sustainability

MDPI

Article

Sustainable Vehicles-Based Alternatives in Last Mile Distribution of Urban Freight Transport: A Systematic Literature Review

Cintia Machado de Oliveira [1,2], Renata Albergaria De Mello Bandeira [1,3,*], George Vasconcelos Goes [1,*], Daniel Neves Schmitz Gonçalves [1] and Márcio De Almeida D'Agosto [1]

1 Program of Transportation Engineering COPPE/UFRJ. Technology Center, Building H–Room 117, University City–Rio de Janeiro, Rio de Janeiro 999074, Brazil; cintia.machado.oliveira.1@gmail.com (C.M.O.); daniel.schmitz.jf@gmail.com (D.N.S.G.); dagosto@pet.coppe.ufrj.br (M.D.A.D.)
2 Federal Center of Technological Education Celso Suckow da Fonseca, Rio de Janeiro 999074, Brazil
3 Military Institute of Engineering, Praça General Tibúrcio 80, Praia Vermelha, Rio de Janeiro 999074, Brazil
* Correspondence: re.albergaria@gmail.com (R.A.D.M.B.); ggoes@pet.coppe.ufrj.br (G.V.G.)

Received: 21 June 2017; Accepted: 24 July 2017; Published: 29 July 2017

Abstract: The advent of new technologies in last mile deliveries is about to cause a disruption in the traditional business model applied in urban cargo transportation, thus presenting innumerous research opportunities in this field of knowledge. In this context, identifying new operation models and vehicles that could be applied for last mile deliveries in urban areas becomes crucial. Therefore, this paper aims to identify, through a systematic literature review, the main types of vehicles addressed in the literature that could be used in the last mile of urban freight distribution in order to increase the sustainability of this type of operation. The results indicate a trend for the implementation of smaller and lighter vehicles for last mile deliveries in urban areas: 47% of the studies suggest, among other alternatives, the use of bicycles and tricycles; while 53% of the articles support the use of light commercial vehicles. Another trend observed in this type of distribution, indicated in 64% of the studies, is the shift from conventional (fossil fuels) to alternative sources of energy (electricity).

Keywords: last mile; urban freight distribution; vehicle; city logistics

1. Introduction

The increasing level of urbanization worldwide leads to higher levels of transport activity related to cargo distribution and service provision. This phenomenon generates social, environmental, and economic impacts, mainly related to traffic congestion and noise, pollutants, and greenhouse gas (GHG) emissions, as well as a greater risk of traffic accidents [1–3]. In order to mitigate these effects, cities need to advance their transformation and allow the innovative exploration of urban freight operations, especially in relation to the development of new technologies [4].

The consequence of these problems has been examined in last mile distribution. It is in this stage that the largest share of the logistic cost is evidenced [5]. According to Joerss et al. [6], the logistics cost in last mile delivery reaches up to 70 billion euros per year, and in 2015 it increased at a 10% growth rate. Therefore, suppliers and stakeholders are encouraged to minimize their transport costs while attempting to reduce the social, environmental, and economic impact of their operations, meanwhile maintaining a satisfactory level of service [7]. Consequently, the quest for solutions through greater cooperation and integration of their activities is underway by adopting new technologies and using resources efficiently [8].

According to the Urban Freight Research Roadmap [9], the future of urban cargo transportation will be influenced by the advent of new technologies. Joerss et al. [6] also reinforce that the business model actually applied in the last mile may be disrupted due to the new technologies that are likely to reach the market over the next ten years. For these authors, traditional delivery with diesel light-duty vehicles will account for only 20% of last mile deliveries in urban areas, by autonomous guided vehicles with parcel lockers and bike courier services. For areas with low to average density, Joerss et al. [6] even suggest the use of drones for same day deliveries. Along these lines, Winkenbach [10] highlights that we are on the crest of substantial progress in last-mile deliveries, with innovative models such as the use of electric vehicles and crowdsourcing delivery companies.

Therefore, there is potential for new technologies to improve last mile deliveries, which may lead to an entirely new transportation infrastructure and commercial delivery models [11]. Nonetheless, the profitability of some these new technologies may be yet questionable due to the high investments required for their implementation. Therefore, the early adoption of these new technologies may concentrate in developed countries due to a high labor cost, while in the developing world any major technology change is more difficult to make happen since labor costs will likely remain low [6].

In this context, it becomes essential to develop strategic initiatives which will enable a better understanding regarding the implementation of these new technologies in last mile deliveries. Consequently, there are innumerous opportunities for research in this field of knowledge, from predicting the advent of new technologies, to understanding in which contexts they could be applied, and explaining differences in the social acceptance of these technologies as well as the constraints and motivations associated with their adoption. Nonetheless, the first step is to identify the new operation models and vehicles that could be applied in last mile deliveries. This paper, therefore, aims to determine the state of art of the literature regarding the new forms of operations and technologies in last mile distribution in urban areas through a systematic literature review. Its objective is to identify the main types of vehicles addressed in the literature that could be used in the last mile of urban freight distribution in order to increase the sustainability of this type of operation.

The remainder of this paper is organized as follows. The next section details the methodology and research protocol used for the systematic literature review (SLR). Section 3 presents the results of the SLR on last mile distribution, describing a research synthesis and presenting a critical analysis. Finally, in Section 4, conclusions. limitations, and new research opportunities are presented.

2. Methodology and Research Protocol

A systematic literature review aims to report the state of a particular field of knowledge [12]. It requires the use of systematic procedures for higher data reliability [13,14], which must follow well-defined protocols to locate existing studies, select and evaluate the contributions, then analyze and synthesize the data, and finally present the main findings. The intent is to obtain and portray a clear and objective conclusion about "what is" and "what is not” known in a particular sphere of knowledge [13,15]. Thomé et al. [16] highlight that a systematic literature review is an important research effort by itself, and it is not just a review of past publications.

According to Tranfield et al. [15], a systematic literature review must be conducted in three phases: (1) planning; (2) realization; and (3) communication and presentation. For Oliveira et al. [2], the planning activity consists of: (i) identifying the need for revision; (ii) elaborating the proposal for revision; and (iii) developing the protocol of the review. The review activity itself (realization) should be divided into four stages: (i) identification, selection, and inclusion of papers; (ii) evaluation of the selected papers; (iii) extraction of data and information; and (iv) synthesis of data. Finally, the communication and presentation activity is subdivided into: (1) preparing the reports; and (ii) presenting the results [2]. The paper presented here has adopted the procedure for systematic literature review proposed by Oliveira et al. [2], as illustrated in Figure 1.

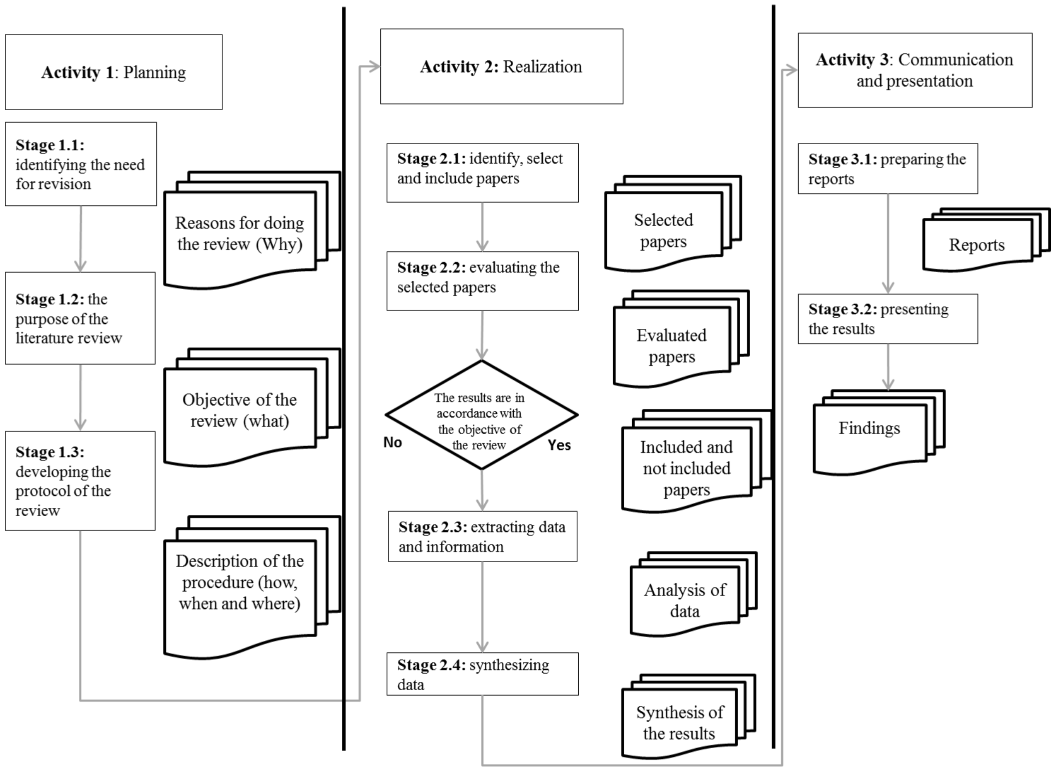

Figure 1. The systematic literature review procedure adopted. Source: [2].

3. Systematic Literature Review on Last Mile Distribution

In this section, we present the steps of the systematic literature review developed and the main results obtained.

For the development of the protocol of the review, the identification activity used the following databases: Web of Science, SCOPUS, Science Direct, DOAJ, and Compendex, as recommended by [16], to use more than two databases in order to ensure the identification of a greater diversity of papers. A combination of the keywords—last mile and (urban freight or urban freight distribution or city logistics) and vehicles—was chosen to identify research that proposes different technologies to adopt in last mile urban deliveries. This choice was based on a preliminary survey of the keywords of six papers related to the scope of the present study. The combination of the terms “last mile” and “(urban freight or urban freight distribution or urban freight transportation or city logistics)” enabled the identification of studies that deal with the last mile in urban freight transport or urban logistics. The objective of complementing these terms with the Boolean operator “and” plus the term “vehicles” is to restrict the search to papers that actually focus on the vehicles adopted in this type of operation.

The search of the chosen keywords in the selected databases was directed to the title, abstract, and keywords of the papers. Since the practice of urban logistics involves the use of technologies that evolve continuously, the last ten years have been considered as the publication period (2007 to 2016). It is understood that the topic is important for the economy of all countries; consequently, a specific delimitation in geographical comprehensiveness was not applied. Initially, the search (identification stage) was restricted to papers published in English in indexed and peer-reviewed international journals, as recommended by Nord et al.; Ngai and Wat; Oliveira et al. [2,17,18] to ensure the quality of the studies.

At first, 157 articles were identified, but the exclusion of duplicate papers (since the search was performed in more than one database) resulted in a list of 137 papers, whose abstracts were read by at least two authors, as recommended by Thomé et al. [16]. The inclusion and exclusion criteria of the papers were based on a content analysis. Papers whose content was related to last mile distribution and urban freight but did not specifically focus on the type of vehicle adopted were not considered. In conclusion, the information obtained was recorded in a database, in order to facilitate the classification, investigation, and evaluation of the studies used in this research. The selection process was iterative, seeking agreement among co-researchers. It culminated in the selection of 46 papers for complete reading. Of these, 20 were eliminated by following the exclusion criteria presented. Therefore, 26 studies were included for the development of the systematic literature review. The results of this stage are presented in Table 1.

Table 1. Synthesis of the stage of identification, selection, and inclusion of papers.

Database	Identified Papers	After Deleting Duplicates	Selected Papers	Included Papers
Science Direct	108	108	17	17
Web of Science	12	6	6	2
EBSCO	2	1	1	0
DOAJ	7	6	6	0
Scopus	5	4	4	3
Compendex	13	12	12	2
Total	157	137	46	26

A systematic literature review must provide a research synthesis and an analysis [19], such as follows.

3.1. Research Synthesis

Figure 2 presents the distribution of papers evaluated by the scientific journals in which they were published, with the highest concentration in Procedia - Social and Behavioral Sciences (seven papers), Transportation Research Procedia (six papers), and Research in Transportation Business & Management (four papers). It is emphasized that the periodicals Procedia-Social and Behavioral Sciences and Transportation Research Procedia are open access products focusing entirely on publishing full sets of conference proceedings.

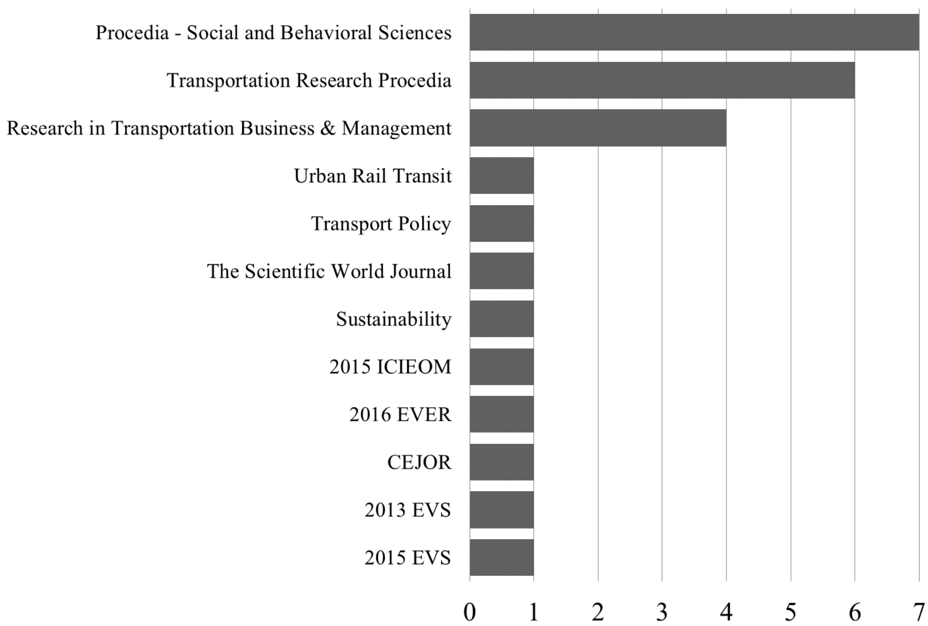

Figure 2. Distribution of papers selected by journal. Source: authors.

Figure 3 illustrates the year of publication of all papers included in this systematic literature review. In relation to the time span, there was a concentration of publications in 2014 (10) and 2015 (9). It should be noted that the number of publications in 2016 only considers papers published until the month of July (date of the survey). This observation may justify the smaller number of papers published (5) in that year. It is important to stress that none of the identified papers published from 2007 to 2012 ended up being included in (after full-text reading) or even selected for (after reading the title and abstract) the systematic literature review. This result corroborates with the premise adopted in this paper that the study of the technologies related to last mile delivery in urban areas is a recent approach.

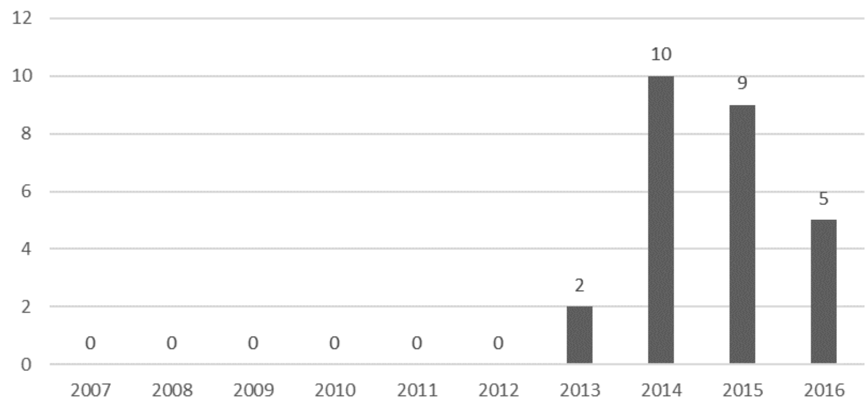

Figure 3. Distribution of papers based on publication date. Source: authors.

Figure 4 shows the geographical distribution of the articles identified after the exclusion of the duplicates (137 papers in total), while Figure 5 shows the geographical distribution of the included papers (26 papers in total), which are the list of the papers that were actually evaluated after the interactive selection process. In the case of the identified papers (Figure 4), the highest frequency of publications comes from the United States and England. However, after the conclusion of Stage 2.1 (identifying, selecting, and including papers), the geographic dispersion of the publications had changed. The concentration of papers originating from Europe increased (20), followed by Asia (4). South America and Oceania have one paper each.

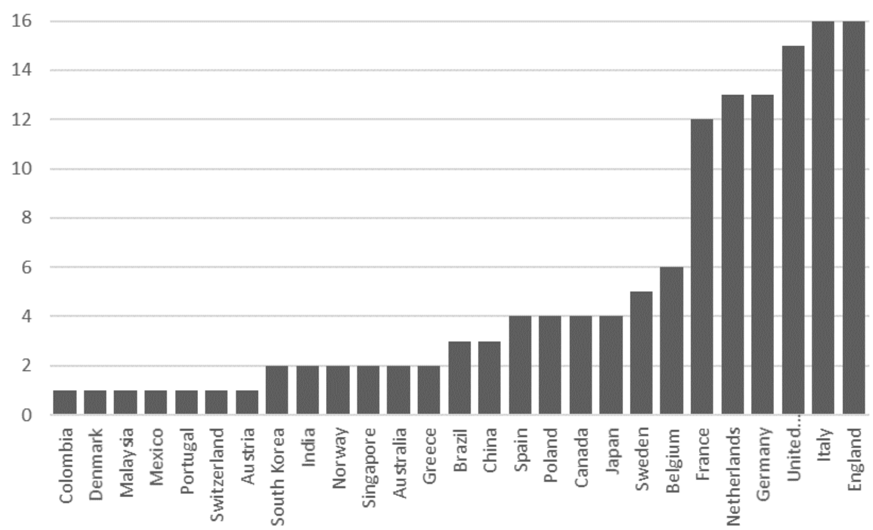

Figure 4. Geographical distribution of identified, non-duplicate, papers. Source: authors.

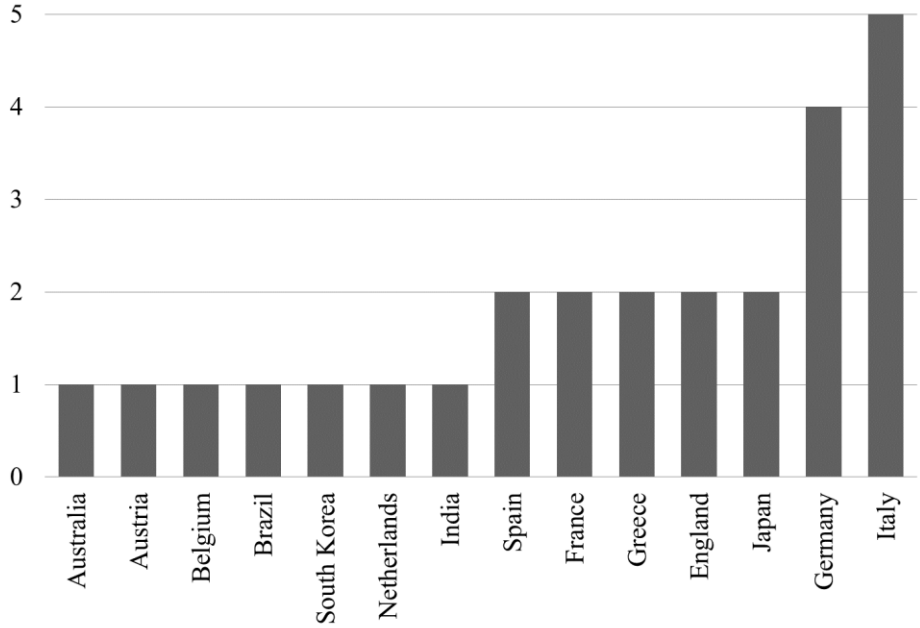

Figure 5. Geographical distribution of included papers. Source: authors.

The geographical distribution of the articles also shows a marked predominance of publications originating from developed countries. Regarding the classifications of countries based on their level of development created by the International Monetary Fund (IMF) [20], there are no publications from underdeveloped countries, and only two papers were from developing countries (Brazil and India).

Table 2 presents all types of identified vehicles that are being discussed in the literature as alternatives to trucks in last mile distribution, as well as the barriers, opportunities, and benefits (economic, environmental and social) related to their use that were discussed in each paper.

Table 2. Synthesis of the systematic literature review's results.

Author	Type of Vehicle or Equipment Used	Source of Energy	Barriers	Benefits/Opportunities		
				Economics	Environmental	Social
Tozzi et al. [21]	Light commercial	Diesel and Methane (dedicated)	-	-	-	-
Lebeau et al. [22]	Light commercial	Electric	Fleet acquisition costs; Capacity (weight and dimensions)	-	Reduction of CO_2 emissions and atmospheric pollutants	-
Sadhu et al. [23]	Bicycle [1] Tricycle [2]	Human	Customers concerns	Energy consumption; Delivery time; Traffic congestion	Reduction of CO_2 emissions and atmospheric pollutants	Job creation/Health problems
Visser et al. [24] **	Light commercial [3]	Diesel and Biodiesel	-		Reduction of CO_2 emissions and atmospheric pollutants	Quality of life
Gruber et al. [25] **	Bicycle / Tricycle	Electric	Road and recharge infrastructure; Customers concerns	Operational cost; Energy consumption;	Reduction of CO_2 emissions and atmospheric pollutants	-
Roumboutsos et al. [5]	Light commercial	Electric	Operational cost; Recharge infrastructure	-	Reduction of CO_2 emissions, atmospheric pollutants and noise	-
Foltyński [26]	Trolleys [4]/Bicycle/ Tricycle, Light commercial and Motorcycles [5]	Electric	-	Traffic congestion	-	-
Oliveira et al. [27] **	Bicycle/Tricycle	Human	-	Delivery time	Reduction of CO_2 emissions and atmospheric pollutants	-
Montwiłł [28]	Light commercial	Electric	-	-	-	-
Diziain et al. [29]	Bicycle/Tricycle	Electric	Cargo consolidation centre; Road and recharge infrastructure	-	Reduction of CO_2 emissions and atmospheric pollutants	-
Thompson and Hassall [30]	Light commercial	Diesel	-	-		-
Schliwa et al. [31]	Bicycle/Tricycle	Human	Customers concerns; Cargo consolidation centre; Capacity (weight and dimensions)	Energy consumption; Delivery time	Reduction of CO_2 emissions and atmospheric pollutants	Job creation
Alessandrini et al. [32]	Light commercial (Autonomous)	Electric	Recharge infrastructure	-	Reduction of CO_2 emissions and atmospheric pollutants	-
Faccio and Gamberi [33]	Light commercial	Electric	-	Operational cost	Reduction of CO_2 emissions and atmospheric pollutants	Quality of life
Lebeau et al. [34]	Light commercial	Electric	Fleet acquisition costs	-	Reduction of CO_2 emissions and atmospheric pollutants	-

Table 2. *Cont.*

Author	Type of Vehicle or Equipment Used	Source of Energy	Barriers	Benefits/Opportunities		
				Economics	Environmental	Social
Andaloro et al. [35]	Light commercial	Electric	Fleet acquisition costs; Capacity (weight and dimensions)	-	Reduction of CO_2 emissions and atmospheric pollutants	-
Dampier and Marinov [36]	Bicycle/Tricycle	Human	Cargo consolidation centre	Delivery time; Traffic congestion	Reduction of CO_2 emissions and atmospheric pollutants	-
Schau et al. [37]	Light commercial	Electric	Cargo consolidation centre; Road and recharge infrastructure; Capacity (weight and dimensions); vehicles charging time	-	Reduction of CO_2 emissions and atmospheric pollutants	-
(Margaritis et al. [38]	Light commercial	Electric	-	-	-	-
Navarro et al. [39] **	Bicycle/Tricycle	Electric	Cargo consolidation centre; Road and recharge infrastructure; Capacity (weight and dimensions)	-	Reduction of CO_2 emissions, atmospheric pollutants and noise	-
Rizet et al. [40] **	Light commercial	Electric	Recharge infrastructure (electric)	Traffic congestion	Reduction of CO_2 emissions and atmospheric pollutants	-
Gruber and Kihm [41]	Bicycle/Tricycle	Electric	-	-	-	-
Heitz and Beziat [42]	Bicycle/Tricycle	Electric	Cargo consolidation centre;	Operational cost	Reduction of CO_2 emissions and atmospheric pollutants	-
Anderluh et al. [43]	Bicycle/Tricycle	Electric	-	Traffic congestion	Reduction of CO_2 emissions, atmospheric pollutants and noise	-
Taniguchi et al. [44]	Light commercial	Diesel	Cargo consolidation centre	-	Reduction of CO_2 emissions, atmospheric pollutants and noise	-
Schier et al. [45]	Bicycle/Tricycle	Electric	-	-	Reduction of CO_2 emissions and atmospheric pollutants	Quality of life

** Papers that guided the choice of words used to identify the studies of this systematic literature review. Source: authors. 1 A bicycle specially designed for carrying large or heavy loads. It can be human or electric-powered. 2 Vehicles with three symmetrically arranged wheels fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or a maximum design speed of more than 45 km/h [46] . It can also be human-powered. 3 Vehicles for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes [46]. 4 Small vehicle with two or four wheels that can be used to transport large or heavy loads. 5 Two-wheel vehicles without a sidecar (category L3e) or with a sidecar (category L4e), fitted with an engine having a cylinder capacity of more than 50 cm^3 if of the internal combustion type and/or having a maximum design speed of more than 45 km/h [46].

3.2. Analysis

Figure 6 represents the distribution of papers according to the type of vehicle and the power source adopted for last mile urban freight transportation.

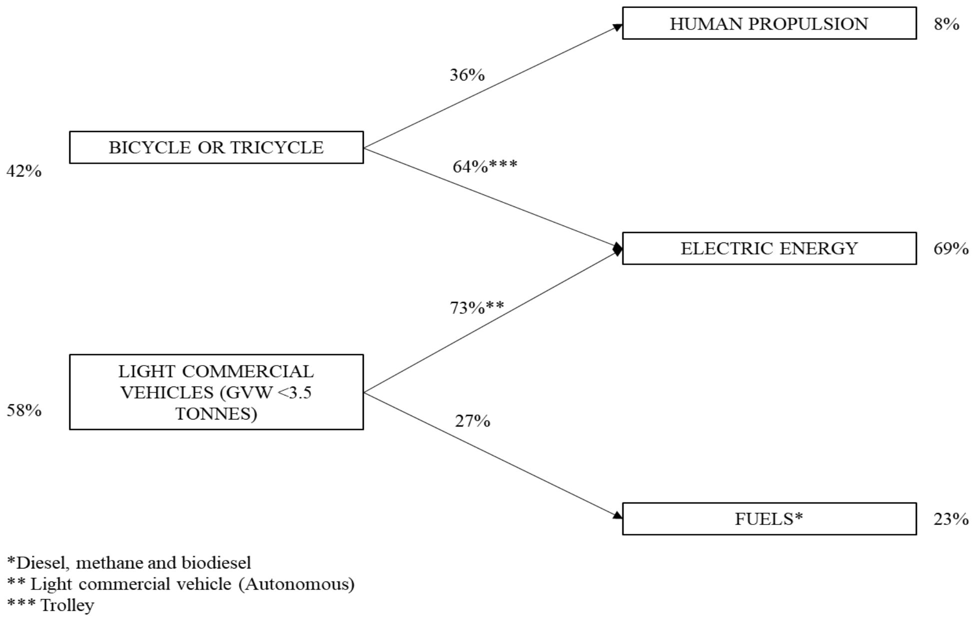

Figure 6. Distribution of the included papers in relation to the type of vehicle and the energy. Source: authors. GVW, Gross Vehicle Weight.

From the total papers studied and considered, 42% proposed bicycle/tricycle as the best alternative for last mile urban deliveries, and with regard to the energy used, 64% of studies pointed to electric energy and 36% to human propulsion. On the other hand, light commercial vehicles, which are vehicles with a Gross Vehicle Weight (GVW) of not more than 3.5 tonnes, which means the value specified by the manufacturer as the loaded weight of a single vehicle (the same criterion is used by the Brazilian authorities), were considered in 58% of the studies, among which 73% of them indicated the use of electricity and 27% referenced the use of other sources of energy (diesel dedicated, diesel/methane, and diesel/biodiesel). It is noteworthy that Alessandrini et al. [32] considered the use of an unmanned light commercial vehicle powered by electricity. Foltyński [26] suggested the use of bicycles, tricycles, and motorcycles together with light commercial vehicles (all electric), as alternatives for last mile delivery.

According to Schoemaker et al. [47], the number of light commercial vehicles in Europe has increased by 15% between 1990 and 2003, while the number of vehicles with a gross weight (GW) of over 3.5 tonnes has increased by 6.6% during the same period. This demonstrates the tendency to increase the implementation of light commercial vehicles in urban freight transport. In addition, according to [48], urban freight transport is inefficient in most cities, including those in developed countries, with low population density rates. For example, in London, the occupancy rate of this type of vehicle varied between 40 and 60% in 2006 [47], which reinforces the adoption of smaller vehicles as an efficient and sustainable alternative. This practice has already been applied by different companies, including in developing countries, such as Brazil, where tricycles have been used by companies such as Coca-Cola [49], aiming to reduce the effects of traffic congestion and traffic restrictions imposed by the authorities. Therefore, it appears that delivery companies may have a tendency to use smaller vehicles in last mile distribution; for example, tricycles and bicycles, corroborating to the results of this systematic literature review. The specialized literature suggests the reduction of vehicle sizes used in the last mile, specifically in the adoption of bicycles, tricycles, and light commercial vehicles

(Table 2). Nonetheless, it is a logistical challenge to integrate the trend of reducing the size of vehicles (consequently with lower load capacity) in last mile urban delivery with the operation of regional freight transport that, in pursuit of sustainable and efficient transportation, uses larger and heavier vehicles with higher capacity [9]. For this reason, it becomes essential to use deconsolidation centers around urban areas.

Regarding the type of energy used by the proposed vehicles, considering all 26 papers included in this systematic literature review, it was verified that 69% deal with vehicles powered by electricity. This result demonstrates the potential use of electric vehicles in urban freight transport, especially in last mile distribution, since electrification is widely considered as a viable strategy for reducing the oil dependency and environmental impacts of road transportation [50]. The other types of energy used in the applications analyzed were: methane, biodiesel, diesel (23%), and human propulsion (8%).

Concerning the barriers, defined here as obstacles that prevent the implementation of the proposals, we identified an unacceptability by some customers for signing contracts with companies that use a bicycle delivery service, because this market is still characterized by small and medium companies [25,31]. However, acceptance is an aspect of minor importance and good suitability [41]. Another barrier refers to the infrastructures of cities, especially to the power supply systems for electric vehicles, and the need for the construction of consolidation centers in order to facilitate cargo distribution by electric vehicles and smaller vehicles [40,42,44].

Regarding the economic benefits, the studies proposed the reduction of energy consumption, delivery time, and traffic congestion [31,36,40], since bicycles are able to use exclusive bicycle paths and avoid imposed traffic constraints [23]. The environmental benefits have focused on reducing greenhouse gas emissions, air pollutants, and noise emissions, whilst the social benefits included the possible generation of jobs and an improvement in the quality of life of the population. It is important to reinforce the conclusions of [23], which pointed out the health problems that could be caused by the use of bicycles (with human propulsion) and the excess load weight (some cases about 195 kg).

With reference to the scope of its application, it was possible to obtain information about the average speed developed by the vehicles considered in the studies and the cargo capacity, as well as the characteristics of the cities where the studies were applied. The average bicycle/tricycle speed varied from 2 to 6 km/h [23], while that of a light commercial vehicle reached 25 km/h [25]. Regarding cargo capacity, Gruber et al. [25] suggested a value of 100 kg for the capacity on electric bicycles in Germany, whereas [31] revealed the existence of a weight limitation of 60 kg for shipments on electric-assisted bicycles in England. However, Schier et al. [45], in their survey of last mile distribution in urban areas, consider that electric-assisted bicycles and tricycles can carry between 50 and 250 kg. In the case analyzed by Sadhu et al. [23], in New Delhi, up to 195 kg on human-powered bicycles can be transported per trip.

Among the included papers, 81% consider a case study or an application in one or more cities (as shown in Table 3). Berlin, Paris, and Tokyo are the most studied cities. Tokyo is a megacity with 13.5 million inhabitants, Berlin is the fifth most populous city in Europe with four million inhabitants and a high concentration of economic activities [51], and Paris has a high population density (21,000 inhabitants/km^2) as well as a high concentration and diversification of economic activities [42]. Only one study considered a megacity located in a developing country: New Delhi (India) with 23 million inhabitants, distributed in its metropolitan region. Although there was a study developed in Brazil, its analysis was developed in Belo Horizonte, which is not one of the two Brazilian megacities (São Paulo and Rio de Janeiro). There was heterogeneity in relation to the population of the studied cities, ranging from 87,000 to 13 million inhabitants. Moreover, it has been observed that approximately 70% of the cities have densities above 1000 inhabitants/km^2. This result was expected, since the demand for urban freight transportation is important in densely populated areas [42].

Table 3. Cities with case studies in decreasing order of density levels.

Country	City	Number of Citations in Papers	Population	Density
France	Paris	3	2.2 million inhabitants	20,980 inhabitants/km^2
Spain	Barcelona	1	1.6 million inhabitants	15,895 inhabitants/km^2
Brazil	Belo Horizonte	1	2.5 million inhabitants	7561 inhabitants/km^2
Japan	Tokyo	2	13 million inhabitants	6354 inhabitants/km^2
Spain	Valence	1	792,000 inhabitants	5844 inhabitants/km^2
India	New Delhi	1	250,000 inhabitants	5720 inhabitants/km^2
Netherlands	Amsterdam	1	779,000 inhabitants	4908 inhabitants/km^2
Austria	Vienna	1	1.7 million inhabitants	4069 inhabitants/km^2
Germany	Berlin	3	4.1 million inhabitants	3848 inhabitants/km^2
Italy	Padua	1	210,000 inhabitants	2267 inhabitants/km^2
Germany	Erfurt	1	206,000 inhabitants	754 inhabitants/km^2
England	Newcastle	1	259,000 inhabitants	719 inhabitants/km^2
Italy	Parma	1	178,000 inhabitants	601 inhabitants/km^2
Italy	Lucca	1	87,000 inhabitants	431 inhabitants/km^2
Australia	Sidney	1	4.7 million inhabitants	391 inhabitants/km^2
England	Cambridge	1	123,000 inhabitants	307 inhabitants/km^2

Through the results of the present study, it was possible to verify a change in the way of operating the last mile distribution. Traditionally, deliveries were performed by semi-light, light, and medium-duty diesel trucks, with the aid of manual trolleys. However, due to restrictions on truck movement in urban areas (mainly because of their dimensions), smaller vehicles are becoming more common. Consistent with the results of this study, 58% of the references found cited light commercial vehicles (GVW < 3.5 tonnes). Even so, factors such as traffic congestion and the specific geographic characteristics of cities (ground surface relief, presence of a historical centre, and population density) generated impedances that led to the gradual use of even smaller vehicles like tricycles, bicycles, and motorcycles, as evidenced in 42% of the references identified in this study.

An increase in the trip extension of last mile distribution was also observed, as some companies started to adopt a combination of light commercial vehicles, tricycles, bicycles, and motorcycles at this stage of the distribution chain. Hence, the trip extension to support last mile demand in urban areas varied between 10 and 30 km [39,51]. Therefore, as a full-charge drive of an electric two-wheeler ranges from 20–160 km [50], their autonomy appears to be sufficient for urban freight distribution operations.

Considering the type of energy, there was a tendency towards electrification and a concern to promote the socioenvironmental sustainability of the companies' operations. The use of electric energy for transport is pertinent to considerably reduce greenhouse gas emissions, especially CO_2, the main cause of global warming [50–53].

4. Conclusions

This research aimed to identify, through a systematic literature review, the main types of vehicles addressed in the literature that could be used in the last mile of urban freight distribution in order to increase the sustainability of this type of operation. We chose to use the systematic literature review as the research strategy in this paper because, by systematically reporting procedures and methods, it improves the accuracy and also allows verification [16]. As a result, the paper presents a synthesis and an analysis of the state of the art of the academic literature in the field of urban freight transportation, regarding the type of vehicles that can be used in the last mile of these operations.

The scientific literature indicates that the size reduction of the vehicles (and likewise capacity) used for last mile deliveries in urban areas as a more sustainable and efficient alternative for this type of operation. It is noteworthy that pressures imposed on traffic, due to aspects related to land use, such as restrictions on truck movement and geographic/historical aspects, have made the operation of last mile deliveries, traditionally done by trucks, a challenge. For this reason, the observed frequency of references suggests that deliveries should be done by bicycles/tricycles/motorcycles (42%) or light commercial vehicles (58%). Nonetheless, this alternative implies further issues that require more studies, such as the consequences for the operational level of service by increasing the number of trips made by smaller vehicles, and how to adapt the road network to integrate these types of vehicles, notably bicycles and tricycles. Another relevant point to be addressed in future studies are the impacts of the adoption of bicycles and tricycles, especially regarding the health of the workers and the problems that can be caused by the excessive weight of the load (as shown in the literature, some cases reached up to 195 kg).

In addition, the results of the systematic literature review also demonstrate the potential use of electric vehicles in urban freight transport, especially in last mile distribution, as an alternative with potential benefits in terms of sustainability and efficiency. This shift on the source of vehicle propulsion from fossil fuels to electric energy was indicated in 69% of the studies. These data show a concern not just to avoid the adverse effects of a congested road network, but also to take measures based on the social and environmental sustainability of urban freight transportation. Therefore, it is fundamental to develop new studies that analyze how the growth of electric vehicles can be integrated into the supply chain, and how it can be an opportunity for cooperation between all of the stakeholders.

Finally, one can conclude that there are numerous opportunities for research in this field of knowledge, from predicting the advent of new technologies, to understanding in which contexts they could be applied, and explaining differences in the social acceptance of these technologies as well as the constraints and motivations associated to their adoption.

Moreover, it is important to reinforce that, according to the scope of the paper, we chose the keywords to limit the search in our systematic literature review only to studies that specifically focus on the type of vehicle adopted in the last mile of urban deliveries. Therefore, other potential alternatives to increase the sustainability of urban logistics, such as the use of parcel lockers or crowdsourcing, would not be identified in our paper, since they are not a vehicle-based solution, which is the object of study in this paper. Intermodal solutions, such as the use of rail transportation to urban freight transportation with the integration of another road mode to the last mile of the delivery would not be identified either, since we focus only on the "last lag" (last mile) of urban freight transport. This may be considered a limitation of our study, but also an opportunity of future research, since new systematic literature reviews can be developed focusing on these topics.

Author Contributions: Cintia Machado de Oliveira initiated the idea presented in this work. George Vasconcelos Goes, Renata Albergaria de Mello Bandeira, Cintia Machado de Oliveira and Daniel Neves Schmitz Gonçalves carried out the systematic literature review and analyzed the data. They wrote the paper under the guidance of Márcio de Almeida D'Agosto, who revised the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. McKinnon, A.C.; Browne, M.; Whiteing, A.E. *Green Logistics : Improving the Environmental Sustainability of Logistics*; Kogan Page Publishers: London, UK, 2015.
2. Oliveira, C.M.; D'Agosto, M.D.A.; Mello, A.L.D.d.; Assumpção, F.D.C.; Gonçalves, F.D.S.; Gonçalves, D.N.S. Identificando os desafios e as boas práticas para o transporte urbano de cargas, por meio de uma revisão bibliográfica sistemática. *Transportes* **2016**, *24*, 9. [CrossRef]
3. Muñoz-Villamizar, A.; Montoya-Torres, J.R.; Faulin, J. Impact of the use of electric vehicles in collaborative urban transport networks: A case study. *Transp. Res. D Trans. Environ.* **2017**, *50*, 40–54. [CrossRef]
4. Björklund, M.; Gustafsson, S. Toward sustainability with the coordinated freight distribution of municipal goods. *J. Clean. Prod.* **2015**, *98*, 194–204. [CrossRef]
5. Roumboutsos, A.; Kapros, S.; Vanelslander, T. Green city logistics: Systems of innovation to assess the potential of e-vehicles. *Res. Transp. Bus. Manag.* **2014**, *11*, 43–52. [CrossRef]

6. Joerss, M.; Schröder, J.; Neuhaus, F.; Klink, C.; Mann, F. Mckinsey & company parcel delivery: The future of last mile. McKinsey & Company: Travel, Transport Logist. 2016. Available online: http://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/how-customer-demands-are-reshaping-last-mile-delivery (accessed on 26 July 2017).
7. Sanchez Rodrigues, V.; Piecyk, M.; Mason, R.; Boenders, T. The longer and heavier vehicle debate: A review of empirical evidence from germany. *Transp. Res. D Trans. Environ.* **2015**, *40*, 114–131. [CrossRef]
8. Steadieseifi, M.; Dellaert, N.P.; Nuijten, W.; Van Woensel, T.; Raoufi, R. Multimodal freight transportation planning: A literature review. *Eur. J.Oper. Res.* **2014**, *233*, 1–15. [CrossRef]
9. Urban Freight Research Roadmap. 2014. Brussel, Belgium. Available online: http://www.ertrac.org/uploads/documentsearch/id36/ERTRAC_Alice_Urban_Freight.pdf (accessed on 26 July 2017).
10. Winkenbach, M.; Roset, A.; Spinler, S.; Winkenbach, M.; Roset, A.; Spinler, S. Strategic redesign of urban mail and parcel networks at la poste strategic redesign of urban mail and parcel networks at la poste. *Interfaces* **2016**, *46*, 445–458. [CrossRef]
11. Lee, H.L.; Chen, Y.; Gillai, B.; Rammohan, S. Technological Disruption and Innovation in Last-mile Delivery. Available online: https://www.gsb.stanford.edu/sites/gsb/files/publication-pdf/vcii-publication-technological-disruption-innovation-last-mile-delivery.pdf (accessed on 26 July 2017).
12. Rowley, J.; Slack, F. Conducting a literature review. *Mang. Res. News* **2004**, *27*, 31–39. [CrossRef]
13. Cook, D.J.; Mulrow, C.D.; Haynes, R.B. Systematic reviews: Synthesis of best evidence for clinical decisions. *Ann. Intern. Med.* **1997**, *126*, 376–380. [CrossRef] [PubMed]
14. Brereton, P.; Kitchenham, B.A.; Budgen, D.; Turner, M.; Khalil, M. Lessons from applying the systematic literature review process within the software engineering domain. *J. Syst. Softw.* **2007**, *80*, 571–583. [CrossRef]
15. Tranfield, D.; Denyer, D.; Smart, P. Towards a methodology for developing evidence-informed management knowledge by means of systematic review* introduction: The need for an evidence- informed approach. *Br. J. Manag.* **2003**, *14*, 207–222. [CrossRef]
16. Thomé, A.M.T.; Scavarda, L.F.; Scavarda, A.J. Conducting systematic literature review in operations management. *Prod. Plann. Contr.* **2016**, *27*, 408–420. [CrossRef]
17. Nord, J.H.; Nord, G.D. Mis research: Journal status assessment and analysis. *Inform. Manag.* **1995**, *29*, 29–42. [CrossRef]
18. Ngai, E.W.T.; Wat, F.K.T. A literature review and classification of electronic commerce research. *Inform. Manag.* **2002**, *39*, 415–429. [CrossRef]
19. Torraco, R.J. Writing integrative literature reviews: Guidelines and examples. *Hum. Resource Dev. Rev.* **2005**, *4*, 356–367. [CrossRef]
20. Nielsen, L. Classifications of Countries Based on Their Level of Development: How It is Done and How It Could be Done. IMF Working Paper. 2011. Available online: https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Classifications-of-Countries-Basedon-their-Level-of-Development-How-it-is-Done-and-How-it-24628 (accessed on 26 July 2017).
21. Tozzi, M.; Corazza, M.V.; Musso, A. Recurring patterns of commercial vehicles movements in urban areas: The parma case study. *Procedia–Soc. Behav. Sci.* **2013**, *87*, 306–320. [CrossRef]
22. Lebeau, P.; Macharis, C.; van Mierlo, J.; Maes, G. Implementing electric vehicles in urban distribution: A discrete event simulation. *WEVJ* **2013**, *6*, 38–47.
23. Sadhu, S.L.N.S.; Tiwari, G.; Jain, H. Impact of cycle rickshaw trolley (crt) as non-motorised freight transport in delhi. *Transport Policy* **2014**, *35*, 64–70. [CrossRef]
24. Visser, J.; Nemoto, T.; Browne, M. Home delivery and the impacts on urban freight transport: A review. *Procedia–Soc. Behav. Sci.* **2014**, *125*, 15–27. [CrossRef]
25. Gruber, J.; Kihm, A.; Lenz, B. A new vehicle for urban freight? An ex-ante evaluation of electric cargo bikes in courier services. *Res. Transp. Bus. Manag.* **2014**, *11*, 53–62. [CrossRef]
26. Foltyński, M. Electric fleets in urban logistics. *Procedia–Soc. Behav. Sci.* **2014**, *151*, 48–59. [CrossRef]
27. Oliveira, L.; Regina Pinto Oliveira, B.; de Assis Correia, V. Sciencedirect simulation of an urban logistic space for the distribution of goods in belo horizonte, brazil. *Procedia–Soc. Behav. Sci.* **2014**, *125*, 496–505. [CrossRef]
28. Montwiłł, A. The role of seaports as logistics centers in the modelling of the sustainable system for distribution of goods in urban areas. *Procedia–Soc. Behav. Sci.* **2014**, *151*, 257–265. [CrossRef]
29. Diziain, D.; Taniguchi, E.; Dablanc, L. Urban logistics by rail and waterways in france and japan. *Procedia–Soc. Behav. Sci.* **2014**, *125*, 159–170. [CrossRef]

30. Thompson, R.G.; Hassall, K. Implementing high productivity freight vehicles in urban areas. *Procedia–Soc. Behav. Sci.* **2014**, *151*, 318–332. [CrossRef]
31. Schliwa, G.; Armitage, R.; Aziz, S.; Evans, J.; Rhoades, J. Sustainable city logistics—Making cargo cycles viable for urban freight transport. *Res. Transp. Bus. Manag.* **2014**, *15*, 50–57. [CrossRef]
32. Alessandrini, A.; Campagna, A.; Site, P.D.; Filippi, F.; Persia, L. Automated vehicles and the rethinking of mobility and cities. *Transp. Res. Procedia* **2015**, *5*, 145–160. [CrossRef]
33. Faccio, M.; Gamberi, M. New city logistics paradigm: From the "last mile" to the "last 50 miles" sustainable distribution. *Sustainability* **2015**, *7*, 14873–14894. [CrossRef]
34. Lebeau, P.; De Cauwer, C.; Van Mierlo, J.; Macharis, C.; Verbeke, W.; Coosemans, T. Conventional, hybrid, or electric vehicles: Which technology for an urban distribution centre? *Sci. World J.* **2015**, *2015*, 2–11. [CrossRef] [PubMed]
35. Andaloro, L.; Napoli, G.; Sergi, F.; Micari, S.; Agnello, G.; Antonucci, V. Development of a new concept electric vehicle for last mile transportations. Proceedings of EVS28 28th International Electric Vehicle Symposium and Exhibition, Goyang, South Korea, 2015.
36. Dampier, A.; Marinov, M. A study of the feasibility and potential implementation of metro-based freight transportation in newcastle upon tyne. *Urban Rail Transit* **2015**, *1*, 164–182. [CrossRef]
37. Schau, V.; Rossak, W.; Hempel, H.; Spathe, S. Smart city logistik erfurt (scl): Ict-support for managing fully electric vehicles in the domain of inner city freight traffic: A look at an ongoing federal project in the City of Erfurt, Erfurt, Germany. Proceedings of IEOM 2015–5th International Conference on Industrial Engineering and Operations Management, Dubai, United Arab Emirates, 2015.
38. Margaritis, D.; Anagnostopoulou, A.; Tromaras, A.; Boile, M. Electric commercial vehicles: Practical perspectives and future research directions. *Res. Transp. Bus. Manag.* **2016**, *18*, 4–10. [CrossRef]
39. Navarro, C.; Roca-Riu, M.; Furió, S.; Estrada, M. Designing new models for energy efficiency in urban freight transport for smart cities and its application to the spanish case. *Transp. Res. Procedia* **2016**, *12*, 314–324. [CrossRef]
40. Rizet, C.; Cruz, C.; Vromant, M. The constraints of vehicle range and congestion for the use of electric vehicles for urban freight in france. *Transp. Res. Procedia* **2016**, *12*, 500–507. [CrossRef]
41. Gruber, J.; Kihm, A. Reject or embrace? Messengers and electric cargo bikes. *Transp. Res. Procedia* **2016**, *12*, 900–910.
42. Heitz, A.; Beziat, A. The parcel industry in the spatial organization of logistics activities in the paris region: Inherited spatial patterns and innovations in urban logistics systems. *Transp. Res. Procedia* **2016**, *12*, 812–824. [CrossRef]
43. Anderluh, A.; Hemmelmayr, V.C.; Nolz, P.C. Synchronizing vans and cargo bikes in a city distribution network. *Cent. Eur. J. Oper. Res.* **2016**, *25*, 1–32. [CrossRef]
44. Taniguchi, E.; Thompson, R.G.; Yamada, T. New opportunities and challenges for city logistics. *Transp. Res. Procedia* **2016**, *12*, 5–13. [CrossRef]
45. Schier, M.; Offermann, B.; Weigl, J.D.; Maag, T.; Mayer, B.; Rudolph, C.; Gruber, J. Innovative two wheeler technologies for future mobility concepts. Proceedings of 2016 11th International Conference on Ecological Vehicles and Renewable Energies, EVER 2016, Monte Carlo, Monaco, 6 April 2016.
46. EU: Vehicle Definitions. Transportpolicy.net. Available online: http://transportpolicy.net/index.php?title=EU:_Vehicle_Definitions (accessed on 26 July 2017).
47. Schoemaker, J.; Allen, J.; Huschebeck, M.; Monigl, J. Quantification of urban freight transport effects Best Urban Freight Solutions II. 2005. Available online: http://www.bestufs.net/download/BESTUFS_II/key_issuesII/BESTUF_Quantification_of_effects.pdf (accessed on 26 July 2017).
48. Dablanc, L. *Freight Transport for Development Toolkit: Urban Freight*; World Bank: Washington, DC, USA, 2009.
49. Ferreira, A.F. A utilização de triciclos na distribuição física de bebidas no rio de janeiro. Uma abordagem qualitativa sobre a operação the use of tricycles in the physical distribution of beverages in rio de janeiro city. A qualitative approach of the operation. Available online: www.revistaret.com.br/ojs-2.2.3/index.php/ret/article/view/369 (accessed on 26 July 2017).
50. Weiss, M.; Dekker, P.; Moro, A.; Scholz, H.; Patel, M.K. On the electrification of road transportation—A review of the environmental, economic, and social performance of electric two-wheelers. *Transp. Res. D Trans. Environ.* **2015**, *41*, 348–366. [CrossRef]

51. Cox, W.; Pavletich, H. 13th Annual Demographia International Housing Affordability Survey Rating Middle—Income Housing Affordability 2017. Available online: http://www.demographia.com/dhi.pdf (accessed on 26 July 2017).
52. Tozzi, M.; Corazza, M.V.; Musso, A. Urban goods movements in a sensitive context: The case of parma. *Res. Transp. Bus. Manag.* **2014**, *11*, 134–141. [CrossRef]
53. Rezvani, Z.; Jansson, J.; Bodin, J. Advances in consumer electric vehicle adoption research: A review and research agenda. *Transp. Res. D Trans. Environ.* **2015**, *34*, 122–136. [CrossRef]