role in providing safe and easy connections to Victorians. It seeks to assist economic and regional development by managing and improving the effectiveness and efficiency of the road transport system as well as develop a more integrated and sustainable road transport system. The interest of PTV and VicRoads lies within the transport network with more emphasis on public transport and regulating the movements of trucks.

The PTV and VicRoads, for example, can influence speed limit and traffic lights management. Also, the removal of railway boom gates as currently being carried out and removal of other LMD constrains are within their powers.

Trader associations have high power and high interest in last mile logistics. At a local level, they lobby local councils. Trader Association, as local lobbyist on the other hand, mount pressure on local governments in terms of provision of vehicles loading and unloading for use of business premises. Despite the high power of the stakeholders in this quadrant, their power appears limited to register any impact on the constraints of LMD as they cannot make any policy or legislation to improve the LMD.

4.5.3 Quadrant 3 – Low Power-Low Interest

Non-Governmental organisations and other road users are located within this quadrant. They represent unaffected bystanders in last mile logistics. Their power to effect changes and interest in LMD is relatively low. This group of stakeholders has no vested interest in LMD. They are only interested in delivery of goods in full and on time (DIFOT).

Other road-users (i.e., motorists) frustrate LMD drivers as a result of their actions. Particularly, the LMD vehicle drivers are frustrated by lack of proper knowledge of lane changing behaviour of other road users. Such lane changes and merging in front of the LMD vehicles sometimes results in collision.

4.5.4 Quadrant 4 – Low Power-High Interest

Drivers, local community, and business owners are stakeholders with low power but high interest in the last mile logistics. They are, however, directly affected by decision of the context setters and players. Majority of the drivers are identified as small-scale operators, often on short-term contract. They are more likely to bear additional costs of LMD and are most affected by last mile impedance. The extent of passing the cost to the end-users is often limited given the uncertainty of daily traffic flow.

Business owners and local community (End users in B2B) are at the receiving end of the supply chain. Delays caused by the identified constraints increased delays and damaged products. Particularly, retailers lost income as a result of delays in delivery of merchandise.

5. FRAMING THE LAST MILE DELIVERY STRATEGIES

Mitigating the LMD challenges requires well thought strategic framework to help tackle some of the challenges expected to emerge in the Worst-Worst scenario. A typical framework represents a set of objectives, strategies, and actions to help inform and guide the development of logistics planning and public policies that affect LMD. To develop this framework, the scenario outcomes identified in **Figure 3** are first translated into six major objectives, which are connected to the key goal of LMD. Five strategies along with a combination of actions are then developed to achieve these LMD objectives. The LMD strategy framework is presented below in **Figure 6** to **Figure 10** individually.

Strategy 1: *Land Use Zoning Strategy (LZS)*

Land Use Zoning Strategy (LZS) is proposed to regulate LMD vehicle movements and integrate LMD into the land use planning process, as all policies are land referenced. Land use zoning is a planning tool used by planning authorities to designate permitted uses of land and control development. The purpose of strategy is to regulate LMD vehicle movements across Metropolitan Melbourne and integrate LMD consideration into the land use planning process. This will include delineation of a zone for logistics functions and integration of LMD vehicle demand with off-street loading and unloading provision availability. Such land use zoning strategy requires demarcating LMD logistics zones to facilitate freight movements and operational requirements particularly along principal and major activity centres. It should include reserving areas for logistics provision and for off-street loading and unloading operations into the Victorian Planning Provisions and relevant Planning Schemes.

As all policies are land referenced, the strategy will assist in solving problems related to gridlock and congestion, remove LMD delay and increase usage of transport system. The use of underground loading area, delivery tunnel and planning scheme amendments to incorporate LMD in planning decisions are actions that can be deployed to implement this strategy (**Figure 6**).

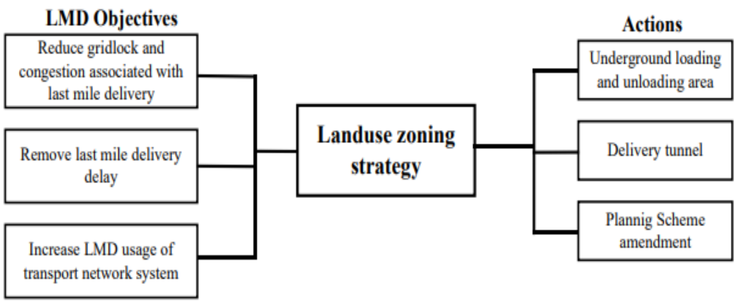

Figure 6 Land use zoning strategy and associated actions

For example, this strategy can be applied within Maribyrnong (a city Council area in Victoria), through the implementation of demarcation between the Footscray Metropolitan Activity Centre and the Highpoint Activity Centre. This can be tested and applied to other councils within Metropolitan Melbourne or areas of similar land use activities conditions. In addition, designation of off-street loading/unloading and curb side loading zones including cut-outs (**Figure 6**) of wide sidewalks for delivery or waiting when loading area is still occupied is important in this strategy. A new logistics zoning system can be introduced and legislated to demarcate logistics zones to differentiate the scale and intensity of freight movements.

Strategy 2: *LMD Corridor Strategy (LMDCS)*

LMD Corridor Strategy (LMDCS) is proposed to develop linear freight routes between the CBD and activity centres or between activity centres to improve last-mile efficiency (Boyer, Prud'homme, & Chung, 2009; Ko, Sari, Makhmudov, & Ko, 2020). Use of such dedicated delivery corridor with time-window based loading/unloading will help reduce the environmental footprint of LMD, ease traffic bottlenecks, reduce LMD operational costs, and avoid conflicts between LMD truck drivers and other road users. This strategy will target the use of underground loading and unloading area, use of delivery tunnel, provision of dedicated road corridor with increased speed limit and removal of roadside parking to enhance LMD vehicles as the actions proposed in this strategy (**Figure 7**).

For example, certain type of vehicles may be permitted in specific zones of Activity Centre only at specified times, or they may simply be excluded from the area all together. Dedicated LMD routes can be created and be made clear during the peak-hours via implementing a clearway policy where no parking is permitted along the roadside or curb. Optimisation of LMD networks within Activity Centre in inner city region can potentially solve problems caused by increased commercial vehicle movements (Fusco *et al.*, 2003; Taniguchi *et al.*, 2003). In addition, off-peak hour and night delivery can be included in this strategy. Such night delivery will need to involve silent trucks to operate within the city centre in late hours to avoid road congestion and manage noise pollution. Incentives for operators who agreed to this delivery can be taken into consideration to supplement cost incurred by operators in hiring staff to man the premises for the delivery.

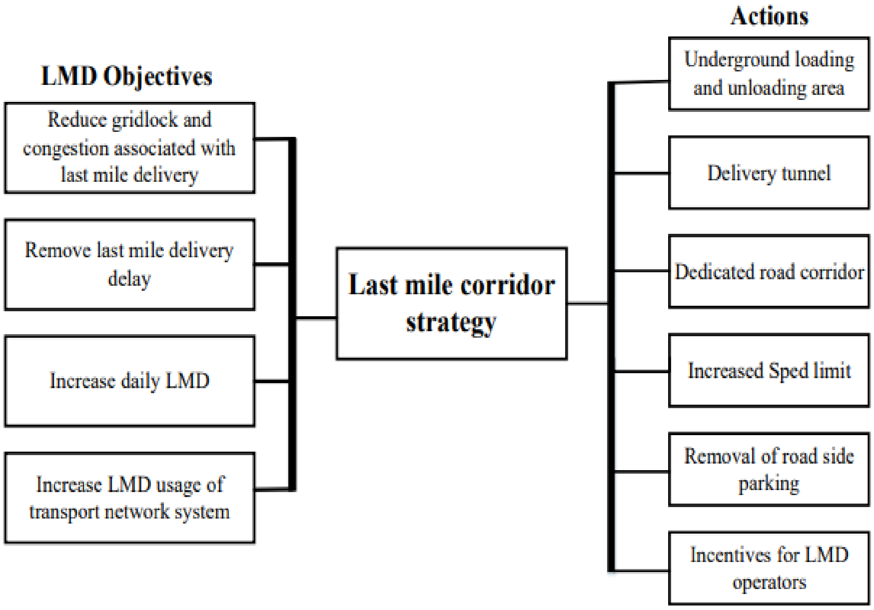

Figure 7 Last mile corridor strategy and applicable actions

Strategy 3: *Distribution Network Strategy (DNS)*

Distribution Network Strategy (DNS) is designed to reduce the LMD inefficiency linked to unconsolidated deliveries, delays at loading bays, lower load factor and empty running (Crainic *et al.*, 2009; Lee & Jeong, 2009) through freight consolidation, tasks coordination and resource sharing. The Novelog project by European Commission (Adams and Morrow 2019) demonstrates the application of this strategy. The Urban Consolidation Centre (UCC) will enable goods to be de-bundled and redistributed for delivery into fewer fuel-efficient delivery vehicles. This strategy integrates people, facilities, and transportation infrastructure as a single unified logistics system. UCC can be established to facilitate delivery, de-bundling, storing and redistributed to help improve supply chain coordination and a reduction in the number of trucks driving into or through the activity centres (**Figure 8**).

An efficient functioning of UCC, however, necessitates logistics collaboration between key stakeholders which should be based on openness, risk sharing and mutual trust as well as shared reward to help mitigate potential delay in delivery of goods in the last-mile component of the supply chain (Lindawati *et al.* 2014; Park *et al.* 2016). The use of underground loading and unloading complemented with intelligent transport systems (ITS) will assist in achieving the objective and tackle the challenges associated with the problem.

Strategy 4: *Multi-modal Use Strategy (MMUS)*

Multi-modal Use Strategy (MMUS) is to promote the use of multi-mode transport to combine trucks, train/trams, cargo bikes or other non-fossil fuelled vehicles for different part of LMD. An urban rail or tram system can be integrated into the LMD system in Melbourne (Ozturk & Patrick, 2018). Implementation of the Multi-Modal use strategy, for example, will help reduce gridlock and congestion arising from the increased number of inbound LMD vehicles into the CBD and can remove LMD delay. More importantly, this strategy has the advantage of significantly reducing the total dependence of LMD on road, which will ease congestion, enhance road safety, and reduce CO_2 emission from LMD vehicles (**Figure 9**).

Torino in Italy has utilised rail station located close to the urban CBD to organise and allow temporary warehouses (Pronello *et al.*, 2017). Such opportunity allows for a transitional transfer arrangement through a multi modal LMD system. With increased expectation in LMD requirements, traditional delivery measures will unlikely satisfy the customers. The use of drones and robots (Giannopoulos 2009; Hoffman and Prause 2018) would transform delivery of goods in the face of 'internet of things' (devas *et al.*, 2021). Drones for delivery will offer considerable benefits with ability to travel at a faster and sustainable speed without encountering the hurdles imposed by current built environment impedance.

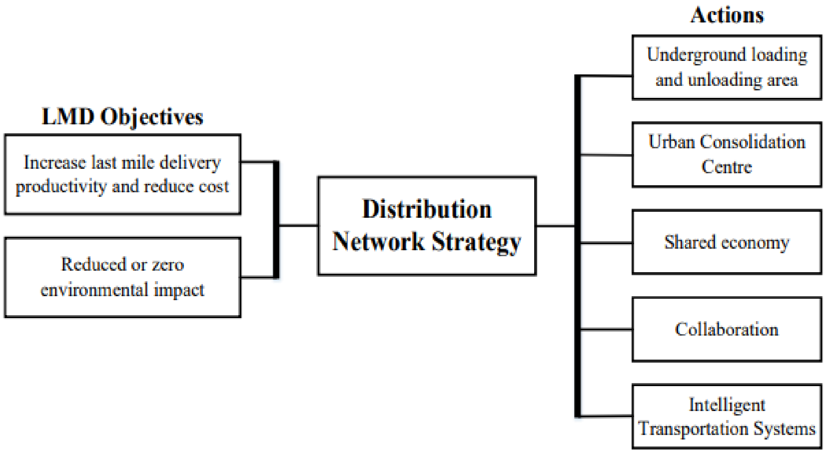

Figure 8 Actions to mitigate LMD challenges through distribution network strategy

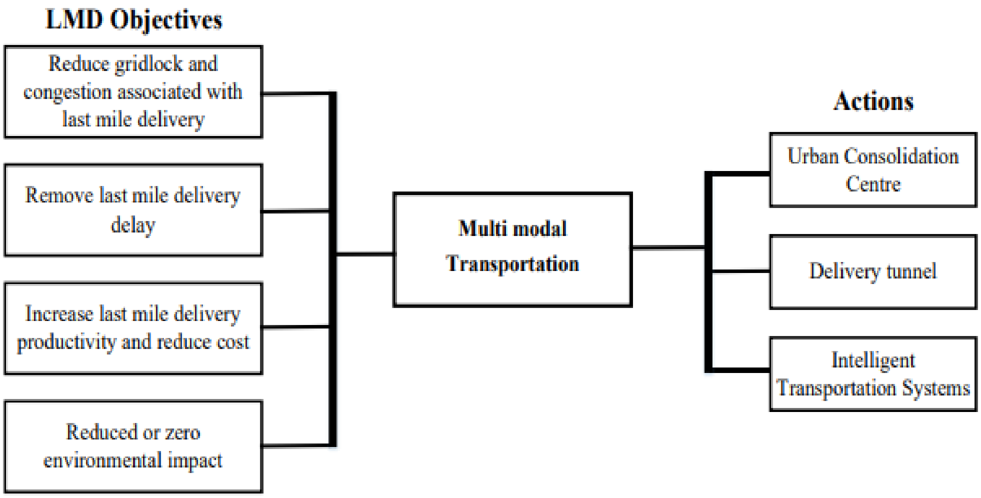

Figure 9 Actions to achieve the objectives of the multimodal land transport strategy

Strategy 5: *Stakeholder Engagement Strategy (SES)*

Stakeholder Engagement Strategy (SES) is suggested to engage administrators, operators, and the community through consultation to help augment LMD decision-making process. Key stakeholders identified in the scenario thinking process are capable of exerting positive influence and persuade the industry to ensure cost-efficient, and sustainable LMD through their actions. Consideration of this strategy will tackle the worst –worst scenario to remove LMD delay, increase usage of transport network by LMD vehicles, reduce or remove environmental impact and assist in low cost and efficient LMD. Required actions from the stakeholders relate to encouraging shared economy and provision of incentives for operators and retailers **(Figure 10**).

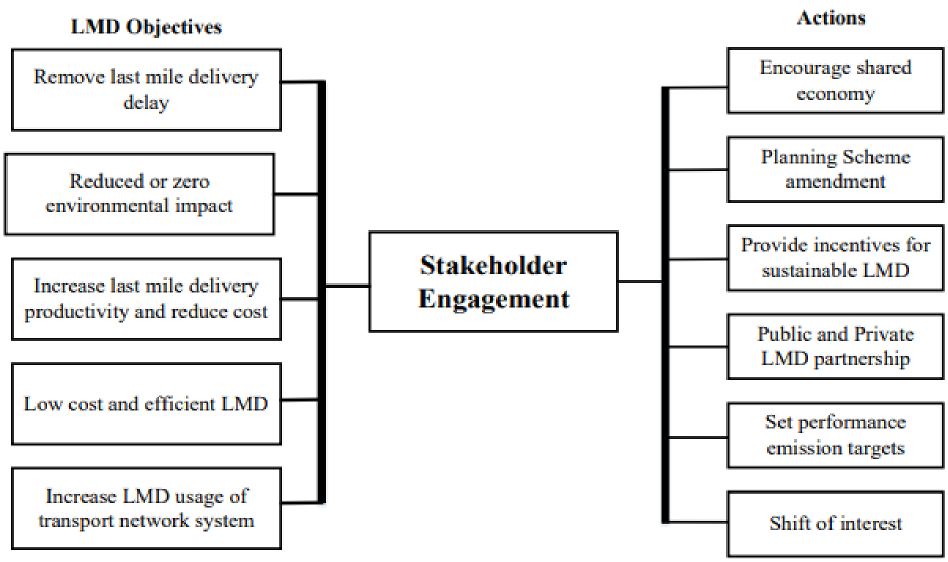

Figure 10 Action to achieve the outcome objectives associated stakeholder engagement in decision making

The above five LMD strategies are presented in a matrix format in **Figure 11**. The advantages and disadvantages of the strategies to the stakeholders rest in their responsiveness and efficiency as well as regulated or deregulated circumstances under which they operate. For example, in a fully regulated environment, LMD corridor strategy will be highly responsive to freight movement between activity centres and CBD to meet consumers' demand. On the other hand, its responsiveness will not be responsive to freight movements to retailers.

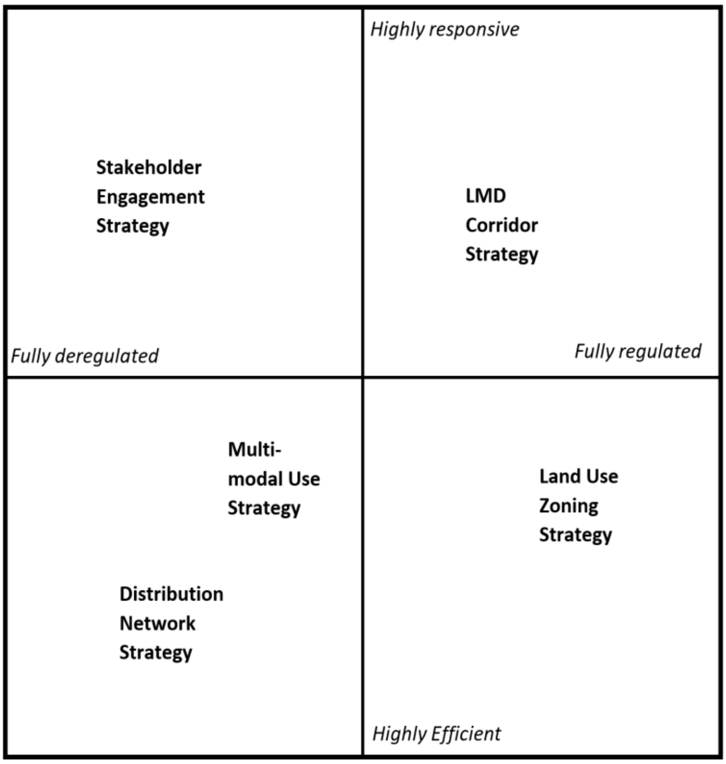

Figure 11 Matrix-based strategic framework

The dedicated corridor will facilitate faster freight loading/unloading with increased speed to support delivery in full and on time (DIFOT). Further, the land use zoning strategy will be highly cost efficient by avoiding traffic congestion and delays. The regulated land use earmarks portion of land and roads dedicated for commercial, residential, or mixed use. This helps the freight movement quite efficient reducing not only the cost but also vehicular emission. However, when land use and dedicated road corridors are not appropriately regulated, LMD will be more costly.

The freight-efficient land use minimises social costs (private plus external costs) associated with LMD dealing with goods movement including reverse and waste logistics (Holguin-Veras *et al.* 2021). Under fully deregulated context, stakeholders compete among themselves where they remove LMD delay, increase usage of transport network, reduce environmental impact, and assist in low cost and efficient LMD.

Distribution network strategy supports freight consolidation by sharing resources like people, facilities and intelligent transports that offer an efficient unified logistics system. Further, multi-modal transport facilitates various modes of transport like rail, truck, small vans, and cargo bikes that help increase LMD efficiency by considerably reducing the dependence of LMD on road.

The Matrix-based strategic framework (Fig 11) is considered to be applicable for all discussion of LMD, not only to Melbourne. The strategies can be applied to cities with similar last mile delivery problems and context.

6. CONCLUSIONS

This study has developed LMD scenarios based on transport infrastructure and planning constraints by implementing the scenario thinking method. Strategies and actions plans are proposed to mitigate LMD challenges. Various constraints with different levels of impedance to LMD were identified in planning and transport systems and then grouped into six thematic clusters. Four plausible LMD scenarios are constructed using Infrastructure Supply and Land use Intensity dimensions. The Worst/Worst scenario highlighted the need for strategic planning to mitigate risk associated with the likely outcomes of severe supply chain disruption, congestion, and delay, LMD stagnation and ageing infrastructure.

State and local government (HP:LI) and Truck Association/drivers (LP:HI) were key stakeholders with different levels of power and interest. City planners representing the administrator in LMD will need to statutorily implement strategies recommended to mitigate against the worst/worst future scenarios and ensure low level LMD impedance. Stakeholders with high interest and high power could play a critical role in mobilising support through lobbying both the government and industry for improving supply chain efficiency.

6.1 Contributions

The theoretical contribution is the adoption of a comprehensive approach that integrates LMD impedance with the spatial context within which it operates. Most studies have theorised LMD as a business function in an isolated distribution system without the need of incorporating constraints of urban planning systems. The consideration of the urban planning constraints of the urban transportation environment hitherto not reported in extant literature is presumably multi-disciplinary and theoretically novel. Furthermore, this research seamlessly extends the theory of constraints to scenario thinking process to enrich the conceptualisation of scenario building for plausible future. The matrix-based strategic framework offers a new insight on how the strategies operate with a trade-off between regulated and deregulated environment where the LMD is efficient versus responsive.

The methodological contribution is the implementation of a scenario thinking approach to tackling multi-dimensional problem of LMD in B2B context. Multi-stakeholder engagement of local council, state government agency, last mile operators, and retailers through scenario thinking workshop has generated rich and diverse set of data to help formulate future LMD scenarios and storylines This methodological approach to building multitude of future LMD scenarios and last mile strategies has added new knowledge and deeper insights to the discussion on LMD challenges and opportunities in a rapidly digitalised urban supply chain network.

The practical contribution is the development of a matrix-based strategic framework that incorporates regulation-informed and efficiency-responsive operational strategies to manage last mile delivery in large cities. This framework also helps map stakeholders' interest and power to strategically align and improve LMD efficiency. The distribution objectives, strategies and recommended actions offer strategic as well as operational guidance to key stakeholders who were identified to hold high interest and high power with the capacity to mitigate potential risk of supply failure and manage supply uncertainty to deal with the burgeoning demand for last mile logistics provisions. The strategies recommended can be applied to any large cities like Melbourne in the western nations with similar urban structures and the regulatory environment to effectively manage last mile delivery challenges.

6.2 Limitations and Future Research

There are several limitations of this study. First, the scoping of Scenario Thinking approach is restricted to a two-dimensional representation of the future of last mile logistics. This may limit capturing the impact of the interplay of multitude dimensions in formulating multiple scenarios and representations. Incorporating more than two dimensions in scenario building would, however, increase the complexity of building the scenarios and would be difficult to comprehend visually and cognitively.

Second, the future last mile scenarios are collectively constructed, although the perceptions of the plausible outcomes for different scenarios vary for different stakeholders (e.g., LMD drivers versus transport planners). Stakeholders' perceptions at times can be contradictory and too diverse to be converged through consensus. The future research will explore the possibility of building stakeholder-specific perception of the future of last mile logistics. An interview component could also be appended to the methodology to help triangulate the results for validation.

Third, the analysis is restricted only to the Worst-Worst scenario to help capture the likely future outcomes. Future study will extend the analysis to other scenario narratives to not only identify challenges but also opportunities for improvement in Best-Best or Best-Worst situations.

Finally, the LMD strategies formulated in this study are of little operational value. Future research will simulate and optimise the outcomes under these LMD strategies to help inform operational as well as planning decisions.

As the future logistics delivery mechanisms are evolving to meet the consumers' dynamic online buying behaviour, equipped by ubiquitous technology applications (Peppel *et al.*, 2022), a strategic approach to LMD is now needed that consider consumers' competition through LMD service system (Hayel *et al.*, 2016), crowd-sourcing for managing the growing congestion emanating from demand for same-day delivery (Castillo, Bell, Rose, & Rodrigues, 2018), and sustainability of LMD in an increasingly complex urban systems (Alharbi, Cantarelli, & Brint, 2022).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the authors upon reasonable request.

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