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Diversity in Employment of Electric Commercial Vehicles in Urban Freight Transport: A Literature Review

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ABSTRACT

Employment of Electric Commercial Vehicles (ECVs) constitutes measures to achieve sustainable Urban Freight Transport (UFT). Despite a critical need for ECVs, in industry, the market penetration of ECVs in UFT has remained relatively low. To increase such market penetration, one crucial issue to consider is to obtain a satisfactory match between characteristics of ECVs and requirements of UFT. However, matching diverse types of ECVs and various delivery tasks in UFT leads to many possibilities. The present paper refers to such possibilities as diversity and denotes them as ECV-UFT combinations. Potentials inherent in this diversity seem ignored by the majority of the literature. Therefore, the present paper explores the significance of studying such diversity for the market penetration. In particular, the paper identifies the primary areas of focus and the extent of the diversity already considered in the literature. To accomplish this identification, a Systematic Literature Review (SLR) is applied. The SLR follows a sequence of activities, including selecting sources and keywords, as well as classifying and summarizing results. Findings unveil that the literature has primarily focused on issues concerning the feasibility of ECVs, the adaptation of logistics and vehicle concepts, and support of stakeholders. Furthermore, little consideration of the diversity in the employment of ECVs in UFT is observed as a consequence accounting for the low market penetration. Finally, building on the diversity to increase market penetration, the paper proposes to extend ECV-UFT combinations in the outlined primary areas of focus as future research work.

KEYWORDS: electric commercial vehicles · sustainable urban freight transport · market penetration · diversity

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1 INTRODUCTION

Urban Freight Transport (UFT) is a segment of freight transport. The UFT segment is used mainly to carry goods using commercial vehicles by or for commercial entities into, out of and within urban areas [1, 2]. In this role, the overall goal of the UFT is to satisfy needs of citizens but also support the efficient economic and social development [3, 4]. Most of the UFT commercial vehicles use engines designed to ignite diesel fuel to generate the energy needed for transportation. One drawback of such engines is that they produce noises and air pollutants. In addressing these environmental challenges, the European Commission [5] recommends for development and deployment of new and sustainable fuels as well as propulsion systems.

Electric Commercial Vehicles (ECVs) constitute one category of vehicles recommended to address the outlined challenges. The ECVs consists of four types including Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric

Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs) [6]. In their features, the ECVs are partially or entirely powered by electric energy. It contributes to decreasing noises, Greenhouse Gas (GHG) emissions, and amount of energy consumption. In regard to areas of commercial use, the ECVs appear suitable in the UFT due to conducive environments. The UFT provides suitable conditions to employ the ECVs on account of the high use rates of fleet vehicles; route predictability, as well as; the low commercial and industrial electricity rates [7, 8]. Given these points, the environmental benefits resulting from ECVs and suitable prevailing conditions in UFT encourage stakeholders of the UFT to consider employing the ECVs.

Furthermore, some policies support the employment of ECVs in UFT. For example, the financial incentives, such as subsidies for the purchase price and setup of charging infrastructures and tax exemptions stimulate the possibility to purchase and employ ECVs in UFT [7]. Similarly, there are non-financial incentives offered to users of the ECVs in exclusion of other vehicles. The incentives such as preferential parking, initiating repair centers, permission to drive on high occupancy or bus lanes, and privileges to accessing to low emission zones in city centers, also facilitate the employment of ECVs in UFT [7, 9].

Nevertheless, despite the notable environmental benefits and supporting policies, yet the actual number of ECVs currently employed in UFT is relatively low. According to the report of ICCT [10], in Europe, the light electric commercial vehicles (gross vehicle weight $< 3.5t$) including the BEVs, HEVs, and PHEVs, accounted for 0.7% of total sales of light commercial vehicles in 2016. In a related perspective, Navigant Research [11] forecast that the market share of diesel medium – and heavy – duty trucks (gross vehicle weight $\geq 3.5t$) will remain the dominant in next decade. To this end, the outlined progresses imply that there is a low market penetration of ECVs, especially in the UFT. The low market penetration calls up for a need to address this problem.

There is much literature works contributing to addressing this challenge. For example, works in [7, 12, 13] have applied the survey and case study methods to explore and analyze factors related to cost, technology, infrastructures, sources of electricity, and incentives to increase an understanding of the problem. Other similar studies, which focus on reducing impacts resulting from aforementioned factors, have been carried out too. For instance, the literature [14–18] has proposed and formulated the Electric Vehicle Routing Problem (EVRP) to minimize impacts concerning the limited driving range and charging infrastructures. Equally, to improve the battery systems in the ECVs, the literature [19, 20] has addressed management of energy in batteries. Moreover, propositions on how to reduce impacts resulting from a need for fast charging [21]; retail infrastructure costs [22], and; spatial planning of public charging infrastructures [23] have been considered as well. On the whole, to increase the market penetration of ECVs in UFT, the existing works have studied the factors causing the low market penetration including the identification of factors and reducing the impacts of factors.

On top of the EVRP, battery systems, and charging infrastructures issues, the feasibility to employ the ECVs in UFT has been evaluated in different ways. It has been evaluated through modeling and simulation [24–26] as well as tested by trials [27, 28]. Similarly, the demonstrative projects such as the EU project FREVUE [29] and the national project MELODYS [30] also have conducted the related evaluation. In the overall, studies on the low market penetration are increasingly attracting attention and gradually making progress. In speeding up this progress, there is also a critical need to obtain a satisfactory match between product characteristics and consumer preferences [31]. In this paper, the product characteristics refer to the features of ECVs. Moreover, the consumer preferences refer to the requirements of delivery tasks in UFT.

However, the diverse types of ECVs and various delivery tasks in UFT complicate the identification of a satisfactory match. The diverse types of ECVs result from the differences concerning the configurations, propulsion systems, and energy storages [6]. In the UFT, the various delivery tasks are in relation, for example, to the type of goods, the number of deliveries, and the length of a trip [32]. Thus, employing diverse types of ECVs to satisfy requirements of various delivery tasks in UFT presents many possibilities. This paper refers to such possibilities as diversity and denotes them as the *ECV-UFT combinations* (defined further in section 2).

The concept of diversity has been involved in urban passenger transport systems [33]. For instance, in consideration of diverse types of electric vehicles, the selection of suitable electric passenger cars [34, 35] or buses [36, 37] have been studied. Moreover, to understand the requirements of customers, the customer preferences for electric vehicles [31, 38] have been conducted as well. Apart from aforementioned studies in the urban passenger transport systems, little attention is paid to the rich diversity, which arises as a result of employing ECVs in UFT. This reason, in particular, drives a motivation of the present paper. The overall goal is to explore the significance of studying the diversity in the employment of ECVs in UFT for providing a broader contribution that seems ignored by the majority of the existing literature. In achieving this goal, the paper answers the following research questions:

a) What is the primary focus of the literature addressing employment of ECVs in UFT?
b) To what extent has the diversity been considered in the literature?
c) What are future research agenda to address?

The study on the primary focus and the extent of the diversity provides practitioners a novel viewpoint to outline the state of the art concerning the employment of ECVs in UFT. Besides, the extent of the diversity explores the significance of the diversity for obtaining the satisfactory match to increase the market penetration of ECVs in UFT. Resulting from answers of the first two research questions, the paper suggests future research areas to facilitate the market penetration.

The remainder of this paper is organized as follows. First of all, the definition and characteristics of UFT, ECVs, as well as the diversity in the employment of ECVs in UFT are introduced in section 2. After that, the methodology of conducting the SLR is illustrated in section 3. Our results are then recapped in section 4. Discussion of these results and the possible future research are presented in section 5. Finally, section 6 concludes this paper.

2 CHARACTERIZING DIVERSITY IN EMPLOYMENT OF ECVs IN UFT

This section introduces three concepts that concern the employment of ECVs in UFT. Sections 2.1 and 2.2 focus on introducing the definitions and features of UFT and ECVs. By drawing from introduced features, section 2.3 proposes a concept of diversity in the employment of ECVs in UFT.

2.1 Urban Freight Transport

Urban freight transport is a segment of road freight transport. It comprises commercial vehicles, as means to deliver goods in UFT. On the basis of the Gross Vehicle Weight (GVW), commercial vehicles are classified into light-duty commercial vehicles; medium-duty commercial vehicles, and; heavy-duty commercial vehicles [39, 40]. Besides the commercial vehicles, the UFT comprises many stakeholders. In a viewpoint of supply chain perspective, the UFT stakeholders range from shippers, freight carriers, to receivers [2, 41, 42]. Usually, the task of shippers is to supply goods. Typical examples of shippers are manufacturers, wholesalers, and retailers. Succeeding suppliers are freight carriers. Freight carriers perform the next task, which is to transport the goods. Some freight carriers are shippers because they transport their goods using their commercial vehicle fleets. Also, some freight carriers deliver goods by cooperating with Third-Party Logistics (3PL) providers. After that, receivers unload goods transported by the freight carriers. In urban areas, the primary receivers are the commercial receivers, such as shops, retail outlets, hotels, and restaurants, as well as the private households. Although suppliers, freight carriers, and receivers are primary stakeholders, other stakeholders are such as the national/regional governments, urban motorway operators, city residents, and visitors [41, 43–45]. Authors add that stakeholders of UFT emerge upon considering the perspectives of public authorities, resource supply, and participants

The receivers and their requirements, such as the type of goods and the number of deliveries, determine the delivery tasks of freight carriers in UFT. In terms of differences underlying the delivery tasks, the UFT may be classified into five markets, which are: retail, express/post, Ho(tel)Re(staurant)Ca(tering), construction, and waste collection (Table 1) [2, 43, 46].

Retail market: The retail market contains retail chains, independent retail and e-commerce [2]. The retail chains distribute goods to their stores by operating their medium- or heavy-duty commercial vehicles to increase delivery efficiency. The independent retailers, on the other hand, are commonly small or medium stores, to whom, diverse suppliers supply goods at a rate of three to ten times a week. Another emerging retail market is the e-commerce. The e-commerce is typically focused on home delivery [44] to transport goods purchased online to recipients (homes, offices, or pickup points) by using couriers and parcel services [47]. These services apply commonly light-duty commercial vehicles to and within residential areas with the conduct of many stops on their routes [42].

Express/Post: The express/post market is constituted by the letter post-market as well as the courier, parcel, and express market. The national postal operators mainly conduct the letter post market in hub-and-spoke networks. The courier, parcel, and express market, similar to the home delivery in e-commerce, deliver heterogeneous goods to diverse receivers with many stops.

HoReCa: The HoReCa market comprises HoReCa chains and independent HoReCa. The typical characteristic of this market is just-in-time supplies, requested in small quantities and fresh. Such characteristic leads to frequent deliveries. Nevertheless, this frequent delivery is specific to the independent HoReCa market, since the HoReCa chains (such as large hotel and restaurant chains) intend to achieve economies of scale through centralized procurement as well as more consolidated and less frequent deliveries [2].

Construction: The construction market is a fragmented industry, which delivers a wide range of building material to building sites for infrastructural projects and residential constructions. These construction activities are project-based. However, the fragmented industry and the project-based construction activities may results in commercial vehicles running either empty or part-loads as well as consuming long waiting time to gain access to construction sites [2].

Waste Collection: The waste collection market in urban areas is mainly responsible for collecting municipal waste, manufacturing/industrial waste, hazardous waste, and construction waste. These wastes include a wide variety of materials, such as paper, food, glass, plastic, metal, medicaments, colors, batteries, and building material [46]. The delivery tasks in this market depend on the diverse types of waste. For instance, the collection of household waste

Table 1: Characterization of the UFT markets (adapted from [2, 42])

UFT Markets	Short Description	Characteristics
Retail	Delivery of finished products mainly to shops and retail outlets	Using own account medium/heavy-duty commercial vehicles (retail chains); Frequent deliveries and diverse suppliers (independent retail); Using light-duty commercial vehicles with many stops (e-commerce)
Express/post	Transport of letters, parcels, and providing express services for households and companies	National postal operators and using hub-and-spoke networks (letter post); The high number of receivers per delivery tour with heterogeneous loads (courier, parcels, express)
HoReCa	Carry of food and beverage to hotels, bars, restaurants, canteens and event catering	Just-in-time supplies; Centralized procurement and less frequent deliveries (HoReCa chains); Frequent deliveries (independent HoReCa)
Construction	Delivery of a wide range of building material to building sites for infrastructural projects and residential constructions	A wide range of building material; Fragmented industry; Project-based construction activity
Waste collection	Collection of municipal waste, industrial waste, hazardous waste, and construction waste to waste disposal facilities	A wide variety of material; Many stops (household waste); Frequent collection (industrial waste)

is conducted weekly or every two weeks with many intermediate stops, whereas the collection of industrial waste is carried out daily and with less intermediate stops than the household waste collection [46].

In essence, the UFT appears a complicated system that involves a range of diversity in stakeholders, delivery tasks, and categories of vehicles. Among the diversity, in this paper, the various delivery tasks correspond to the previously outlined UFT markets, which are five in total. In the context of studying the employment of ECVs in UFT, this paper involves the diversity resulting from the five UFT markets.

2.2 Electric Commercial Vehicles

The categorization of ECVs can rely on differences regarding the configurations, propulsion systems, and energy sources. On account of these differences, the ECVs can be categorized into BEVs, FCEVs, HEVs, and PHEVs (Table 2). The BEVs are powered entirely by electric energy stored in batteries. Electric motors convert the stored electric energy into mechanical energy to propel the vehicle wheels. The onboard batteries are recharged by plugging into an electric power source [48]. The FCEVs are fueled with pure hydrogen gas stored directly on the vehicle [49]. This fuel cell produces electric energy using the hydrogen to drive the vehicles. Unlike the BEVs and the FCEVs, which are powered by one propulsion devices (electric motors), the HEVs and the PHEVs can be powered by two propulsion devices, namely the Internal Combustion Engine (ICE) and electric motors. The primary difference between HEVs and PHEVs is whether the onboard batteries can be recharged by external electric power sources. In the HEVs, the onboard batteries are commonly recharged by absorbing the power from the ICE and converting the regenerative braking energy. In the PHEVs, apart from the two modes of recharging batteries in the HEVs, the onboard batteries of PHEVs can be recharged by external electric power sources as well.

There are a few of strengths and limitations in these four types of ECVs. Without considering the raw material used to produce electricity and hydrogen from the life cycle's perspective, BEVs and FCEVs emit zero tailpipe emissions and are independent of fossil fuels. Nevertheless, since the HEVs and the PHEVs remain the ICE on board, their tailpipe emissions are higher than the BEVs and the FCEVs but lower than the conventional vehicles. Furthermore, because of the two propulsion devices, the HEVs and the PHEVs

Table 2: A summary of four types of ECVs and their characteristics (Source: [6])

Types	Characteristics	Strengths	Limitations
BEVs	Propulsion: electric motor drives; Energy storage: battery, supercapacitor; Infrastructure: charging stations	Zero local emissions; High energy efficiency; Independent of fossil fuels; Commercially available	Relatively short range; High initial cost; Insufficient charging infrastructures
HEVs	Propulsion: electric motor drives & internal combustion engines; Energy storage: battery, supercapacitor, fossil or alternative fuels; Infrastructure: gasoline stations	Low local emissions; High fuel efficiency; Long driving range; Commercially available	Dependent on fossil fuels; Higher cost than ICE vehicles; Control, optimization, and management of multiple energy sources
PHEVs	Propulsion: electric motor drives, internal combustion engines; Energy storage: battery, supercapacitor, fossil or alternative fuels; Infrastructure: gasoline stations, charging stations	Low local emissions; High fuel efficiency; Long driving range; Commercially available	Dependent on fossil fuels; Higher cost than ICE vehicles; Control, optimization, and management of multiple energy sources; Insufficient charging infrastructures
FCEVs	Propulsion: electric motor drives; Energy storage: hydrogen tank; Infrastructure: hydrogen filling stations	Zero local emissions; High energy efficiency; Independent of fossil fuels; Satisfied driving range	High fuel cell cost; Difficulty of storage and transport of hydrogen; Insufficient hydrogen filling stations

may overcome some limitations of both ICE vehicles and BEVs (improvement of fuel efficiency and driving range). However, the control, optimization, and management of multiple energy sources in HEVs and PHEVs are harder than the BEVs. Additionally, high costs of these four types and insufficient charging/filling stations also hinder the employment of ECVs in UFT.

Obviously, there are respective strengths and limitations of each type of ECVs. To obtain a satisfactory match, it is crucial to consider the outlined characteristics of each type in the employment of ECVs in the UFT.

2.3 Diversity in Employing ECVs in UFT

The diverse types of ECVs and various UFT markets complicate the process of employing ECVs in UFT. The employment process entails choosing types of ECVs and identifying requirements for each market in UFT. Oliveria et al. [31] emphasize that, towards increasing the market share of a product, it is crucial to obtain a satisfactory match between product characteristics and consumer preferences. Concordant to a context of the present paper, increasing the number of ECVs employed in UFT requires satisfying the match between characteristics of types of ECVs and requirements of markets in UFT.

There are some literary works, which have studied the match in the urban passenger transport systems. For instance, Zubaryeva et al. [34] and Mohamadabadi et al. [35] have addressed issues regarding suitable choice of electric passenger cars. Zubaryeva et al. [34] identified potential lead markets for electric-drive passenger cars (BEVs and PHEVs) in Europe. Mohamadabadi et al. [35] ranked fuel-based passenger vehicles including gasoline, diesel, gasoline-electric (HEVs), E85 ethanol, B100 biodiesel, and compressed natural gas. Furthermore, Tzeng et al. [37] and Vahdani et al. [36] have concentrated on investigating the proper choice of electric buses. Tzeng et al. [37] evaluated the alternative-fuel buses (diesel, hydrogen, electric, hybrid electric) for the urban areas in Taiwan. Vahdani et al. [36] proposed fuzzy multiple criteria decision-making methods to solve the problem of alternative-fuel buses selection. In addition to the selection of vehicles, some works studied the customer preferences for electric passenger cars [31, 38]. Oliveria et al. [31] surveyed with choice-based conjoint analysis and multi-criteria decision analysis to understand customer preferences concerning electric passenger cars in Portugal. Ziegler

[38] examined the German customer preferences for buying electric passenger cars. On the whole, the studies addressing issues related to the satisfactory match have been explored by selecting proper electric vehicles and understanding the customer preferences in the urban passenger transport systems.

Compared to the literature on the choice of vehicles and customer preferences in urban passenger transport systems, few studies have addressed the same topic in the UFT systems. Nevertheless, in recent years, attention on this topic has appeared to shift gradually towards the UFT systems. For example, Watróbski et al. [50] propose a multi-criteria analysis-based approach to select proper vehicle types of available BEVs for UFT. Lebeau et al. [8] explore the vehicle choice behavior of transport companies by applying conjoint-based choice analysis. It generally appears that, the choice of proper fuel types of electric vehicles and the identification of requirements for different customers are taken into account not only in urban passenger transport systems but also increasingly in UFT systems.

Nevertheless, to increase the market penetration of ECVs in UFT, the satisfactory match between characteristics of ECVs and requirements of markets in UFT appears missing in existing works. This lack results from the diversity which is overlooked in the employment of ECVs in UFT markets. As shown in Fig. 1, the freight carriers of the five UFT market have their respective preferences and requirements. However, the studies on the choice of ECVs in terms of their characteristics and the identification of transport companies' preferences have only completed a part of the task concerning the satisfactory match. The selection of a satisfactory match from the possibilities, which result from the match between diverse types of ECVs (x_1, x_2, x_3, x_4) and various UFT markets (y_1, y_2, y_3, y_4), seems ignored. These possibilities present the diversity in the employment of ECVs in UFT systems.

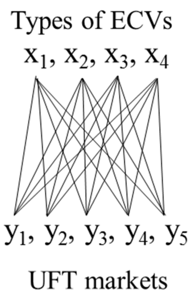

Fig. 1: Example of the match between four types of ECVs and five markets in UFT

To this end, the primary focus of this paper is to consider such diversity in employing ECVs in UFT. The paper denotes this diversity in employing ECVs in UFT as the *ECV-UFT combinations*. The definition of such combinations proceeds as follows. Firstly, the set V is defined to hold the four types of ECVs:

$$V = \{BEVs, HEVs, PHEVs, FCEVs\} \quad (1)$$

The number of subsets in the set V is 16 (2^4) including the empty set and V itself. These subsets of set V are shown as follows: ∅, {BEVs}, {HEVs}, {PHEVs}, {FCEVs}, {BEVs, HEVs}, {BEVs, PHEVs}, {BEVs, FCEVs}, {HEVs, PHEVs}, {HEVs, FCEVs}, {PHEVs, FCEVs}, {BEVs, HEVs, PHEVs}, {BEVs, HEVs, FCEVs}, {BEVs, PHEVs, FCEVs}, {HEVs, PHEVs, FCEVs}, {BEVs, HEVs, PHEVs, FCEVs}.

Secondly, the set M is defined to hold the five markets in UFT:

$$M = \{Retail, Express/Post, HoReCa, Construction, Waste\} \quad (2)$$

The number of subsets of M is 32 (2^5). The formation of subsets in set M is same as the set V. In this paper, the empty subsets of V and M indicate the unspecified types of ECVs and unspecified markets in UFT, respectively. The set of the ECV-UFT combinations is given by the Cartesian product of the sets V and M as indicated in Eq. 3:

$$C_{ECV\text{-}UFT} = V \times M = \{(v, m) \mid v \in V, m \in M\} \quad (3)$$

Accordingly, the number of subsets in the set $C_{ECV\text{-}UFT}$, namely the total number of ECV-UFT combinations, is 512. This result is calculated by the product of the subsets' numbers of V and M ($2^4 \cdot 2^5$). On the basis of the many subsets in $C_{ECV\text{-}UFT}$, Table 3 shows a group of subsets in the set $C_{ECV\text{-}UFT}$ as an example to explain the formation of the ECV-UFT combinations.

Table 3: Examples of the subsets in $C_{ECV\text{-}UFT}$

Subsets in $C_{ECV\text{-}UFT}$	**Subsets in $C_{ECV\text{-}UFT}$**
BEVs - Unspecified	(BEVs, HEVs) - Unspecified
BEVs - Retail	(BEVs, HEVs) - Retail
BEVs - Express/post	(BEVs, HEVs) - Express/post
BEVs - (Retail, Express/post)	(BEVs, HEVs) - (Retail, Express/post)
HEVs - Unspecified	Unspecified - Unspecified
HEVs - Retail	Unspecified - Retail
HEVs - Express/post	Unspecified - Express/post
HEVs - (Retail, Express/post)	Unspecified - (Retail, Express/post)

Table 4: Keywords used in search queries

First query	Second query
TOPIC (electric OR hybrid OR "plug-in hybrid" OR "fuel cell")	TOPIC (electric OR hybrid OR "plug-in hybrid" OR "fuel cell")
AND TOPIC (vehicle OR van OR truck)	AND TOPIC (vehicle OR van OR truck)
AND TOPIC (urban OR city)	AND TOPIC ("last mile")
AND TOPIC (freight OR distribution OR logistics)	

This group of subsets refers to all possibilities in the combinations between two types of vehicles (BEVs and HEVs) and two UFT markets (retail and express/post) including the empty set (unspecified). The total number of the subsets in this group is derived from the product of the subsets' numbers of two vehicle types and two UFT markets ($2^2 \cdot 2^2 = 16$). The brackets in some subsets represent that the elements in the brackets are one subset. For instance, in the subset: (BEVs, HEVs) - Retail, the two vehicle types are considered as one subset in the set V and the retail market is the subset in the set M. This subset presents a situation that the two vehicle types can be simultaneously employed in the same UFT market. Following this example, the combinations between four types of ECVs and five UFT markets generate 512 possibilities in the set $C_{ECV\text{-}UFT}$. This number implies that assessment of satisfactory match for increasing the market penetration of ECVs also has to consider the diversity outlined in this section.

3 METHODOLOGY

This paper applies a Systematic Literature Review (SLR) to accomplish its goal. The SLR is preferred because it provides a rigorous and systematic protocol to search and select scientific articles related to a particular topic as well as analyzing and synthesizing contributions of such articles to derive findings [51–53]. Conducting this rigorous protocol enable reviews to minimize the risk of bias and obtain transparent as well as reasonable conclusions [54]. This paper adapts the SLR methodology from Benetti et al. [51]. It comprises five steps, which are a statement of objective, selecting sources, selecting keywords and articles, classification and summarization of results.

Statement of Objective: The objective of carrying the SLR is to identify the primary focus of existing works and the extent of diversity (the number of ECV-UFT combinations) already considered in the literature. The role of this identification is to collect evidences for exploring the significance of studying the diversity in the employment of ECVs in UFT.

Selecting Sources: The literature is searched mainly in four academic databases, which are Web of Science, Scopus, IEEE Explore and Springer Link. These databases are preferred because they cover multidisciplinary journals, books, and conference proceedings. In addition, searching articles in these databases enables us to track and understand state of the art comprehensively in regard to the employment of ECVs in UFT.

Selecting Keywords and Articles: This step specifies keywords to use in searching relevant literature from databases, as well as criteria for filtering articles. Thus, to search the literature on the employment of ECVs in UFT, the keywords *"electric"*, "*vehicle"*, "*urban"*, and "*freight"* (Table 4) are specified. In addition to these keywords, there are synonyms, such as *van* and *truck* (vehicle), *city* (urban), and *distribution*, *logistics* as well as *last mile* (freight). These synonyms are also used in querying the databases. Furthermore, the related terms, such as *hybrid*, *plug-in hybrid*, and *fuel cell* are also considered in the query. Each database is searched using two queries. The specified key terms are searched in titles, abstracts, and keywords of the literature.

After specifying the keywords, a search process is conducted to select articles. Four criteria including time span, language, repetitions, and pertinence are applied to filter the articles. Firstly, a time span to search for the latest literature is chosen. As far as the world has approximately increased their attention on ECVs in UFT since last decade, then this paper uses a time span that ranges from 2007 to 2018. Further criterion concerns articles published in the English language. To this effect, the two queries were conducted in the four databases to yield 2752 articles. Further filtration of the articles involves checking for redundancy (repetitions). Deleting redundant resulted in a total of 1957 articles. An additional task involves examining titles and abstracts of such articles to identify their pertinence. Since some articles focus on studying buses, bikes, tricycles, passenger cars, rail and sea transport, which are irrelevant to the ECVs and the UFT, such impertinent articles are excluded. In the end, a total of 60 articles are obtained.

Classification: In this step, the 60 articles are classified for further analysis. This classification stands on the primary focus of the article. Accordingly, base criteria for this classification are the areas of focus, and the issue addressed in each article (as presented in Table 5).

Summarizing Results: Finally, the areas of focus, the number of ECV-UFT combinations considered in the literature, the publication years, countries of origin, and subject areas are illustrated as the results by using tables and diagrams. The goal of summarizing these results is to enable further analysis.

4 RESULTS

This section presents results obtained after searching and filtering the literature. The analysis of results falls in the following categories: years of publication; country of origin; subject areas; thematic description, and; existing ECV-UFT combinations. Beginning with years of publication, Fig. 2 shows the number of articles published per year (from 2007 to March of 2018). The figure portrays that publications addressing issues related to ECVs in UFT had increased in a period between the years 2014 to 2017.

The second consideration entails analysis of results in a perspective of countries in which the publications originated (Fig. 3). As far as authors of articles may originate from different countries, this figure is plotted in terms of the affiliations of first authors. In a summarized form, a total of 47 published articles originated from Europe; eight articles originated from North America, three articles originated from Asia. South America and Africa had one article each.

Furthermore, Fig. 4 summarizes the subject areas of these articles as part of the results. These areas are determined by journal subjects in whom these articles are published. Notably, different categories of the same subject area, such as the transportation category

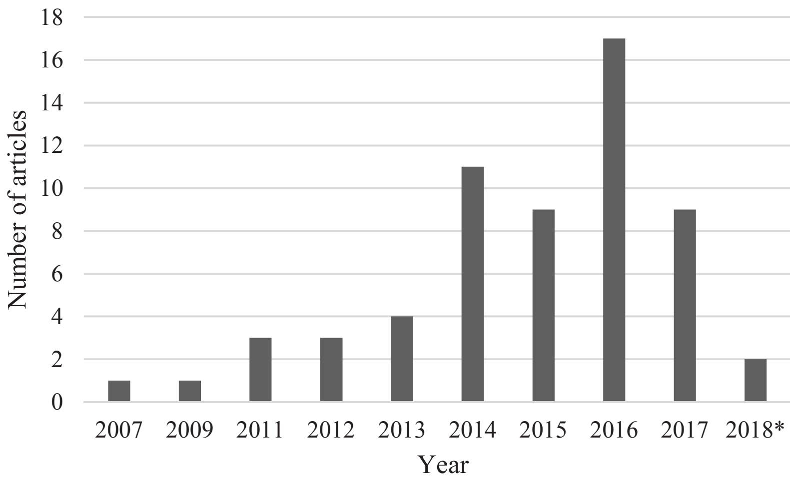

Fig. 2: Number of articles in each year

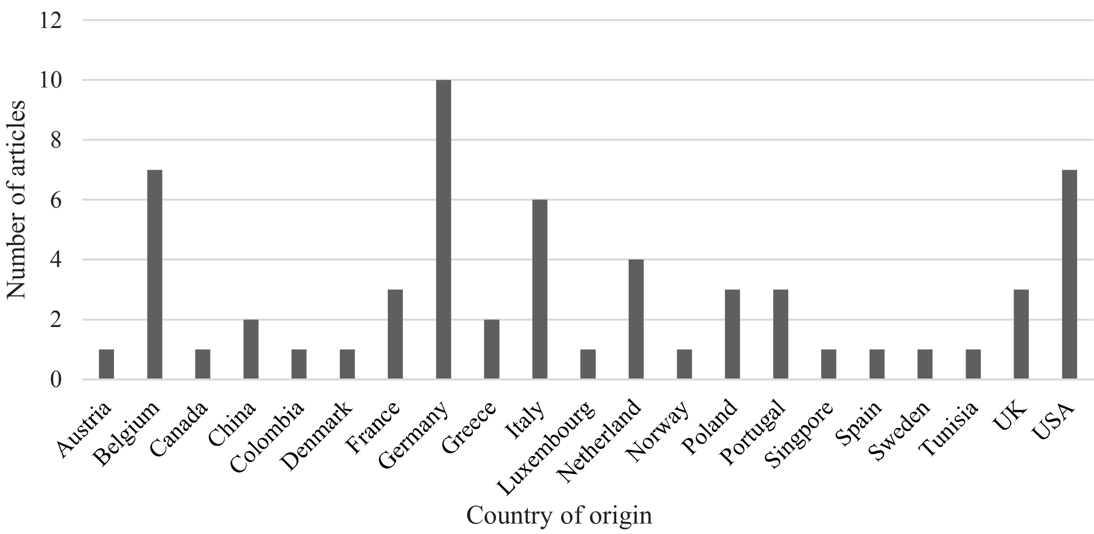

Fig. 3: Number of publications per country of origin

and the urban studies category in social science are considered as a one-subject area, namely social science. In addition, some journals involve more than one subject area. For example, the journal Transport Research Part D involves two subject areas: social science and environmental science. To this effect, all these subject areas, which are involved in the same journal, are also counted in Fig. 4.

The thematic description of reviewed articles involves three main aspects: area of focus, issues addressed, and approach or method used (Table 5). This description reveals that existing literature has focused mainly on four areas to address fifteen issues. The four areas are feasibility, adaptations of logistics concept, adaptations of vehicle concept, and support of stakeholders.

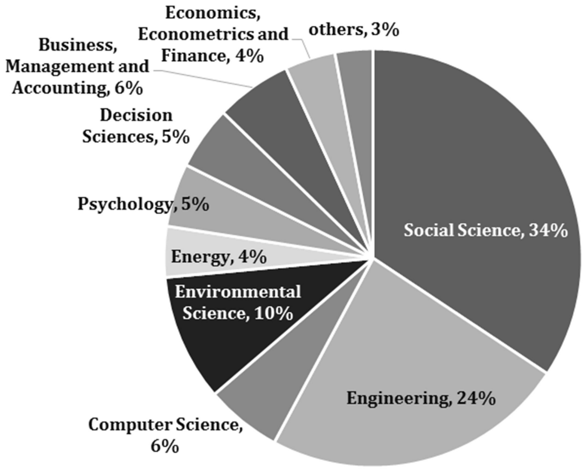

Fig. 4: Percentage of subject areas in the articles selected by the SLR

Table 5: Thematic description of the articles

Area of Focus	Issue Addressed	Approach/Method	Literature
Feasibility	Limitations and opportunities	Review, survey, case study, the system of innovation	[7, 9, 63–65, 55–62]
	Competitiveness of employing ECVs in UFT	Simulation, case study	[25, 26, 74–82, 66–73]
Adapting logistics concept	EVRP	Simulation	[14, 16, 83–89]
	UCCs + BEVs	Simulation, case study	[90–94]
	ICT	Machine learning	[95, 96]
	Charging-while-driving	Simulation	[97]
	Multi-city urban logistic model	Simulation	[98]
	Sharing parking places	Simulation	[99]
	Day and night delivery	Simulation	[100]
Adapting vehicle concept	New architecture	Simulation	[101, 102]
	Improvement of the control system	Simulation	[103]
	Size of onboard energy for HEVs	Simulation	[104]
Supporting stakeholders	Preferences of transport companies for ECVs	Survey	[8, 105]
	Business model	-	[106]
	Proper choice of ECVs for UFT	Multi-criteria analysis	[50]

The first area focuses on studying the feasibility of employing ECVs in UFT. Limitations, opportunities, and competitiveness of this employment were mainly discussed. The second area focuses on the adaption of existing logistics concept. Several possible solutions were proposed by adapting the existing logistics concept to fit the characteristics of ECVs. Similarly, some other possible solutions adapted existing vehicle concepts to satisfy the requirements of UFT in the third area. Finally, to facilitate the employment of ECVs in UFT, the fourth area explored possible solutions for supporting stakeholders. According to the number of articles in each area, there are 32 articles (53%) studied the feasibility of ECVs, 20 articles (33%) adapted logistics concept, 4 articles (7%) adapted vehicle concepts, and the rest of 4 articles (7%) explored solutions for supporting stakeholders. Among these articles, three of them in the area of supporting stakeholders are related to the satisfactory match. Besides, there is no articles directly studied the diversity in the employment of ECVs in UFT.

In spite of this, the diversity in the employment of ECVs in UFT may be indirectly considered in the literature. To present the extent of the diversity has been indirectly studied in the literature, the ECV-UFT combinations, which have been discussed in the extracted 60 articles, are subsequently summarized in Table 6. The number of each ECV-UFT combination appeared in the literature and in which topics these ECV-UFT combinations have been studied are introduced in this table.

In total, the 60 articles involved 16 ECV-UFT combinations. Some articles considered only one vehicle type in one UFT market, such as BEVs-Retail and HEVs-Express/post. On the contrary, some articles discussed diverse vehicle types in various UFT markets, such as (BEVs, HEVs, PHEVs)-(Retail, Express/post). These diverse vehicle types and various UFT markets in the brackets are respectively regarded as one subset. Furthermore, the results show that operating BEVs in an unspecified UFT (BEV-Unspecified) is the most popular combination studied

Table 6: Existing ECV-UFT combinations

ECV	UFT	Frequency	Feasibility	Logistics	Vehicles	Stakeholders
BEVs	Unspecified	31	√	√	√	√
BEVs	Retail	9	√	√	×	√
BEVs	Express/post	3	×	√	×	×
BEVs	Retail, Express/post	3	√	√	√	×
HEVs	Unspecified	2	√	×	×	×
BEVs	Retail, Express/post, HoReCa, Construction, Waste	2	√	×	×	×
HEVs	Express/post	1	×	×	√	×
BEVs	Waste	1	√	×	×	×
BEVs	Retail, HoReCa	1	×	√	×	×
BEVs	Retail, Express/post, Construction	1	√	×	×	×
BEVs	Retail, Express/post, HoReCa, Waste	1	√	×	×	×
BEVs, HEVs	Unspecified	1	√	×	×	×
BEVs, PHEVs	Unspecified	1	√	×	×	×
BEVs, HEVs, PHEVs	Retail, Express/post	1	×	√	×	×
BEVs, HEVs, PHEVs	Retail, HoReCa	1	√	×	×	×
BEVs, HEVs, PHEVs, FCEVs	Unspecified	1	√	×	×	×

in the existing works. Moreover, this combination has appeared in entire four topics. Following the BEV-Unspecified combination, the BEV-Retail and the BEV-Express/post combinations have attracted relative high attention. Besides, the area of feasibility has involved the most types of ECV-UFT combinations (75%) appeared in the literature in comparison with the other three areas.

5 DISCUSSION

This section presents discussion to increase an understanding conveyed by analyzed results. The discussion takes into account the main areas of focus and the existing ECV-UFT combinations. As a result of this discussion, future research works, which once addressed can increase market penetration of ECVs in UFT, are accordingly proposed.

According to results in Fig. 3, the majority of the continents have paid the attention on the employment of ECVs in UFT. In these continents, Europe and North America seem ahead of other continents. Furthermore, results on the subject areas (Fig. 4) show that dealing with the employment of ECVs in UFT involves interdisciplinary studies. To this effect, improving employment of ECVs requires involving not only studies in the social science, engineering, computer science, and environmental science but also energy, psychology, decision science, business, management, and accounting.

5.1 Employment of ECVs in UFT – the Primary Focus

In dealing with the employment of ECVs in UFT, the literature appears to focus primarily on four areas, namely: feasibility, adaptations of logistics concept, adaptations of vehicle concept, and support of stakeholders (Table 5). Therefore, subsequent subsections present respective discussions.

5.1.1 Feasibility

In a standpoint of feasibility, the literature has identified the limitations, opportunities, and competitiveness of employing ECVs in UFT. In identifying these issues, most of such literature relies on the survey, case study, simulation as research methods. The literature identifies many opportunities, which drive the employment of ECVs in UFT. Some of these opportunities are the positive environmental performance (low emissions, noise, and energy consumption) and the positive social attitude (drivers and freight operators) [60–62, 64]. Some other opportunities are the financial incentives (subsidies, tax exemption) and the non-financial incentives, such as preferential parking for ECVs, initiating repair centers for ECVs, allowing ECVs to drive on high occupancy or bus lanes, and privileges of accessing to low emission zones in city centers [7, 9].

Besides such opportunities, the literature has also identified limitations, which hinder the employment of ECVs in UFT. The limitations include:

- Cost: high purchase price, battery price, infrastructure costs [57, 60–62, 64]
- Technology: long charging time, limited driving range, payload capacity, battery lifetimes [57, 58, 60, 63, 64]
- Infrastructure: networks, diverse types of charging stations (battery charging with cables, battery swapping, or battery wireless charging), compatibility, grid issues [56, 60]

In addition to outlined matters, there are other issues. These issues comprise security, limited availability of vehicles, few proper business models and lack of a comprehensive understanding between freight operators and policy makers [9, 60, 61, 65].

The literature evaluates competitive advantages to employ ECVs in UFT, as compared to diesel commercial vehicles. The evaluation of this competitiveness focuses mainly on the economic and environmental perspectives. The economic perspective discusses the impact of the purchase cost, battery cost, fuel cost, and financial incentives for the competitiveness. The environmental perspective deals with some performances, such as CO_2 emissions and energy consumption. The results of the evaluation show that the competitive advantages of ECVs depend on their powertrains and GVW. In general, the light-duty BEVs are the most competitive vehicles to operate in some parts of UFT, such as express/post market [68, 69, 72]. For the medium-duty vehicles, diesel commercial vehicles remain the most interesting solution from the financial point of view [67, 75]. In the segment of heavy-duty vehicles, HEVs are more competitive with running in city areas rather than highway [67, 70].

As one of the implications in the area of feasibility, it can be implied that the replacement of diesel commercial vehicles with ECVs in UFT appears possible. Additionally, some solutions and research perspectives have been suggested to address the issues raised by the studies on the feasibility. For example, from the economic point of view, the literature [24, 25, 66, 68, 75] proposes to reduce the battery cost and the purchase price; to raise the fuel price (diesel and petrol), and; increase vehicle utilization (traveled distance per year per vehicle). From the technological point of view, it is recommended to develop Information and Communications Technology (ICT), infrastructures (networks and inductive systems), as well as EVRP by taking into account fleet sizes and charging strategies [7, 56, 57, 60, 63]. From the policies' point of view, Taefie et al. [9] suggest to implement a city toll on the long-term and allow drivers with a class B license to drive ECVs over 3.5t. In addition, Roumboutsos et al. [55] suggest transferring leadership from central to municipal authorities for promoting the employment of ECVs in UFT.

5.1.2 Adaptations of Logistics Concept

In order to fit characteristics of ECVs, some works in literature have focused on adapting the existing logistics concepts, which are primarily designed for operating diesel commercial vehicles. The limited battery capacities of BEVs, as one of the characteristics, have been mainly discussed in this perspective of logistics. Schneider et al. [16], Guo et al. [88], and Panagiotis et al. [89] have formulated the EVRP in the condition of recharging BEVs at depots and available charging stations en route. On the contrary, Conrad and Figliozzi [14] and Aggoune-Mtalaa et al. [85] proposed vehicle routing models to recharge BEVs at customer locations rather than recharging stations. In exclusion of these articles that focus on homogeneous fleets, Van Duin et al. [83], Mirhedayatian and Yan [86], as well as Rezgui et al. [87] have investigated the EVRP with heterogeneous fleets. In addition to literature addressing the EVRP, Deflorio and Castello [97] study a concept of charging-while-driving to assess traffic and energy performance of electric power systems for dynamically charging ECVs while driving. Schau et al. [96] and Kretzschmar et al. [95] adapted existing ICT systems to predict the range of BEVs for fitting the limitation of battery capacities. Thus, to fit the limited battery capacities, the studies on the EVRP, the ICT, and the charging-while-driving have been conducted in the area of adapting logistics concept.

To further fit the characteristics of ECVs into UFT, some works focused on innovating logistics concept. The combinations of UCCs and BEVs are one of the innovative logistics concepts. This concept suggested to constructing UCCs in relative proximity to the urban areas and replacing diesel commercial vehicles with BEVs to deliver goods in the cities [90, 91]. In this context, the limited driving range of BEVs is not a restriction anymore, because the daily traveled distance is shorter than the driving range [94]. Moreover, although the low payload capacity of BEVs led to more traffic, the total distance traveled, and CO_2 emissions were reduced by conducting this concept [90–92, 94]. In addition to the concept of UCCs, Faccio and Gamberi [98] introduced an innovative distribution network to integrate the distribution of goods in a cluster of linked small cities. Furthermore, to decrease the congestion resulting from the limited parking spaces, Boussier et al. [99] modeled a management process of the parking places sharing between car drivers and dedicated areas of goods deliveries. Besides, to reduce the total cost and increase the utilization of ECVs, Taefi [100] proposed an innovative combination of the day and night delivery by using BEVs. Given these points, to support the employment of ECVs in terms of their existing limitations, some works are contributing to this support by adapting the existing logistics concepts.

5.1.3 Adaptations of Vehicle Concept and Supporting Stakeholders

To improve existing limitations of ECVs for satisfying the requirement of UFT, there are some works focused on the area of adapting vehicle concepts. For example, to fit the diverse delivery tasks in UFT, Andaloro et al. [101] defined and developed a flexible and modular light-duty BEVs with high payload capacity and a rolling chassis, which allows the integration with different powertrains and different upper bodies (vans or box vans). Molfino et al. [102] designed a new architecture for light-duty BEVs to autonomously load and unload palletized or boxed goods. Clarembaux et al. [103] improved the perception and control system of light-duty BEVs for parking/docking process. In addition, to adapt medium-duty HEVs to the parcel and delivery service, Lewis et al. [104] studied a fuel cell HEV to properly size the fuel cell and battery by using real-world operational data and duty cycles. On the whole, to improve the limitations of ECVs for efficiently delivering goods in diverse UFT, the flexible and modular BEVs, the autonomous loading and unloading, the intelligent parking/docking, the high payload capacity, and the proper size of fuel cell and battery in HEVs have been studied in the adaption of vehicle concept.

Besides the vehicle and logistics concept, the possible solutions for supporting stakeholders have been explored as well. For instance, to support authorities increasing their understanding on the limitations of adopting ECVs in UFT, Lebeau et al. [8, 105] investigated the choice behavior of transport companies for BEVs by applying survey and conjoint based choice analysis. To support transport companies selecting appropriate BEVs for UFT, Watróbski et al. [50] proposed a unique approach in terms of multi-criteria analysis and discussed as well as ranked 36 available BEVs in the market. Furthermore, to support authorities employing ECVs in large scale, Cheng and Liu [106] provided a business operating model, which respectively considered different practitioners (battery plants, energy supply companies, automobile companies) as individual operating companies, to compare and discuss their advantages and disadvantages. To sum up, in the area of supporting stakeholders, the existing works studied the preferences of stakeholders for ECVs, proposed approaches of selecting proper ECVs, and discussed possible business models to facilitate the employment of ECVs in UFT.

5.1.4 Trend in the Literature

Regarding the percentage of articles in each area (section 4), it appears that there is an unbalanced and a quite distinct focus in the literature. In particular, 53% of total articles focused on the area about the feasibility of ECVs. Moreover, there are 33% of total articles considered the adaptions of logistics concept. The least focus is seen in the adaptation of vehicle concept (7%) and support of stakeholders (7%). These proportions

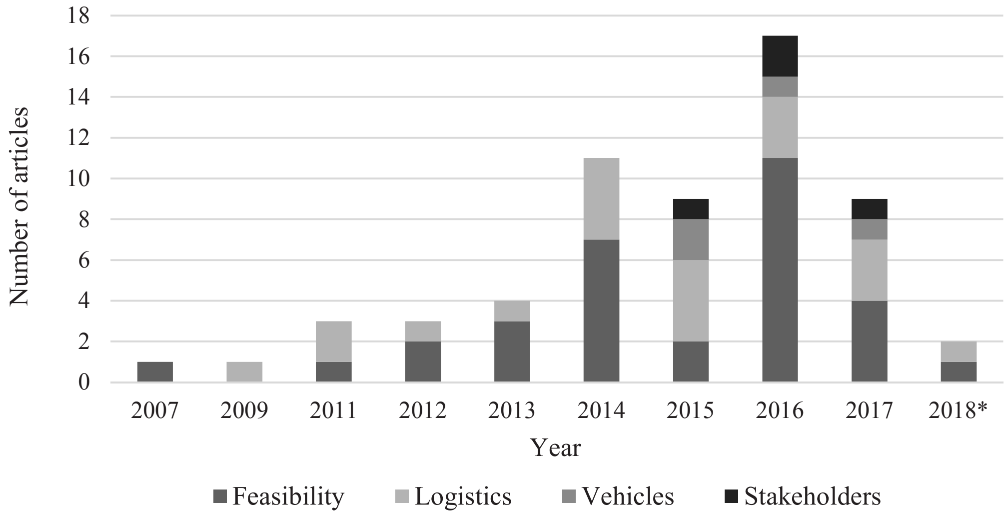

Fig. 5: Number of articles in each area

reveal that many studies focus on addressing the feasibility of ECVs as the main area. In spite of this, upon observing the number of articles in each area of focus from 2007 to March 2018 (Fig. 5), there is a trend of shifting the attention from the area of feasibility to other areas.

Since 2015, the areas of focus have been enriched. The attention has started to be paid not only on the area of feasibility but also on the rest of three areas. It indicates that exploration of possible solutions to accelerate the employment of ECVs in UFT has gradually become a focus since the feasibility of employing ECVs in UFT has been widely accepted in academia. Accordingly, the areas of adapting logistics and vehicle concepts as well as supporting stakeholders have been increasingly studied in the literature. Although the majority of articles still focus on feasibility studies, the Fig. 5 shows that the trend of shifting the attention to the other areas has emerged in the existing works. This trend implies that the areas of focus may shift to exploring possible solutions in the context of the feasibility of some ECV-UFT combinations that have been studied.

5.2 Existing ECV-UFT Combinations

Although there are four areas of focus, which studied the employment of ECVs in UFT, the diversity in the employment, from which the satisfactory match can be obtained, have been overlooked. To explore the significance of the diversity and to what extent the diversity has been indirectly involved in the literature, the number of existing ECV-UFT combinations is counted in section 4. The result shows that there are 16 ECV-UFT combinations studied in the 60 articles. To render this result comparable with the number of total ECV-UFT combinations (512), the all possible subsets in these 16 ECV-UFT combinations are further derived. The procedure of deriving the subsets is same as the formation of the 512 ECV-UFT combinations. For instance, the combination of the three vehicle types (BEVs, HEVs, PHEVs) and the two UFT markets (Retail, Express/post) constitutes 32 ($2^3 \cdot 2^2$) possible subsets including empty sets. In total, there are 236 possibilities derived from the calculation of all possible subsets in each of the 16 ECV-UFT combinations. Since some subsets are repeatedly calculated, there are finally 82 possible ECV-UFT combinations derived from the existing 16 ECV-UFT combinations exclusive of the repeated subsets. The details of the 82 possible ECV-UFT combinations are shown in Appendix Table 8. Obviously, in comparison with the total number of ECV-UFT combinations, the 82 possible ECV-UFT combinations accounts for only a small portion of this total number (16%). This percentage indicates that the literature has paid least attention to many other possible ECV-UFT combinations (approximately 84%).

The least attention paid by the literature may lead to the low market penetration of ECVs. In other words, the results derived from few specific ECV-UFT combinations in the literature may only contribute to understanding and solving few specific scenarios. For instance, in the area of feasibility, few ECV-UFT combinations were examined. It leads to a limited understanding concerning the feasibility of the rest of ECV-UFT combinations. This shortage of comprehensive understanding may result in the hesitation of decision-makers in considering the employment of ECVs in UFT. To this effect, this hesitation may influence the market penetration of ECVs.

Furthermore, in the areas of adapting logistics and vehicle concepts as well as supporting stakeholders, studies on few specific ECV-UFT combinations may only provide few specific solutions. For instance, according to the results obtained from Table 6, the most popular ECV-UFT combination is the BEV whose market remains unspecified. It implies that a majority of existing works mainly focused on studying the operation of BEVs in an unspecified UFT. The solutions proposed from this combination may only contribute to a few specific decision-makers, who intend to employ BEVs. Similarly, this limited range of possible solutions may also influence the market penetration.

Given these points, the little diversity studied in the literature may hinder the improvement of the market penetration of ECVs in UFT. To this effect, three articles in Table 5 emphasizes the significance of taking into account the diversity as follows. Lebeau et al. [67] revealed the opportunities of reducing costs of UFT by including different fuel types of commercial vehicles in a fleet. Watróbski et al. [50] stated the importance of considering the specificity of the delivery tasks in UFT to properly choose BEVs. Christensen et al. [77] noticed the significance of the diversity and investigated the suitable commercial sectors of UFT to employ BEVs.

5.3 Future Research

Towards increasing the market penetration of ECVs in UFT, future research may firstly focus on extending the range of studies about the ECV-UFT combinations. This extension in the future research contains the ECV-UFT combinations, which have not been studied in the literature yet. For instance, taking into account the HEVs and PHEVs to complete the delivery tasks in construction and waste markets (Table 7) can be a part of the extension. Furthermore, in this extension, it is essential to examine the feasibility of these ECV-UFT combinations. The results of the studies on the feasibility may provide researchers and practitioners a comprehensive view about other possible ECV-UFT combinations. In a long-term perspective, the range of this extension may also integrate the FCEVs into the UFT.

Some projects have initiated this extension. For instance, in National Renewable Energy Laboratory, the performance of the heavy-duty HEVs and the medium-duty PHEVs have been evaluated in retail and express/post market [107]. Additionally, FREVUE project has demonstrated light-, medium-, and heavy-duty BEVs in entire five markets of UFT [108, 109].

For the ECV-UFT combinations, whose feasibility has been studied in the literature, the future research may focus on shifting the attention to the exploration of possible solutions in the perspectives of logistics, vehicles, and stakeholders. In other words, after confirming the feasibility of some ECV-UFT combinations, the studies about these ECV-UFT combinations may step into other areas of focus concerning the possible solutions to facilitate the market penetration.

Similarly, after extending the ECV-UFT combinations and examining the feasibility of these non-existing ECV-UFT combinations in the literature, the future research may focus on adapting the logistics and vehicle concepts regarding these extended ECV-UFT combinations. In these two areas, the existing logistics and vehicle concepts are adapted to fit the context of diverse ECV-UFT combinations. These innovative adaptions may provide possible solutions to encourage researchers and practitioners taking into consideration the employment of ECVs in UFT. Besides, the solutions for supporting stakeholders (policy makers, freight operators, or grid managers), such as incentives, practical methodologies, and new business models, may also a potential perspective for future research.

As a part of possible solutions for supporting stakeholders, the future research may focus on the assessment and selection of the satisfactory match between the feasible ECV-UFT combinations. As stated in section 2.3, although some works [8, 50] considered the diverse types of ECVs and various requirements of markets in UFT, appropriate methodologies for assessing the diverse ECV-UFT combinations and selecting the satisfactory match have not been proposed and discussed yet. Accordingly, to increase the market penetration of ECVs, the extension of ECV-UFT combinations in the four areas of focus as well as the assessment of the diversity to obtain the satisfactory match between the ECVs and the UFT are primary future research work.

Table 7: Examples of possible ECV-UFT combinations in future research

ECV – UFT combinations	ECV – UFT combinations	ECV – UFT combinations
HEV – Construction	PHEV – Construction	(HEV, PHEV) – Construction
HEV – Waste	PHEV – Waste	(HEV, PHEV) – Waste
HEV – (Construction, Waste)	PHEV – (Construction, Waste)	(HEV, PHEV) – (Construction, Waste)

6 CONCLUSION

This paper provides an overview of the literature addressing the employment of ECVs in UFT. It focuses primarily on the diversity, which results from the match between diverse types of ECVs and various delivery tasks in UFT. This diversity is denoted as ECV-UFT combinations in this paper. The goal of the present paper is to explore the significance of studying such diversity for increasing the market penetration of ECVs. To achieve this goal, a systematic literature review is applied. This review involves identifying the primary areas of focus and the extent of the diversity in the literature.

According to the topics and issues addressed in the literature, reviewed articles fall into four areas of focus, which are the feasibility of ECVs, adaptions of logistics concepts, adaptions of vehicle concepts, and support of stakeholders. In addition, by observing the number of articles in each area within a decade, the attention of studying the employment of ECVs in UFT is shifting from examining the feasibility of ECVs to the exploration of possible solutions in the perspectives of logistics, vehicles, and stakeholders. In spite of this, the diversity in the employment of ECVs in UFT has been overlooked in these existing works.

The number of existing ECV-UFT combinations is accordingly calculated to indirectly present the extent of the diversity in the literature. The results show little consideration on potentials underlying diversity in the employment of ECVs in UFT. This little diversity may be among factors impacting the market penetration of ECVs on account of lacking a comprehensive view. This incomprehensive view may result in a hesitation of decision-makers to consider the employment of ECVs in UFT. Given these points, the present paper has contributed to proposing the concept regarding the diversity, reviewing the state of the art in the employment of ECVs in UFT, and presenting the significance of the diversity for obtaining the satisfactory match to increase the market penetration. Although these insights are deduced by means of a strict scientific methodology, it is acknowledged that this review in this emerged research field may not be exhausted. The reason for this non-exhausted review is that some works in academic databases may have been omitted, when we conducted this review.

For the future research, it is worth paying attention on the diversity by extending the ECV-UFT combinations in the four areas of focus. For the ECV-UFT combinations, which have not been studied in the literature yet, the future research may focus on examining the feasibility of these ECV-UFT combinations. After increasing the understanding on the feasibility of the majority of ECV-UFT combinations, the future research may rank the feasibility of the ECV-UFT combinations. For the high ranked ECV-UFT combinations, the future research may step into the exploration of possible solutions in the perspectives of logistics, vehicles, and stakeholders.

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Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

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APPENDIX:

Table 8: Possible ECV-UFT combinations

ECV – UFT combinations
BEVs - Unspecified
BEVs - Retail
BEVs - Express/post
BEVs - HoReCa
BEVs - Construction
BEVs - Waste
BEVs - (Retail, Express/post)
BEVs - (Retail, HoReCa)
BEVs - (Retail, Construction)
BEVs - (Retail, Waste)
BEVs - (Express/post, HoReCa)
BEVs - (Express/post, Construction)
BEVs - (Express/post, Waste)
BEVs - (HoReCa, Construction)
BEVs - (HoReCa, Waste)
BEVs - (Construction, Waste)
BEVs - (Retail, Express/post, HoReCa)
BEVs - (Retail, Express/post, Construction)
BEVs - (Retail, Express/post, Waste)
BEVs - (Retail, HoReCa, Construction)
BEVs - (Retail, HoReCa, Waste)
BEVs - (Retail, Construction, Waste)
BEVs - (Express/post, HoReCa, Construction)
BEVs - (Express/post, HoReCa, Waste)
BEVs - (Express/post, Construction, Waste)

ECV – UFT combinations
PHEVs - HoReCa
PHEVs - (Retail, Express/post)
PHEVs - (Retail, HoReCa)
FCEVs - Unspecified
Unspecified - Unspecified
Unspecified - Retail
Unspecified - Express/post
Unspecified - HoReCa
Unspecified - (Retail, Express/post)
Unspecified - (Retail, HoReCa)
(BEVs, HEVs) - Unspecified
(BEVs, HEVs) - Retail
(BEVs, HEVs) - Express/post
(BEVs, HEVs) - HoReCa
(BEVs, HEVs) - (Retail, Express/post)
(BEVs, HEVs) - (Retail, HoReCa)
(BEVs, PHEVs) - Unspecified
(BEVs, PHEVs) - Retail
(BEVs, PHEVs) - Express/post
(BEVs, PHEVs) - HoReCa
(BEVs, PHEVs) - (Retail, Express/post)
(BEVs, PHEVs) - (Retail, HoReCa)
(BEVs, FCEVs) - Unspecified
(HEVs, PHEVs) - Unspecified
(HEVs, PHEVs) - Retail

ECV – UFT combinations
BEVs - (HoReCa, Construction, Waste)
BEVs - (Retail, Express/post, HoReCa, Construction)
BEVs - (Retail, Express/post, HoReCa, Waste)
BEVs - (Retail, Express/post, Construction, Waste)
BEVs - (Retail, HoReCa, Construction, Waste)
BEVs - (Express/post, HoReCa, Construction, Waste)
BEVs - (Retail, Express/post, HoReCa, Construction, Waste)
HEVs - Unspecified
HEVs - Express/post
HEVs - Retail
HEVs - HoReCa
HEVs - (Retail, Express/post)
HEVs - (Retail, HoReCa)
PHEVs - Unspecified
PHEVs - Retail
PHEVs - Express/post

ECV – UFT combinations
(HEVs, PHEVs) - Express/post
(HEVs, PHEVs) - HoReCa
(HEVs, PHEVs) - (Retail, Express/post)
(HEVs, PHEVs) - (Retail, HoReCa)
(HEVs, FCEVs) - Unspecified
(PHEVs, FCEVs) - Unspecified
(BEVs, HEVs, PHEVs) - Retail
(BEVs, HEVs, PHEVs) - Express/post
(BEVs, HEVs, PHEVs) - HoReCa
(BEVs, HEVs, PHEVs) - (Retail, Express/post)
(BEVs, HEVs, PHEVs) - (Retail, HoReCa)
(BEVs, HEVs, PHEVs) - Unspecified
(BEVs, HEVs, FCEVs) - Unspecified
(BEVs, PHEVs, FCEVs) - Unspecified
(HEVs, PHEVs, FCEVs) - Unspecified
(BEVs, HEVs, PHEVs, FCEVs) - Unspecified