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The Sustainability Dimensions in Intelligent Urban Transportation: A Paradigm for Smart Cities

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Abstract: The transportation sector has traditionally been considered essential for commercial activities, although nowadays, it presents clear negative impacts on the environment and can reduce social welfare. Thus, advanced optimization techniques are required to design sustainable routes with low logistic costs. Moreover, these negative impacts may be significantly increased as a consequence of the lack of synergy between the sustainability objectives. Correspondingly, the concept of transport optimization in smart cities is becoming popular in both the real world and academia when public decision making is lit by operations research models. In this paper, however, we argue that the level of urban smartness depends on its sustainability and on the level of information and communication technologies developed in the city. Therefore, the operations research models seek to achieve a higher threshold in the sustainable transport standards in smart cities. Thus, we present a generic definition of smart city, which includes the triple bottom line of sustainability, with the purpose of analyzing its effects on city performance. Finally, this work provides a consolidate study about urban freight transport problems, which show that sustainability is only one facet of the diamond of characteristics that depict a real smart city.

Keywords: operations research; sustainable logistics; sustainability indicators; smart city

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1. Introduction

The current transport system poses growing and significant challenges for sustainability, while current mobility schemes have focused much more on the private vehicle, which has conditioned both the ways of life of citizens and cities, such as urban and territorial sprawl. In fact, transport has a very considerable weight in the framework of sustainable development, due to environmental pressures, the associated social and economic effects and interrelationships with other sectors. The continuous growth that this sector has experienced over the last few years and its foreseeable increase, even considering the change in trend due to the current situation of generalized crisis, make the challenge of sustainable transport a strategic priority on local, national, and global scopes. Transport logistics has an important role in the economic growth of a city. Hence, transport activities involve many stakeholders and, in turn, different targets, which may be opposed. According to Eurostat [1], the transport sector employs around 10 million people and accounts for about 5% of the GDP in the EU. The efficiency of most companies heavily depends on this industry since transport and storage account for 10–15% of the cost of a finished product for European companies. The total EU-27 road transport accounted for just over three-quarters of the total inland freight transport in 2018 based on tonne–kilometers performed [2].

From a social perspective, it can be highlighted that over 26,000 people lost their lives in road accidents within the EU-27 in 2019, and 22,000 in 2020 [3]. There has been a steady decrease in the number of persons killed on European roads over the last decade.

Regarding the environmental concerns, Eurostat [2] states that transport and storage activities accounted for almost 15% of the greenhouse gas emissions and 24% of the emissions of ozone precursors, considering all the economic activities in 2017.

Consequently, the sustainability concept into logistics systems is considered a solution approach for solving urban transport problems and reaching a suitable balance between economic, social and environmental aspects. Sustainability integrates the three dimensions (economic, social and environmental), which mutually influence each other. This approach has gained much attention in today's transport management to identify the key factors to covering the stakeholders' interests and synergy between sustainability dimensions [4]. Furthermore, there are other multiple external factors, such as the weather, traffic accidents, traffic signs, and rush hours, which have a strong influence on the routes' performance [5]. These factors are closely related to random events, which raise the risk of route failures, increasing the costs and negative impacts [6]. Consequently, recent sustainable strategies rely on including new technology and structured tools to manage a massive amount of data for supporting decision making on the fly.

Generally speaking, environmental and social concerns have been increasing along with industrial needs. Companies are required to become more sustainable, i.e., achieving a suitable balance between economic, environmental and social dimensions in their processes. Thus, the concept of efficiency has to be expanded to include multiple criteria in the decision-making process. Green initiatives have led to the emergence of smart cities, which combine economic growth, improvements in living standards, and reduction in the negative impacts caused by commercial activities. All logistic systems in smart cities aim to implement optimization techniques, technological advances, and information and communication systems to make freight transport a flexible system, adept at meeting social and industrial needs [7].

In this respect, Ahvenniemi et al. [8] present a discussion about the concept of a sustainable city and smart city. Therein, the concept of the smart city is strongly related to technology but not on sustainability issues. In contrast, a sustainable city holds a much stronger focus on the triple bottom line (economic, environmental and social dimensions), aiming at balancing the trade-offs among dimensions. In this context, we address the concept of the smart city as a headway of a sustainable city. Therefore, a smart city is all about providing products and services in a smart way. It is also about connectivity, where technology allows to connect stakeholders through real-time system information. As a result, a constant flow of information, money, and goods provides accurate information to make smart decisions.

Accordingly, we argue that a smart city is a sustainable city that is supported by technology [9]. In this context, here, we present an analysis of the sustainability relevance in the transportation sector. The main contributions of this paper are as follows: (i) a comprehensive differentiation of concept of smart city and sustainable city; (ii) the definition and characterization of the three sustainability lines into the freight transport; and (iii) an overview of the effect of sustainability on the freight transport system, where operations research and management science techniques play an important role in formalizing, modeling, and solving such complex problems, allowing their integration with information and communication technologies. That is, this paper formalizes the relationship between the concept of smart cities and sustainable cities. To the best of our knowledge, no article makes a formal link between these two concepts. A smart city is a city in which technology is applied to enhance urban operations, infrastructure, strategies, and policies. Thus, this article emphasizes technology and sustainability dimensions as key elements to achieve the transition to smart cities.

The rest of the paper is organized as follow: Section 2 presents the smart city concept. Following a thorough analysis of recent works, Section 3 elaborates a consolidation of sustainability dimensions. Section 4 describes some challenges that smart cities raise. They are aimed at operations research in freight transport activities. Then, Section 5 presents a perspective about how the sustainability concept and technology define a smart city. Finally, Section 6 draws the main conclusions and identifies potential lines of future work.

2. Smart City

Taniguchi et al. [10] introduce the concept of city logistics as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy". Then, city logistics lies in profitable logistics systems where the efforts aim at minimizing transport cost. Later, the need for efficient and environmentally acceptable urban transportation system is conjoined by the idea of a green city. Thus, environmental issues are critical concerns all over the world. As a result, the logistics system aims at environmentally responsible and friendly operations. Due to global warming and the overuse of natural resources caused by transport activities, the natural environment has become an important variable in the decision-making process [11]. Therefore, the interest in developing green logistics from companies, government, and the public is increasing in order to change the environmental performance of suppliers and customers [12]. Figure 1 summarizes the initiatives trajectory to reach environmentally responsible and friendly operations in urban places.

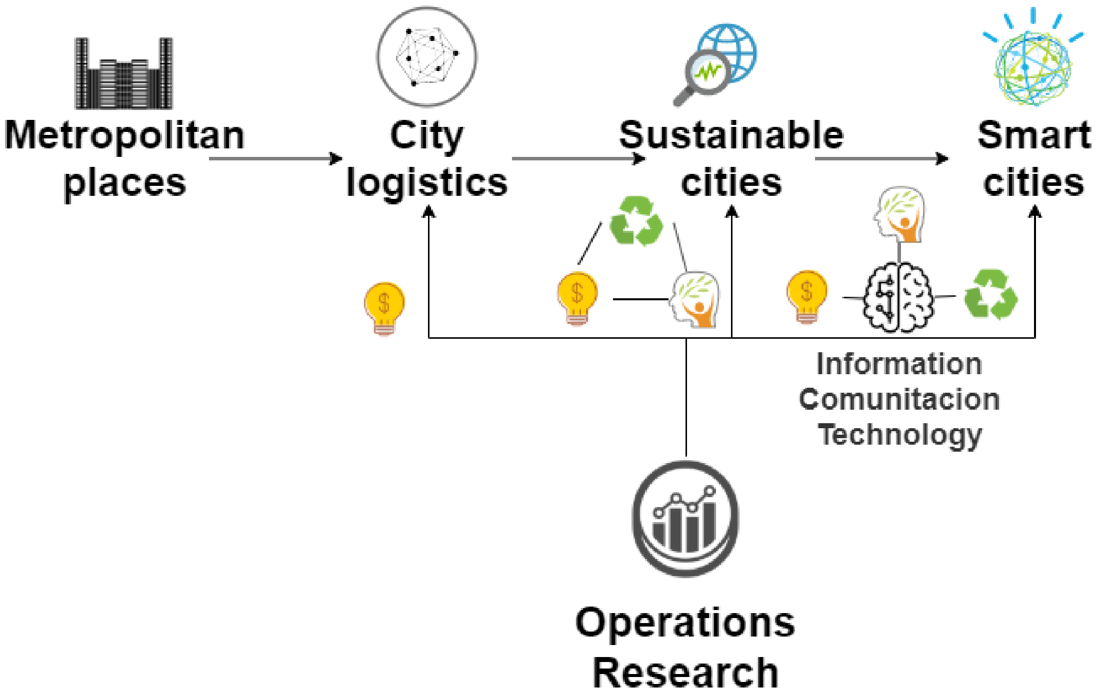

Figure 1. The background of the smart city concept.

Similarly, social and industrial needs are not only concerned with the economic impact of decisions, but also with the effects on society, such as the effects of pollution on the environment. Consequently, the sustainable city concept has gained importance, due to the increasing pressure for the balance among economic, social and environmental dimensions in the logistics system. The sustainability initiatives are introduced as a way to conciliate the economic development and natural resource consumption in city logistics. Thus, sustainability indicators arise from the philosophy to determine a development that meets the current industrial and social needs and preserves resources for future generations [13]. There is also a growing public concern about living conditions and environmental preservation, especially in the context of modern cities.

On the one hand, the sustainability concept in city logistics promotes determining educational programs about sustainable actions, which lead freight transport to a greener system. On the other hand, the transition from a sustainable city to smart city refers to sustainability oriented processes and technology integration. This initiative leads to the emergence and integration of new technology, which aims at an optimal synchronization of transport operations [14–16]. In this sense, an optimal synchronization links the operations research for supporting transportation decisions. Thus, the decision-making process meets multidimensional needs and fits rapid market changes by on-the-fly decisions. Therefore, information, communication and technology are key factors to turn a city into a smart place. Thus, a smart city is a place that is well connected, sustainable, and resilient against urban dynamics. Currently, there is extensive discussion around the smart city concept [17,18]. The smart city definition may derive from a combination of the definitions above: a smart city is a metropolitan place that is embedded with harmonic systems that provide a balance between economic development, environmental preservation and promote a high quality of life [19]. In this context, there is a consensus around the multidimensional factors or triple bottom line related to sustainability dimensions [20]. Therefore, the concept of smart cities arises to face the constant changes in economy, environment, and society, in addition to the environmental preservation concerns and city development.

Consequently, the sustainability concept has been gaining increasing attention. Following an extensive literature review, Faulin et al. [12], Vega-Mejía et al. [20], and McKinnon et al. [13] evidence that the sustainability concept is usually limited to the environmental dimension but it also involves economic and social issues. In this sense, there are criteria for sustainability that could be against each other. As a consequence, the smart city concept appears as an engaging approach to achieve an agreement on how to trade off the different sustainability dimensions. Thus, a sustainable development followed by the technology integration might turn a metropolitan place into a smart city. Then, to reach an optimal balance between economic, social and environmental benefits, it is necessary to integrate sustainability criteria to make "smart" decisions. Thus, sustainability in the smart city concept appears as a solution to support the decision making involved in transport logistic. Many actors interoperate for freight mobility in cities. An efficient communication system allows stakeholders to share information with each other for the decision-making process. As a result, new information and communication technology have been integrated to support city operations sustainably [21]. Similarly, new technology, such as electric vehicles, have become integrated as innovative ways to handle freight transport, aiming at minimal negative impact on the environment, quality of life, and economic growth. In this sense, the definition of a sustainable city evolves to the concept of the smart city through the integration of new technology [22]. Additionally, there are few tools to support the measurement of economic, social and environmental impacts caused by freight transport. These impacts could be subjective because of the heterogeneity of the stakeholders involved. As a result, some objectives cannot be filled for all stakeholders, even after considering the three sustainability dimensions [19]. Thus, after the objectives and stakeholders interests are identified, the next step is building a consensus that influences the city performance in terms of sustainability [23].

Interrelationships between smart city and transportation are noticeable. In fact, some authors consider that the smart city favors smart transport, while others consider that without intelligent transportation, there would not be any smart city. For example, for Zawieska and Pieriegud [24], the smart city context is a catalyst for the development of sustainable transport policies. According to the authors, the implementation of the smart city concept significantly contributes to the further reduction in transportation-related emissions. On the other hand, as stated by Škultéty et al. [25], smart transportation systems are a requirement for a smart city. The truth is that both concepts are intrinsically related, and the transportation field is a key factor in the degree implementation of any smart city.

3. Sustainability Indicators

From the freight transport perspective, the main challenges of a smart city are preserving economic growth and quality of life in implementing sustainable strategies. Thus, multidimensional indicators have been integrated as benchmarks to determine the indicators of well-performing of cities. These indicators involve the economic, social and environmental dimensions, which are also nested with stakeholders objectives [23]. Accordingly, the focus of this paper is not an extensive compilation of a large number of papers and studies about sustainable urban freight transport. Here, we encompass and summarize contributions about sustainability dimensions, addressing smart logistics systems. In the transport sector, one of the main stakeholders is the government, who plans, controls, and imposes regulations for transport activities. Furthermore, there are many initiatives that are aimed at enhancing life quality. For example, the World Health Organization program "Living well, within the limits of our planet" aimed at decreasing noise and pollution by the city design and integration of new regulations [26]. As a way of responding to the aforementioned initiatives, a number of relevant initiatives have been released by private and public organizations, e.g., (i) Lean and Green Europe (www.lean-green.eu (accessed on 23 September 2021)); (ii) US/Canada Smartway Transport Partnership (www.nrcan.gc.ca (accessed on 23 September 2021)); or (iii) UNCTAD Sustainable Freight Transport and Finance (https://unctad.org/ (accessed on 23 September 2021)). In summary, the traditional paradigm of freight distribution in urban zones is changing with the introduction of the sustainability concept and the integration of new technology. Thus, these sustainability initiatives are linked to monetary factors, such as taxes and subsidies. In this manner, the monetary indicators that encourage companies to adopt a sustainable behavior [27] are a good example of that policy. Generally speaking, monetary incentives and indicators quickly yield a direct effect on the behavior of any system. Additionally, negative impacts caused by transport activity are refereed as external costs. These costs have recently received more attention in decision-making processes [28]. Likewise, there are different classification costs in the literature to capture the negative impacts and understand the stakeholders objectives [13,28]. From the perspective of the sustainability dimension and external costs, different operational indicators could be developed. Thus, these indicators extend the decision criteria for fulfilling the stakeholders objectives. Table 1 visualizes the core of indicators related to the sustainability dimensions and stakeholders objectives.

The mentioned indicators summarize the objectives or challenges of cities in becoming a smart city. These attributes cover the objectives for metropolitan places to become smart cities. In fact, these indicators adhere attributes to the logistic systems. In Table 1, it is evident that the three dimensions are interlaced with each other [29]. The cities' development is pushed by natural resource protection and management, enhancing the environmental and economic indicators that have an effect over the social dimension. Consequently, transport problems are enriched by additional characteristics or constraints that aim to take into account the attributes' sustainability. The new approach of urban freight transport problems is supported by the literature, including a large variety of models to measure the negative impacts. This section provides a summary of the methods aimed at assessing the cities' performance from a sustainability perspective. This summary leads to the identification of main factors in each dimension for designing effective decision criteria.

Table 1. Core of sustainability criteria. Based on Kiba-Janiak [23].

		Initiatives from Stakeholders		
Sustainability Dimensions	**Objectives**	**Government**	**Companies**	**Customers**
Economic	Congestion reduction	Introduction of time windows	Reduction in travel time	Road traffic and accessibility to locations
	Profitability objective	Introduction of subsidies for less polluting transportation	Shipping and delivery times	Service levels
		Foster consolidation strategies	Logistic cost reduction	Lower product price
			Vertical and horizontal cooperation	Unloading and loading zones
Social	Health objectives	Public health costs	Workload balance regulations	Human health
	Safety objectives	Heavy vehicles within the city	Insurance companies costs	Road safety (accident, death, and injuries)
Environmental	Nuisance reducction			
	Fuel consumption reduction	Legislation about allowed boundaries	Introduction of new technologies (alternative fueled vehicles)	Social welfare
	Emission reduction			
	Infrastructure protection	Road protection	Multimodal transport and energy efficiency in buildings	Infrastructure use

3.1. Economic Dimension

The economic impact covers the synergies between social and environmental effects. In brief, it concerns the management of natural resource use, promotion of innovation, the costs because of negative externalities (e.g., public health costs), the city monetary situation, and regulation effects on the transport system. As a result, governments have designed instruments and monetary indicators to estimate the cost of impacts [30]. Ranaiefar and Amelia [28] present an estimations about the externalities and costs involved. Thus, an estimation of the transport cost can be made, involving the externalities' impact. Table 2 displays a summary of the externalities' cost.

Table 2. Externalities' costs based on Ranaiefar and Amelia [28].

Externality	USD/km	USD/ton-km
Congestion	[2.28–14.82]	0.3375
Accidents	0.096	[0.68–1.25]
Air pollution	[2.38–19.98]	[0.0625–11.6875]
Climate change	[2.60–3.74]	[0.0125–3.68]
Noise pollution	[0.00–89.21]	[0.00–3.31]
Water pollution	-	[0.0019–0.031]
Energy security	-	[0.14–0.52]
Infrastructure	[4.13–5.90]	-

Hence, the new technology integration demands large investment on the infrastructure. For instance, the integration of electric vehicles implies infrastructure changes, such as charging stations and places for battery storage. The use of electric vehicles in transport activities is related to several urban changes in terms of infrastructure and distribution strategies. On the one hand, some of these challenges relate to infrastructure and fleet configurations [31]. On the other hand, electric vehicles have started to replace conventional vehicles in city logistics, redefining transport operations [32].

3.2. Social Dimension

The performance in social terms is a combination of the environmental and economic impacts. Consequently, the social impacts are more subjective, which make their analysis more complex and intricate. Hence, in some scenarios, often no clear distinction can be made between economic, social and environmental impacts. On the one hand, environmental impacts are focused on resources management and receptors, such as nature. On the other hand, economic impacts are related to capital issues, such as job creation, business activity, or earnings, while social impacts are more concentrated on human beings. Thus, social impacts are an effect and consequence of the economic and environmental impacts, although not in an immediate way. For instance, the health condition, safety condition and city livability are attributes from the air pollution, noise, and climate change, among other factors, which involve social and environmental issues [29]. Meanwhile the economic and environmental aspects can be described by quantitative measures, and the social dimension involves intangible factors [33]. As a result, the social impact is a measure that is hard to estimate because of the stakeholders' perceptions [13]. Furthermore, this indicator may be measured by the customer or employee viewpoint [34].

Thus, social impacts of transport are caused by a multiplicity of factors, which might also reinforce each other. In order to mitigate this snowball effect, in this section, road safety is studied as a social indicator. Road safety constitutes one of the most critical indicators and is related to the infrastructure condition, driver fatigue (workloads) distractions, and high speed. According to Wang et al. [35], speed variations are directly related to the accident risk of both pedestrians and vehicles.

In addition, having multiple traffic signs may encourage drivers to carry out dangerous maneuvers, which affect the road safety [36]. Recently, a set of social rules were established through regulations in Europe concerning driving and working hours and rest times in order to tackle driver fatigue and improve working conditions [37,38]. Similarly, the workload and accident road index might be mutually dependent indicators. Thus, governments have imposed regulations concerning the introduction of time windows for freight transport, driving and working hours of drivers. These rules concern stricter limits on the number of driving hours, working hours and breaks taken by a driver. Therefore, these regulations and the service times have to be taken into account when designing schedule and distribution routes. In this respect, Matl et al. [39] review equity functions (mainly referring to allocating workloads and balancing the utilization of resources) for bi-objective Vehicle Routing Problem models, whereas Bashiri et al. [40] present two mixed integer programming models to tackle the economic and social aspects related to the workload balance and their influence on accident risk.

3.3. Environmental Dimension

Concerning transport environmental dimension , we can say that travel time, travel distance, and vehicle weight play a crucial role in the fuel/energy consumption and carbon emissions generated by delivery vehicles. Thereby, Ubeda et al. [41] aimed at reducing transport costs and emissions by considering the distance and some variations in the vehicle maximum capacity. It is concluded that enhancing load factors, which may be achieved by using heterogeneous fleets, is an efficient way to obtain significant savings and environmental benefits.

Similarly, Demir et al. [42] present a comparison among four models that evaluate the fuel consumption and emissions levels. These models are based on the method of Bowyer et al. [43], which measures fuel consumption per second (mL/s). The first model measures the energy spent when the vehicle is moving, accelerating and slowing down, the aerodynamic drag, and the rolling resistance. Similarly, weight, speed, and road gradient are taken into account along with the required energy to achieve the corresponding mobility. This model has an error of 5% considering a few variations in the road gradient. Despite such a small gap, Demir et al. [42] affirm that their model is not capable of measuring the aforementioned functions and values in some stops. The second studied model conserves the same parameters but splits the objective function into four parts. The first and the second parts define the fuel consumption according to acceleration and the speed from initial until the final point of each route. Additionally, that model considers the changes in kinetic energy per traveled kilometer in the acceleration and deceleration moments. The third part of that second model defines the fuel consumption when the vehicle is moving, or stopping (idle time). Similarly, this model considers the average travel speed, an average travel distance, and kinetic energy changes. The fourth part integrates the consumed fuel in acceleration and deceleration. According to Demir et al. [42], this model presents only an error of 1%, although it is a complex method to implement, due to the specific structure of its four equations.

The third model is another variant proposed by Bowyer et al. [43], and considers only two potential statuses in one equation: when vehicles are traveling and idling. This model takes into account the average speed, the average traveled distance, the kinetic energy, and the idle time, in order to reflect different traffic situations. The fourth and last model is composed of three parts. The first part is based on the engine force, which represents the power of traction. In this part, the model takes into account the requirements of the motor, such as weight, air density, rolling resistance, aerodynamic drag, and then calculates the demanded engine energy. The second part of the equation considers the vehicle speed driven in top gear. Finally, in the last part of this fourth model, it calculates the fuel consumption, considering the demanded energy by the engine force. Likewise, it also calculates the engine speed and other parameters related to the efficiency and engine friction.

Moreover, Kuo [44] consider the fuel consumption for a vehicle routing problem with time dependent in order to take into account the travel speed and the travel time.

For calculating the fuel consumption, the route is split in sections. Equation (1) allows calculating the fuel consumption from i to j (F_{ij}) in which d_{ij} is the distance from i to j. $GPH^k_{i,j}$ represents the gallons per hour by the vehicle k, and v^k_{ij} represents the travel speed.

$$F_{ij} := GPH^k_{i,j} \cdot \frac{d_{ij}}{v^k_{ij}} \tag{1}$$

Zhang et al. [45], based on Kuo [44], solve a classical model for the vehicle routing problem, taking into account carbon emissions. In this case, fuel consumption costs are defined by the load capacity. Usually, the fuel consumption cost is estimated from the oil cost and the released emissions are measured from a pollution benchmark, which allows calculating its marginal cost. Equation (2) shows the functions considered by Zhang et al. [45], where F_{ij} represents the fuel consumption from i to j, in which d_{ij} is the distance from i to j. Finally, LPH^k_{ij} represents the fuel consumption per unit time, p is a factor that penalizes the additional load (M,) and L_{ij} is the weight of the transferred goods.

$$FC_{ij} := LPH^k_{ij} \cdot \frac{d_{ij}}{v^k_{ij}} \cdot \left\{ 1 + p \cdot \frac{L_{ij}}{M} \right\} \tag{2}$$

Furthermore, some tools have been developed to measure the pollution level in urban zones, and they are becoming very popular. For example, the $MEET$ model assesses the released emissions by heavy trucks, which takes into account speed, weight, gradient road, and distance. Similarly, we can mention the $COPERT$ model, which is the EU standard vehicle emissions calculator. It uses vehicle population, mileage, speed, and ambient temperature, among others entries, to calculate pollutant emissions and energy consumption for a specific country or region. Another interesting model to cite is the signalized intersection design and research aid ($SIDRA$) system, which is similar to the $COPERT$ model, but $SIDRA$ considers some constraints related to driver factors [42,46].

Additionally, the sustainability concept promotes the use of vehicles running on alternative fuel technologies; in particular, electric vehicles (EVs) represent a promising option to mitigate the negative impacts caused by transport activities in city logistics. The specific benefits depend on the sources employed to generate energy [47]. The main technical disadvantages of electric vehicles are the short driving range, reduced payload, and long time for charging. Thus, Holland et al. [48] show that the energy production usually has a lower environmental impact than gasoline production, and Figliozzi et al. [49] compare the life-cycle CO_2e emissions of an electric tricycle versus a diesel cargo van to make urban freight distribution. This study finds some urban scenarios in which CO_2e emissions minimization is reached using electric tricycles, and other scenarios in which the best option from the environmental point of view is using diesel cargo vans. There are some cases where the electric vehicles do not achieve good results when the whole life-cycle period is considered. Moreover, electric vehicles demand high levels of energy production, and for that reason, recent studies integrate this estimation to assess the performance of using electric vehicles instead of traditional ones [50]. A survey on the use of electric vehicles in logistics and transportation, discussing opportunities and challenges, is proposed by Juan et al. [51]. Finally, Wang et al. [52] study the influence of environmental criteria on the total cost and demonstrate that additional criteria imply additional costs and require an accurate operations synchronization in the supply chain.

In conclusion, a balance between sustainability dimensions tends to be hard because of the interrelationships between socioeconomic actions and environmental aspects. Likewise, the sustainability perspective is a way to obtain synergies between the stakeholders interests aimed at sustainable development. Thus, the three dimensions of the sustainable transportation problem are interdependent and mutually influence each other. Therefore, the challenge relies on minimizing the trade-offs between all the dimensions.

4. Urban Freight Transport

This section provides a review of sustainability problems found in urban freight transport. The urban freight distribution is the link in the supply chain that operates within the city, with the aim of supplying both business establishments and the final customer. This operation is gaining presence and relevance because of the evolution of consumer habits and advances in technology, which has caused electronic commerce to register a huge growth in recent years. However, this phenomenon has created or increased issues in the areas of transport operation profitability, driving restrictions (time and/or space), environmental impact, and congestion, among the involved stakeholders with conflicting objectives that are important to cope with. Firstly, urban freight transportation companies seek to maximize their profits by reducing delivery times, increasing the availability of load and unload zones, and improving their customer service quality. Secondly, the public sector, and particularly the local entities, aims at increasing the attractiveness of the city by promoting employment and reducing congestion and the environmental impact. Thirdly, residents look for a more enjoyable city, which requires increased pedestrian safety, better public transportation, and low levels of noise and air pollution. Finally, the goods receivers want their products on time at the lowest cost, which implies high delivery time, flexibility and delivery reliability.

The increasing social concern for the environment and sustainable growth, in general terms, requires the transformation of cities. In this context, urban freight transport problems are analyzed, cross-referencing impacts on sustainability. Here, the main sustainable traits are highlighted, including them in the optimization models. For example, the classical vehicle routing problem (VRP) may be enriched to include characteristics that allow the reduction in environmental and social impacts in urban zones concerning transport activities. Generally speaking, VRP consists of a set of delivery vehicles with limited capacity, which are available to serve customers with known demands. Typically, the aim is to minimize the total travel distance and/or time. Some additional decision criteria and constraints may be introduced, which leads to new variants, called rich VRP [53]. These variants include attributes and constraints, which describe realistic settings. This section summarizes the approach of urban freight transport models, particularly, sustainable routing-related problems.

4.1. The Trade-Off Costs between Sustainability Dimensions

The sustainable objectives aiming at triple bottom notion strategies for balancing the sustainability dimensions. As mentioned before, the integration of the three dimensions could be the basis to promote synergies between stakeholders involved in freight transport. Therefore, the decision-making process should conduct a thorough analysis of the logistic system to identify the key factors allowing the corresponding cooperative effects. The synergy concern on reaching an optimal or suitable balance between each other implies understanding the interests and perspective of stakeholders. According to the literature, the government, consumers, shopkeepers and transport companies are the main stakeholders for freight transport. In fact, the interests synergy could lead transport systems to a sustainability-oriented balance. Thus, building interests consensus from stakeholders is a relevant part of integrating the sustainability dimensions into the decision criteria [23].

Consequently, sustainability pillars are starting to be considered decision criteria in distribution processes [54]. While economic impacts can be measured through increases in operational costs, both social and environmental assessments tend to be subjective. As aforementioned, the externalities are perceived as economic indicators in order to quantify the performance and impacts of transport activities. The economic perspective allows to take the negative impacts into account in the decision-making process [28]. Economic, environmental, and social impacts are strongly interrelated [13]. Therefore, the prevention and mitigation costs for negative impacts need to be considered in financial reports. Prevention costs are due to the economic regulations associated with natural resources consumption or pollutant emissions. These costs are typically imposed by governments to avoid, or minimize, social and environmental consequences of transport operations. Regarding mitigation costs, they are related to penalties associated with the generation of more emissions than are allowed [30]. In addition, companies design preventive and mitigating actions, implementing sustainable strategies, such as the use of alternative fuel vehicles. [55].

Given the importance of these facts, the sustainable development strategy of the European Union defines sustainable transport as one of its seven key challenges. In this context, the increasing social concern is compelling companies to change purely commercial objectives in order to consider sustainability. This new vision seeks to compensate the negative impacts of transport activities without neglecting economic profits [56]. Despite the fact that the literature on transport is extensive, there is a lack of work on urban transport, taking into account social and environmental issues simultaneously [57].

4.2. Freight Transport Problems

Urban freight transport usually works with typical mobility patterns, such as off-peak hours and peak hours, scheduling time for loading and unloading merchandise, time windows for freight transport, and accessibility to park stations, among others. Due to urban patterns, local authorities and shopkeepers determine similar time schedules for commercial activities, such as the pick-ups and deliveries of goods and services. As a consequence, freight and passenger transport is concentrated in specific peak hours, generating, therefore, a direct mutual influence between them. Indeed, traffic congestion, road accidents, and operational delays reveal the effect of both transport protocols (freight and people) in urban zones [58]. As a result, modeling the logistics system is needed to obtain operations synchronization, considering urban patterns. Furthermore, modeling techniques allow measuring the influence of operational, tactical and strategical decisions on the urban freight transportation performance. For instance, urban zones accessibility is a parameter to consider when the distribution routes are being designed. Thus, a low accessibility rate pushes carriers to increase the number of vehicle to cover the deliveries zone [59].

Generally speaking, an urban distribution network integrates factories, distribution centers, retailers and final customers. Indeed, urban freight transport is a continuous flow from the city outskirt to the city center. Consequently, urban logistic activities involve pedestrians, passengers, and freight transport performance at the urban zone, which, all together, disturb the traffic flow [60]. In addition, new market trends, such as e-commerce, include the residential area in the distribution network. Even so, it increases randomness and dynamism behavior in the supply chain [61]. This effect severely affects traffic congestion, road accident rates, high levels of fuel consumption, long operation times, and air pollution [35]. Therefore, advanced optimization techniques for supporting logistic decisions are needed to manage sustainably urban patterns, markets dynamics, and stakeholders interests.

Freight transport problems are studied as vehicle routing problems, which include some variants with different hypotheses. At this manner, the integration of sustainability criteria addressing the VRP classical problem to be a rich vehicle routing problem [53] seems to be a very natural process. Thus, an optimal number of vehicles required for orders delivery is the first step to decrease fuel consumption and pollutants emissions. Being an extension of the classical VRP, this rich problem is also $\mathcal{NP}$-hard. Recently, the relevance of this research line has increased for combinatorial optimization problems, due to the popularity of the sustainability problem in the scientific literature. The complexity of this problem concerns the classical constraints of a VRP and some additional ones related to managing multiple attributes, such as the balance between sustainability dimensions and the use of new technology [62]. Thus, many logistics and transportation problems in smart cities can be modeled as rich VRP variants. Due to the difficulty and the relevance of managing multiple attributes and constraints, the rich VRP has started to be widely studied [13]. On the one hand, the green VRP (Green-VRP) is a rich VRP, which considers routing problems, using alternative fuel vehicles [63]. On the other hand, an initial Green-VRP variant is the called pollution routing problem or PRP [64]. In the PRP, the main objective is to minimize energy consumption, which includes time windows as a realistic constraint. Figure 2 provides a scheme that summarizes different attributes and constraints frequently associated with the Green-VRP [65].

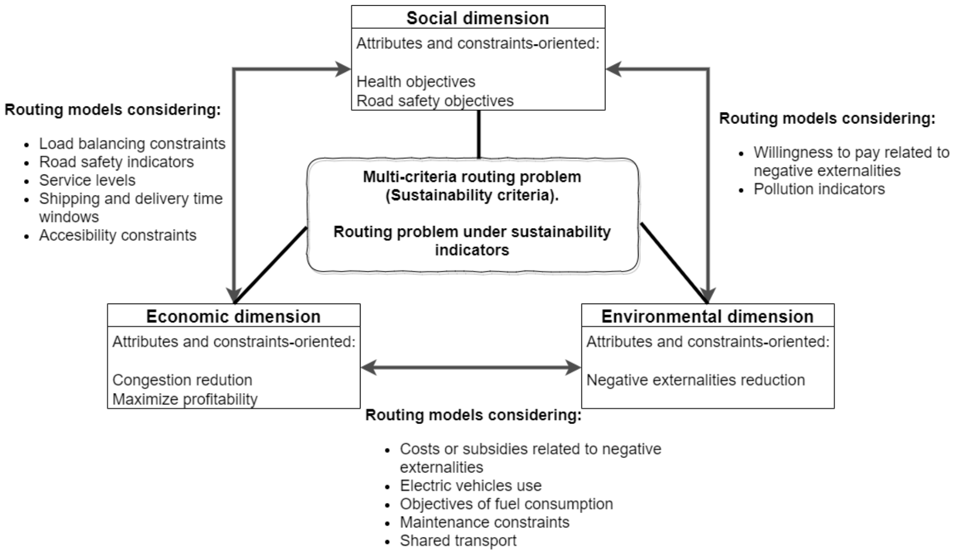

Figure 2. Sustainable approach for urban freight models.

4.3. Models Considering Socioeconomic Factors

There are good examples in the literature considering socioeconomic factors. We have chosen a selection of them to show the intensity of involvement of transport problems in solving socioeconomic problems. Firstly, Grosso et al. [66] present the VRP with time windows for planning delivery routes in a city, subject to some accessibility constraints. The main objective of that problem is to minimize the transport cost considering a penalty to be allowed to deliver in the restricted zone outside the time window. There, a sequential procedure is proposed: (i) classical Clarke and Wright heuristics is used to define the initial solution, (ii) considering the initial solution, a genetic algorithm is implemented to diversify and determine a better solution, (iii) a tabu search algorithm intensifies the solution search by several local searches. Secondly, Denant-Boèmont et al. [67] focus on the noise impact caused by road freight transportation in rural zones. They implement a contingent valuation method to find the willingness to pay related to noise nuisances caused by freight transport. Thirdly, Afshar-Bakeshloo et al. [68] introduce the satisfactory-green vehicle routing problem. They propose multi-objective mixed integer linear programming, where the transport cost is minimized and customer satisfaction is maximized. This model tackles the trade-offs between customers satisfaction, total costs and emission levels.

Finally, de Armas et al. [69] solve a VRP with multiple time windows and constraints related to the traveled distance and time/distance balance. Thus, variable neighborhood search metaheuristics is implemented, obtaining high quality solutions. Likewise, Oyola and Løkketangen [70] propose a mathematical model with equity constraints. There, the main objective is to minimize the difference of tour lengths and load among some candidate routes. A GRASP algorithm and Pareto frontier is implemented to reach some suitable trade-offs between objectives.

4.4. Models Considering Environmental Factors

A survey on the use of electric vehicles in logistics and transportation, discussing opportunities and challenges, is proposed by Juan et al. [51]. The electric vehicle routing problem is related to the limited capacity of batteries, which might require multiple recharging stops. Hence, Erdoğan and Miller-Hooks [63] introduce the Green-VRP, allowing intermediate stops by implementing procedures based on the well-known Clarke and Wright's savings heuristics [71] and the density-based clustering algorithm described in the paper itself. Additionally, Demir et al. [72] solve a pollution routing problem (PRP) with time windows, where customers sequences are firstly defined and, afterwards, the travel speeds are optimized by means of adaptive large neighborhood search (ALNS) metaheuristics. Furthermore, Juan et al. [31] address the Green-VRP with multiple driving ranges with the purpose of obtaining greener routes. The goal of this work is to define alternative fleet configurations based on electric vehicles and hybrid-electric vehicles. Thus, the authors describe an integer programming formulation and a multi-round heuristic algorithm that iteratively constructs a solution. Similarly, Schneider et al. [73] propose an ALNS metaheuristic with some local searches with the aim of minimizing the total distribution cost, which include the cost of using a fleet of vehicles plus the current routing cost. Additionally, these authors consider intermediate stops in recharging stations. Furthermore, the ALNS metaheuristics is hybridized with the adaptive variable neighborhood search framework by Schneider et al. [74], who deal with a routing problem with electric vehicles–related constraints and also consider intermediate stops. Other good examples of routing models with environmental factors are explained in the following lines: (i) Koç and Karaoglan [75] design a simulated annealing metaheuristics, based on an exact method, to solve the Green-VRP for the small-scale instances proposed by Erdoğan and Miller-Hooks [63], (ii) Hiermann et al. [76] study the VRP with electric vehicles, time windows, and recharging stations, and (iii) Hof et al. [32] consider electric vehicles to solve a location-routing problem, where the objective is to determine whether the battery swap stations should be defined from candidate locations or closer to the set of customers.

Apart from the previous single-objective analysis of the Green-VRP, we can focus our attention on a multicriteria analysis to have a richer approach to this kind of problems. Thus, the Green-VRP with multiple objectives, including both monetary and environmental costs are discussed by Sawik et al. [77]. For instance, Yu et al. [78] solve a multi-objective ride-sharing problem, similar to the dial-a-ride problem. In this paper, the carbon emissions are minimized, while the ride profit is maximized. Correspondingly, they affirm that the distribution plan changes according to the preferences and objectives of the decision makers.

Equally, stochastic combinatorial optimization has received increasing interest over the last few decades [4,79]. Reaching popularity, its applications in different transportation scenarios, mainly those in cooperation, are present by back-hauling routes [80]. Accordingly, the freight delivery scenarios pinpoint the most frequent random variables to be defined: customers demands, service and travel times, and frequency of order placing [81]. All the previous articles highlight the importance of dealing with uncertainty, and study realistic characteristics, such as urban transport dynamics. In most existing works, travel times are assumed to be constant, but this is not a realistic assumption. Hence, Ritzinger et al. [4] propose to deal with uncertain travel times by modeling them as stochastic and time-dependent variables. Gendreau et al. [5] provide a literature review on these topics. Travel times may vary by exogenous variables, such as traffic congestion, weather conditions, moving targets, or mobile obstacles. They might also be influenced by endogenous variables, e.g., by varying the vehicles' speeds or by choosing highways over standard roads.

Finally, Eshtehadi et al. [82] address a VRP with stochastic demands and travel times. These authors develop a solving approach based on an exact method that is able to solve instances with up to 20 nodes considering multiple scenarios. The authors tackle the stochasticity, describing two scenarios that represent the best and the worst conditions for demand and travel times. Additionally, the use of simulation in freight distribution arenas has been very common in the last 20 years, making the mixture of the simulation and optimization tools the best approach to tackle mobility problems [83]. To conclude this literature review, Table 3 summarizes some illustrative works that shed a light on the most studied attributes and constraints for urban freight transport modeling.

5. Discussion

According to the contents of the previous sections, the concept of sustainability encompasses three fundamental dimensions: environmental, society, and economy. These dimensions reflect the pillars of notable and persisting progress of a city. Therefore, a sustainable growth of cities is conceived as an improvement that is socially and ethically responsible. As mentioned before, the three dimensions are mutually related. Then, the influence of each other of any sustainable initiative might be a negative and positive one. However, a positive influence might represent a negative one on any other sustainability dimension. Therefore, the challenge relies on striving for positive influences that are addressed to obtain suitable trade-offs in sustainable goals.

In practical terms, practitioners can include the concept of sustainability within operations as (i) benchmark values or (ii) indicators. On the one hand, benchmark values can be absolute, based on technical or political boundaries, reference values, or measures based on local averages, sector comparisons, or trends. On the other hand, the indicators evaluate the operation outputs. In practice, the choice of sustainability indicators is subjective and depends on the economic sector and business purpose. The inclusion of the sustainability concept in operations is a starting point for discussing sustainability to enhance learning and awareness of sustainability [84].

From the academic perspective, the sustainability of a system is (i) assessed, using the selected indicators, (ii) goal-oriented to reference values defined by managers, and (iii) constrained to boundaries defined by managers. These are modeling approaches to include the concept of sustainability in the systems under study. The selection of approaches depends on the method and objective of the study; decisions are made on the method and available data. The interchange between researchers, users, and practitioners can improve the understanding of the trade-offs and synergies between sustainability concept and practical issues. Likewise, this interchange gives insights into the complexity and constraints in improving system sustainability through the design of management policies and strategies [85].

Generally speaking, several approaches promote policy-defining and strategies to mitigate the negative impacts on the economy, society and the environment. However, social impacts present a subjective effect because they can be valued from different perspectives. Thus, the social dimension might be the factor which reflects the synergy among sustainability dimensions. For example, the social and the environmental dimensions are affected by air pollution, noise, climate change and overuse of natural resources, among others. Similarly, travel times, changes in product prices, operational costs, earnings, and employment affect the economic dimension, as well as the social one. Consequently, the negative impacts on the society caused by transport activities, i.e., externalities, are not easy to estimate [86,87]. Therefore, this dimension is usually neglected because its impacts overlap the ones from the remaining dimensions. In this context, social impacts depict a polemic facet because they can, at the same time, reflect an economic or environmental influence and can be evaluated according to stakeholders perceptions, causing different opinions and judgments.

Table 3. Summary of urban freight transport models and sustainability-based approaches.

Reference	Indicators/Objectives	Attribute	Constraints	Solution Approach
		Economic and Social		
Grosso et al. [66]	Access Time Windows	SO	TW	AM
Denant-Boèmont et al. [67]	Willingness to pay related externalities	NI		CVM
Afshar-Bakeshloo et al. [68]	Access Time Windows	MO	TW	EM
de Armas et al. [69]	Route balance		TW, TL, RB	AM
Oyola and Løkketangen [70]	Route balance	MO	TL, RB	EM
		Economic and Environmental		
Yu et al. [78]	Green VRP	MO	RS	EM
Erdoğan and Miller-Hooks [63]	Green VRP	IS	ML	AM
Demir et al. [72]	PRP	PI	TW	AM
Juan et al. [31]	VRP with hybrid-electric vehicles	AF		AM
Schneider et al. [73,74]		DR	ML	AM
Koç and Karaoglan [75]	Green VRP	DR	ML	AM
Hiermann et al. [76]		DR	TW	AM
Hof et al. [32]	Green VRP and location problem	DR		AM
Sawik et al. [77]		MO		AM
Eshtehadi et al. [82]	Green VRP	ST, SD		AM
Muñoz-Villamizar et al. [47]		MO		EM
Attribute	SO: Single-0bjective. MO: Multi-objective. NI: Noise impact measure. IS: Intermediate stops PI: Pollution Indez. AF: Alternative Fleet Configurations. DR: Driving Range ST:Stochastic Travel Time. SD: Stochastic Demand. CVM: Contingent Valuation Method			
Constraint	TW: Time Window. TL: Tour Lengths. RB: Route Balance ML: Maximum Route Length. RS: Ride-sharing			
Solution approach	EM: Exact Method. AM: Approximated Method			

In this context, the management of freight transport involves stakeholders, which are integrated because of their collective interests. Thus, the sustainability dimensions are the background of operational metrics, which assess the operational synergy among stakeholders. The relationship between transport and the environment from the perspective of efficiency has become one of the nerve centers of sustainability. This assertion means that an operational condition of sustainable processes is to achieve absolute, and not only relative, dissociation between socio-economic processes, environmental pressures, and unsustainable dynamics. It is about production, consumption, and moving people and freight better, with fewer resources and less environmental impact, where the core decisions related to sustainable transportation are located. The dissociation of economic forces from environmental pressures requires the decarbonization of production, consumption and transportation systems. That is why the progressive decrease in energy and carbon intensity in consumption and transport production systems is generally recognized as a key factor in the economic transition to sustainable pathways. Hence, the optimization criteria are redefining to consider the sustainability dimensions and handle objectively the interests stakeholders.

Consequently, a smart city drives the government, society, transport and economic system to a balance between the sustainability dimensions. Furthermore, the smart city concept embraces new technologies as a solution for making cities in better places. Thus, smart cities are a desired outcome of technology integration in a sustainable city. Therefore, a smart city incorporates sustainability goals in a progressive and genuine manner.

6. Conclusions and Future Research

Optimizing logistics is becoming increasingly important for companies and governments to boost sustainable growth. Indeed, transport activities have dramatic effects on the environment and social welfare, which have been ignored for many decades. The unstoppable technological developments allow us to deal with more complex and realistic problems. Moreover, technology use enriches the transportation problems, adding new operational constraints. Thus, sustainability has proved to be an enduring and compelling concept because it points toward a balanced and clear direction. Similarly, this sustainable analysis of transportation and mobility should be flexible enough to adapt the distribution process against a dynamic environment, ensuring a balance among sustainability dimensions. The most recent studies allow understanding that there is not a standard balance for sustainability dimensions, but a suitable one, according to the decision-maker perspective. Therefore, the inclusion of the sustainability concept into the logistic system evolves to mitigate and reduce the negative externalities of transport activities.

Consequently, the freight transport system in a smart city can be addressed by (i) real-time flow of products, information and money, (ii) information and communication systems that are supported by a well-connected and sharing network, and (iii) wiser on-the-fly decisions to handle the dynamism of urban zones and reduce negative impacts. The concept of wise decisions encompasses the sustainability dimensions. Thus, a smart city is supported by strategies that manage not only the operational challenges of urban distribution plans, but also the trade-off between sustainability dimensions. Therefore, the logistic system in smart cities relies on powerful tools for supporting decision-making and handling stakeholders' interests. These decisions concern regulations and incentives, which drive the transport operations toward sustainable ones.

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References

1. Eurostat. Roadmap to a Single European Transport Area: Towards a Competitive and Resource Efficient Transport System. White Paper. 2011. Available online: https://www.eea.europa.eu/policy-documents/roadmap-to-a-single-european (accessed on 23 September 2021).
2. Eurostat. *Energy, Transport and Environment Indicators*; Publications Office of the European Union: Luxembourg, 2020. Available online: https://ec.europa.eu/eurostat/web/products-statistical-books/-/ks-dk-20-001 (accessed on 23 September 2021).
3. Eurostat. *Road Accident Fatalities*; Publications Office of the European Union: Luxembourg, 2020. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Road_accident_fatalities_-_statistics_by_type_of_vehicle (accessed on 23 September 2021).
4. Ritzinger, U.; Puchinger, J.; Hartl, R.F. A survey on dynamic and stochastic vehicle routing problems. *Int. J. Prod. Res.* **2016**, *54*, 215–231. [CrossRef]
5. Gendreau, M.; Ghiani, G.; Guerriero, E. Time-dependent routing problems: A review. *Comput. Oper. Res.* **2015**, *64*, 189–197. [CrossRef]
6. International Electro-Technical Commission. Orchestrating infrastructure for sustainable Smart Cities Executive Summary. Technical Report. 2014. Available online: https://www.iec.ch/whitepaper/smartcities/ (accessed on 23 September 2021).
7. Smart Freight Transport Center. Smart Freight Leadership—A Journey to a More Efficient and Environmentally Sustainable Global Freight Sector. Technical Report. 2017. Available online: http://www.smartfreightcentre.org/sfl/smart-freight-leadership-publication (accessed on 23 September 2021).
8. Ahvenniemi, H.; Huovila, A.; Pinto-Seppä, I.; Airaksinen, M. What are the differences between sustainable and smart cities? *Cities* **2017**, *60*, 234–245. [CrossRef]
9. Barceló, J. Future Trends in Sustainable Transportation. In *Sustainable Transportation and Smart Logistics*; Elsevier: Amsterdam, The Netherlands, 2019; pp. 401–435.
10. Taniguchi, E.; Noritake, M.; Yamada, T.; Izumitani, T. Optimal size and location planning of public logistics terminals. *Transp. Res. Part E Logist. Transp. Rev.* **1999**, *35*, 207–222. [CrossRef]
11. Bektaş, T.; Ehmke, J.F.; Psaraftis, H.N.; Puchinger, J. The role of operational research in green freight transportation. *Eur. J. Oper. Res.* **2018**, *274*, 807–823. [CrossRef]
12. Faulin, J.; Grasman, S.; Juan, A.; Hirsch, P. *Sustainable Transportation and Smart Logistics: Decision-Making Models and Solutions*; Elsevier: Amsterdam, The Netherlands, 2018.
13. McKinnon, A.; Browne, M.; Whiteing, A. *Green Logistics: Improving the Environmental Sustainability of Logistics*; Kogan Page Publishers: New York, NY, USA, 2015.
14. Bibri, S.E.; Krogstie, J. Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustain. Cities Soc.* **2017**, *31*, 183–212. [CrossRef]
15. Ullah, Z.; Al-Turjman, F.; Mostarda, L.; Gagliardi, R. Applications of Artificial Intelligence and Machine learning in smart cities. *Comput. Commun.* **2020**, *154*, 313–323. [CrossRef]
16. Lv, Z.; Hu, B.; Lv, H. Infrastructure Monitoring and Operation for Smart Cities Based on IoT System. *IEEE Trans. Ind. Inform.* **2020**, *16*, 1957–1962. [CrossRef]
17. Nguyen, D.; Rohács, J.; Rohács, D.; Boros, A. Intelligent total transportation management system for future smart cities. *Appl. Sci.* **2020**, *10*, 8933. [CrossRef]
18. Camero, A.; Alba, E. Smart City and information technology: A review. *Cities* **2019**, *93*, 84–94. [CrossRef]
19. Montoya-Torres, J.R.; Muñoz-Villamizar, A.; Vega-Mejía, C.A. On the impact of collaborative strategies for goods delivery in city logistics. *Prod. Plan. Control* **2016**, *27*, 443–455. [CrossRef]
20. Vega-Mejía, C.A.; Montoya-Torres, J.R.; Islam, S.M. Consideration of triple bottom line objectives for sustainability in the optimization of vehicle routing and loading operations: A systematic literature review. *Ann. Oper. Res.* **2019**, *273*, 311–375. [CrossRef]
21. Alizadeh, T. An investigation of IBM's Smarter Cites Challenge: What do participating cities want? *Cities* **2017**, *63*, 70–80. [CrossRef]
22. Allam, Z.; Dhunny, Z. On big data, artificial intelligence and smart cities. *Cities* **2019**, *89*, 80–91. [CrossRef]
23. Kiba-Janiak, M. Key success factors for city logistics from the perspective of various groups of stakeholders. *Transp. Res. Procedia* **2016**, *12*, 557–569. [CrossRef]

24. Zawieska, J.; Pieriegud, J. Smart city as a tool for sustainable mobility and transport decarbonisation. *Transp. Policy* **2018**, *63*, 39–50. [CrossRef]
25. Škultéty, F.; Beňová, D.; Gnap, J. City logistics as an imperative smart city mechanism: Scrutiny of clustered eu27 capitals. *Sustainability* **2021**, *13*, 3641. [CrossRef]
26. The European Parliament and the Council of the European Union. Regulation (EU) No 1379/2013, 2013. Available online: http://data.europa.eu/eli/reg/2013/1379/oj (accessed on 23 September 2021).
27. Serrano-Hernandez, A.; Faulin, J. Internalizing negative externalities in vehicle routing problems through green taxes and green tolls. *Stat. Oper. Res. Trans.* **2019**, *43*, 75–94.
28. Ranaiefar, F.; Amelia, R. *Freight-Transportation Externalities*; Elsevier Inc.: Amsterdam, The Netherlands, 2011; pp. 333–358. [CrossRef]
29. Silva, B.N.; Khan, M.; Han, K. Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustain. Cities Soc.* **2018**, *38*, 697–713. [CrossRef]
30. Santos, G.; Behrendt, H.; Maconi, L.; Shirvani, T.; Teytelboym, A. Part I: Externalities and economic policies in road transport. *Res. Transp. Econ.* **2010**, *28*, 2–45. [CrossRef]
31. Juan, A.A.; Goentzel, J.; Bektaş, T. Routing fleets with multiple driving ranges: Is it possible to use greener fleet configurations? *Appl. Soft Comput.* **2014**, *21*, 84–94. [CrossRef]
32. Hof, J.; Schneider, M.; Goeke, D. Solving the battery swap station location-routing problem with capacitated electric vehicles using an AVNS algorithm for vehicle-routing problems with intermediate stops. *Transp. Res. Part B Methodol.* **2017**, *97*, 102–112. [CrossRef]
33. 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]
34. Delucchi, M.A.; McCubbin, D.R. External Costs of Transport in the US In *A Handbook of Transport Economics*; Edward Elgar Publishing: Cheltenham, United Kindom, 2010; pp. 341–368. [CrossRef]
35. Wang, X.; Fan, T.; Li, W.; Yu, R.; Bullock, D.; Wu, B.; Tremont, P. Speed variation during peak and off-peak hours on urban arterials in Shanghai. *Transp. Res. Part C Emerg. Technol.* **2016**, *67*, 84–94. [CrossRef]
36. Xie, K.; Wang, X.; Huang, H.; Chen, X. Corridor-level signalized intersection safety analysis in Shanghai, China using Bayesian hierarchical models. *Accid. Anal. Prev.* **2013**, *50*, 25–33. [CrossRef]
37. European Transport Safety Council. *Tackling Fatigue: EU Social Rules and Heavy Goods Vehicle Drivers*; Technical Report October; European Transport Safety Council: Brussels, Belgium, 2011. Available online: http://www.trb.org/Main/Blurbs/166202.aspx (accessed on 23 September 2021).
38. European Transport Safety Council. *Reducing Deaths in Single Vehicle Collisions*; Technical Report April; European Transport Safety Council: Brussels, Belgium, 2017. Available online: http:https://etsc.eu/reducing-deaths-in-single-vehicle-collisions-pin-flash-32 (accessed on 23 September 2021).
39. Matl, P.; Hartl, R.F.; Vidal, T. Workload equity in vehicle routing problems: A survey and analysis. *Transp. Sci.* **2017**, *52*, 239–260. [CrossRef]
40. Bashiri, M.; Sharafi, A. Green Vehicle Routing Problem with Safety and Social Concerns. *J. Optim. Ind. Eng.* **2016**, *10*, 93–100.
41. Ubeda, S.; Arcelus, F.J.; Faulin, J. Green logistics at Eroski: A case study. *Int. J. Prod. Econ.* **2011**, *131*, 44–51. [CrossRef]
42. Demir, E.; Bektaş, T.; Laporte, G. A comparative analysis of several vehicle emission models for road freight transportation. *Transp. Res. Part D Transp. Environ.* **2011**, *16*, 347–357. [CrossRef]
43. Bowyer, D.P.; Akcelik, R.; Biggs, D.C. Guide to Fuel Consumption Analysis for Urban Traffic Management. Technical Report. 1985. Available online: https://elibrary.worldbank.org/doi/abs/10.1596/29971 (accessed on 23 September 2021).
44. Kuo, Y. Using simulated annealing to minimize fuel consumption for the time-dependent vehicle routing problem. *Comput. Ind. Eng.* **2010**, *59*, 157–165. [CrossRef]
45. Zhang, J.; Zhao, Y.; Xue, W.; Li, J. Vehicle routing problem with fuel consumption and carbon emission. *Int. J. Prod. Econ.* **2015**, *170*, 234–242. [CrossRef]
46. Ntziachristos, L.; Gkatzoflias, D.; Kouridis, C.; Samaras, Z. COPERT: A European road transport emission inventory model. *Environ. Sci. Eng.* **2011**, *3*, 445–459.
47. 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. Part D Transp. Environ.* **2017**, *50*, 40–54. [CrossRef]
48. Holland, S.P.; Mansur, E.T.; Muller, N.Z.; Yates, A.J. *Environmental Benefits from Driving Electric Vehicles?* Technical Report; National Bureau of Economic Research: Cambridge, MA, USA, 2015. Available online: https://www.nber.org/papers/w21291 (accessed on accessed on 23 September 2021).
49. Figliozzi, M.; Saenz, J.; Faulin, J. Minimization of urban freight distribution lifecycle CO2e emissions: Results from an optimization model and a real-world case study. *Transp. Policy* **2020**, *86*, 60–68. [CrossRef]
50. Lee, D.Y.; Thomas, V.M.; Brown, M.A. Electric urban delivery trucks: Energy use, greenhouse gas emissions, and cost-effectiveness. *Environ. Sci. Technol.* **2013**, *47*, 8022–8030. [CrossRef] [PubMed]
51. Juan, A.A.; Mendez, C.A.; Faulin, J.; de Armas, J.; Grasman, S.E. Electric vehicles in logistics and transportation: A survey on emerging environmental, strategic, and operational challenges. *Energies* **2016**, *9*, 86. [CrossRef]

52. Wang, F.; Lai, X.; Shi, N. A multi-objective optimization for green supply chain network design. *Decis. Support Syst.* **2011**, *51*, 262–269. [CrossRef]
53. Caceres-Cruz, J.; Arias, P.; Guimarans, D.; Riera, D.; Juan, A.A. Rich vehicle routing problem: Survey. *ACM Comput. Surv. (CSUR)* **2015**, *47*, 32. [CrossRef]
54. Serrano-Hernandez, A.; Ballano, A.; Faulin, J. Selecting Freight Transportation Modes in Last-Mile Urban Distribution in Pamplona (Spain): An Option for Drone Delivery in Smart Cities. *Energies* **2021**, *14*, 4748. [CrossRef]
55. Scheuer, S. *EU Environmental Policy Handbook. A Critical Analysis of EU Environmental Legislation: Making It Accessible to Environmentalists and Decision Makers*; European Environmental Bureau (EEB): Brussels, Belgium, 2005.
56. Voegl, J.; Hirsch, P. The Trade-Off Between the Three Columns of Sustainability: A Case Study From the Home Service Industry. In *Sustainable Transportation and Smart Logistics*; Elsevier: Amsterdam, The Netherlands, 2019; pp. 467–486.
57. Geurs, K.T.; Boon, W.; Van Wee, B. Social impacts of transport: Literature review and the state of the practice of transport appraisal in the Netherlands and the United Kingdom. *Transp. Rev.* **2009**, *29*, 69–90. [CrossRef]
58. Muñuzuri, J.; Cortés, P.; Onieva, L.; Guadix, J. Modelling peak-hour urban freight movements with limited data availability. *Comput. Ind. Eng.* **2010**, *59*, 34–44. [CrossRef]
59. Hunt, J.D.; Stefan, K.J. Tour-based microsimulation of urban commercial movements. *Transp. Res. Part B Methodol.* **2007**, *41*, 981–1013. [CrossRef]
60. Teo, J.S.E.; Qureshi, A.G. Evaluating city logistics measure in e-commerce with multiagent systems. *Procedia Soc. Behav. Sci.* **2012**, *39*, 349–359. [CrossRef]
61. Ruan, M.; Lin, J.J.; Kawamura, K. Modeling urban commercial vehicle daily tour chaining. *Transp. Res. Part E Logist. Transp. Rev.* **2012**, *48*, 1169–1184. [CrossRef]
62. Corlu, C.; De La Torre, R.; Serrano-Hernandez, A.; Juan, A.; Faulin, J. Optimizing energy consumption in transportation: Literature review, insights, and research opportunities. *Energies* **2020**, *13*, 1115. [CrossRef]
63. Erdoğan, S.; Miller-Hooks, E. A green vehicle routing problem. *Transp. Res. Part E Logist. Transp. Rev.* **2012**, *48*, 100–114. [CrossRef]
64. Bektaş, T.; Laporte, G. The pollution-routing problem. *Transp. Res. Part B Methodol.* **2011**, *45*, 1232–1250. [CrossRef]
65. Lin, C.; Choy, K.L.; Ho, G.T.S.; Chung, S.H.; Lam, H.Y. Survey of green vehicle routing problem: Past and future trends. *Expert Syst. Appl.* **2014**, *41*, 1118–1138. [CrossRef]
66. Grosso, R.; Muñuzuri, J.; Escudero-Santana, A.; Barbadilla-Martín, E. Mathematical Formulation and Comparison of Solution Approaches for the Vehicle Routing Problem with Access Time Windows. *Complexity* **2018**, *2018*, 4621694. [CrossRef]
67. Denant-Boèmont, L.; Faulin, J.; Hammiche, S.; Serrano-Hernandez, A. Managing transportation externalities in the Pyrenees region: Measuring the willingness-to-pay for road freight noise reduction using an experimental auction mechanism. *J. Clean. Prod.* **2018**, *202*, 631–641. [CrossRef]
68. Afshar-Bakeshloo, M.; Mehrabi, A.; Safari, H.; Maleki, M.; Jolai, F. A green vehicle routing problem with customer satisfaction criteria. *J. Ind. Eng. Int.* **2016**, *12*, 529–544. [CrossRef]
69. De Armas, J.; Melián-Batista, B.; Moreno-Pérez, J.A.; Brito, J. GVNS for a real-world rich vehicle routing problem with time windows. *Eng. Appl. Artif. Intell.* **2015**, *42*, 45–56. [CrossRef]
70. Oyola, J.; Løkketangen, A. GRASP-ASP: An algorithm for the CVRP with route balancing. *J. Heuristics* **2014**, *20*, 361–382. [CrossRef]
71. Clarke, G.; Wright, J.W. Scheduling of vehicles from a central depot to a number of delivery points. *Oper. Res.* **1964**, *12*, 568–581. [CrossRef]
72. Demir, E.; Huang, Y.; Scholts, S.; Van Woensel, T. A selected review on the negative externalities of the freight transportation: Modeling and pricing. *Transp. Res. Part E Logist. Transp. Rev.* **2015**, *77*, 95–114. [CrossRef]
73. Schneider, M.; Stenger, A.; Goeke, D. The electric vehicle-routing problem with time windows and recharging stations. *Transp. Sci.* **2014**, *48*, 500–520. [CrossRef]
74. Schneider, M.; Stenger, A.; Hof, J. An adaptive VNS algorithm for vehicle routing problems with intermediate stops. *OR Spectr.* **2015**, *37*, 353–387. [CrossRef]
75. Koç, Ç.; Karaoglan, I. The green vehicle routing problem: A heuristic based exact solution approach. *Appl. Soft Comput.* **2016**, *39*, 154–164. [CrossRef]
76. Hiermann, G.; Puchinger, J.; Ropke, S.; Hartl, R.F. The electric fleet size and mix vehicle routing problem with time windows and recharging stations. *Eur. J. Oper. Res.* **2016**, *252*, 995–1018. [CrossRef]
77. Sawik, B.; Faulin, J.; Pérez-Bernabeu, E. A multicriteria analysis for the green VRP: A case discussion for the distribution problem of a Spanish retailer. *Transp. Res. Procedia* **2017**, *22*, 305–313. [CrossRef]
78. Yu, Y.; Wu, Y.; Wang, J. Bi-objective green ride-sharing problem: Model and exact method. *Int. J. Prod. Econ.* **2019**, *208*, 472–482. [CrossRef]
79. Bianchi, L.; Dorigo, M.; Gambardella, L.M.; Gutjahr, W.J. A survey on metaheuristics for stochastic combinatorial optimization. *Nat. Comput.* **2009**, *8*, 239–287. [CrossRef]
80. Belloso, J.; Juan, A.A.; Faulin, J. An iterative biased-randomized heuristic for the fleet size and mix vehicle-routing problem with backhauls. *Int. Trans. Oper. Res.* **2019**, *26*, 289–301. [CrossRef]

81. Bozorgi, A.M.; Farasat, M.; Mahmoud, A. A Time and Energy Efficient Routing Algorithm for Electric Vehicles Based on Historical Driving Data. *IEEE Trans. Intell. Veh.* **2017**, *2*, 308–320. [CrossRef]
82. Eshtehadi, R.; Fathian, M.; Demir, E. Robust solutions to the pollution-routing problem with demand and travel time uncertainty. *Transp. Res. Part D Transp. Environ.* **2017**, *51*, 351–363. [CrossRef]
83. Serrano-Hernandez, A.; Faulin, J.; Hirsch, P.; Fikar, C. Agent-based simulation for horizontal cooperation in logistics and transportation: From the individual to the grand coalition. *Simul. Model. Pract. Theory* **2018**, *85*, 47–59. [CrossRef]
84. De Olde, E.M.; Oudshoorn, F.W.; Bokkers, E.A.; Stubsgaard, A.; Sørensen, C.A.; De Boer, I.J. Assessing the sustainability performance of organic farms in Denmark. *Sustainability* **2016**, *8*, 957. [CrossRef]
85. Wittmayer, J.M.; Schäpke, N. Action, research and participation: Roles of researchers in sustainability transitions. *Sustain. Sci.* **2014**, *9*, 483–496. [CrossRef]
86. Denant-Boemont, L.; Hammiche, S. Economic Measurement of Environmental Costs for Transportation Activity. In *Sustainable Transportation and Smart Logistics*; Elsevier: Amsterdam, The Netherlands, 2019; pp. 153–167.
87. Denant-Boemont, L.; Faulin, J.; Hammiche, S.; Serrano-Hernandez, A. Valuations of Transport Nuisances and Cognitive Biases: A Survey Laboratory Experiment in the Pyrenees Region. *Environ. Model. Assess.* **2021**, in press. [CrossRef]