Selecting Freight Transportation Modes in Last-Mile Urban Distribution in Pamplona (Spain): An Option for Drone Delivery in Smart Cities

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Abstract: Urban distribution in medium-sized cities faces a major challenge, mainly when deliveries are difficult in the city center due to: an increase of e-commerce, weak public transportation system, and the promotion of urban sustainability plans. As a result, private cars, public transportation, and freight transportation compete for the same space. This paper analyses the current state for freight logistics in the city center of Pamplona (Spain) and proposes alternative transportation routes and transportation modes in the last-mile city center distribution according to different criteria evaluated by residents. An analytic hierarchy process (AHP) was developed. A number of alternatives have been assessed considering routes and transportation modes: the shortest route criterion and avoiding some city center area policies are combined with traditional van-based, bike, and aerial (drone) distribution protocols for delivering parcels and bar/restaurant supplies. These alternatives have been evaluated within a multicriteria framework in which economic, environmental, and social objectives are considered at the same time. The point in this multicriteria framework is that the criteria/alternative AHP weights and priorities have been set according to a survey deployed in the city of Pamplona (Navarre, Spain). The survey and AHP results show the preference for the use of drone or bike distribution in city center in order to reduce social and environmental issues.

Keywords: freight urban transportation; drones; analytic hierarchy process; energy optimization

1. Introduction

As a key dimension of transport sustainability, environmental concerns in general and air pollution in particular is one of the greatest threats to human health in urban areas [1]. In particular, freight transport is responsible for a large share of this mobility-related emissions. Considering only freight distribution, road transport is the largest subsector causing air pollution [2,3]. For that reason, the consideration of energy/fuel consumption and/or CO_2/greenhouse gas emissions in transport related optimization problems has gained much importance in recent years [4,5]. Nonetheless, the objective of reducing air pollution usually conflicts with other ones such as economic or social welfare objectives. On the one hand, the economic criteria push companies to increase their operations and their transport activities. On the other hand, social welfare may be threatened with the increase of logistics operations, particularly in urban environments [6].

1.1. Urban Freight Transportation

The increasing urbanization process has huge effects on current urban freight trans-portation schemes; thus, this urban sprawl accelerates the construction of infrastructures, increases the demand for energy and other bulk goods, and increases the frequency and

speed of the goods flow. This development leads to raising the transportation demand. Hence, this city expansion further impacts on freight transport carbon emissions in the long term [7–9]. This situation has involved the use of different simulation models to make decisions in transportation [10].

Moreover, due to the fact that e-commerce is increasing, urban deliveries are becoming even more difficult. Additionally, customers are demanding small packages more frequently and more trucks and vans are needed to satisfy their demands [11]. This situation is particularly noticeable in the last-mile urban distribution, which is the last step of the logistic supply chain. It involves the delivering of packages directly to the customer and it can be performed using different procedures: truck or vans, electric engine powered bikes or trikes, other electric transport modes, or drones, among others. Managing this process in an efficient and sustainable routine is a real challenge. In fact, customers are willing to pay more for a product if their delivery service is satisfactory [12–14]. While this distribution protocol is profitable for top retailers, the more modest distributors found difficult to meet demand and service-level expectations [15]; therefore, the competition of fast-delivery service providers as well as the popularity of e-commerce are making the urban environment a real challenge to cope with in dense and delicate European cities, such as Pamplona (Spain).

1.2. The Pamplona Case

Pamplona is a medium-sized city located in Northern Spain and belongs to the Spanish Network of Smart Cities, which makes Pamplona a city with a strong concern about the smartness of its infrastructures, particularly, the ones associated to mobility of people and goods. Moreover, the Pamplona city center has a medieval structure with narrow streets, where a van can struggle to navigate the streets. Additionally, many bars, restaurants, and other establishments are placed there; therefore, numerous transport and freight vehicles pass every day to supply all the pubs, shops, and households. This situation has created several problems, and citizens of Pamplona's city center have been complaining about these problems in recent years. Figure 1 shows an panoramic view of the city center of Pamplona.

In order to reduce freight transport traffic, Pamplona City Council launched (since 10 October 2017) a sustainable urban mobility plan with the aim of closing the city center streets to private vehicles and only allowing previously authorized vehicles to pass. Many restrictions have been implemented in order to improve the traffic flow. The traffic for freight carriers in the controlled access areas is only allowed during working days from 08:00 a.m. to 11:00 a.m. and from 2:00 p.m. to 4:30 p.m. in the afternoon. Moreover, city center residents are allowed to use up to two vehicles within this area. Furthermore, disabled people, shopkeepers for the pick-up of bulky or heavy items, transporters carrying out loading and unloading operations, and finally owners of parking spaces, hotels, taxis, construction works, and emergency vehicles are also allowed to enter. In fact, since the introduction of the access control system at the end of October 2017, the decrease in vehicle traffic has been estimated at 45%. As a result, traditional urban freight deliveries in Pamplona [16] had to be adapted to these new regulations.

Figure 1. Pamplona City Center.

1.3. Aim of This Study

This article proposes the use of multicriteria analysis for selecting the suitable transportation modes and routes for performing the last-mile distribution in the city center of Pamplona (Spain). On the one hand, the use of alternative transportation modes is considered. Electric vans and trucks, bicycles or tricycles (conventional and electric engine powered), as well as drones are among these options. On the other hand, we consider the identification or creation of ad hoc itineraries (or green routes). These itineraries or routes for deliveries may prevent crossing some sensitive areas that need to be preserved because of their environmental or social value. Here the role of drones or autonomous vehicles is particularly useful, because it is easier to find and design those green routes when the itineraries of those vehicles are completely controlled beforehand. As a result, city centers in small cities will gain transport fluidity and provide more room for social and economic activities. Thus, the contributions of this article are three-fold. Firstly, we draw social perceptions from citizens in medium-sized cities with respect to urban freight transportation in saturated city centers. Secondly, we developed an AHP using the preferences from residents that are specially suffering from transportation-related issues in the city center—that is, as novelty for the AHP development, judgments from a relatively large group of persons are combined in order to form a weighted analysis. Lastly, we propose some alternatives of transportation modes and routes considering a three-dimensional objective.

The rest of this article is organized as follows. Section 2 investigates related literature where different aspects of sustainability are implemented in transportation. Section 3 describes the AHP and determines the criteria. Section 4 provides details about the survey location and implementation, and the proposed urban freight modes. Finally, Section 5 exposes the AHP analysis results and Section 6 draws the conclusions, limitations, and future research.

2. Literature Review

Recent approximations to transportation sustainability have been widely studied in the literature with one, two, or more rarely, three dimensions, at the same time. These criteria always have to do with economic, environmental, and social aspects of transportation. To

this respect, Table 1 summarizes the identified criteria and subcriteria for a selection of academic articles.

Table 1. Sustainability aspects covered in a collection of selected papers in the transportation area.

Reference	Economic			Environmental			Social		
	Cost	Time	Load	Air	Noise	Visual	Safety	Life Quality	Road Use
He et al. [17]	✓								
Archetti and Bertazzi [18]	✓								
Serrano-Hernandez et al. [19]		✓		✓					
Serrano-Hernandez et al. [20]	✓		✓	✓					
Quintero-Araujo et al. [21]	✓		✓	✓					
Paddeu et al. [22]	✓		✓						
Allen et al. [23]	✓		✓						
Salama and Srinivas [24]	✓								
Jackson and Srinivas [25]	✓	✓							
Erdoğan and Miller-Hooks [26]				✓					
Moghdani et al. [27]				✓					
Liu et al. [28]	✓			✓					
Wygonik and Goodchild [29]	✓			✓					
Ranieri et al. [30]				✓					
Klompmaker et al. [31]					✓				
Lu et al. [32]					✓				
Morillas et al. [33]					✓				
Sánchez et al. [34]				✓	✓				
Demir et al. [35]				✓	✓	✓			
Pathak et al. [36]				✓	✓	✓			
Reyes-Rubiano et al. [37]	✓	✓					✓		
Boschmann and Kwan [38]							✓	✓	✓
Hamurcu and Eren [39]	✓			✓					✓
Faulin et al. [40]	✓	✓		✓	✓				
Islam and Saaty [41]	✓	✓		✓					
Sawik et al. [42]	✓			✓					
Sawik et al. [43]	✓			✓					
This paper	✓	✓	✓	✓	✓	✓	✓	✓	✓

2.1. Economic Criterion

Traditionally, the literature mainly focused on the economic criterion in which the sole objective is seeking for the cheapest solution in order to perform deliveries. Here, many optimization models have been developed following the general vehicle routing problems framework or any of its variants [44,45]. These models may be adjusted and applied to the urban characteristics as in the case of He et al. [17] and Archetti and Bertazzi [18]. Additionally, other economics aspects have been included in transportation-related decision-making processes such as the travel time or the cargo efficiency, i.e., the ability to fully load the vehicles. In the urban environment, Serrano-Hernandez et al. [19] investigated the impact of collaborative practices among companies on the delivery service quality, measured as lead times, and they concluded that significant savings in lead times (up to 51%) can be achieved if wholesalers cooperate. Related to this, the horizontal cooperation [46] among logistic companies or activities is seen as one of the most-promising solutions in order to increase the cargo efficiency of last-mile distribution. In this respect, there are several studies that analyze its practical implications. For example, Serrano-Hernandez et al. [20] showed how collaboration reduces the transportation costs (and environmental impacts) at the time they included many trust-related issues in forming a coalition. Likewise, Quintero-Araujo et al. [21] analyzed, at the same time, the routing and location of consolidation centers in an collaborative environment with savings up to 60% in both costs and CO_2 emissions. Furthermore, Paddeu et al. [22] provides the additional insight of considering a range of

stakeholders, and Allen et al. [23] proposed a freight traffic controller in order to organize the collaboration in parcel deliveries. Finally, Salama and Srinivas [24] and Jackson and Srinivas [25] consider drone deliveries in scenarios of urban last-mile distribution from a strategic point of view. In the former, The authors propose mixed integer linear programming models for last-mile delivery using multiple drones and a single truck. In the latter, the authors developed a discrete-event simulation model for comparing different delivery strategies considering trucks or drones. It was found that aerial distribution is the most cost effective and quickest.

2.2. Environmental Criterion

The consideration of environmental criteria in urban logistic decision making is gaining momentum. As a first attempt, the traditional vehicle routing problem (VRP) can be modified to consider air pollution in the objective function [4]. These models are based on the idea of reducing the energy consumption will lead to a reduction of air pollutants emissions, as firstly described in Erdoĝan and Miller-Hooks [26]. Similarly, Moghdani et al. [27] performed a recent survey in the Green VRP, enhancing the main innovative contributions in the routing-related transportation sustainability area. Some other examples related to air pollution following a different approach are presented in Liu et al. [28] and Wygonik and Goodchild [29]. The former proposed the procedure of collection–delivery points in order to avoid home delivery. Thus, congestion and air pollution are mitigated and citizens' life quality is improved. In the latter, authors found that the design of the delivery service as well as the urban form heavily affect the CO_2, NO_x, and PM_{10} emissions. In particular, roadway density and proximity of a service area to the regional warehouse are the key determinants for mitigating the air pollution. Finally, this topic is further discussed in the survey proposed in Ranieri et al. [30]. Their main findings for making city centers more sustainable are promoting the use of electric vehicles, optimizing the location of urban consolidation centers, collaborative practices among different companies, routing optimization, and better infrastructures. Noise pollution can also be integrated in the environmental sphere, which it is particularly noticeable in urban environments. Sleep disruption, communication issues, trouble focusing, and reduced cognition resulting in loss of work productivity are some of the adverse effects noise traffic produces [31,32]. In fact, as concluded by Morillas et al. [33], there is a connection between noise pollution and urban planning and morphology. Likewise, Sánchez et al. [34] highlighted the importance of attitudes and psychological aspects in order to mitigate the noise pollution from road transportation.

Finally, the last identified environmental aspect dealing with urban transportation is related to the visual impact which is especially remarkable in the historic centers and monumental areas. This effect, despite being less important, can distort the perception of the urban landscape, reducing the attractiveness of the historic center or the entire city. As pointed out by Demir et al. [35] and Pathak et al. [36], this aspect is difficult to assess but it has a doubtless effect in the city definition.

2.3. Social Criterion

The social aspects are more difficult to discover and rarely are included in optimization approaches. Still some studies determined the safety, life quality, and road use, as relevant factors when planning last-mile transportation. With respect to road safety, the reduction of accidents is explicitly considered by Reyes-Rubiano et al. [37] and Abdullahi et al. [47] in a multiobjective approach (travel times, distances, and accidents) using simheuristics. They conclude the expected traveling time costs and the distance costs represent a high proportion of the expected total costs, being the accidents only partially determinants. Moreover, there are some aspects associated to life quality that comprises perceptions that prevent from fully enjoying the space. In fact, according to Boschmann and Kwan [38] quality of life is a multidimensional construct that should examine the conditions for seeking happiness and fulfilling needs. Lastly, these authors determine road use as the

ability of coexistence of different transportation means in the city (cycles, freight vehicles, private car, and public transportation).

2.4. Multicriteria Analysis

Apart from the previous literature reviews, there is a rich literature regarding multi-criteria methodologies applied to transportation [42,43], which considers at least two of aforementioned sustainability aspects. From that, it is particularly interesting the study of Hamurcu and Eren [39] that combines economic, social, engineering, and environmental criteria within an analytic network process, which is similar to the approach we propose in this paper, to decide the best route for a monorail in Turkey. Similarly, Faulin et al. [40] designed an analytical hierarchy process (AHP) to select distribution routes to mitigate the pollution impact of transportation activities crossing the Pyrenees from Spain to France. Other applications that specifically used the AHP in the transportation arena are described in Islam and Saaty [41]. There, it is highlighted how multicriteria approaches in general and the AHP in particular can be applied in a manifold of real life settings in transportation sector; therefore, the use of multicriteria models to make decisions in transportation in general, and more specifically in green mobility, is widely used in the literature due to the diversity of goals involved in those problems. We propose an AHP to deal with the conflicting economic, social, and environmental objectives. Table 1 summarizes the sustainability aspects implemented in a selection of academic studies.

Furthermore, considering all the references in this literature review we can assert that the analysis of transportation sustainability is showing an increasing interest in the research community, in order to find more friendly environmental decisions that allow a reduction of the transport footprint. This quest of greener decisions is multifaceted, and most of the previous references are revealing different ways to step forward following that path. This search for sustainability in urban mobility is supported by means of the use of big data of information concerning traveling, pollution amount, routes optimization, remote control of vehicles, to name a few new technologies in smart cities.

3. Methodology

3.1. Applied Model

Considering the multifaceted nature of the problem to tackle, we used the analytical hierarchy process (AHP) to establish priorities in selecting the transportation modes and the routes. The AHP is a multicriteria optimization procedure to quantify the relative importance of each of several conflicting objectives or criteria employed in the decision-making process for a number of alternatives. In particular, we based our analysis on the method proposed by Saaty [48]. Moreover, this method lies in analyzing the problem and establishing a sequence of hierarchical levels. The first level represents the overall goal that we want to achieve. The second level involves all the criteria taken into account when the decision is made. Lastly, the different alternatives are detailed in the third level. Thus, the decision is considered based on the relative importance that each alternative achieves in each criteria. An example of this procedure to tackle environmental decisions in transportation in Navarre were developed by Faulin et al. [40]. Finally, the selection of the AHP method instead of any other multicriteria approach is based on its robustness when collective opinions are gathered. In our case, since the main input data are coming from surveys, the AHP framework allows us to combine all subjective judgments into a range of weighed alternatives.

This methodological protocol is developed by performing a four-step process: Firstly, the criteria are compared one another by couples, in order to rate their importance obtaining the criteria priority vectors. Secondly, each alternative is pairwise compared in respect to the criteria used in the model resulting in the alternative priority vectors. Additionally, the priority vectors can be summarized in the priority matrix by listing the decision alternatives vertically and the criteria horizontally; therefore, the row entries are the priority vectors for each criterion. Thirdly, the overall priority vector is obtained with the matrix information

and the criteria priority vector. This overall priority vector refers to the final importance of each alternative considering all criteria at the same time. The last step consists of computing the consistency ratio, which depicts the consistency of the subjective input in the pairwise comparison matrix.

As illustration, the objectives, the established criteria (see Table 1, and the different alternatives portrayed in our research are shown in Figure 2. In the next subsections, the criteria, the alternatives, and the way we obtained the data are described.
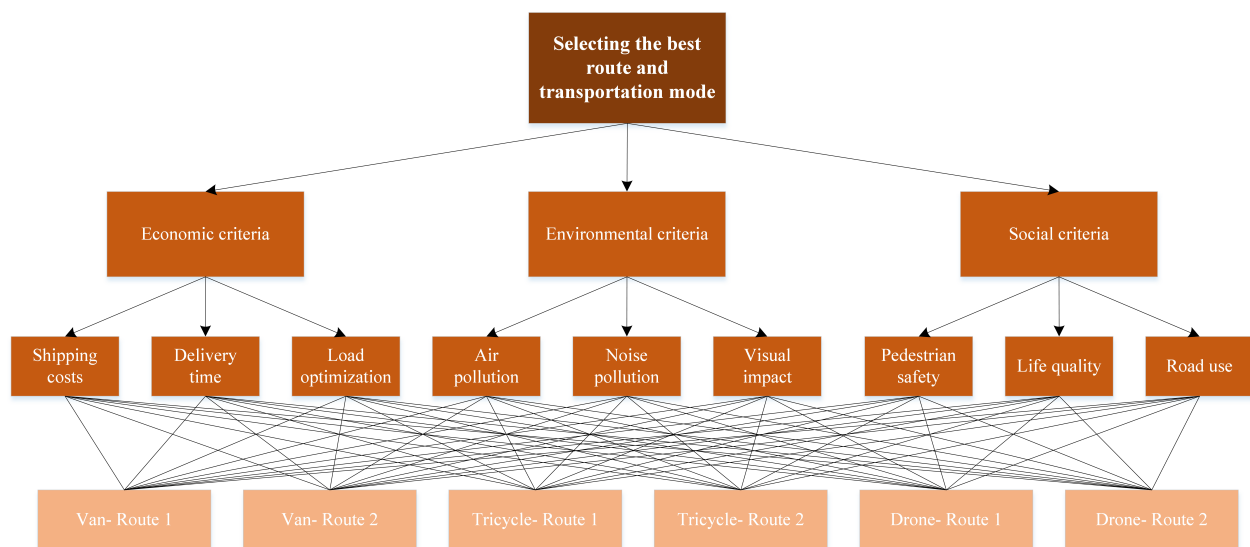

Figure 2. Network of the defined criteria and subcriteria for the AHP implementation in the Pamplona last-mile distribution problem.

3.2. Model Criteria

In a multicriteria model, the precise definition and connection of the criteria are critical for obtaining outstanding results. Here, we have used sustainability dimensions as the global criteria for analyzing the alternatives: these are economic, environmental, and social criteria. Within each criterion some subcriteria have been defined in order to make easier the comparisons among them. The selection of these criteria are based on two sources. On the one hand, they are based on the literature review in Section 2 in which we identified relevant papers dealing with sustainability aspects in transportation. On the other hand, they are based on Alvarez et al. [49] results. In that paper, stakeholders in Pamplona were surveyed in order to investigate social perceptions with respect to freight transportation in the city. For residents, they found air and noise pollution, and heavy traffic of goods delivery, among other concerns, as important problems in Pamplona city center. We describe the AHP criteria and subcriteria in the following paragraphs:

Criterion 1: Economic.

- Subcriterion 1: Shipping costs. Firstly, the marginal shipping cost are lower for larger capacities, which makes the traditional van the cheapest alternative. Similarly, driving smaller distances will also reduce the shipping costs. Nevertheless, given the regulation for deliveries in the city center of Pamplona, the final comparison is not clear. That is, a cargo-bike may perform the deliveries at any time, without time-windows constraints that allow them to better optimize their routing planning. We explain these details at our AHP respondents and leave them to freely show their preferences with respect to the shipping cost.

- Subcriterion 2: Delivery time. Similarly to the previous point, time-windows heavily constrain good routing solutions for the traditional van deliveries. At the same time, bike deliveries need to schedule a greater number of routes to distribute the same number of parcels. Additionally, drone distribution may only deliver one

parcel at a time, but it avoids traffic jams and flies in straight line, which reduces the traveling time.

- Subcriterion 3: Loading optimization. This subcriterion measures the ability of a vehicle to achieve the full load for their operations so the number of routes are minimize. That means that a vehicle with higher capacity will have a better performance than a smaller one. Again, the particular characteristics of the last-mile distribution in the city center are explained to the respondent that freely give their opinion in this point.

Criterion 2: Environmental.

- Subcriterion 4: Air pollution. Freight transport emissions depend, in large part, on the type of fuel used. Despite the current great variety of different alternative fuels, diesel continues to be the main fuel used by goods vehicles [4]. Only a small amount is moved by electrically powered road vehicles; however, electric vehicles are not entirely sustainable due to the fact they depend on the primary energy source used to produce the batteries [50].
- Subcriterion 5: Noise pollution. Street activity noise generated by freight transportation tends to be nonstop, and hence considered a more significant issue than noise caused by other transport modes, e.g., railroad or aircraft noise, which are irregular.
- Subcriterion 6: Visual impact. The presence of vehicles in the city center may bother residents and visitors. Thus, the visual intrusion is assessed for each specific vehicle and route.

Criterion 3: Social.

- Subcriterion 7: Pedestrian safety. This item considers the physical disturbance of freight vehicles for pedestrians walking in the city center.
- Subcriterion 8: Life quality. The city center is a very dynamic area in which bars, shops, and households coexist. For that reason, the presence of freight vehicle may disturb and prevent the users from fully enjoying the city center.
- Subcriterion 9: Road use. It is of utmost importance that cyclists, vans, and pedestrians are able to circulate on the streets without causing any setback to their passage.

4. Data Collection

This step involves gathering the data through a survey, which was deployed the first week of May 2020, using an online questionnaire and distributed among the residents of Pamplona. In particular, we used email distribution lists from the Public University of Navarre and the Pamplona Local Council. All in all, we accounted for 107 observations. As in other online surveys, there is an over representation of young participants with respect to the Pamplona population. Additionally, we observed a high education level bias. Nevertheless, we consider this sample to be appropriate for our experiments even though the generalization is not guaranteed. The general descriptive data are shown in Table 2.

Table 2. General survey descriptive data.

	18–24	25–34	35–44	45–55	55–64	>64	
Men	22	5	10	10	8	0	55
Women	16	10	5	13	6	2	52
	38	15	15	23	14	2	107

4.1. Survey Implementation

The survey is divided into three sections. The first one consists of a brief summary of the questionnaire purpose and contains the classification questions. There, an hypothetical scenario is presented in which some parcels have to be delivered in a point in the city center. Then, two possible routes are introduced: (1) surrounding the city center and (2) crossing the city center. Likewise, three transportation modes to be used are explained, i.e., traditional van, cargo-bike, and drone. Then, Figure 3 is shown to the respondents.

The second part of the survey is based on the comparison between different economic, social and environmental aspects, in order to know the relative importance given to these problems that regularly occur in the goods transportation. Thus, the subcriteria previously listed, in the methodology section, are pairwise compared. Finally, the third part of the survey is aimed at obtaining preferences for the alternatives with respect to the criteria.
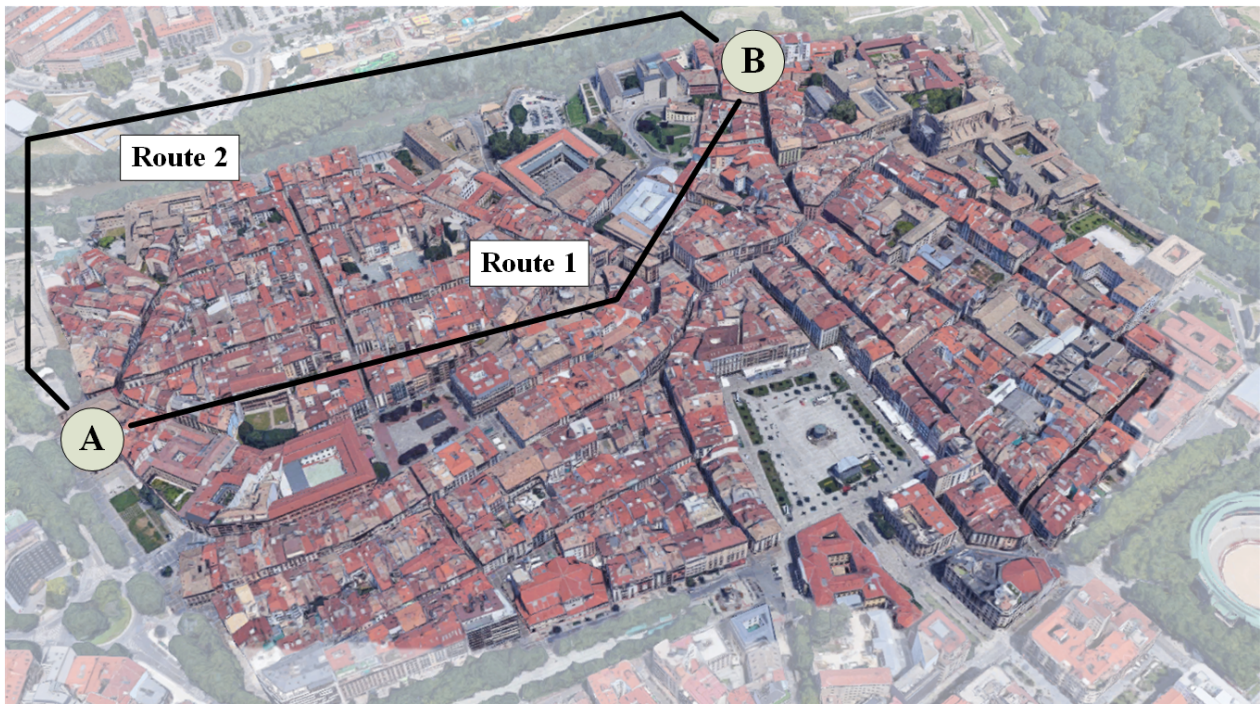

Figure 3. Pamplona City Center with the two alternatives routes to connect points A and B.

The second and third parts of the questionnaire are based on pairwise comparisons. These are performed directly asking the respondent about their preferences among alternatives, following the methodology proposed in the AHP procedure. We followed the general choice-based question showed in Table 3. Afterwards, the responses are coded using the numerical rating column in the same Table 3. Notice that the questionnaires comparisons were based on slide bars.

Furthermore, note that the number of comparisons is too large for a respondent to entirely complete a questionnaire. For that reason, the questionnaire randomly selects a set of questions to show. These set of questions correspond to the different AHP levels, i.e., comparison of criteria, comparison of subcriteria, or comparison of alternative with respect to just one subcriteria. When this questions set is completed, the respondent may continue answering a new set. Consequently, we closed the survey once we had at least 30 observations for each comparison.

Table 3. General choice-based question for rating the preferences.

Compared to the Second Alternative, the First Alternative Is:	Numerical Rating
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Moderately rejected	1/3
Strongly rejected	1/5

4.2. Urban Freight Modes

The alternatives for the AHP are the combinations of transport modes and routes. In this respect, three transportation alternatives have been considered:

- Cargo bike: A three-wheeled bicycle with a built-in trailer for transporting loads up to 200 kg. They can have an electric motor to help the driver to provide power to the bike, or they can be human driven without any external support.
- Traditional delivery van: They are small internal-combustion-engine vehicles that are used for the last-mile distribution. They are designed to transport up to 1500 kg.
- Drone: Unmanned aircraft vehicle, which can fly autonomously once it has been programmed or used by an operator with a remote controller. The usual drone load capacity is one parcel up to 2.5 kg.

With regard to the routes alternatives, we defined a starting point (A) and a destination point (B) in the city center in which two possible routes can be used. Figure 3 illustrates the two routes (Route 1 and Route 2). Note that these routes are different depending on the transportation mode. Traditional vans must respect one-direction streets and traffic lights, bikes may use bidirectional biking-lanes whilst drones fly in straight line. The description of the two routes are the next one:

- Route 1. Crossing the Pamplona City Center.
- Route 2. Surrounding the Pamplona City Center.

Thus, we account up to six alternative routes, which we describe in the following way: cargo bike-route 1, cargo-bike-route 2, van-route 1, van-route 2, drone-route 1, and drone-route 2.

5. Results

The analysis of the performed surveys includes a pairwise comparison of their results in order to tune the parameters in the AHP model, knowing, at the same time, the residents' priorities. Those results are averaged and transformed into traditional pairwise comparison matrices for the AHP application. These matrix comparisons are described in Tables A1–A13 in Appendix A. Additionally, the results for the criteria and subcriteria priorities are listed in Table 4.

Table 4. Criteria and subcriteria priorities.

Criteria	Criteria Priority	Subcriteria	Subcriteria Priority
Economic	0.09	Shipping cost	0.61
		Delivery time	0.3
		Load optimization	0.09
Environmental	0.3	Air pollution	0.48
		Noise pollution	0.41
		Visual impact	0.11
Social	0.61	Pedestrian safety	0.45
		Life quality	0.45
		Road use	0.1

Concerning the survey, the respondents value the social aspects much more than anything else, making the economic criteria the least valued. Within subcriteria, the shipping cost and the air pollution are the most important ones inside the economic and environmental criteria, respectively. Moreover, the pedestrian safety and the life quality are equally preferred among the social criteria.

When analyzing the alternatives with respect to the criteria, we found the drone outperforms the rest of transportation modes. Similarly, Route 2, i.e., the route surrounding the city center is the preferred one. In particular, the drone alternative wins in the following subcriteria: delivery time, road use, pedestrian safety, life quality, air and noise pollution,

and visual impact. The bicycle mode is preferred for the shipping cost subcriterion and vans are preferred in the case of the vehicle load optimization one. Avoiding entering the city center to deliver packages is the best option for almost all the subcriteria. Nevertheless, the use of the bicycle as well as the drone may cross the city center in the case of reducing the shipping cost, the delivery time, or the air pollution. In any case, the vans are preferred to enter into the city center. The summary of the priority vectors is shown in the Table 5.

Table 5. Priority matrix.

Decisional Matrix	Bike- R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2
Shippment Cost	0.33	0.19	0.09	0.13	0.17	0.09
Delivery Time	0.13	0.06	0.11	0.14	0.37	0.19
Vehicle Optimization	0.16	0.08	0.17	0.34	0.13	0.13
Road Use	0.2	0.11	0.04	0.11	0.27	0.28
Pedestrian Safety	0.04	0.21	0.06	0.16	0.24	0.3
Life Quality	0.14	0.1	0.07	0.08	0.25	0.37
Air Pollution	0.29	0.12	0.06	0.02	0.28	0.23
Noise Pollution	0.18	0.15	0.04	0.08	0.25	0.3
Visual Impact	0.19	0.16	0.08	0.06	0.2	0.31

Likewise, the overall priorities are listed in Table 6. As can be observed, the drone is the preferred transportation mode, followed by cargo-bicycles, and the use of traditional vans. For the aerial distribution, the route surrounding the city center is preferred instead of crossing it. This is mainly explained by the importance of the next subcriteria: life quality, pedestrian safety, and noise pollution. Similarly, this route is also preferred for van transportation. In this case, the factor that mainly affects this decision is related to the load optimization criterion—this means that respondents think that avoiding entering the city center will allow for a better utilization of their load capacity. Finally, crossing the city center is preferred when using the cargo-bikes. For this point, the reasonable assessment in economic, environmental, and most of social subcriteria compensate for the negative perception of pedestrian safety.

Table 6. Overall priority vector.

Alternative	Priority
Drone-R2	0.2927
Drone- R1	0.2484
Bike- R1	0.1524
Bike- R2	0.1429
Van- R2	0.1016
Van- R1	0.0620

The last step consisted of checking the pairwise comparisons consistency. This is performed using the recommendations given in Saaty [48]. Generally speaking, comparisons were consistent with some exceptions. They are referred to the economic criteria, and vehicle optimization, air pollution, and visual impact subcriteria. The main reasons behind these inconsistencies are due to the different perspectives for evaluating each alternative and the potential confusion when reading and understanding the criteria. Nevertheless, we considered that these values do not alter our main conclusions. Information related to the consistency ratio computations is available in Table 7.

Table 7. Consistency calculation details.

	Consistency Index	Random Index	Consistency Ratio
Among criteria	0.0298	0.58	0.0514
Economic criteria	0.0760	0.58	0.1311
Social criteria	0.0314	0.58	0.0541
Environmental criteria	0.0167	0.58	0.0288
Shipment cost	0.1340	1.24	0.1081
Delivery time	0.1188	1.24	0.0958
Vehicle optimization	0.3032	1.24	0.2445
Road use	0.1884	1.24	0.1519
Pedestrian safety	0.1452	1.24	0.1171
Life quality	0.1327	1.24	0.1071
Air pollution	0.3238	1.24	0.2611
Noise pollution	0.0964	1.24	0.0777
Visual impact	0.1898	1.24	0.1531

6. Conclusions

In this paper, we have developed an analytical hierarchy process (AHP) for selecting the best transportation mode (traditional van, cargo-bike, or drone) and route (crossing or surrounding the city center) in the last-mile distribution in the city center of Pamplona (Spain) according to the residents' opinions. We considered three groups of criteria dealing with economics, environmental, and social aspects for evaluating the six alternatives for combining the vehicles and routes. In order to compare the alternatives with respect to the criteria, an online survey was deployed in the city. This also allowed us to obtain the perception of the residents with respect to the criteria proposed. From the analysis of survey data as well as the AHP application, we draw the following conclusions:

- Social dimension is much more valued than economic or environmental aspects. In fact, pedestrian safety and life quality are the factors most appreciated by the respondent. It is particularly interesting that economic criteria are not critical for this analysis.
- Drone is seen as the best alternative for deliveries in the city center. Aerial distribution can be very useful in areas where traffic is heavy, counting not only vehicles, but also pedestrians. Hence, the Pamplona city center is a good example of this balance of people and distribution vehicles, where neighbors, traders, transporters, and tourists live together on a daily basis. Nevertheless, according to Figliozzi [51] the lower environmental impact of the use of drones and their easiness of control makes it a promising urban delivery mode, mainly with the use of new advanced technologies of managing big data, 5G, IoT, or autonomous vehicles. For now, the biking delivery is the preferred option in the short run.
- Avoiding entering the city center is preferred for drones and vans. This is not the case for the cargo-bikes, which people prefer to cross the city center. These reasons are motivated mainly for environmental and social aspects, as bike delivery is cleaner, less intrusive, and safer than other transportation modes. As such, it integrates better into the urban environment making it friendlier to residents.

The consideration of the use of drones in urban last-mile distribution and other mobility applications is a hot research topic also highlighted by other authors [51,52], making drone delivery a promising way of capillary distribution in urban scenarios. Furthermore, Macrina et al. [53], Lemardelé et al. [54] presents and discuss the current advantages of the use of drones in urban distribution along with its potential future applications. It is clear that drones can play an essential role in last-mile delivery in the near future. Nevertheless, these expectations of drones will be even higher in other applications in smart cities. They could be used not only for goods delivery scenarios, but also in aiding people in urban accidents and disasters, traffic surveillance, crowd security, humanitarian logistics, among other situations that involve the use of IoT, 5G, and coordination actions that should be controlled by the managers of a smart city.

6.1. Managerial Implications

From the practical implication point of view, this study highlights the increasing urban delivery issues from a multidimensional scope that takes into account also the residents' perspectives of urban distribution. This analysis ought to be valuable for decision makers in order to plan the future of the urban deliveries. As this article states, the promotion of alternative transportation means, e.g., drones or cycles, as well as the design of ad hoc transportation corridors. Similarly, those decision makers also can take advantage of advanced technologies related to IoT applied to smart transportation: smart traffic lights, smart parking, and connected vehicles.

6.2. Limitations and Future Research

This article presents some limitations that may threaten its generalizability. The main weakness is the small number of stakeholders selected for this study, i.e., just residents as well as the small sample size. In fact, urban mobility is a complex phenomenon and involves many stakeholders with often conflicting objectives; however, the conclusions drawn here should correspond to the desired urban freight mobility by residents. Secondly, the socioeconomic, cultural, and urban characteristics of Pamplona city and citizens may be different from other cities, but still remain pretty similar to other medium-sized cities in Europe.

Finally, there are some open opportunities at both academic and policy sides. On the one hand, more information should be obtained from the population in order to better understand the significant approval for the aerial distribution. In this sense, a survey-based research focusing on drone transportation is intended in the city of Pamplona in near future. Similarly, it is necessary to understand that this research is only based on resident evaluations, and should be enriched in the future with other views and opinions. Future research will include evaluation from other stakeholders such as carriers, owners, and local authorities. On the other hand, policy makers may understand the conclusions depicted here—that is, if the use of last-mile drone distribution is promoted, the city transportation infrastructure should be adapted to that new distribution mode, building drone infrastructure and adapting legislation [55]. Additionally, as pointed out in our paper, going around the highlighted urban areas, the city center of Pamplona for example, will make the implementation of drone delivery much more attractive. In fact, the use of drone swarm platforms located in some points in the city may avoid problems related to noise and accidents, optimizing delivery time and cost simultaneously.

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Appendix A. Pairwise Comparison Matrices

This appendix shows the pairwise comparison matrices for the development of the AHP. Notice that entries correspond to the preferences described in Table 3 of row item with respect to column item.

Table A1. Pairwise comparison matrix for the criteria.

	Economic	Social	Environmental	Priority
Economic	1	1/5	1/5	0.09
Social	5	1	3	0.61
Environmental	5	1/3	1	0.3

Table A2. Pairwise comparison matrix for the economic subcriteria.

Economic	Shipping Cost	Delivery Time	Load Optimization	Priority
Shipping cost	1	3	5	0.61
Delivery time	1/3	1	5	0.3
Load optimization	1/5	1/5	1	0.09

Table A3. Pairwise comparison matrix for the social subcriteria.

Social	Road Use	Pedestrian Safety	Life Quality	Priority
Road use	1	1/5	1/5	0.1
Pedestrian safety	5	1	1	0.45
Life quality	5	1	1	0.45

Table A4. Pairwise comparison matrix for environmental subcriteria.

Environmental	Air Pollution	Noise Pollution	Visual Impact	Priority
Air pollution	1	1	5	0.48
Noise pollution	1	1	3	0.41
Visual impact	1/5	1/3	1	0.11

Table A5. Pairwise comparison matrix for each alternative with respect to shipping cost.

Economic Shipping Costs	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	3	3	3	5	3	0.33
Bike-R2	1/3	1	3	5	1/3	3	0.19
Van-R1	1/3	1/3	1	3	1/3	1/3	0.09
Van-R2	1/3	1/5	1/3	1	3	3	0.13
Drone-R1	1/5	3	3	1/3	1	3	0.17
Drone-R2	1/3	1/3	3	1/3	1/3	1	0.09

Table A6. Pairwise comparison matrix for each alternative with respect to delivery time.

Economic Delivery Time	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	3	1/3	1/3	1/5	3	0.13
Bike-R2	1/3	1	1/3	1/3	1/3	1/3	0.06
Van-R1	3	3	1	1/3	1/5	1/3	0.11
Van-R2	3	3	3	1	1/5	1/5	0.14
Drone-R1	5	3	5	5	1	3	0.37
Drone-R2	1/3	3	3	5	1/3	1	0.19

Table A7. Pairwise comparison matrix for each alternative with respect to load optimization.

Economic Load Optimization	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	3	3	1/3	3	1/5	0.16
Bike-R2	1/3	1	1/5	1/5	1/5	5	0.08
Van-R1	1/3	5	1	1/5	5	3	0.17
Van-R2	3	5	5	1	5	3	0.34
Drone-R1	1/3	5	1/5	1/5	1	5	0.13
Drone-R2	5	1/5	1/3	1/3	1/5	1	0.13

Table A8. Pairwise comparison matrix for each alternative with respect to road use.

Social Road Use	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	1/3	5	3	1/5	3	0.20
Bike-R2	3	1	3	1/5	1/5	1/3	0.11
Van-R1	1/5	1/3	1	1/3	1/5	1/3	0.05
Van-R2	1/3	5	3	1	1/5	1/5	0.11
Drone-R1	5	5	5	5	1	1/5	0.27
Drone-R2	1/3	3	3	5	5	1	0.28

Table A9. Pairwise comparison matrix for each alternative with respect to pedestrian safety.

Social Pedestrian Safety	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	1/3	1/3	1/3	1/3	1/5	0.04
Bike-R2	3	1	5	1/3	1/3	3	0.21
Van-R1	3	1/5	1	1/5	1/5	1/3	0.06
Van-R2	3	3	5	1	1/5	1/5	0.16
Drone-R1	3	3	5	5	1	1/5	0.24
Drone-R2	5	1/3	3	5	5	1	0.30

Table A10. Pairwise comparison matrix for each alternative with respect to life quality.

Social Life Quality	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	3	5	3	1/5	1/5	0.14
Bike-R2	1/3	1	1/3	5	1/5	1/3	0.10
Van-R1	1/5	3	1	1/5	1/5	1/5	0.07
Van-R2	1/3	1/5	5	1	1/3	1/5	0.08
Drone-R1	5	5	5	3	1	1/3	0.25
Drone-R2	5	3	5	5	3	1	0.37

Table A11. Pairwise comparison matrix for each alternative with respect to air pollution.

Environmental Air Pollution	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	5	5	5	5	1/5	0.29
Bike-R2	1/5	1	5	5	1/5	1	0.12
Van-R1	1/5	1/5	1	5	1/5	1/5	0.06
Van-R2	1/5	1/5	1/5	1	1/5	1/5	0.02
Drone-R1	1/5	5	5	5	1	5	0.28
Drone-R2	5	1	5	5	1/5	1	0.23

Table A12. Pairwise comparison matrix for each alternative with respect to noise pollution.

Environmental Noise Pollution	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	5	5	3	1/5	1/3	0.18
Bike-R2	1/5	1	3	5	1/5	1	0.15
Van-R1	1/5	1/3	1	1/5	1/3	1/5	0.04
Van-R2	1/3	1/5	5	1	1/3	1/5	0.08
Drone-R1	5	5	3	3	1	1/3	0.25
Drone-R2	3	1	5	5	3	1	0.30

Table A13. Pairwise comparison matrix for each alternative with respect to visual impact.

Environmental Visual Impact	Bike-R1	Bike-R2	Van-R1	Van-R2	Drone-R1	Drone-R2	Priority
Bike-R1	1	1/3	5	5	5	1/5	0.19
Bike-R2	3	1	3	5	1/5	1/3	0.16
Van-R1	1/5	1/3	1	1/3	1/5	1	0.08
Van-R2	1/5	1/5	3	1	1/5	1/5	0.06
Drone-R1	1/5	5	5	5	1	1/5	0.20
Drone-R2	5	3	1	5	5	1	0.31

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