Pick-Up Point Location Optimization Using a Two-Level Multi-objective Approach: The Enna Case Study

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Abstract. The E-commerce sector has experienced considerable growth and is connected to a growing demand for urban logistics services. It could have huge impacts on cities and the environment. The goal of the companies is to make the system more efficient, for example, by optimizing delivery tours. In general, sustainable logistics aims to reduce the carbon footprint, pollution and waste at all stages, including the distribution of goods to the end customer. Hence the need to balance the different social, economic and environmental objectives. The explosion of e-commerce has transformed consumer habits; new distribution standards, such as same-day deliveries, have multiplied the number of trips in city centers. Other problems emerge, particularly the fragmentation of deliveries and unattended deliveries. Companies must not neglect the environmental impact of their actions since reducing greenhouse gas emissions is one of the most significant challenges of our time.

Alternative shipping methods, such as pick-up points, allow deliveries to be concentrated in fewer points. In addition, this distribution mechanism benefits consumers by giving them maximum flexibility by letting them choose when and where to pick up their parcels. Although some European examples show that collection and delivery points offer a sustainable solution, this is not always true. This paper investigates the walking accessibility of collection and delivery points in a small urban centre in Sicily using spatial syntax methodology, calculating 5-min isochrones and evaluating walking infrastructures. The paper focuses on a particularly innovative topic, highlighting access to pick-up points from a user perspective and proposing a methodology that considers different aspects of the urban environment.The results show that good spatial accessibility of the pick-up points is not always linked to an equally good level of population coverage and the goodness of the associated pedestrian infrastructures.

Keywords: Pick-up points · Collection-and-delivery points · Urban logistics · Sustainability

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1 Introduction

The main challenges to be addressed in the coming decades have been signed and sub-signed by 193 UN member countries. These are summarised in the 17 goals of 'Transforming our world: the 2030 Agenda for Sustainable Development' [1]. These themes are closely connected to goals 13, 9 and 11 of Agenda 2030. Goal 13 stresses taking urgent action to combat climate change and its impacts for its general implications on the reduction of CO_2 emissions. Goal 9 emphasizes building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation, representing the focus from a business and, thus, a supply-side perspective. However, Goal 11 underlines to make cities and human settlements inclusive, safe, resilient and sustainable, representing the demand-side system regarding citizens and end-consumers. These three objectives are central to research in the area of urban transport [2]. Due to their characteristics, E-commerce and last-mile logistics represent sectors affected by the abovementioned objectives.

B2C (Business-To-Consumer) e-commerce is one of the most important research topics [3]. E-commerce, buying goods online with home delivery, and the impact on last-mile logistics that this practice has had, have evolved significantly over the last twenty years. The E-commerce growth trend has been considerable in the last few years. Statistics (as shown in Fig. 1) reveal that the total sales volume has tripled over the previous six years. At the same time, approximately one billion dollars more was increased in 2021 compared to the 2020 trend. This trend was largely influenced by the COVID-19 pandemic and the associated restrictions [4].

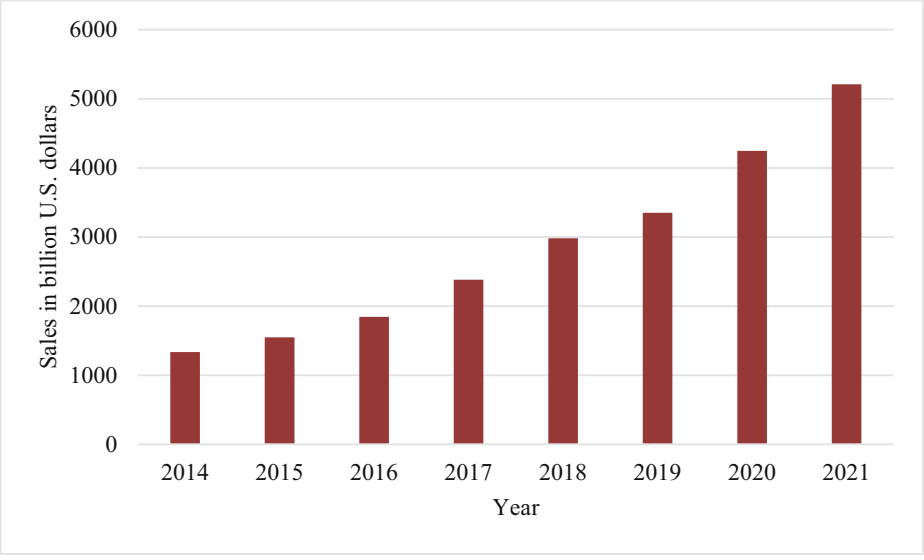

Fig. 1. E-commerce trend in the last decade. Source: Statista [5]

The growth of e-commerce has led to a restructuring in the habits of logistics companies [6]. The main feature has been to change the structure of the distribution supply chain [7]. Whereas the 'classic' supply chain sees the producer linked to the consumer via an intermediary, such as the retailer, now the producer/distributor comes into direct contact with the user. It has led to two significant consequences:

- the change in the habits of the user, who can choose direct-to-home delivery, influencing home-shopping mobility;
- the need for companies to equip themselves with efficient tools to optimize delivery tours.

Among the consequences of the rise of e-commerce at the urban level are:

- The fragmentation of deliveries. In 'classic' city logistics, the distributor has to deliver large quantities to a few points, located at retailers. In contrast, the current scheme involves deliveries of small quantities to many points;
- Consequently, the increase in vehicular touring has led to increases in negative externalities, pollution, CO2 emissions and accidents.

Among the emerging problems related to e-commerce is that of non-delivery. The customer's absence at home causes an empty trip and requires a re-trip. The benefit of tour optimization is thus lost, and instead, the negative externalities already highlighted increase [8].

The pick-up point is among the tools the distribution company and users have to deal with this problem [9]. Pick-up points are points, often located at public activities, representing a decoupling node in the supply chain at the last mile: the distributor deposits the parcels at the node, and customers can pick up the parcels by going to the node [10]. The scheme is substantially modified according to the image described in Fig. 2.

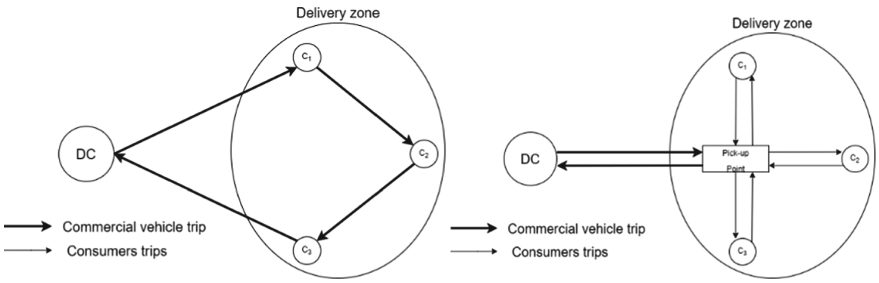

Fig. 2. Classic delivery scheme (left) and the implementation of a pick-up point (right)

Once a delivery zone is identified, the company reduces the number of pick-up points, resulting in fewer vehicle trips. The advantages of pick-up points are emphasized in the literature. In particular, some researchers have highlighted, starting from the study of different European countries, how pick-up points have decreased missed deliveries, optimized tours and reduced operating costs [11]. However, the decrease in vehicle trips has been matched by an increase in users' home-to-shopping trips. The user no longer has to travel to the retailer but to another point that performs the same function.

The user's home-shopping trip can take place in two ways:

- the displacement is generated solely by the need to go to the pick-up point;
- the movement occurs for other reasons (home-work, home-study, etc.) and thus only adds another element to the trip chain.

In the present work, the first motivation, trips generated by the need to travel to the pick-up point, is analyzed. In literature, it is shown how, in the case where the user uses a private vehicle such as a car to travel to the pick-up point, the benefits of the location of the pick-up point are cancelled out; this mainly occurs when the user is more than 5 min' walk from the point [12]. Therefore, the greatest possible demand coverage should also be considered when positioning pick-up points. This choice is made without considering a medium to long-term horizon; it is seen more as a new and different alternative offered to the user than as a tool to reduce negative externalities [13].

This article develops a methodology to evaluate the pick-up point network in an urban reality. Particular focus is given to small- to medium-sized realities, where a good optimization of traffic flows may be the source of a noticeable improvement in community life. To this end, the following elements are assessed in the proposed methodology.

- the pedestrian accessibility at 5 min from each pick-up point, with the instrument provided by the isochrones; this element allows for an assessment of the potential demand contained within the area relative to the point under consideration;
- the topological accessibility of each point, assessed using the instruments of the space syntax; the integration measure makes it possible to assess the position of a point in the network, and is an element characterizing the supply system. Reference is made to the discussion by Hillier et al. [14], also considering the high range of applications of space syntax present in the literature [15];
- the characteristics of the pedestrian infrastructure and the actual pedestrianization of the area surrounding the individual point considered.

The novelty of the research lies in the analysis of the positioning of pick-up points in an urban centre. The novel findings will help decongest the traffic flow by reducing tours and thus emissions and improving the pedestrianization of the area to allow for better user accessibility.

Section 2 presents the considered case study, the urban reality of Enna, a municipality in the South of Italy. Due to its characteristics describing the study area and underlining some particularities and issues. The methodology necessary to specify the objectives and identify a solution path is presented in Sect. 3. Section 4 presents the results of the study. Finally, Sect. 5 summarises some conclusions and proposes future developments.

The research is mainly addressed to different types of addressees: public administrators and technicians, to support planning strategies and implementations in urban realities, logistics companies for the implications contained within the overall objectives, and researchers who develop operational models that have social and environmental goals along with optimization of efficiency.

2 Study Area

The study area identified for the research is the area of Enna Alta, one of the two parts of the municipality of Enna. Enna is a municipality of approximately 25,000 inhabitants located in the central part of Sicily, in the extreme south of Italy, the provincial capital of the same name. Enna Alta constitutes the city's historical centre and is built on top of a hill. Therefore, it is naturally bounded by the steep walls of the hill. The total number of inhabitants of the area studied is 15,229 [16].

The geographical positioning of the area of Enna Alta, on top of a plateau, determines certain urban and geographical characteristics that make the study of this reality interesting:

- A highly interconnected road network internally, but with few points of contact with the external area, which naturally delimits the study area;
- Very high and variable average slope characteristics due to the orography of the area;
- High presence of steps within the urban area, as there are axes entirely composed of steps.

Twelve pick-up points were identified within this area, referencing those available from Amazon [17], and the analyses were conducted on QGis [18]. Figure 3 shows the distribution of pick-up points.



Fig. 3. Urban area studied and pick-up points

A first evaluation reveals an essential element: the pick-up points tend to be aggregated into two clusters on a territorial basis: a group in the East area (points 1-2-3-4-5) and a group in the West area (7-8-9-10-11), with only point 6 separated from the two groups.

The main characteristics of the urban network of Enna are then summarized. The average slope range on the acceptable arches is 0–0.5%, while pavement with good characteristics is greater than 1.50 m in width. Figure 4. And Fig. 5 show the slope and functional characteristics of the network arches.

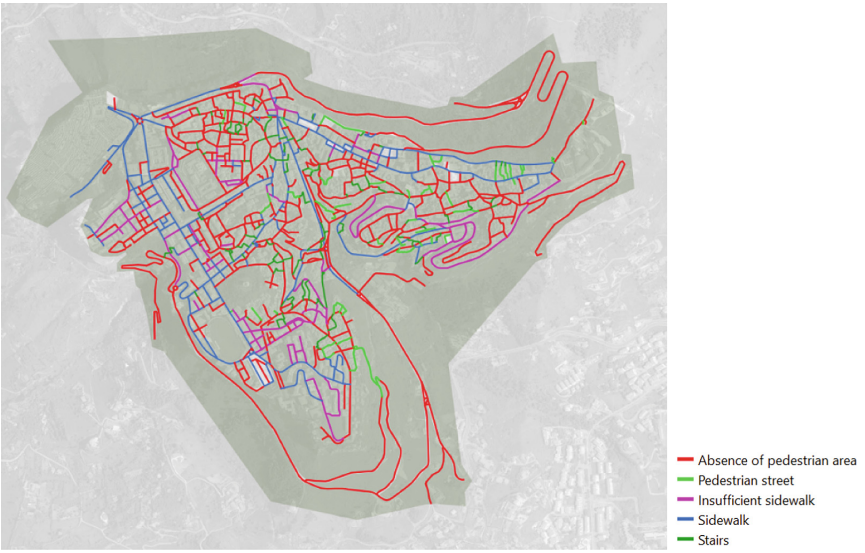

Fig. 4. Walking infrastructures classification

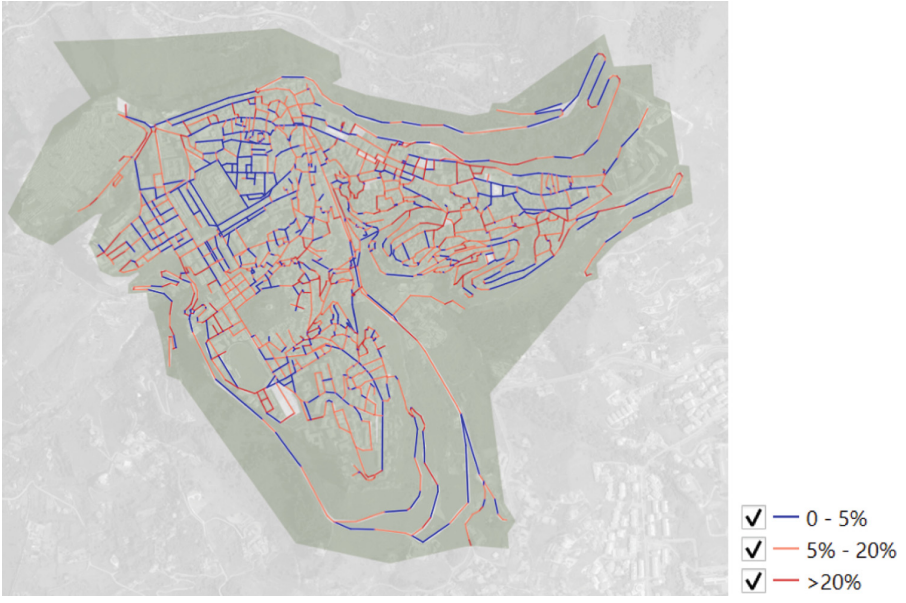

Fig. 5. Average road slopes

Table 1 shows the characteristics of the pedestrianization of the area.

Table 1. Pedestrianization of the area in percentages. Pedestrianization of the area in percentages.

Type of arc	% of the total network
Sidewalk	21%
Pedestrian street	5%
Stairs	6%
Insufficient sidewalk	13%
Absence of pedestrian area	55%

The figures show how the study area presents high average slopes and a discontinuous pedestrian network. The absence of pavements in most of the central streets is due to the historical and architectural characteristics of the city centre; in the outer areas, however, these are mainly peripheral streets, with portions of suburban streets. Just over 35 per cent of the study area has roads with an average gradient of less than 5 per cent.

The elements considered represent the basis on which the methodology described in the following section is applied.

3 Methodology

The proposed methodology is developed in three steps: demand (step one) and supply (steps two and three) characteristics.

Step one: The use of isochrones is used as a tool for evaluating and analyzing the accessibility of points within the network is documented in the literature, such as for LPT accessibility [19, 20]. In this study, the objective is to determine the accessibility of the pick-up point system by evaluating the pedo-national 5-min isochrony, following up on what was defined in the introductory section.

Consider the study area characterized by a number n = 1, 2, n…, S of zones, each characterized by an area An and a POPn population. Consider a network of pick-up points characterized by several points p = 1,2,…, P. Define ip as the area delimited by the 5-min pedestrian isochrony generated by point p.

For each area ip, it is possible to evaluate the area obtained by the intersection with the generic An; the intersection area is defined as An,p.However, for each area n, we consider the population POP_n uniformly distributed within the area. We denote by POPn,p the proportion of the POP_n population counted within the area $A_{n,p}$ and evaluate with:

$$POP_{n,p} = \frac{A_{n,p}}{A_n} POP_n \tag{1}$$

The total POP_l population within the IP area is obtained as:

$$POP_p = \sum_{n=1}^{S} POP_{n,p} \tag{2}$$

Step Two: The second step is related to the characterization of configurational space. Space syntax is used, identified as the set of techniques for the study and analysis of spatial configurations [21]. The basis of the space syntax is the axial map; the axis is an element that links one space with another.

The map can be disaggregated into segments at the intersections to improve the analysis' accuracy [22]. Among the measures of centrality identified by the space syntax, it is worth mentioning the To-movement measures, which identify the characteristics of a space as a potential destination [23]. In this sense, they represent an element to parameterize the accessibility of a segment on the network. All centrality measures are influenced by the geometric distance between the origin and destination space, expressed as the sum of angular deviations from an origin to a destination [24].

The measure used is the Normalized Angular Integration, NAIN, which is calculated with reason r = 300 m, i.e. the distance travelled in 5 min with an average speed of 1 m/s [25]. In this study, $NAIN_{r=300}$ m is evaluated for each segment, and the segment value on which it directly insists is considered for each point.

Third step: The third step is related to evaluating the characteristics of the pedestrian infrastructure. In this sense, the area on which the pick-up point is located is characterized by two elements. The first is an element that characterizes the orography of the terrain, i.e. the slope. It is emphasized that an excessive slope represents an important li-mite for different categories of users. The average slope of the segments belonging to that isochrone is evaluated for each isochrone. If L_p is the total length of the network intersected by the isochrone ip, and if L_p,s is the length of the network intersected by the isochrone with a slope belonging to a certain range, three indicators are adopted to assess the goodness of the slope of the area:

$$L\%_{p,s} = L_{p,s}/L_p, \tag{3}$$

It measures the proportion of the network with a given range slope present within the isochrone out of the whole network present. It is a parameter specific to each isochrone.

$$PEND_p = L_{p,s}/L_{TOT,5} \tag{4}$$

It measures the share of slope belonging to the given range present within the isochrone concerning the total analyzed network with an average slope belonging to the given range. It serves as a measure of the concentration, in a given isochrone, of acceptable pedestrian height.

$$PTOT_p = L_{p,s}/L_{TOT} \tag{5}$$

It measures the share of range slope present within the isochrone out of the total network present. The other element is the pedestrianization characteristics of the urban area. Five potential categories of axes are identified:

- footpath, a street arc in which there is pedestrian infrastructure in its own right of way, having width characteristics that allow for pedestrianization that is considered acceptable;
- pedestrian thoroughfare, an arc in which pedestrian-only traffic is interested;

- stairway, an arch in which the infrastructure is entirely stepped. It represents an advantage for the absence of promiscuity with vehicle traffic but is a limitation for the circulation of certain categories of users;
- deficient pavement, a road arch in which the pedestrian infrastructure has poor characteristics, has a narrow width. It does not qualify as a pedestrian street;
- absence of pedestrianization, an arch in which pedestrian transit in its own right of way is impossible.

The average slope of the segments making up the isochrone is evaluated for each isochrone. If L_p is the network's total length intersected by the isochrone i_p, and if $L_{p,w}$ is the network length intersected by the isochrone with good pedestrianization characteristics. Thus, three indicators are adopted to assess the goodness of pedestrianization in the area:

$$L\%_{p,w} = L_{p,w}/L_p, \tag{6}$$

It measures the share of acceptable pedestrianization present within the isochrone out of the total network present in the isochrone and is a parameter specific to each isochrone.

$$WALK_p = L_{p,w}/L_{TOT,w} \tag{7}$$

It measures the share of acceptable pedestrianization present within the isochrone compared to the total of the analyzed network with good pedestrianization characteristics. It measures the concentration of adequate pedestrian share in a given isochron.

$$WTOT_p = L_{p,w}/L_{TOT} \tag{8}$$

It measures the share of acceptable slope present within the isochrone out of the whole network. Hence, evaluating these three elements makes it possible to characterize the pick-up point in three complementary aspects, population, pedestrian infrastructure and configurational and geometric accessibility. Finally, at the end of the characterization, it is possible to make a quantitative judgement on the positioning of each of them. The results of the methodology described, applied to the case study presented in Sect. 2, are illustrated in Sect. 4.

4 Results

4.1 Application

This section illustrates the numerical results, following the approach described in Sect. 3.

First step. For the population study, reference was made to ISTAT data [26]. The study was limited to the census plots within the area. It is not a problem, since the peripheral parcels are not entirely contained in the area. Thus discarded areas have zero population and therefore do not influence the study. At each pick-up point, the isochronous was generated. Figure 6 shows an example of the i4 and i7 isochrones.

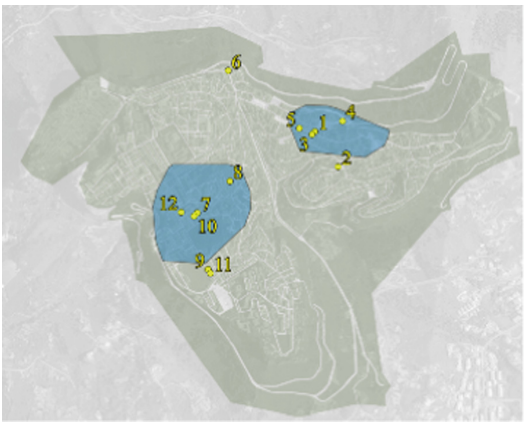

Fig. 6. Definition of Isochrones i_4 and i_7

Table 2. POPp values for each area p. Consider how POP_{TOT} refers to the union of the areas.

p	1	2	3	4	5	6	7	8	9	10	11	12	TOT
POP_p	1527	1856	1495	738	1594	1758	2418	2410	1786	2360	1547	1923	9113
$POP\%_p$	10%	12%	10%	5%	10%	12%	16%	16%	12%	15%	10%	13%	60%

Table 2 shows the characteristics of the population percentage covered by each pick-up point and the total percentage covered in 5 min by the ITOT area.

Each pick-up point has a good population coverage, always between 10% and 15% of the total, except for point 4. Overall, 5-min pedestrian accessibility is guaranteed for 60% of the resident population. The resident 40% is mainly located in the South and North-West areas, which are uncovered by pick-up points.

Second step. The configurational analysis returns the $NAIN_{r=300\,m}$ values mapped in Fig. 7. It is pertinent to note that the analysis was conducted by DepthmapX [27].

The NAIN value considered ranges from a minimum of 0.3 to a maximum of 3.74. Within the scenario considered, the results in terms of NAIN, and reference quartile, for each of the points considered are summarised in Table 3.

The result shows a significant finding: a high Integration value for each point considered. All the points, except p = 1,2,4, are positioned within the first quartile, among the segments characterized by greater accessibility; the others present high values. However, this is mainly due to the deep interconnection of the inner area of Enna.

Third step. Finally, the evaluation of the pedestrian areas within each isochrone is summarised in Table. 4.



Fig.7. $NAIN_{r=300\ m}$ for the study area

Table 3. $NAIN_{r=300\ m}$ and the respective reference quartile for each segment associated with the generic point p.

P	1	2	3	4	5	6	7	8	9	10	11	12
$NAIN_{r=300m}$	1,61	1,62	1,71	1,51	1,7	1,72	1,74	1,75	1,8	1,65	1,8	1,69
Quartile	2	2	1	2	1	1	1	1	1	1	1	1

Table 4. Summary of the indicators on the goodness of the pedestrianisation of the area related to the generic point p.

P	1	2	3	4	5	6	7	8	9	10	11	12	TOT
$WTOT_p$	3,4%	3,3%	3,5%	2,6%	3,5%	2,3%	3,5%	2,9%	3,4%	3,5%	3,2%	3,6%	15,5%
$L\%_{p,s}$	37,7%	29,6%	37,8%	44,8%	37,2%	24,4%	29,6%	26,4%	33,7%	29,7%	35,8%	33,5%	30,2%
$WALK_p$	13,3%	12,8%	13,4%	9,8%	13,4%	8,8%	13,6%	11%	13%	13,4%	12,4%	14%	59,5%
$STOT_p$	2,1%	2,4%	2,1%	1,9%	2,2%	3,7%	3,8%	3,8%	2,2%	3,6%	2%	3,7%	15,2%
$L\%_{p,s}$	22%	20,7%	22%	32,8%	22,6%	39,4%	31,7%	34,7%	22,1%	29,8%	22,5%	33,1%	29,5%
$SLOPE_p$	5,8%	6,7%	5,8%	5,4%	6,1%	10,2%	10,8%	10,7%	6,1%	10%	5,5%	10,3%	42,5%

The results show a pedestrianization characteristic of each area ranging between 20% and 40%, around an overall value of 30%. It should be noted that the arches with good pedestrianization characteristics and the entirely pedestrianized arches were only considered in the analysis. It excludes the stairs due to their characteristic, implying potential

difficulties for users with motor disabilities, older adults and users with pushchairs. Similar percentages are obtained for the evaluation of slopes. In general, point 4 presents the best value of pedestrianization. More than 44% of the total value of the network entirely contained in the isochrone is pedestrianized. The WTOT and WALK, PTOT and PEND measures allow the pedestrianization characteristics scaled over the entire network to be assessed.

Interestingly, the percentage of the pedestrian network contained in the isochrony is almost 60%, implying that activities tend to be concentrated in the walkable area. Only 40%, on the other hand, is the percentage of the network with an acceptable slope contained within the isochrone. 15% is the percentage of pedestrian and adequate slope network contained within the isochrone compared to the total road system in the study area.

5 Discussion and Conclusion

This research focuses on a current issue related to the increase in e-commerce and online sales that have prompted many people to purchase and pick up parcels at several pick-up points in urban areas. The research work, in particular, shows the preliminary definition of a methodology to evaluate the existing network of pick-up points by considering three different aspects, namely the geometric accessibility of the points in the network, population coverage and walkability characteristics of the area relative to the point. It made it possible to classify the points according to these criteria, obtaining an evaluation of both the pick-up point system and the characteristics of the built-up area.

The first significant element is undoubtedly related to the nature of the residential area. From a geometric point of view, the high accessibility values show the deeply interconnected nature of the built-up area of the case study. For this reason, the study of pedestrianization makes it possible to cover the aspect related to the characteristics of the infrastructure instead. Although geometrically accessible, the built-up area presents adverse pedestrianization characteristics discouraging the use of the point. It occurs although most points are located in the most central built-up area. Consequently, despite the good overall coverage in terms of population (approx. 60% of the total), users may not be encouraged to use the points, even if they reside within the theoretical 5-min pedestrian zone.

This work may suggest network evaluation criteria for delivery companies to optimize distribution strategies, considering the urban reality in which distribution occurs. On the other hand, it may help public administrators and planners to have quantitative elements to support traffic and pedestrian flow analyses.

Other future developments are possible. Possibilities include evaluating residents' actual use of these points within the studied centre. On the other hand, the chance of developing a methodology that, starting from the basis described in this article, can provide decision-supporting tools for positioning a new pick-up point, considering the already existing network.

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