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Evaluating initiatives for improvement of urban freight deliveries: A case study of Sydney metropolitan area

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Abstract

City logistics involves diverse stakeholders and faces ongoing challenges. Implementation of initiatives that are acceptable to all stakeholders is critical. In this paper, we apply the multi-actor multi-criteria analysis (MAMCA) to address stakeholders' perspectives in initiative selection. By focusing on the Sydney Greater area as a case study, we first identify the main stakeholders and their objectives and then conduct separate surveys for each group. The result from MAMCA analysis shows that advanced planning and modelling is the most effective alternative for stakeholders to achieve their objectives. This initiative includes better understanding of the ideal metropolitan freight network structure, exploring advanced applications of technology in last mile freight, and refinement of TfNSW freight forecasting models. We apply a sensitivity analysis to test the outcomes when stakeholders' impacts are not equal in launching initiatives and discuss the results.

Keyword: MAMCA; City logistics; Urban freight delivery; Last-mile logistics

1.Introduction

Since the start of the COVID-19 pandemic, work-from-home has become a new norm, and with it, online shopping and home deliveries started to increasingly dominate the retail markets. Consequently, customer expectations are rapidly changing and fast delivery services are on the rise (Vonage, 2021). The global ecommerce sales have been growing even before COVID-19, and soared from $1.3 trillion in 2014 to $4.2 trillion in 2020 (US Department of Commerce, 2022). With escalating demands for home delivery, we are observing increasing volumes of truck movements in our cities, and a decline in the optimal utilisation of their volumetric capacity (Thompson, Nassir & Frauenfelder, 2019; Zhang & Thompson, 2019). Trucks are major contributors to traffic congestion and accidents and the unprecedented surge in home delivery trucks has exacerbated the challenges associated with their operations in the urban transport systems.

The main stakeholders in urban freight logistic delivery systems are customers, couriers, governments, and the general public. Home delivery has several disadvantages for the entire stakeholders. Due to lack of economy-of-scale on shipping parcels directly to customers' doorsteps, the last-mile part of deliveries is the most expensive and least efficient delivery part for couriers, which nearly accounts for 28% of the total delivery cost (Goodman, 2005). As other couriers' operational problems, the difficulties in finding

delivery addresses in urban and suburban areas and parking spaces in urban Central Business District (CBD) areas can be counted. Carriers also need to invest on expanding their vehicle fleets and personnel to keep the service efficiencies because of the expected growing trend in number of home deliveries and the frequency of delivery addresses in the future. Moreover, these direct deliveries increase the movements of delivery trucks or vans in the transportation network which is associated with worsening air pollution, traffic congestion, and conditions of roads pavements; hence, it leads to an unsustainable freight distribution network needing the governments' interventions.

The success of a collaboration initiative is tied with its acceptability by the involved stakeholders in the initiative, resulting in attention to the stakeholders ' requisites in planning and controlling of the collaboration initiative. Hence, this research aims to explore the acceptability level of several urban freight initiatives from standpoints of the involved stakeholders and then design and implement the initiative with the highest acceptability level from the entire stakeholders. This approach is novel for the City of Sydney and requires stakeholder engagement prior to the design and testing of the initiatives during the modeling and evaluation stages of the project.

The study will provide a short-list of initiatives that have high potential for mitigating the adverse public impacts from COVID-19 normal and increased ongoing delivery operations in Sydney. These initiatives will be considered for undertaking trials. Based on the systems approach to City Logistics (Taniguchi, Thompson, Yamada and van Duin, 2001) a pre-implementation (ex-ante) evaluation on initiatives based on criteria associated with maximising public policy benefits will be undertaken. Consequently, this will provide the basis for a list of recommendations relating to government schemes that should be implemented throughout the Sydney metropolitan area.

Key Questions intended to be examined:

- Which performance measures are important for the stakeholders, including government, shippers, residents, receivers, and couriers?
- Which initiatives are most attractive for each of the respective stakeholders?
- Which initiatives are most attractive for the government to implement throughout metropolitan Sydney with due consideration of all stakeholders?

Consideration will be given to the practicality, viability, equity, acceptability for key stakeholders relating to the implementation of the schemes throughout metropolitan Sydney. The paper is organised as follows. Firstly, a literature review is conducted to provide an overview of approaches to find optimal urban freight delivery initiatives. Then the methodology and data preparation for MAMCA is presented. Subsequently, workshop process is outlined, before the results & concluding remarks are presented.

2.Literature Review

Various methodologies exist to evaluate launching initiatives in city logistics. They can be categorised into cost-effectiveness analysis (CEA), the economic-effects analysis (EEA), the social cost-benefit analysis (SCBA), and the multi-criteria decision analysis (MCDA). CEA assesses all economic aspects of new alternative implementation, especially their output' procedures (Rutten 1996). While EEA is to examine the impacts of any implementations, such as a project, or policy on the economy on a regional scale (EBP 2022), SCBA is adjusted to consider all economic, social, and environmental aspects (nef 2013). These three methods deal with only the economic dimension or evaluate a single objective. Therefore, the MCDA approach that focuses on the evaluation of several initiatives has gained much attention in recent years.

To successfully implement logistics policies, they need to be accepted by logistics stakeholders, including authorities, customers, shippers, and transport operators. In such a multi-stakeholder environment, the objectives of all stakeholders should consider being able to design a more sustainable freight system for the future. The multi-actor multi-criteria analysis (MAMCA) is a methodology to evaluate to what extent different alternatives contribute to the objectives of principal players. Adapted from MCDA, multi-criteria multi-actor analysis (MAMCA) methodology developed by Macharis 2004 aims to support a sustainable decision-making process in logistics and transport activities. One of the advantages of using MAMCA is the engagement of stakeholders in different stages of the decision-making process, including problem definition, problem formulation, and evaluation of the problem-solving procedure. By incorporating various interests, MAMCA is applicable when there are different alternatives, objectives, and criteria from diverse stakeholders to prioritise the assessment of alternatives per stakeholder (Kin, Verlinde, Mommens, & Macharis 2017; Perera & Thompson 2021; Rai, Lier, Meers, & Macharis 2017).

2.1. MAMCA

There are several studies in which MAMCA applied to assess the stakeholder groups' perspective about new alternatives. Verlinde et al. 2014 introduced the concept of the mobile depot and evaluated the economic viability of this initiative. She not only concluded that internalised external costs, higher capacity use, and higher drop density could increase the profitability of companies but also emphasised that mobile depot was beneficial for citizens in terms of social sustainability. A framework was proposed based on the MAMCA methodology to measure and assess the sustainability and liveability of transportation (Miller, Witlox, & Tribby 2013). In Belgium, a study was undertaken to assess the social and economic impacts of night-time delivery by applying transport sectors, receivers, and the employees' points of view (Witlox, Frank, W Debauche, Cathy Macharis, E Van Hoeck 2010). Later, Ghorbanzadehet al. (2019) applied MAMCA to increase the knowledge of local government about other stakeholders. They evaluated residents' public transportation demands in Turkey by considering transport quality, tractability, and service quality as their objectives.

Figure 1 shows different steps of MAMCA methodology. Here, we briefly introduce the steps. Readers are referred to Macharis et al. (2009) to find the complete description and details of each step.

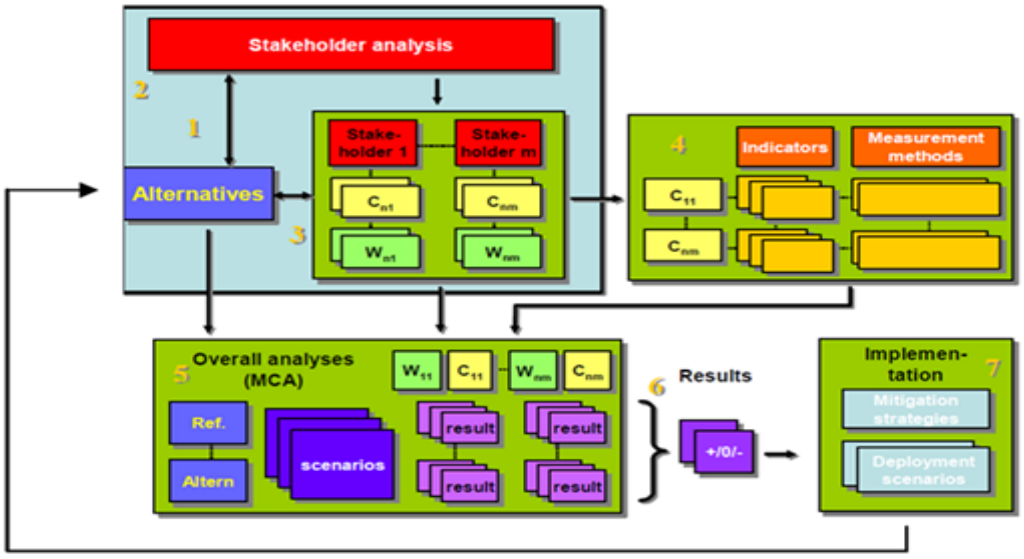

Figure 1. The seven-step methodology of the MAMCA

Step 1: In this step, a set of alternatives (i.e., solutions) are suggested for the problem of concern. For example, if the problem is related to improving the performance of Last-Mile Freight Delivery Systems (LMFDSs), employing parcel lockers or electrifying delivery vehicles could be a couple of possible alternatives.

Step 2: Identification of stakeholder groups that can impact or be impacted by the alternatives identified. For example, parcel receivers or couriers are two stakeholder groups in the LMFDS-related problem. Moreover, a weighting system is proposed for the point of views of the stakeholders, where normally equivalent weights are considered for the entire stakeholders.

Step 3: In this step, some criteria are defined from the standpoint of each stakeholder. The criteria should be in line with their corresponding stakeholders' objectives and their purposes. Also, the weight of each criteria from its corresponding stakeholder should be configured. Different approaches can be taken to measure the weights such as direct allocation, allocation of 100 points, trade-off methods, etc. As an example, minimizing environmental pollution can be a criterion from the view of residents in the problem of improving performance of LMFDSs.

Step 4: In this step, one or more indicators (variables or metrics) are suggested for each criterion to measure whether, or to what extent, the alternatives contribute to the criterion. For example, Carbon Dioxide (CO2) level (PPM) can be an indicator for the criterion about minimizing total air pollution.

Step 5: A Group decision support method (GDSM) is employed in this step to assess the overall performance of every alternative. The PROMETHEE, ELECTRE, and Analytical Hierarchy Process (AHP) methods are some examples of GDSMs that can be employed in this step.

Step 6: Based on the assessments provided by the stakeholders in the preceding step as well as their expected performance of each initiative in improving the criteria, most attractive options (urban freight initiatives) for each stakeholder group and cumulatively is identified. Hence alternatives can be ranked based on each stakeholder group and collectively. Furthermore, sensitivity analyses can be performed on the method's inputs such as the weight of each stakeholder in the analysis to see how robust the alternatives are once the viewpoint of one or many stakeholders take precedence over other stakeholders.

Step 7: The final step includes implementation, which considers the deployment approaches for implementing the c*hosen alternative into practice.*

3.Methodology and Data

In this section, we explain how the input data for the MAMCA analysis is collected and set-up. Accordingly, in Subsection 3.1, a summary of workshops held by the University of Melbourne is provided by which a set of freight initiative groups as the MAMCA's alternatives are stipulated. The involved five stakeholder groups, the government, couriers, shippers, parcel receivers, and residents, and their corresponding objectives, criteria, and indicators are introduced in Subsection 3.2. In Subsection 3.3, a brief summary for the five surveys (i.e., for every stakeholder one particular survey is designed) conducted to collect the importance of the criteria as well as the impact of each alternative on each criterion from the standpoint of each stakeholder is provided. In this regard, the criteria's weights as well as alternatives' weights in terms of improving the criteria are measured and tabulated.

3.1. Workshop

The workshops were conducted with the University of Melbourne research team and Transport for NSW advisors. The purpose of the workshops was to identify novel government initiatives for addressing urban freight trends in the Sydney metropolitan region. They also helped identify the stakeholders to survey, and the relevant criteria for each respective stakeholder group.

Planning

In preparation for the workshops, a worksheet along with an agenda for each workshop was prepared, including the development of polls in a web-based application. The worksheet consisted of a matrix structure, with the urban freight trends identified in Phases 1 and 2 of the project mapped against a set of general roles that the government could adopt. These span from a top-down authoritative role to a more inclusive, collaborative partner. The roles included: Regulation; Planning; Data & Information; Facilitation; Infrastructure Provision; & Active Participation.

The overall trends identified included: B2C Growth, where a rise in average orders/person is expected to greater freight traffic across metropolitan Sydney; Faster Deliveries, where a shifting consumer trend of shorter delivery windows, flexible pick up locations and greater customisation of products is expected; Smarter Technologies, where industry trend towards a autonomous, connected, electric and shared assets use is expected; Sustainability, where the focus is on reducing congestion, emissions, urban sprawl and VKTs of freight vehicles, and improving safety; Spatial Changes, where the rise in work from home patterns is causing greater dispersion of freight distribution across the supply chain network.

All aspects, including the agenda, worksheet and the polls were designed in collaboration between the UoM researchers and TfNSW advisors. The worksheet structure including the overarching trends and government roles were refined with consultation of TfNSW. The agenda activities, including the type and order of activities were considered with consultation of TfNSW. The workshop was initially intended to run for two hours, however due to time constraints, another two-hour session was added to complete the agenda tasks. All sessions were conducted online via Zoom.

Conduct

Initially the urban freight trends were reviewed. This included reviewing the general approaches that the industry may adopt in response to the shifting consumer expectations. Following that, the urban freight trends were mapped against the six roles of government, helping to brainstorm specific government responses to these trends. Both the UoM research team and TfNSW advisors were involved in the brainstorming process.

Once the matrix was populated, polls were used to rank and group the various government responses. The polls were used to rank and categories the specific initiatives identified. The key question asked was: 'Which of the initiatives discussed are most significant for TfNSW?' This was an open-ended question designed to elicit most relevant initiatives for TfNSW. This implied consideration of timeliness and viability from the perspective of TfNSW. Once a list was populated, they were categorised into common themes, which formed the overarching workshop initiatives as discussed in the Outcomes section below.

Outcomes

Table 1. Workshop Outcomes: Initiatives Summary

No	Key Themes	Initiative

1	Advanced planning and modelling	● Understanding the ideal metropolitan network ● Advancing application of technology in last mile freight ● Encouraging optimized vehicle scheduling ● Refinement of TfNSW freight models ● Establishing data-channels for the provision of ongoing freight activity data to inform modelling activities
2	Prioritising access for low emission vehicles	● Promote use of light electric vehicles such as e-cargo bikes to perform last-mile deliveries in urban/CBD areas ● Prioritise access (such as in priority lanes) for electric freight vehicles ● Providing priority access for light electric vehicles to loading zones
3	Industry and Partner engagement	● Establish an ongoing industry forum (Short Term) ● Establish ongoing partnerships with industry for investment/trials of ideal(Mid Term)
4	Support development of facilities	● Support the development of Urban consolidation centres (Mid Term) ● Support the implementation of micro-consolidation centres in urban areas/CBD (Short Term) ● Provision of charging and swapping stations in urban/CBD areas for light electric vehicles performing last-mile deliveries (Short Term)
5	Pilot Ecosystems	● Incorporate various above approaches 1-4 into precinct practices ● Low emission delivery zone that limits the type of vehicle (electric) that is permitted (Short Term) ● Time of day restrictions for freight vehicles entering certain zones (Short Term)
6	Training Programs	● Schemes aimed at smaller operators to improve optimal efficiency. Provide information on technology and practices that may lead to improvements in operational efficiency (Short Term) ● Share best practice guidelines and research for stakeholders in industry and LGAs S for efficient freight activity (Short Term) ● Education on consolidation schemes (for operators and building managers) (Short Term)

Out of over 30 initiatives identified, six categories were structured: Advanced planning and modelling, which includes planning for hubs and use of technologies such as digital twins; Prioritising access for low emission vehicles, which can include providing priority access to LEVs within urban centers and loading zones; Industry and partner engagement, utilised for establishing forums and funding trials; Support development of facilities, includes elements that assist in performing consolidation activities for the LMD such as UCCs and Microhubs; Training Programs, that could be targeted towards smaller couriers more incorporating innovative technologies to enable better planning and decision making around pricing, vehicle loading and scheduling activities; Pilot ecosystems, involves a test bed incorporating a number of initiatives.

3.2. MAMCA structure

According to the workshop outputs, providing the sets of alternatives, stakeholder groups, and criteria for every stakeholder, the hierarchy structure used to model the problem is visualized in Figure 2.

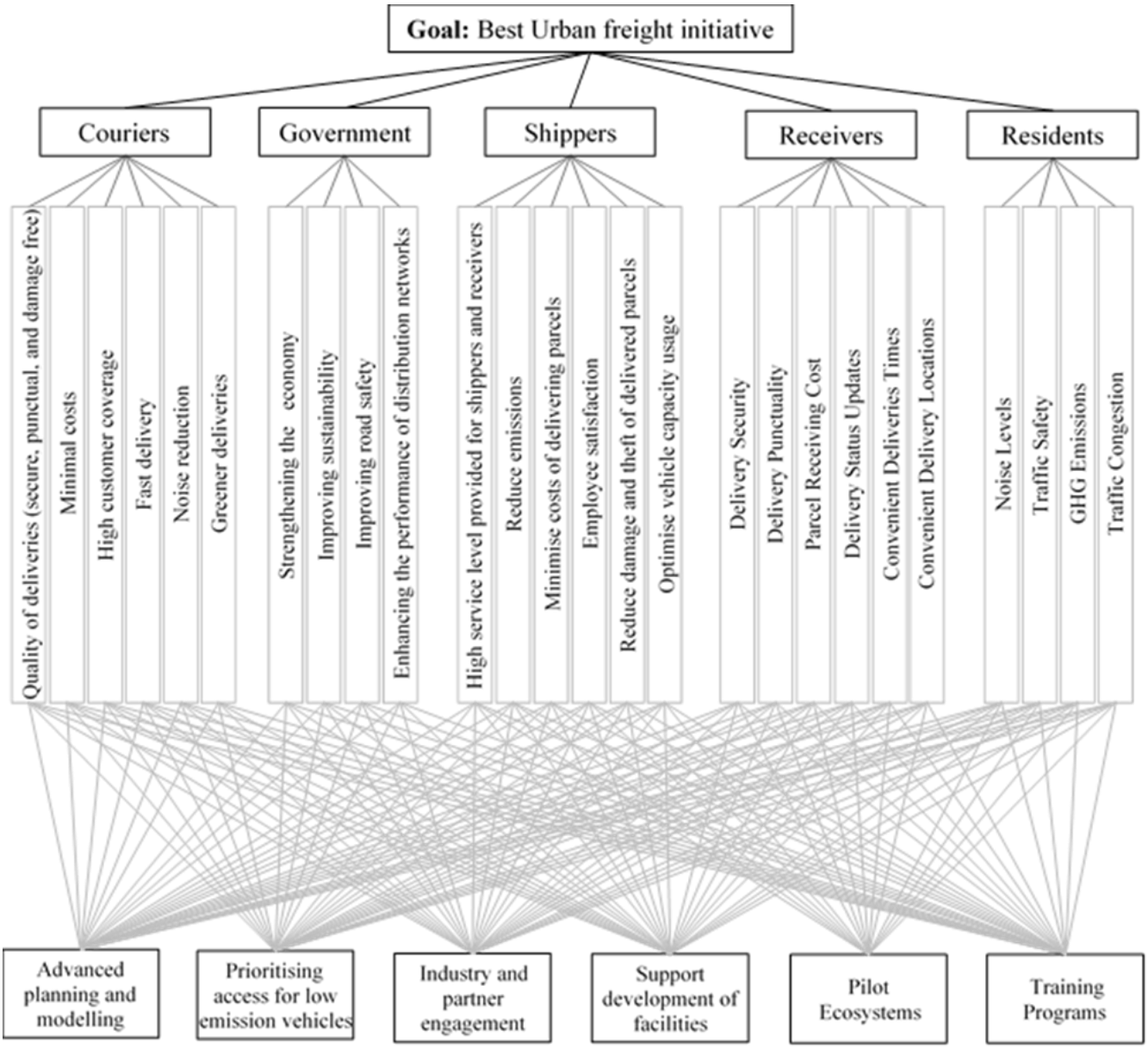

Figure 2. A visualization of the hierarchical structure applied to our model

The first layer of hierarchy classification consists of different actors: couriers, shippers, government, parcel receivers, and residents. Within a MAMCA this hierarchy consists further of different actors. In the next layer, relevant criteria are included for each of these actors. Finally, the alternatives or initiatives are placed at the bottom layer of the hierarchy. It is worth mentioning that for every stakeholder's criterion, only one criterion and for every criterion. For example "GHG emission" is a criterion for the objective of minimizing total air pollution. This criterion is measured by total CO2 equivalent (PPM) as its indicator. For simplicity, we excluded objectives and criteria from Figure 2.

3.3. Survey results and MAMCA input data

Six main stakeholders are identified in Sydney Greater areas, including governments, shippers, couriers, customers, and residents. For each stakeholder, a survey is designed to figure out their preference objectives and alternatives. Details about the population, confidence level, the required sample size, number of contacted individuals, the response rate, and distribution channel are summarised in Table 2.

After receiving responses, objectives and alternatives are ranked based on a group decision support (GDS) method. For this purpose, their scores are calculated by multiplying allocated weights for surveys' options (determined by Liker scales ranging from 1 to 9) by the number of times each option is selected.

Table 2. Survey details

Stakeholder	Population	Confidence level & margin error	Required sample size	# Contacted individuals for filling survey	# collected responses & response rate (%)	Survey distribution channel
Residents & receivers	5.4 million	95% & 3%	1067	-	2208 & -	Qualtrics distribution channels
Couriers	>5	-	10	77	7 & 9.1%	Email
Shippers	>5	-	10	72	4 & 6%	Email
Governments	>50	-	10	65	19 & 29%	Email

For parcel receivers and residents in the Sydney metropolitan area, a survey is designed and executed in Qualtrics with a sample size of 2208 respondents. The appropriate sample size is found using the Qualtrics sample size calculator, where confidence level and margin error are set 95% and 3%, respectively. The age, gender, and income profiles of residents are explored based on Census data 2016 and set as requirements in the way of collecting a sample size representing the population. Given the population of the Sydney metropolitan area around 5.4 million people, at least 1067 responses are needed. The demographic details of the collected sample and the sydney metropolitan area population are summarized and compared in Table 3. Results show that the sample is reasonably representative of the national population in relation to age, education and gender.

Table 3. Respondents vs. population profiles

Attribute	Frequency	Breakdown	Census 2016
Gender			
Male	1061	48.05%	51.1%
Female	1147	51.95%	49.90%
Age			
18-30	476	41.56%	42.61%
31-40	464	30.01%	31.09%
41-50	460	8.83%	10.00%
51-60	369	8.71%	7.28%
61-70	253	6.46%	5.22%
71 and older	186	4.42%	3.80%
Annual income			
Less than $30000	484	21.92%	-
$30000 to $60000	526	23.82%	-
$60000 to $90000	511	23.14%	-
$90000 to $120000	373	16.89%	-
More than $120000	314	14.22%	-
Employment status			
Employed full time	1157	52.40%	51.20%
Employed part time	396	17.93%	38.6%
Retired	348	15.76%	
Disabled	39	1.77%	
Student full time	89	4.03%	-
Unemployed	179	8.11%	5.90%

Dwelling type			
Stand-alone house	1341	60.73%	66.40%
Apartment	727	32.93%	32.10%
Other	140	6.34%	3.50%
Delivery per year (count)			
Under 5	244	11.05%	-
5-10	456	20.65%	-
11-20	534	24.18%	-
+20	974	44.11%	-
Household size			
1	341	15.44%	16.00%
2	701	31.75%	36.60%
3 or 4	934	42.30%	47.40%
5 or more	232	10.51%	

Eleven different input datasets are used and categorized as follows: Stakeholders weights (one input dataset, as shown in Table A1), importance of each criteria from standpoint of stakeholders (five input datasets since we have five stockholders, as shown in Table A2), and expected performance of each alternative in terms of improving the entire criteria (six input datasets since we have six different alternatives, as shown in Table A3)

4.Results and discussion

To construct the multi-actor view and apply the MAMCA analysis, a spreadsheet is designed by the authors. Based on the inputs introduced in Section 3, the MAMCA is run and the results are visualized. This section is organized into two subsections. In Subsection 4.1, the alternatives' scores from the standpoint of the entire stakeholders (i.e., a multi-actor view) or every specific stakeholder (i.e., a single-actor view) are demonstrated and compared, where an equivalent weight (i.e., 0.20) is assigned to every stakeholder. The sensitivity analyses on the stakeholders' weights in the MAMCA process are done in Subsection 4.2, where five different weighting systems are applied and the resulting overall alternatives scores are compared.

4.1. MAMCA results

The overall results of the MAMCA and alternatives' scores are illustrated by Figure 3. The figure has a standard style for MAMCA analyses, where its interpretation is as follows: Vertical bars show the five stakeholders, where the height of each bar represents the stakeholder's weight in the analysis and can be read from the left vertical axis, titled Obj%. As the figure shows, all the stakeholders are given the same weight (0.020). Horizontal lines represent the alternatives (i.e., freight initiatives). The scores of alternatives are given by the right horizontal axis, titled Alt%. The figure can simultaneously show the alternatives' scores from the standpoints of every stakeholder (i.e., interactions of the horizontal lines with the stakeholder vertical line) and the entire stakeholders (i.e., interactions of the horizontal lines with the overall vertical line).

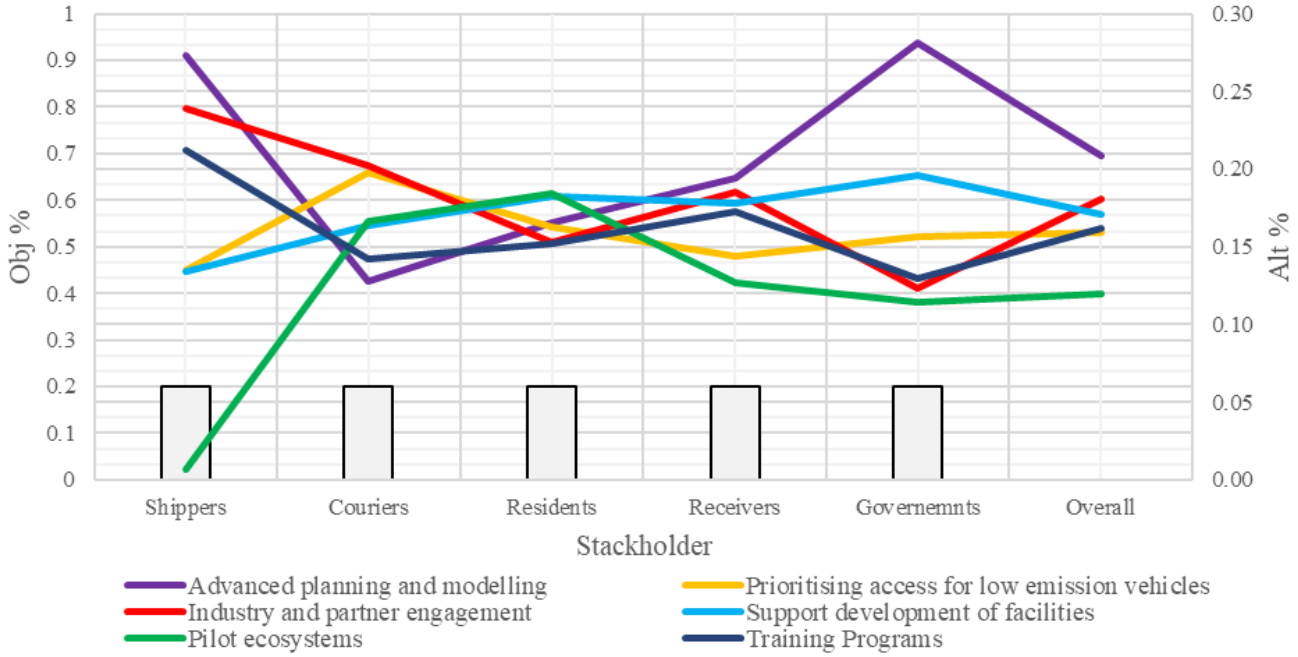

Figure 3. Multi-actor view

As the figure shows, advanced planning and modeling has an overall score equal to 0.21 and is the best urban freight initiative with a significant difference to other initiatives. However, stakeholders have different opinions regarding its usefulness. Governments, shippers, and receivers unanimously give the highest score to the initiative. In this regard, although governments and shippers believe that is the best alternative by far, receivers believe the initiative has an insignificant priority compared to other initiatives. It is interesting that couriers, playing a key role in successfully implementing an urban freight initiative, give the lowest score to advanced planning and modeling. Also, from the standpoint of residents, it is a medium-ranked initiative, although from their viewpoint, scores of all initiatives change in a tight range.

Pilot ecosystems have the lowest overall score (0.12) and rank as the worst initiative from the overall perspective of stakeholders. Shippers, governments, and receivers have again an agreement on unusefulness of the initiative, where shippers strongly disagree with the initiative. An interesting point about the score of pilot ecosystems is that residents rank it at the top, but it has highlighted that insignificant differences between initiatives' scores exist from residents' point of view.

Other four initiatives have gained almost equal overall scores ranging from 0.16 to 0.18. While initiatives like training programs and industry and partner engagement receive different scores from stakeholders, both support development of facilities and prioritizing access for low emission zones has gained similar scores from stakeholders. It shows that entire stakeholders nearly have an agreement on the usefulness level of these two initiatives.

Results show that advanced planning and modeling is the best initiative for implementation when all stakeholders have the same weight. However, a concerning point around the initiative is its score from the standpoint of couriers. Hence, we recommend that the initiative selects for implementation only when the decision maker is confident that couriers will accept to cooperate on it, otherwise, the weight of couriers or any other stakeholders who impact seriously on successfully implementation of an initiative should be raised and see what alternative comes out as the best one. In the next subsection, some

sensitivity analyses are done and their results can support the decision maker to make a better decision in terms of selecting one of the intuitive for implementation. Moreover, in the following a deeper discussion is formed on the score of each initiative from standpoint of every stakeholder, which can help the decision maker as well.

4.2. Sensitivity analyses

In this subsection, a sensitivity analysis is done on the weights of stakeholder groups considered in the MAMCA analysis. Various weighting systems can be designed for this purpose; however, we focus on weighting systems that are oriented towards doubling the weight of a single stakeholder group against others. Therefore, as we have five different stakeholder groups, five "stakeholder"-oriented weighting systems plus a neutral weighting system, in which a similar weight is set for the entire stakeholder groups, are considered for further evaluation and comparison. Table 4 shows the specifications of the weighting systems.

Table 4. Weighting systems considers for stakeholders' weights

Weighting system type	Weights				
	Courier	Shipper	Government	Residents	Receivers
Neutral	0.20	0.20	0.20	0.20	0.20
Courier-oriented	0.33	0.17	0.17	0.17	0.17
Shipper-oriented	0.17	0.33	0.17	0.17	0.17
Government-oriented	0.17	0.17	0.33	0.17	0.17
Residents-oriented	0.17	0.17	0.17	0.33	0.17
Receivers-oriented	0.17	0.17	0.17	0.17	0.33

Accordingly, the MAMCA analysis for each weighting system is run and the overall scores of the six initiatives are extracted, Then, the initiatives in every weighting system are ranked as to the best and worst initiatives are ranked 1 and 6. Figure 4 shows the initiatives' ranks in the weighting systems.

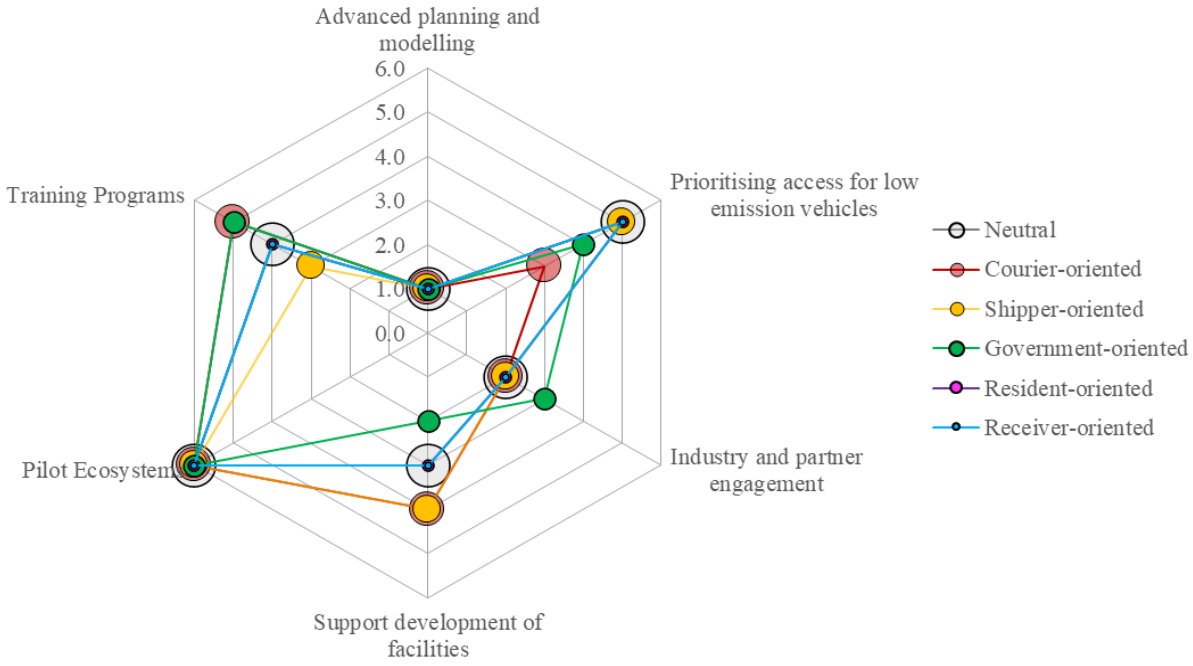

Figure 4. Single-actor view (governments)

As an interesting observation, the figure shows that in the entire weighting systems, the best and worst initiatives are always advance planning and modeling and pilot ecosystems, respectively. It means that the best initiative has an appropriate level of robustness. Moreover, the pilot ecosystem can be excluded from the decision maker's list of promising initiatives. Industry and partner engagement is always ranked as the second-best initiative, except in the government-oriented weighting system. The government is voted to support development of facilities as the second-best initiatives. Accordingly, Industry and partner engagement demands the special attention of the decision maker. Support development of facilities is ranked differently by the stakeholders; however, there is a propensity to lowest ranks (rank 3), while the ranks of training programs or prioritizing access for low emission zones are tended to higher ranks (ranks 4 and 5). Therefore, support development of facilities stabilizes its position on the third-best rank as it has the position in the neutral ranking system as well. The discrimination between ranks of training programs and prioritizing access for low emission zones is not explicitly visible; however, prioritizing access for low emission zones has ranked "5" three times while training programs has ranked "5" only two times. Hence, training programs is a little bit more preferred than prioritizing access for low emission zones.

5.Conclusions and Discussions

New challenges caused by the COVID-19 pandemic in Sydney Greater areas negatively impact the sustainability and efficiency of the distribution network. To tackle the issues, the implementation of some new initiatives are essential. However, the involvement of several stakeholders in city logistics complicates the launching process of alternatives. Therefore, in this research, the MAMCA method that enables us to incorporate various stakeholders' perspectives is selected. As a result of improving awareness about stakeholders' objectives and needs, improves the likelihood of success rate from implementing initiatives.

Six different surveys were designed and distributed in Sydney. The results of the MAMCA show that advanced planning and modeling is the initiative that can best address the needs of all stakeholders. This

initiative can include development of better models for understanding the ideal metropolitan network freight structure. The advancement of models can inform the government on ideal physical transport and land use network structures that can align to Government objectives. This can inform freight planning and (industrial) land use planning on a Metropolitan level. It can incorporate demand patterns influenced by COVID and subsequent social behavior.

Another dimension related to this initiative is exploring advanced application of technology in last mile freight and demonstrating the benefits of adopting new technology and alternate approaches. With the use of digital twin technology, whereby physical elements of a supply chain network have a digital counterpart, simulation and modelling can be used to demonstrate feasibility of new technological solutions for improving business operations and overall network efficiencies. Triple Bottom Line could be used as a framework to assess the impact of novel initiatives on all stakeholders involved. This can serve as a basis to inform and encourage industry players to consider the potential of these technologies within their own supply chain networks.

In terms of planning advancements, this initiative can include the provision of best practice guidelines for operating consolidation facilities for operating consolidation facilities to deliver into urban centres while reducing the overall number of vehicle trips. This category also involves further planning for transfer hubs in local areas such as the Courier Hub in Sydney CBD. These hubs enable the transfer of goods between modes and couriers, enabling greater operational efficiencies to be realised. This initiative would also entail better metropolitan freight models for strategic freight planning in conjunction with urban mobility planning.

On the other hand, pilot ecosystems are considered the least impactful alternative from the stakeholders' points of view. A sensitivity analysis, illustrated in figure 4, provides a deeper understanding of the impacts of stakeholders. It confirms advanced planning and modeling and pilot ecosystems are the most and least effective alternatives, respectively.

In spite of contacting multiple carriers and shippers to engage in the research and response to the survey emailed to them, few responses are collected. Since these companies hardly engage in the research studies while they are the key players in the urban freight logistics systems, it is suggested that future studies come up with innovative data collection techniques providing large enough sample size well representing the population.

Appendix

Table A1. Stakeholders' Weights

Stakeholder	Weight
Courier	0.2
Shipper	0.2
Government	0.2
Residents	0.2
Receivers	0.2

Table A2. Criteria Weights

Stakeholder	Criteria	Weight
Shippers	Quality of deliveries (secure, punctual, and damage free)	0.183
	Minimal costs	0.161
	High customer coverage	0.172
	Fast delivery	0.172
	Noise reduction	0.140
	Greener deliveries	0.172
Couriers	High service level provided for shippers and receivers	0.190
	Minimise costs of delivering parcels	0.180
	Reduce emissions	0.120
	Employee satisfaction	0.170
	Reduce damage and theft of delivered parcels	0.160
	Optimise vehicle capacity usage	0.180
Residents	Noise Levels	0.238
	Traffic Safety	0.273
	GHG Emissions	0.227
	Traffic Congestion	0.261
Receivers	Delivery Security	0.181
	Delivery Punctuality	0.167
	Parcel Receiving Cost	0.174
	Delivery Status Updates	0.159
	Convenient Deliveries Times	0.155
	Convenient Delivery Locations	0.163
Government	Strengthening the economy	0.256
	Improving sustainability	0.272
	Improving road safety	0.243
	Enhancing the performance of distribution networks	0.229

Table A3. Alternative weights in respective to each criterion

Alternative name		Advanced planning and modelling	Prioritising access for low emission vehicles	Industry and partner engagement	Support development of facilities	Pilot Ecosystems	Training Programs
Shippers' criteria	Quality of deliveries (secure, punctual, and damage free)	0.33	0.00	0.20	0.20	0.00	0.27
	Minimal costs	0.33	0.00	0.25	0.17	0.04	0.21
	High customer coverage	0.35	0.00	0.25	0.25	0.00	0.15
	Fast delivery	0.32	0.08	0.24	0.16	0.00	0.20
	Noise reduction	0.00	0.25	0.25	0.00	0.00	0.50
	Greener deliveries	0.25	0.50	0.25	0.00	0.00	0.00
Couriers' criteria	High service level provided for shippers and receivers	0.21	0.20	0.17	0.16	0.08	0.18
	Minimise costs of delivering parcels	0.16	0.10	0.13	0.18	0.25	0.18
	Reduce emissions	0.07	0.19	0.20	0.18	0.15	0.22
	Employee satisfaction	0.13	0.24	0.23	0.13	0.22	0.05
	Reduce damage and theft of delivered parcels	0.16	0.30	0.20	0.05	0.09	0.20
	Optimise vehicle capacity usage	0.02	0.17	0.28	0.27	0.21	0.06
Residents' criteria	Noise Levels	0.15	0.19	0.15	0.17	0.19	0.15
	Traffic Safety	0.16	0.13	0.17	0.19	0.18	0.16
	GHG Emissions	0.17	0.19	0.15	0.17	0.19	0.13
	Traffic Congestion	0.18	0.15	0.14	0.19	0.18	0.16
Receivers' criteria	Delivery Security	0.18	0.14	0.19	0.18	0.14	0.18
	Delivery Punctuality	0.19	0.15	0.18	0.19	0.11	0.18
	Parcel Receiving Cost	0.21	0.15	0.21	0.16	0.11	0.17
	Delivery Status Updates	0.20	0.14	0.17	0.17	0.15	0.17
	Convenient Deliveries Times	0.19	0.16	0.18	0.19	0.10	0.18
	Convenient Delivery Locations	0.19	0.13	0.18	0.19	0.14	0.16
Government' s' criteria	Strengthening the economy	0.23	0.12	0.20	0.27	0.00	0.18
	Improving sustainability	0.22	0.41	0.04	0.05	0.27	0.00
	Improving road safety	0.35	0.00	0.18	0.18	0.16	0.13
	Enhancing the performance of distribution networks	0.35	0.06	0.07	0.29	0.00	0.23

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