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An Application of Triple Bottom Line Model and MCDM Method to Develop Sustainable Last-mile Delivery in B2C E-commerce

Nhu-Mai Thi NONG[1], Duc-Son HA[2], Dinh-Thuan TRAN[3]

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Abstract

Purpose: This study aims to develop sustainable last-mile delivery in B2C e-commerce**. Research design, data, and methodology:** A combined method of bibliometric analysis, deep interview, quantitative survey, and ANP, in which bibliometric analysis was carried out for the identification of trends and drivers of sustainable last-mile delivery, deep interviews with 10 stakeholders were conducted to revise sustainable last-mile delivery drivers, the quantitative survey with the reliability and validity test was employed to ensure of the compatibility between the sustainable development drivers and last-mile delivery services, and ANP was executed to derive priorities of these drivers. **Results:** The drivers of sustainable last-mile delivery development are made up of three key clusters namely economic, social and environmental drivers and 12 sub-drivers, which include reducing failed orders, increasing delivery efficiency, reducing delivery costs and increasing delivery speed for economic driver cluster; increasing delivery space, improving public spaces, reducing traffic jams, and increasing safety and security for social cluster; reducing emissions, reducing noise pollution, reducing visual pollution, and having green policy for environmental cluster. **Conclusions:** The theoretical contribution of this study is the introduction of drivers of last-mile delivery sustainable development and their priorities. In regard to the practical contribution, the study results are roadmaps for stakeholders in pursuing last-mile delivery sustainable development.

Keywords: B2C, E-commerce, Last-mile Delivery, MCDM, Triple Bottom Line.

JEL Classification Code: L81, M10, Q56

1. Introduction

The growth of e-commerce has led to the growth of last-mile delivery (LMD) in Vietnam with far-reaching economic, social and environmental impacts. Economically, LMD is the stage that accounts for a large proportion of total logistics costs, usually accounting for 28% of total transportation costs and can be up to 53% in the case of on-demand delivery. The growth of LMD helps optimize the supply chain, boost online sales and create millions of jobs for shippers, warehouse staff and related services.

Socially, fast and convenient delivery services improve the consumer experience, helping people access products from afar more easily, especially in rural areas. However, this also puts great pressure on delivery staff, as they have to endure heavy workloads, unstable salaries and increased risks of traffic accidents.

1 First and Corresponding Author. Lecturer, Faculty of Commerce and Tourism, University of Finance - Marketing, Hochiminh city, Vietnam. Email: ntnmai@ufm.edu.vn
2 Second Author. Lecturer, Faculty of Business Administration, University of Finance - Marketing, Hochiminh city, Vietnam. Email: haducson@ufm.edu.vn
3 Third Author. Faculty of Commerce and Tourism, University of Finance - Marketing, Hochiminh city, Vietnam. Email: tdthuan@ufm.edu.vn

Environmentally, LMD generates significant CO2 emissions, air and noise pollution due to the increasing number of delivery vehicles. A study by the Institute of Transportation Research (ITDP) shows that the urban transport sector contributes about 20-30% of total CO_2 emissions in large cities. As the number of deliveries increases due to the growth of e-commerce, vehicle emissions also increase significantly. Besides, in LMD, the packaging used to package and protect the product is often plastic, foam or other materials that do not easily decompose. This leads to a significant increase in plastic waste, contributing to environmental pollution. According to a report by the World Wide Fund for Nature (WWF), plastic waste from e-commerce delivery packaging has become a burning problem in Vietnam, as the amount of plastic packaging is estimated to increase every year.

In general, LMD plays an important role in the development of e-commerce but also poses many challenges in terms of cost, labor and the environment. Therefore, synchronous solutions such as route optimization, using green delivery vehicles and applying a nearby warehouse model... need to be implemented to ensure sustainability. However, these solutions require coordination between businesses, governments and consumers in optimizing the supply chain, raising awareness about green consumption, and promulgating appropriate management policies to limit negative impacts on the environment. In light of the practical reasons outlined above, this project was undertaken by the authors to sustainably develop LMD in Vietnam, contributing to the successful implementation of Vietnam's commitment to achieve Net zero by 2050. In addition, the introduction of LMD sustainable development drivers and their priorities is theoretical contribution of this study.

2. Related Theories and Literature Review on Last-mile Delivery

2.1. Related Theories

The Triple Bottom Line model in the context of sustainable development is an important theoretical framework, focusing on the interaction and balance between three main factors: Economy, Society and Environment. This model emphasizes that to achieve sustainable development, it is necessary to simultaneously promote economic growth, ensure social justice and protect the environment (Elkington, 1997). The model provides a framework for measuring business performance and organizational success using economic, social and environmental dimensions (Goel, 2010). The term is also considered a practical framework of sustainability (Rogers & Hudson, 2011). These three driving forces do not exist independently but have a close interrelationship. Developments in one area can positively or negatively affect other areas. Therefore, policy planning and development strategies need to consider all three aspects simultaneously to achieve sustainable development goals.

Economic Drivers: TBL's economic drivers refer to the impact of an organization's business activities on the economy (Elkington, 1997). The economic relationship between the development of the organization and the development of the economy is shown through the organization's contributions to the development of the economy. In other words, TBL focuses on the economic value provided by an organization to the surrounding system in the way that organization develops.

Social Drivers: TBL's social drivers refer to the implementation of business practices that are fair and beneficial to employees, human capital, and the community (Elkington, 1997). An example of this is providing employees with fair wages and health insurance. Social performance highlights how an organization interacts with its community, focusing on matters like employee well-being, community involvement, and just compensation (Goel, 2010).

Environmental Drivers: TBL's environmental component advocates for sustainable practices that preserve environmental resources for future generations. Key elements include energy efficiency, mitigation of greenhouse gas emissions, and limitation of ecological degradation, etc. (Goel, 2010).

This model is applied to this research to identify the driving forces for sustainable LMD development and on that basis to explore the component of driving forces.

2.2. Previous Theories

E-commerce has grown rapidly in recent years, dramatically driving demand for LMD globally. According to many studies, e-commerce not only changes the way consumers go shopping but also puts great pressure on the logistics system and the environment, especially in LMD - which accounts for the majority of costs and emissions of the entire supply chain, usually accounting for 28% of total transportation costs and can be up to 53% in the case of on-demand delivery.

This is especially important in an e-commerce landscape that drives expectations for faster and more flexible delivery (like same-day delivery, delivery within hours). A report from the World Economic Forum in 2022 estimates that global e-commerce generates more than 100 million tons of packaging waste each year. Another study by UNCTAD in 2020 shows that LMD increases traffic pressure, especially in big cities. It can be seen that LMD greatly affects the economy, society and the environment.

Therefore, researching and providing sustainable development solutions for LMD is an urgent scientific task in the period of rapid e-commerce development. When searching for the keyword "last-mile delivery" on the international database Scopus, there are 2,298 research articles suggested by the system. The authors used VOSviewer software version 1.6.20 to analyze the above 2,298 research articles. The results show that there are four groups of topics related to LMD (Figure 1):

(1) Sustainable development of LMD in the context of e-commerce (red).

(2) Road routing and routing methods (green).

(3) Delivery vehicles (blue).

(4) Decision-making methods for choosing last mile delivery (yellow).

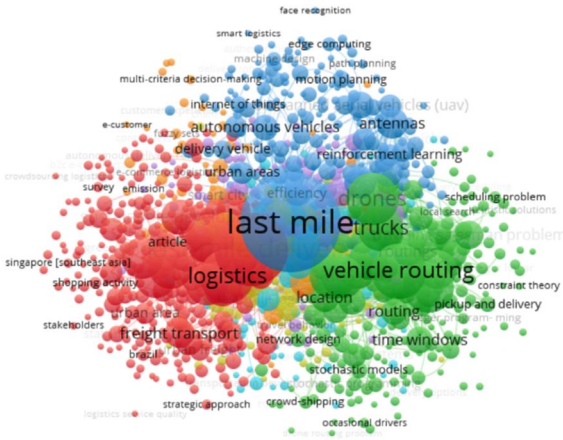

Figure 1: Topics Related to Last-mile Delivery

With the four topic groups mentioned above, sustainable development of LMD in the context of e-commerce is a topic of interest to many researchers and this is also the topic that the authors chose for further analysis.

The authors continued to use the Scopus database to search for research articles related to sustainable development of LMD, resulting in 585 related articles. After using VOSviewer software to analyze the above articles, the authors came up with six related issues as follows (Figure 2):

(1) Research on sustainable development of LMD is conducted mainly in the field of e-commerce (red).

(2) Vehicles used in LMD to protect the environment (green).

(3) studies conducted mainly in cities (blue).

(4) multi-criteria decision-making method (MCDM) is mainly used to make decisions related to sustainable LMD development (yellow).

(5) sustainable development of LMD related to environmental issues (purple).

(6) sustainable development of LMD related to transportation issues (blue)

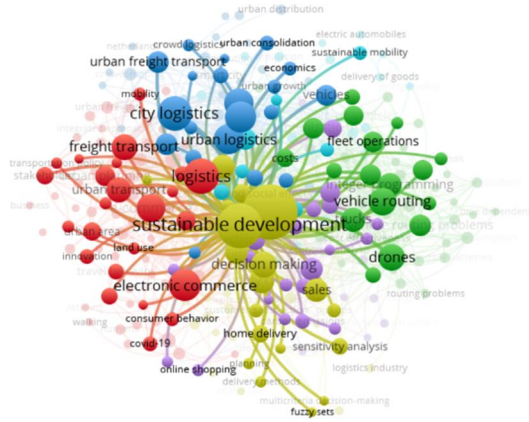

Figure 2: Research Articles Related to Sustainable Development LMD

From the above analysis results, it can be seen that sustainable LMD research is focused on the development of e-commerce, mainly B2C since the keywords "e-commerce" or "electronic commerce" and "customer behavior" frequently appear in the analysis results. Besides, the scope of research is mainly in urban areas because this is where most of the freight forwarding activities take place. However, research is largely focused on European and other developed countries such as the US, China, Singapore... (Figure 3). Few research has been done in emerging countries, which leads to the necessity to develop sustainable LMD drivers for them. The identified sustainable LMD drivers found in developed countries may be served as valuable references for the authors in developing a tailored set of drivers for one of the most dynamic emerging countries in the East Asia region - Vietnam, especially research of Gonzalez et al. (2023), Wang et al. (2021, 2023) and Boggio-Marzet et al. (2023).

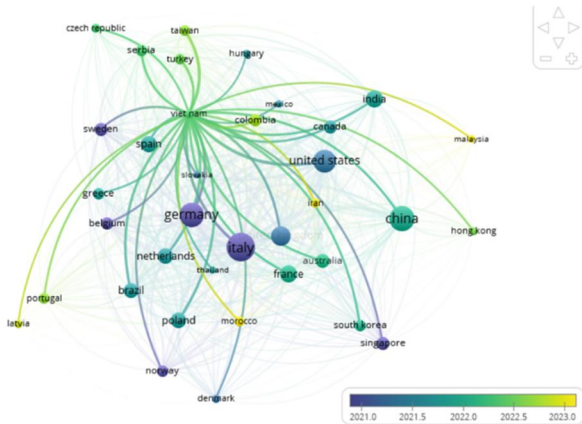

Figure 3: Countries Conducting Research on Sustainable Last-mile Delivery

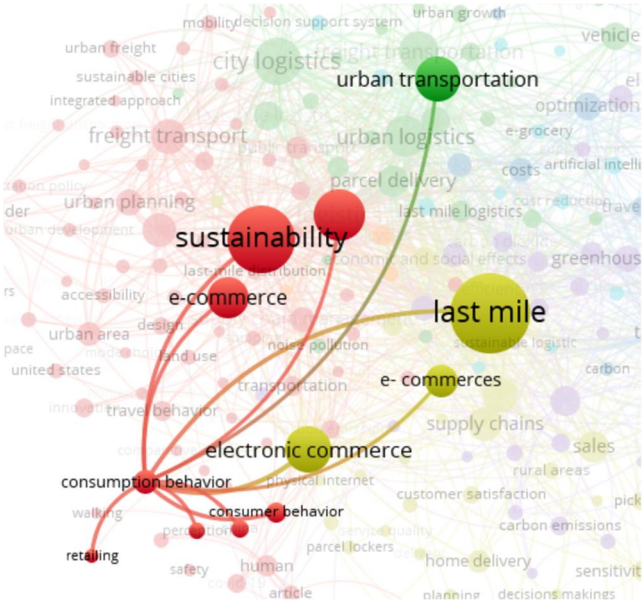

Figure 4: Sustainable Last-mile Delivery from the Consumer Perspective

In addition, studies mainly focus on providing solutions to develop sustainable LMD related to the choice of specific delivery vehicles (Blue, Figure 2) (Blagojević et al., 2023; Bilgili et al., 2024); to route routing (Green, Figure 2) or as the solution comes mainly from the consumer perspective (Figure 4) (Nogueira et al., 2021; Kiba-Janiak et al., 2024) and the logistics company providing delivery services (Blagojević et al., 2023). The number of research articles from the perspective of stakeholders is still limited, especially from the community perspective (Bertolini et al., 2024). This can also be seen as a weakness of previous studies because sustainable development must ensure a balance of interests of stakeholders including customers, e-commerce companies, shipping units, local authorities... (Siegfried & Zhang, 2021), except for two research articles by Gonzalez et al. (2023) and Boggio-Marzet and colleagues (2023). However, the above two articles were both conducted in European countries. With the research of Boggio-Marzet et al. (2023), the authors applied expert methods and surveyed stakeholders to evaluate solutions for developing LMD in the city proposed by the authors based on research, including groups of economic, social, and environmental solutions. The authors based on the highest average evaluation results to choose the appropriate solution for the city. The disadvantage of this study is that the authors have not applied multi-criteria decision analysis methods to optimize analysis results. Similarly, Gonzalez et al. (2023) also conducted a research project on sustainable development of LMD in Spain based on synthesizing feedback from stakeholders through surveys and discussions to propose solutions. These are two of the very few foreign articles that consider stakeholders' interests, but have not yet used multi-criteria and multi-objective analysis tools to solve the problem of opposing interests of solution groups and the interaction between criteria. Most importantly, these two studies were conducted in Europe, where economic, social and environmental conditions are more developed than many other countries in the world.

After conducting literature review, the authors drew the following conclusions:

First, there is still no research using multi-objective decision making (MCDM) in developing sustainable LMD.

Second, solutions for developing sustainable LMD are mainly built from the perspective of the customer or carrier. Very little research has been done to develop sustainable LMD from the perspective of stakeholders. If there are any (02 studies), they only focus on the European market with different economic, social and environmental conditions compared to other countries in the world, including Vietnam.

Third, in Vietnam, there are currently no projects that have conducted research on developing sustainable LMD from the perspective of stakeholders.

The above research gaps will be addressed by the authors in this research with the goal of developing sustainable LMD in Vietnam in all three aspects of economy - society - environment, balancing the interests of stakeholders through the government intervention addressed in green policies and through a multi-objective decision-making method, specifically the network analysis method - ANP in B2C e-commerce. Among e-commerce models, B2C (business to customer) stands out with an impressive growth rate, reaching 18-25% per year, accounting for 2/3 of the country's digital economic value, helping Vietnam reach the top 10 countries with the world's leading e-commerce growth rate. Therefore, B2C e-commerce research is representative of all e-commerce activities. With the above analysis, the authors believe that this topic is a new combination and suitable for the practical situation of Vietnam.

For ANP, it is an unstructured network that handles sources, sinks and cycles, which can handle interdependencies between criteria by calculating aggregate weights through a super matrix, from which the best options will be selected according to priority. ANP was chosen to be applied in this topic for the following reasons: Firstly, according to the review, there is no topic that has applied ANP in researching issues of sustainable public records (Siva et al., 2023); Secondly, ANP is considered a suitable method that can resolve the opposition of interests between groups of criteria (motivation) (Saaty, 2005); Thirdly, ANP can address the interrelationship between criteria (driving forces).

Regarding the driving forces for sustainable LMD development, according to the authors' review of related articles, the economic, social and environmental drivers have the following components (see Table 1 và Figure 5):

Table 1: Driving Forces for Sustainable LMD Development

Drivers	Drivers' components	Explanation	Source
Economic	Reduce the number of failed orders	Return a parcel because customers are not at home	Boggio-Marzet et al. (2023)
	Increase delivery efficiency	Increase vehicle/closet storage space, reduce number of delivery vehicles	Gonzalez et al. (2023), Boggio-Marzet et al. (2023)
	Reduce delivery costs	Reduce the cost consumers pay for delivery	Wang et al. (2021, 2023), Boggio-Marzet et al. (2023)
	Increase delivery speed	Speed up the lead time.	Gonzalez et al. (2023), Wang et al. (2021, 2023), Boggio-Marzet et al. (2023)
Social	Increase delivery space	There are many different delivery spaces	Boggio-Marzet et al. (2023)
	Improve public spaces	Improve loading and unloading areas, reduce illegal parking areas.	Boggio-Marzet et al. (2023)
	Reduce traffic jams	People encounter traffic jams	Gonzalez et al. (2023), Boggio-Marzet et al. (2023)
	Increase safety and security	Reduce accidents involving people, individuals, data, goods and property	Gonzalez et al. (2023), Wang et al. (2021, 2023)
Environmental	Reduce emissions	Reduce PM and NOx emissions	Gonzalez et al. (2023), Wang et al. (2021, 2023)
	Reduce noise pollution	Reduce the noise levels people are exposed to during the day	Gonzalez et al. (2023)
	Reduce visual pollution	Reduce urban landscape distortion due to public space use	Gonzalez et al. (2023)
	Have green policy	Regulations on green activities, green materials, environmental regulations	Wang et al. (2021)

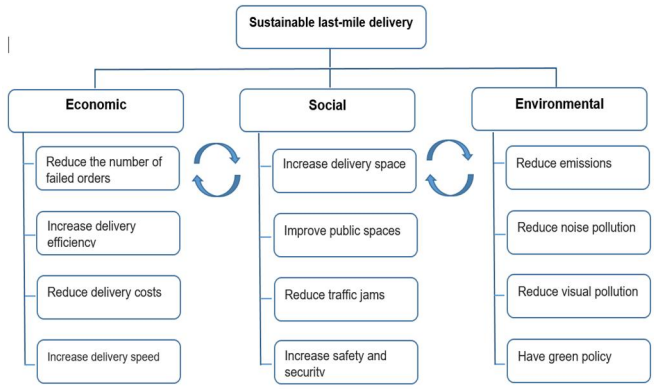

Figure 5: Sustainability Dimensions

3. Research Design and Methodology

As discussed in the preceding sections, group discussion, survey and ANP were applied to define driving forces for sustainable LMD development, illustrated in the research process in Figure 6.

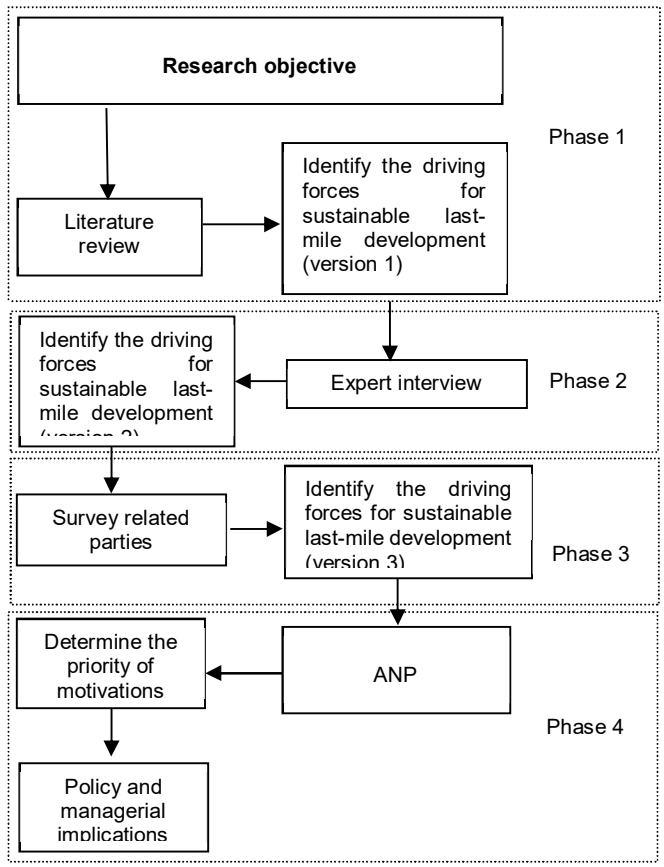

Figure 6: Research Design

• In phase 1, the authors executed a literature review to select criteria to identify the driving forces for sustainable last-mile development.

• In phase 2, interview method was used to determine the driving forces for sustainable LMD development proposed by the authors after conducting literature review. Parties participating in this method are stakeholders' representatives (Gonzalez et al., 2023), including 02 sellers (e-commerce business), 02 logistics service providers, 02 end consumers, 02 officers from government agencies namely Department of Industry and Trade, and Department of Public Works and Transport, 01 expert from Higher education institution, and 01 from e-commerce platform.

Table 2: Background Information of Interviewee

Participant's number	Stakeholders' role	Career/Position
P01	End consumer	Banker
P02	End consumer	Marketing manager
P03	E-commerce platform	Manager
P04	LMD provider	CEO
P05	LMD provider	Manager
P06	E-commerce business	Business owner
P07	E-commerce business	Co-founder
P08	Department of Industry and Trade	Officer
P09	Department of Public Works and Transport	Officer
P10	Logistics expert	Head of Logistics Department

Source: The authors

• In phase 3, based on the interview findings, the key drivers of sustainable LMD development would be formulated into a structured questionnaire employing a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to facilitate the subsequent survey in Hochiminh city, Vietnam.

Table 3: Structured Questionnaire

No.	Drivers for Sustainable LMD	Assessment scale				
		1	2	3	4	5
I	**In terms of Economic aspect**					
1.1	To develop sustainable LMD, economically, it is necessary to reduce the number of failed delivery orders to reduce the pressure of re-delivery (because the customer is not at home or the address is incorrect) so as not to increase shipping costs and impact the environment.					
1.2	To develop sustainable LMD, economically, it is necessary to increase delivery efficiency such as increasing storage space on vehicles/lockers, reducing the number of delivery vehicles.					
1.3	To develop sustainable LMD, economically, it is necessary to reduce the delivery costs that consumers have to pay for delivery activities.					
1.4	To develop sustainable LMD, economically, it is necessary to increase delivery speed, speeding up the time needed for goods to reach the final recipient.					
II	**In terms of Social aspect**					
2.1	To develop sustainable LMD, socially, it is necessary to increase delivery space in different delivery areas/locations.					
2.2	To develop sustainable LMD, socially, it is necessary to improve public spaces (improve loading and unloading areas, reduce illegal parking areas).					
2.3	To develop sustainable LMD, socially, it is necessary to reduce traffic jams.					
2.4	To develop sustainable LMD, socially, it is necessary to increase safety and security such as reducing accidents involving people, individuals, data, goods and assets.					
III	**In terms of Environmental aspect**					
3.1	To develop sustainable LMD, environmentally, it is necessary to reduce emissions such as PM, NOx					
3.2	To develop sustainable LMD, environmentally, it is necessary to reduce noise pollution (reduce the noise level that people are exposed to during the day)					
3.2	To develop sustainable LMD, environmentally, it is necessary to reduce visual pollution (reduce urban landscape distortion due to the use of public space)					
3.4	To develop sustainable LMD, environmentally, Green Policies are needed (Regulations on green operations, green materials, environmental regulations).					

Survey subjects: stakeholders who are relevant to LMD include end consumers, logistics service providers, e-commerce businesses, government representatives.

Sample size: According to Hair et al. (2014), the minimum sample size to use EFA is 50, preferably 100 or more. Therefore, the minimum survey sample will be 100.

Survey area: in Hochiminh city, Vietnam

Method: administered directly and via online platforms such as email and Google forms from 7th April to 20th April, 2025.

Data processing was performed using SPSS 26 software to assess the reliability (via Cronbach's alpha) and calculate the validity of the identified drivers, based on the factor loading coefficients. In addition, several statistical tests were applied to confirm the findings. The primary objective of the project was to identify the driving forces for sustainable LMD development. Thus, the research focused mainly on exploring these drivers by testing their reliability and validity (Hair et al., 2014). Reliability reflects the internal consistency of a measurement tool. It is most commonly assessed using Cronbach's alpha, which typically ranges from 0 to 1. According to Hair et al. (2014), a value of 0.60 or higher is considered acceptable. The validity of drivers and sub-drivers can be assessed through Exploratory Factor Analysis (EFA). EFA helps determine whether driver cluster together as expected, thus supporting construct validity. Key metrics tested in EFA include the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which should be greater than 0.5, and Bartlett's Test of Sphericity, which should be significant ($p < 0.05$), indicating that factor analysis is appropriate. Additionally, factor loadings (ideally ≥ 0.5) are examined to assess how well each item represents the underlying factor, while Eigenvalues greater than 1 and the percentage of variance explained are used to determine the number and strength of sub-drivers extracted (Hair et al., 2014). If any drivers were eliminated during the reliability and validity testing, additional expert interviews would be conducted to explore the reasons and further validate the findings. The identified driving forces were then used to establish the interrelationships among the drivers and their sub-drivers, in order to calculate their respective weights by using the ANP method.

- Finally, in phase 4, the ANP method was employed to determine the relative significance of the evaluation drivers. Interviews were conducted with five stakeholders' representatives to perform pairwise comparisons among the drivers (as shown in Table 4). The research results were subsequently analyzed, leading to the formulation of policy and management recommendations for promoting the sustainable development of LMD.

Table 4: Background Information of Stakeholders Participating in Making Pairwise Comparison

Participant's number	Stakeholders' role	Career/ Position
P01	End consumer	Banker
P02	E-commerce platform	Manager
P03	LMD provider	Manager
P04	E-commerce business	Manager
P05	Department of Industry and Trade	Officer

ANP is a flexible network that accommodates sources, sinks, and cycles, enabling it to manage interdependencies among drivers. It calculates aggregate weights through a supermatrix, from which the optimal solutions are selected based on priority.

The steps for implementing ANP are as follows (Saaty, 2005):

Step 1: The first step involves comparing criteria across the system to construct a supermatrix. This is achieved through pairwise comparison by asking, "How important is a given criterion relative to others?"

A scale from 1 to 9 is used to denote the relative importance, ranging from "equally important" to "extremely important."

$$W = \begin{array}{c} \\ e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \\ e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \\ \vdots \\ e_{m1} \\ e_{m2} \\ \vdots \\ e_{mn_m} \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & & C_2 & \cdots & C_m \\ e_{11}\cdots e_{1n_1} & e_{21}\cdots e_{2n_2} & \cdots & e_{m1}\cdots e_{mn_m} \end{array} \\ \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1m} \\ W_{21} & W_{22} & \cdots & W_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ W_{m1} & W_{m2} & \cdots & W_{mm} \end{bmatrix} \end{array} \begin{array}{l} \\ C_1 \\ \\ \\ \\ C_2 \\ \\ \\ \\ \vdots \\ \\ \\ \\ C_m \end{array}$$

Where, C_m represents the m_{th} cluster, e_{mn} refers to the n_{th} element within the m_{th} cluster, and W_{ij} is the primary eigenvector indicating the influence of elements in the j_{th} cluster on those in the i_{th} cluster. If the j_{th} cluster has no influence on the i_{th} cluster, then $W_{ij} = 0$. The form of the supermatrix is highly dependent on the structure's diversity.

Step 2: Calculate the level of influence (i.e., the main eigenvector) of the elements (drivers) in each component (matrix).

Step 3: Construct the supermatrix based on the eigenvectors and the system structure.

Step 4: Normalize all column totals to unity to obtain the weighted supermatrix.

Step 5: Raise the weighted supermatrix to the limiting power as shown in the equation below to derive the global priority vector.

$$\lim_{k\to\infty} W^k.$$

If the supermatrix exhibits periodic behavior, the limiting supermatrix will not be the only solution. In such cases, the Cesaro total will be computed to establish priority. The general Cesaro total is constructed as follows:

$$\lim_{k\to\infty}\left(\frac{1}{N}\right)\sum_{r=1}^{N} W_r^k,$$

To calculate the average effect of the limiting supermatrix, where **Wr** denotes the r-th limiting supermatrix. Otherwise, the supermatrix will be raised to a large power to obtain the priority weights.

All the aforementioned steps are implemented using the Super Decision Software, developed by Saaty in 2004.

4. Findings

4.1. Phase 1

After a review of literature on sustainable LMD driving forces, the set of driving forces for sustainable last-mile development is summarized in Table 1.

4.2. Phase 2 – Interview Method

From the interview, we find that all stakeholders emphasize the necessity to develop sustainable LMD in all three aspects: economic, social, and environment ones. All driving forces mentioned in Table 1 are highly valued and have a great impact on sustainable LMD development. In terms of economic drivers, all stakeholders laid their focus on reducing the number of failed orders, which can increase costs for LMD providers and cause pollution pressure on the environment. To do that, Participant 05 suggests to replicate alternative pick-up solutions, through which helps reduce the rate of returned and re-delivered goods, and reduce the number of kilometers traveled per order. This suggestion is useful and will be considered in the management and policy implications section. The next important driving force is to reduce delivery costs. Most stakeholders (9 out of 10) agreed that this driver was extremely significant. For LMD providers, they are on their best to reduce this cost by applying various solutions. However, one e-commerce business hopes to keep this cost unchanged as she would like to ensure the benefits for her LMD provider. The other drivers, namely increasing delivery speed and increasing delivery efficiency also attract stakeholders' attention. For social drivers, traffic jams caused by LMD is worrying and needs to be resolved first, then followed by safety and security, delivery space, and public space. In terms of environment, green policies of government are of key drivers as this is the legal corridor for all sustainable LMD development solutions to be thoroughly and effectively implemented. It is, therefore, highly appreciated by stakeholders. The following forces are to reduce noise pollution, reduce visual pollution, and reduce emissions.

4.3. Phase 3 – Quantitative Survey

The drivers explored from literature review and interviews were then utilized in quantitative survey. The survey was executed on 276 stakeholders including 167 end-consumers, 14 e-commerce platforms, 53 e-commerce businesses, 28 LMD providers, 13 executives and managers from Department of Industry and Trade and Department of Public Works and Transport. On the whole, it is well stated that the survey results can be satisfied most the demand of all relevant parties.

The analysis results show that Cronbach's alpha ranged from 0.727 to 0.823, indicating the reliability of data and they can be used for the next statistical analysis (see Table 5). In addition, the mean of these drivers got above 3.60, emphasizing their importance in driving sustainable LMD development.

Table 5: Reliability Test

Driver	No. of items	Cronbach's alpha	Mean
Economic (EC)	4	0.823	3.79
Social (SO)	4	0.802	3.60
Environment (EN)	4	0.727	3.81

Source: The authors

EFA results depicts that: (1) the KMO index produced a value of 0.858, which is greater than a threshold of 0.5, which proves the appropriation of the data for factor analysis; (2) The result of Barlett's test yielded a value of 1176.150 with a significance level of Sig. = 0.000, which is less than 0.05, indicating that the variables are correlated and meet the necessary conditions for factor analysis; (3) The total value of extracted variance = 62.387% > 50%: meets the requirements; then it can be said that these 3 drivers explain 62.387% of the variation in the data; (4) The Eigenvalues of the factors are all high (>1), the 3rd driver has the lowest Eigenvalues of 1.263> 1; (5) All factor loading coefficients exceed 0.5, and no variable is loaded onto both factors simultaneously with similar coefficients (refer to Table 6). This confirms that the factors exhibit both convergent and discriminant validity in the EFA analysis. As a result, the set of three drivers and twelve sub-drivers for sustainable LMD development was identified through EFA.

Table 6: Rotated Component Matrix

Sub-Driver	Driver		
	1	2	3
EC2	.811		
EC1	.797		
EC3	.762		
EC4	.700		
SO1		.808	
SO2		.769	
SO4		.761	
SO3		.659	

Sub-Driver	Driver		
	1	2	3
EN3			.793
EN2			.776
EN1			.682
EN4			.580
Eigenvalue	1.263		
Cumulative	62.387		
KMO	.858		
Sig.	.000		

Source: The authors

4.4. Phase 4 – ANP Method

EFA result is the basis for the authors to proceed ANP analysis. Experts mentioned in Table 4 determined the interrelationships and pairwise comparisons among drivers and sub-drivers (see Figure 7).

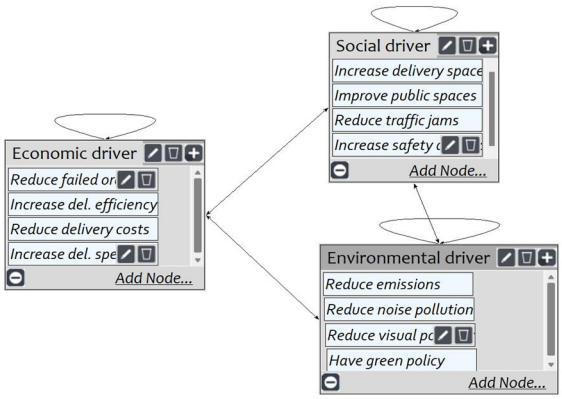

Figure 7: Interrelationships among Drivers and Sub-drivers

Table 7: The Priorities of LMD Sustainable Development Drivers

Name	Normalized By Cluster	Rank in Cluster	Limiting	Rank
Economic driver				
Reduce failed orders	0.3	1	0.12	2
Increase del. efficiency	0.3	1	0.12	2
Reduce delivery costs	0.1	4	0.04	8
Increase del. speed	0.3	1	0.12	2
Social driver				
Increase delivery space	0.14016	4	0.028032	10
Improve public spaces	0.20732	2	0.041464	7
Reduce traffic jams	0.17965	3	0.03593	9
Increase safety and security	0.47287	1	0.094574	6
Environmental driver				
Reduce emissions	0.23946	2	0.095785	5
Reduce noise pollution	0.06483	4	0.025931	12
Reduce visual pollution	0.06599	3	0.026397	11
Have green policy	0.62972	1	0.251887	1

Source: The authors

The priorities of LMD sustainable development drivers are presented in Table 7. It is worth noting that in Environmental Drivers cluster, "Have green policy" is the most meaningful driver in the set of all drivers with its highest Limiting (0.251887). This reflects the growing emphasis on sustainable development and social responsibility in operating strategies as well as the notable role of the government and state management agencies in sustainable LMD development, because according to stakeholders, government policies guide parties to practice green logistics as well as create a legal corridor for sustainable LMD development activities to take place smoothly and appropriately. In addition, this also reflects the growing expectations of society and stakeholders for environmental responsibility and compliance with sustainable development regulations. Besides, "reduce emissions" is also a driver of concern (Normalized = 0.23946; Limiting = 0.095785; ranked 5), indicating the urgent need to optimize delivery vehicles and choose clean technologies. This result is a novel point and contribution of the study compared to the research of Wang et al. (2021) where green policy is less concerned than emission reduction. Meanwhile, drivers such as "reduce visual pollution" and "reduce noise pollution" have significantly lower levels of influence, indicating that they are not yet a priority concern in current delivery models. This result is in the same line with the finding of Boggio-Marzet et al. (2021). However, these are still drivers that need to be gradually integrated when moving towards more harmonious living spaces in dense urban areas.

In Economic drivers, the key sub-drivers include: reducing order failures, increasing delivery efficiency, and increasing delivery speed. All three of these sub-drivers have the highest relative importance index in the group (Normalized = 0.3) and are ranked second in the ranking of limited impact (Limiting = 0.12). This shows that, in the LMD operation, accuracy, reliability, and delivery time are the factors that play a decisive role in customer satisfaction as well as overall operational performance. In contrast, the sub-driver of reducing delivery costs, although meaningful in the long-term strategy, has a lower level of influence (Normalized = 0.1, Limiting = 0.04, ranked 8), showing that in the current period, businesses are willing to trade costs for speed and accuracy, especially in a highly competitive environment as e-commerce. The priorities of drivers in economic cluster totally match with the research results of Wang et al. (2021).

In Social cluster, the safety and security enhancement sub-driver stands out with a Normalized index of 0.47287 and a Limiting index of 0.094574, ranking 6th overall. This shows that security during delivery, especially in complex residential areas, is an important requirement to ensure efficiency and reduce operational risks. Drivers such as

improving public space, reducing traffic jams and increasing delivery space have a lower level of influence (Normalized from 0.14 to 0.21), reflecting the fact that these issues can be regulated indirectly through urban planning solutions and infrastructure policies, rather than direct intervention from logistics operators. This finding has no similarities with Wang et al.'s research (2021), which emphasize the least importance on safety and considered as novel point of this study.

5. Conclusion and Implications

To develop sustainable LMD in B2C e-commerce, Triple bottom line theory was employed to define driving forces of development and ANP method was utilized to define the priorities of drivers. The results show that there are three clusters namely economic, social and environmental drivers, in which the priority vectors of sub-drivers in these clusters are as follows having green policies, reducing failed orders, increasing delivery efficiency, increasing delivery speed, reducing emissions, increasing safety and security, improving public spaces, reducing delivery costs, reducing traffic jams, increasing delivery spaces, reducing visual pollution, and reducing noise pollution.

The theoretical contribution of this study is the introduction of drivers of LMD sustainable development and their priorities. In regard to the practical contribution, the study results are roadmaps for stakeholders in pursuing LMD sustainable development. As the drivers affecting sustainable LMD have different levels of importance, thereby shaping the priority directions in system design and operation. The proposed solutions below are arranged in order of decreasing importance of the drivers.

Firstly, strengthening green policies and legal frameworks to support sustainable development.

The factor "have green policies" is the most influential driver with a Normalized index of 0.62972 and a Limiting index of 0.251887 – the highest among all factors. This shows the urgent need to establish and enforce a legal framework to promote green logistics development at the local and national levels. Priority policies include: encouraging the use of electric vehicles in delivery, regulating urban emissions, providing tax incentives for businesses investing in green technology, and integrating environmental criteria in bidding for public logistics services. In addition, urban delivery infrastructure planning should be developed in conjunction with environmental strategies, such as regulating green delivery zones or low-emission delivery time frames.

Secondly, optimizing operational efficiency: increase speed, accuracy and delivery performance.

The three economic drivers of increased delivery efficiency, reduced failed orders, and increased delivery speed all have a Normalized index of 0.3 and a Limiting index of 0.12, ranking second overall. This shows that businesses need to invest heavily in automation in order sorting, optimal routing algorithms, and real-time tracking tools to reduce the rate of incorrect and late deliveries. An effective solution is to build a distribution system based on the "micro-fulfillment center" model – small warehouses scattered in the inner city, helping to shorten delivery distances and reduce the load on the central warehouse. In addition, it is necessary to integrate AI to forecast delivery demand by time and location, thereby planning appropriate coordination.

Thirdly, accelerating the transition to environmentally friendly delivery vehicles.

The Reduce emissions driver has a Normalized index of 0.23946, and Limiting is 0.095785, ranking 5th. This shows the growing demand from the community and the government for reducing environmental impacts in logistics. Businesses should promote the transition to electric vehicles, electric bicycles, or non-motorized vehicles in inner-city areas, combined with fixed pickup points to reduce the number of deliveries. At the same time, coordination centers should also apply a consolidated delivery policy to reduce the number of deliveries to the same area per day.

Fourthly, ensuring safety and security in LMD.

The driver "increase safety and security" has a Normalized index of 0.47287 and a Limiting index of 0.094574, ranking 6th, reflecting practical concerns about risks in delivery – especially unclaimed deliveries, deliveries outside of business hours or in areas with weak security. Therefore, businesses need to deploy delivery systems with smart authentication (smart lock, OTP confirmation), expand the locker delivery model and strengthen coordination with local authorities to ensure traffic safety and regional security.

Fifthly, improving public spaces, transport and delivery infrastructure

Although having a lower impact, factors such as increasing delivery space (Limiting = 0.028032), reducing traffic jam (Limiting = 0.03593), and improving public space (Limiting = 0.041464) still play a long-term supporting role. Accompanying solutions include: building delivery stations at temporary parking lots, designing priority lanes for deliveries, and arranging specialized parking areas for deliveries during peak hours. This is the premise for integrating the logistics system into smart urban planning.

Developing a sustainable LMD system requires not only technical solutions, but also clear policies and social commitments. Green policies and optimizing operational efficiency are two groups of solutions that need to be

prioritized for early and synchronous investment. These solutions not only help reduce costs and increase productivity, but also contribute to creating an urban logistics ecosystem that is friendly, safe and in line with global sustainable development trends.

These implications are instrumental in guiding businesses and policymakers toward sustainable LMD development solutions in Hochiminh city in particular and in Vietnam in general. Additionally, the research findings may be duplicated for other emerging countries with similar socio-economic environments or a bit change should be done to suit the specific situation in each country.

Despite their theoretical and practical contribution, the study findings are for Vietnamese LMD context. It is, therefore, suggested that further research could be expanded to other countries. Moreover, further step to this study can be the application of other MCDM methods to determine weights of LMD drivers.

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