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On the spatial feasibility of crowdshipping services in university communities

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Abstract

Crowdshipping, i.e. delivering goods via the crowd, aims at combining passenger with freight trips. This concept is particularly useful, especially in urban contexts, since it allows using the spare capacity of vehicles and reducing the negative impacts of urban freight transport. While attractive in principle, a crowdshipping service needs to be appropriately conceived to be effective. In this respect, matching passenger with freight transport demand is one of the main issues to consider. Besides, it is important to promote a sustainable crowdshipping, i.e. perfomed via sustainable transport modes. This paper presents a GIS-based approach to evaluate the spatial feasibility of crowdshipping services using public transport or active modes in the context of a University community. The case study analyzed focuses on e-commerce deliveries and takes into account a campus with venues located in different zones in the city of Catania (Italy). The methodology is designed according to spatial considerations related to the proximity of delivery points and home addresses, students' flows between origins and destinations and main mode of transport used. Results are useful to design the service in a well-established community, which could be considered more inclined to be involved.

Keywords: *e-commerce; students mobility; freight transport sustainability*

1. Introduction

Cities are facing important changes related to their transport systems (Kane and Whitehead, 2017). This can be ascribed to different factors, like the growing city population, the pervasive diffusion and use of new technologies

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enabling new shared mobility services (Inturri et al., 2019; Giuffrida et al., 2020) and concepts like "Mobility as a Service" (MaaS) (Jittapirom et al., 2017) that are progressively changing the way mobility is conceived.

Policy-makers should duly take into account these innovations in their sustainable mobility planning agenda and predicting for disruptive future scenarios. However, usually urban transport planning is more focused on passenger transport, neglecting the freight side, which is particularly relevant in terms of negative impact on the environment and overall city livability (Le Pira et al., 2017). Besides, innovations in freight transport are also occurring, e.g. with the rapid development of e-commerce, and new collaborative concepts emerging, envisioning cooperation between several actors involved in city logistics (Tavasszy, 2020). An emerging and promising sharing economy concept applied to freight transport foresees the combination of passenger with freight transport, i.e. via crowdshipping services. Crowdshipping literally means "delivering goods via the crowd" implying a reduction of dedicated trips. The integration of passenger and freight movements through crowdshipping can be a good solution to reduce the overall number of trips and generate environmental/social benefits (Marcucci et al., 2017). To be effective, a crowdshipping service needs to be appropriately conceived. In this respect, matching passenger with freight transport demand is one of the main issues to consider, especially with respect to passengers using sustainable transport modes.

Optimizing already existing trips is the key of success of crowdshipping. However, involving commuters in such activity is a challenging issue, since there are several conditions (e.g. size, weight and value of goods) that could affect people's attitude to act as crowdshippers. A good *ex-ante* analysis is needed both to investigate its feasibility and willingness to use the service or to act as crowdshippers according to the context of analysis. Marcucci et al. (2017) and Gatta et al. (2019) performed a preliminary investigation and a stated preference survey to infer on the underlying motivations that can facilitate and/or hinder the deployment of a crowdshipping initiative in Rome, starting from University students.

In this respect, University can be considered a good community for the development of crowdshipping services, due to several reasons: (i) given their young age, students are accustomed to e-commerce services, they know the mechanisms and the shipping methods; (ii) their mobility patterns are well-defined both from a spatial point of view (it is easy to know their trip routes, because venues' locations are well-known) and from a temporal point of view (schedule of the main trips corresponds to lessons' one); (iii) they already form a well-established community, in which the service could have a pay back, therefore it is easy to motivate them to perform it.

Based on this premise, this paper aims investigating the spatial feasibility of crowdshipping services in the context of a University community. This is important also from the point of view of a possible matching between the demand with supply so to optimize existing trips. The methodology is based on a GIS analysis based on the case study of Catania (Italy) and takes into account different data related to last-mile delivery facilities (i.e. delivery points), data regarding student flows according to the mode of transport used and University sites location.

2. Methodology and application

In this paper, a spatial method to evaluate the feasibility of a crowdshipping service in the context of a University community will be presented. The study aims at supporting the planning of the service focusing on a set of criteria to choose the most suitable students' routes to be included into a crowdshipping network through a GIS-based spatial approach. A spatial approach allows to consider detailed and multiple spatial issues that should be evaluated in advance when using a purely mathematical optimization; this highlights the importance to adopt a spatial multicriteria method for alternative transport scenario comparison (Lambas et al., 2018; Gonzalez-Urango et al., 2020). Main routes will be selected taking into account: (i) the proximity of e-commerce delivery points to students' Origins-Destinations (OD); (ii) students' most experienced OD pairs; (iii) shortest paths between the selected ODs; (iv) modes of transport available for the selected paths.

The methodology was applied to the case study of the University of Catania (UNICT), a medium-sized city located in the south of Italy, which is adopting several initiatives and measures in order to promote sustainable mobility among its students. In the following, the methodology applied to the case study is presented.

2.1. Territorial framework

Catania is an Italian city of about 300,000 inhabitants lying on the eastern coast of Sicily (Italy). UNICT is one of the oldest universities in the country (founded in 1434) and counts about 40,000 students, 1,250 professors and researchers, 1,000 staff employees, 17 departments, 100 degree courses, and 18 PhD courses. The presence of the University in the city plays a fundamental role: Catania can be considered a University city, and the activities conducted by the University range on different fronts (educational, cultural, sports, recreational). This is also due to the presence of University venues located throughout the city. In particular, it is possible to distinguish two large poles: the Science and Technology campus in the north of the city and the Social Science and Humanities departments in the city center. This scattered location requires the University to be constantly committed with increasing the accessibility to its different venues. To this purpose, UNICT cooperated, during the last years, with the Municipality of Catania and the transport operators (Inturri et al., 2020) to several joint initiatives, among which: (i) in 2013, the design and implementation of the first Bus Rapid Transit (BRT) line serving the Science and Technology campus; (ii) in 2017, the implementation of the so called Metro Shuttle (MS) bus service to cover the last mile of a new metro station opened near a high-demand district, including the abovementioned campus (Ignaccolo et al., 2017),; (iii) in 2018, the policy of unlimited free access to all 40,000 regularly enrolled students to the overall urban public transport network (bus and metro lines, and park-and-ride facilities as well) (Inturri et al., 2020). In order to monitor the impact of these initiatives and following the logic of a continuous service improvement for students, in May 2018 the Mobility Management Office of UNICT disseminated a questionnaire to all its students asking for information on their mobility habits and opinions about public transport quality (Inturri et al., 2020). Based on the results of the survey (until July 2019), this study will develop a methodology to analyze the feasibility of a sustainable crowdshipping service based on the use of public transport and active modes, counting on a database of about 4000 respondents.

2.2. Methodology steps

The methodology is based on the steps described in the following, and presented in the flowchart in Fig.1

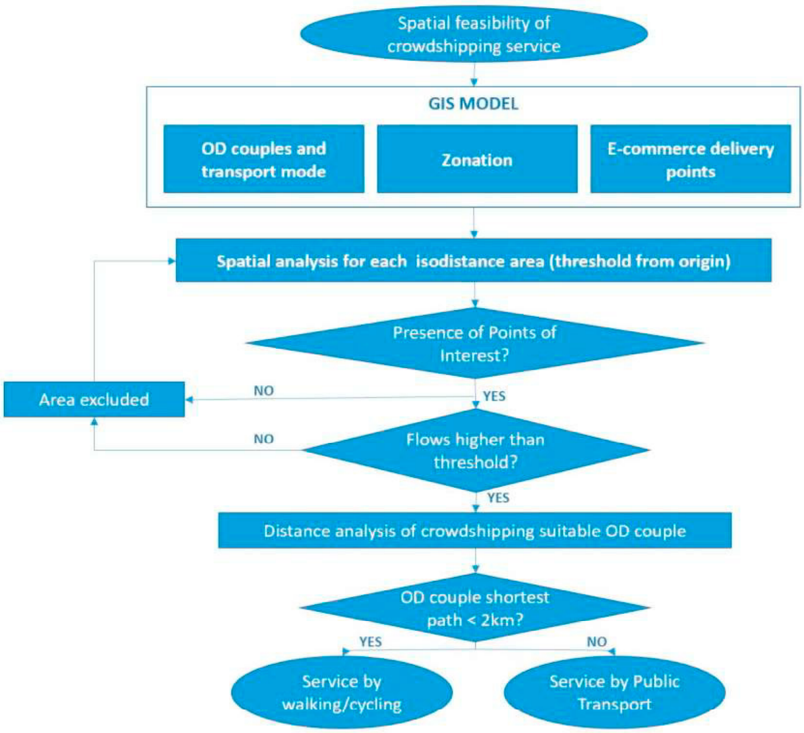

Fig. 1. Methodology flowchart.

1) Students' origin, destination (i.e. university venues) and mode of transport were derived from the survey. The considered study area includes the whole municipality of Catania;

2) Data from the survey were used to reconstruct the OD matrix for students' trips in the peak period (two hours), by adjusting the obtained values with corrective factors in order to scale the survey results to the whole community. The zonation used for the analysis is the one provided by the Urban Traffic Plan (PGTU) of the city, which divides it in 50 zones, according to city's neighborhoods. Fig. 1a shows the study area, the 50 zones' centroids considered as origins, and the location of UNICT venues (destinations);

3) E-commerce delivery points were extracted from web mapping services (GoogleMaps and OpenStreetMap); in particular, for this specific case study, we considered different types of delivery points, i.e.: public post offices; private post offices; e-commerce parcel lockers (Fig. 1b);

4) Proximity analysis measures and data on OD number of trips were used to evaluate the most suitable crowdshipping routes.

Fig. 2 presents the GIS model in terms of map of study area, zone centroids and university venues (a) and e-commerce delivery points (b).

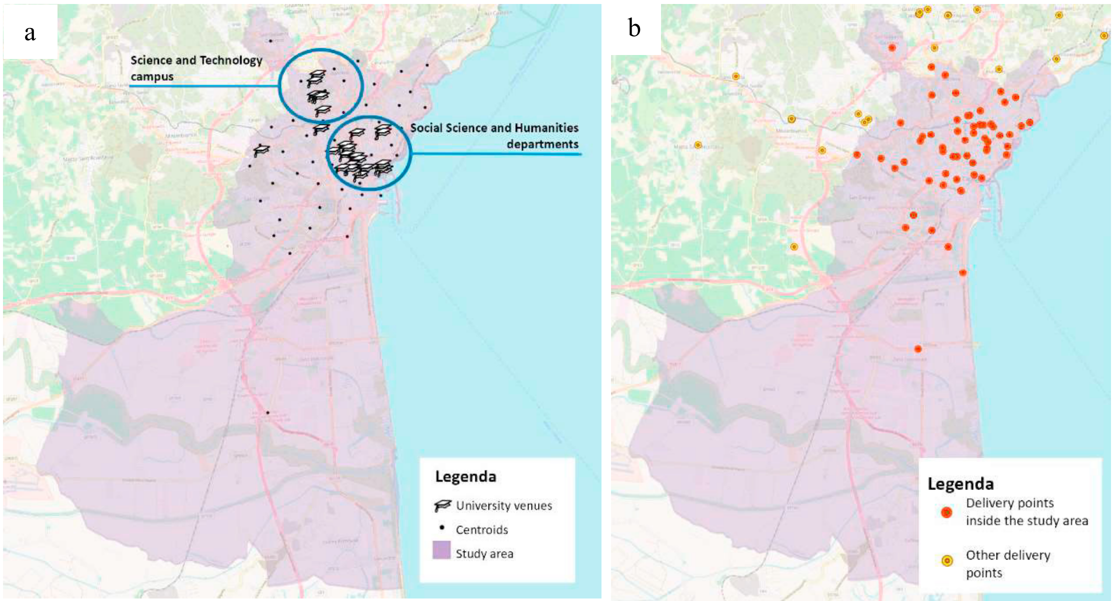

Fig. 2. (a) Map of study area, zone centroids and university venues; (b) map of e-commerce delivery points.

2.3. Analysis of students OD

Georeferenced data on the origin, destination, and additional intermediate destinations included in the survey were used to build the student OD matrix; OD matrix estimation refers to the peak-period considered in the time range between 7:00 and 9:00 AM for trips from home to the University sites, taking into account also intermediate trips between different sites within the day. Data based on survey's results were projected on the entire student population by multiplying the values by corrective factors; most of the trips take place in the urban area of the city. This is also due to the presence of a large number of students from municipalities in the region that do not have many commuting options and generally prefer to live in shared apartments and residences located in the centre of the city. Zooming in on the urban area of the city, it is possible to see that most of the trips have the venues of the Science and Technology campus as destinations. This step was performed in order to exclude from the analysis the low-flow OD couples; for the specific case study, we decided to take into account only flows bigger than 100 trips per hour, since they allow to identify recurrent patterns in frequent trips, with a high potentiality to turn into crowdshippers delivery routes.

2.4. Mapping of e-commerce delivery points and evaluation of walking distances

Delivery points were selected and mapped with the open data discussed in section 2.2. An analysis of the walking distance from origins was performed to select the origins that were more suitable to be considered for the crowdshipping service based on the presence of delivery points and university venues within a given threshold. For the case study, a threshold of 500 m from origins was considered, being a feasible walking distance (Fig. 3a). The threshold area was computed on the real pedestrian network based on OpenStreetMap (OSM) data, by creating isodistance areas from the origins using the ORS Tools plugin in the QGIS environment. The number of delivery points and university venues included in each isodistance area were computed; a thematic map of this result is shown in Fig. 3b, where areas are classified according to the number of facilities (from 0 to a maximum of 6); this classification allowed to exclude the origins without any close delivery points (DP) or university venue (UV). One significant result of this step was that all the zones with a university venue included at least one delivery point and that most of the e-commerce delivery points are located within a walkable distance from main student trip origins, thus providing a good coverage for the delivery service.

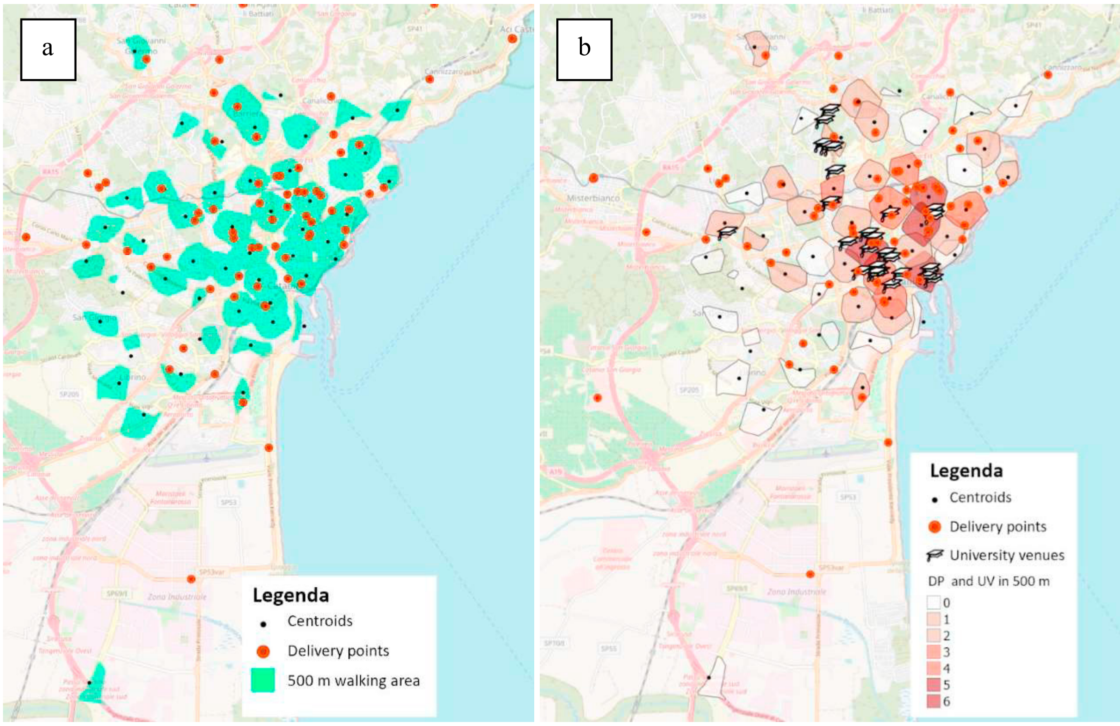

Fig. 3. (a) walking isodistance of 500 m from origins; (b) thematic map of isodistances according to the number of facilities

2.5. Proximity analysis

As stated in section 2.3, for the specific case study, only flows bigger than 100 trips per hour were considered. A combined map of flows and related isodistances areas is shown in Fig. 4. This can give some ideas on the most suitable OD couples to be used for the crowdshipping service, resulting in 12 couples.

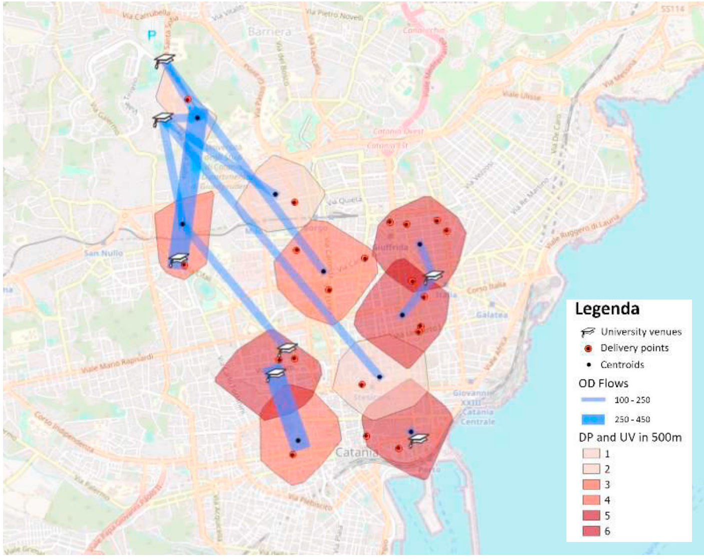

Fig. 4. Map of isodistances areas and student flows.

The last step includes the evaluation of shortest paths between the selected OD couples and the choice of the best mode of transport to be used to perform the service.

OD shortest path calculation was done for all the couples, using the ORS plugin, with routing based on the OSM road network. Finally, a proximity analysis between shortest paths and the public transport network was performed in order to find whether transit lines could be used by students to perform the crowdshipping service, with transit lines routes extracted from the OSM database.

3. Results and discussion

Results of the proximity analysis with transit lines are reported in Fig. 5. More detailed results of the feasibility analysis for the first 12 OD couples are reported in Table 1, which shows the:

(i) length of the shortest path;
(ii) suggested mode of transport according to the distance traveled;
(iii) public transport lines coupled with the path according to the proximity analysis;
(iv) maximum headways of the service considering all the available transit lines.

Path 1, 2, 3, 4, 11 and 12 resulted in a length of less than 2 km. For such distances, cycling and walking could be the best solutions, with walking suggested as main option for distances of less than 1 km. For all the other 6 paths, it was possible to assign an efficient public transport line to be used for the service.

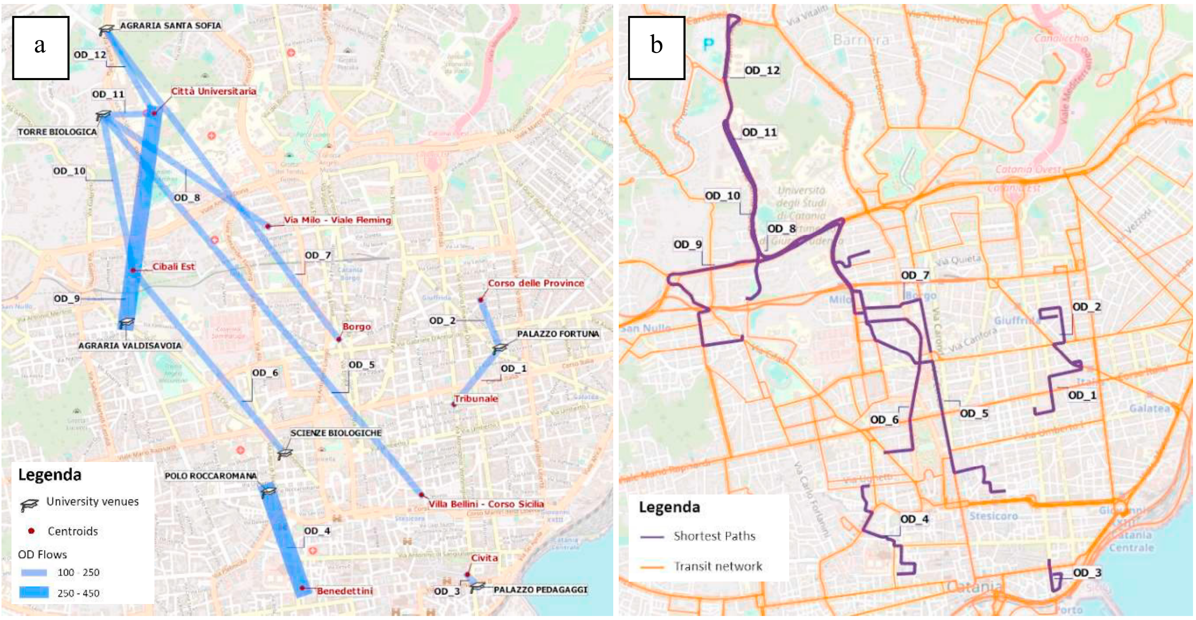

Fig. 5. (a) OD couples with flows ≥ 100; (b) shortest paths and transit network in the area of intervention.

Table 1. Result of proximity analysis.

OD shortest path	Length	Suggested transport mode	Lines in proximity	Max headway
1	0,76 km	Bike/Walking	--	--
2	1,00 km	Bike	--	--
3	0,44 km	Bike/Walking	--	--
4	1,17 km	Bike	--	--
5	4,68 km	Public transport	21 regular, BRT, metro, railway	7 min
6	3,24 km	Public transport	14 regular, BRT, metro, railway	7 min
7	4,50 km	Public transport	14 regular, BRT, metro, railway	7 min
8	2,55 km	Public transport	10 regular, BRT	7 min
9	3,10 km	Public transport	7 regular, BRT, metro, railway	7 min
10	2,14 km	Public transport	9 regular, BRT	7 min
11	0,53 km	Bike/Walking	--	--
12	1,61 km	Bike	--	--

As visible, all these OD couples are suitable trajectories for sustainable crowdshipping services using public transport or active modes. This implies that students can, at least in principle, combine their home-to-University trips with some parcel delivery, limiting trips performed by trucks and thus reducing the negative impacts of urban freight transport. Results of the analysis can give suggestions on how to plan the crowdshipping service according to student flows. However, it is also important to understand student willingness to act as crowdshippers and what are the incentives to perform such a service, e.g. by performing a stated preference survey (Gatta et al., 2019). A deeper analysis is needed to understand its overall feasibility, also in relation to other issues, like privacy or security concerns.

4. Conclusions

This study presented the first step of a wider analysis to foster the implementation of a crowdshipping service for University students that can deliver parcels while performing their daily trips. A GIS-based approach was used to evaluate the spatial feasibility of crowdshipping using public transport or active modes considering to the proximity of delivery points and home addresses, students' flows between origins and destinations and main mode of transport used. Results suggest that student flows can be easily coupled with available transit lines, thus making it possible a sustainable crowdshipping service. Results are useful to design the service. However, student attitude towards crowdshipping and other issues like privacy and regulation, should be further investigated to fully exploit this concept.

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