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Transportation Research Procedia 30 (2018) 101–110

Transportation Research Procedia

www.elsevier.com/locate/procedia

EURO Mini Conference on "Advances in Freight Transportation and Logistics" (emc-ftl-2018)

Sustainable crowdshipping using public transport: a case study evaluation in Rome

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Abstract

The paper analyses the willingness to act as a crowdshipper in the case of a last mile B2C e-commerce for pick up/delivery. Specifically, it focuses on crowdshipping services deployed using the public transport network and considering passengers as crowdshippers already moving for other reasons. In fact, this is the most environmental-friendly type of service one can develop given it avoids performing dedicated trips. The paper uses stated preference to identify the most important features associated with the choice of acting as a crowdshipper and discrete choice models to study the underlying behavior. The implementation case study refers to the city of Rome, Italy, and addresses its metro lines, thus understanding and quantifying the effects of this freight transport strategy for e-commerce in an urban context and providing local policy makers a good knowledge base for its future development.

Selection and peer-review under responsibility of the scientific committee of the EURO Mini Conference on “Advances in Freight Transportation and Logistics” (emc-ftl2018).

Keywords: Crowdshipping; Crowdlogistics; Urban freight transport; City logistics; Discrete choice; Stated choice experiment;

1. Introduction

Crowdshipping is a sharing mobility service that foresees delivering goods via the crowd (McKinnon, 2016). It

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Selection and peer-review under responsibility of the scientific committee of the EURO Mini Conference on “Advances in Freight Transportation and Logistics” (emc-ftl2018).
10.1016/j.trpro.2018.09.012

represents an opportunity to improve "last mile" delivery efficiency. This is particularly important especially in the light of increasing urbanisation and e-commerce development (Slabinac, 2015).

Actually urban areas are facing a growing demand for mobility due to both urban and logistics sprawl. At the same time e-commerce, especially B2C, generates a request for home delivery services which provokes an increase of the social and environmental costs goods distribution systems produce (Taniguchi et al., 2016). The introduction of new delivery models (e.g. crowdshipping) could, at least in principle, stimulate a better use of currently unused transport capacity thus reducing transport costs and emissions (Bubner et al., 2014).

However, several crowdshipping services depend on dedicated trips typically performed by private motorised vehicles with potential rebound effects, such as increased travel times and fuel consumption (Paloheimo et al., 2015).

In order for crowdshipping to prove beneficial, it should be developed as an "environmental-friendly" service. The best way to do so is to substitute dedicated with non-dedicated trips given the least polluting trip is the one not performed. Therefore, it is necessary to study delivery models able to use the already existing commuter's trips without generating additional ones.

The paper innovates by focusing on the use of public transport to deploy crowdshipping services. The paper explicitly does not consider private transport to foster sustainability goals in freight transportation.

It investigates crowdshipping from the supply side (act as a crowdshipper) with the goal of obtaining an overall picture of the relevant issues for its development.

The case study refers to the city of Rome, Italy, with 2,875,447 inhabitants, more than 700,000 trips in the morning peak hour generating about 135 million of hours lost in traffic. In the city centre, 32,700 freight vehicles operate on a daily basis with over 35,000 loading and unloading operations (Danielis et al., 2011).

2. Literature review

Crowdshipping, alternatively termed crowd logistics, crowdsourced delivery, cargo hitching or collaborative logistics, makes use of the excess capacity of available transport modes by using premeditated trips to perform such deliveries (Buldeo Rai, 2017).

Savelsbergh and Van Woensel (2016) report the case of Walmart (2013) which contemplated to get its *in-store customers* (occasional drivers) to deliver items that its *online customers* have ordered. Moreover, it aimed at guaranteeing same-day delivery to online customers, thus requiring employing company drivers in addition to occasional ones. From a city logistics perspective, offering such a service will further increase the number of freight movements, as it will make the coordination and consolidation of direct-to-consumer deliveries even more challenging.

Slabinac (2015) reports the DHL case, a German logistic service provider that implemented crowdshipping in Sweden (MyWays, DHL, 2013). DHL engaged incentivized individuals on their way to provide last mile delivery services from a retailer to a shopper's home by using an *ad hoc* mobile application. Amazon is also exploring settings similar to those used by Walmart and DHL for crowdshipping (Bensinger 2015).

Due to the recent deployment of crowdshipping initiatives around the world (Marcucci et al., 2017a), academic research started to investigate this subject, focusing on both the characteristics of the service and on the related optimization problems. Archetti et al. (2015) formulated Walmart's vision in a new variant of the vehicle routing problem: Vehicle Routing Problem with Occasional Drivers (VRPOD). Walmart has a fleet of capacitated vehicles and drivers available to perform deliveries, as well as occasional drivers. The company seeks to satisfy customer demand (i.e., perform all deliveries) at minimum total costs. The paper addresses the problem using a multi-start heuristic procedure: results show that employing occasional drivers can produce significant benefits, as well as choosing an appropriate compensation scheme for them.

Marcucci et al. (2017b) investigated the necessary pre-requisites a crowdshipping service has to satisfy so to be successful in the urban freight delivery market. The study represents a preliminary investigation, focusing on a survey of 200 students from the University of Roma Tre in the city of Rome. The paper reports that 87% of the students stated their willingness to act as crowdshippers, but this percentage decreases as a function of greater delivery box dimensions and of lower remunerations. On the other hand, 93% would accept to receive goods via a crowdshipping service. But the percentage would drastically decrease if customers cannot contact the crowdshipping

company, if there is no direct contact with the crowdshipper or no package tracking is possible/available. Another interesting result is the maximum possible deviation from the usual path followed that ranges from 1.5 km, in case a non-motorized mode of transport is used, to 3.1 km for private transport.

Buldeo Rai (2017) systematically analysed a set of 42 papers and interviewed 11 logistic practitioners in order to reconstruct the state of practice of crowdshipping. The study suggests that three characteristics substantially affect the sustainability of such an initiative: third party involvement, crowd motivation and its modal choice.

Punel and Stathopoulos (2017), using stated choice experiments, investigated the factors influencing the acceptability and preferences for crowdshipping. They provide first key insights into the attributes affecting preferences for goods delivery performed via occasional drivers. The paper investigates delivery scenarios performed by non-professional shippers, compares them to traditional shipping options and evaluates them assuming a service user's point of view (i.e. demand side).

3. Methodology

The paper uses stated preference (SP) exercises to identify the most important features associated with the choice of acting as a crowd-shipper (i.e. supply side of the service) and discrete choice models to study the underlying behavior.

The adoption of this methodology derives by the need to make it clear how the individual variables can influence the choices of the respondents and, for our knowledge, no other realistic option is available to investigate this specific and innovative service in such a theoretically robust and quantitatively oriented fashion.

The SP scenarios are developed with reference to the city of Rome and its metro network for B2C deliveries. The paper assumes packages can be picked-up/dropped-off in Automated Parcel Lockers (APL) located either inside metro stations or in their surroundings.

3.1. Survey and Data description

Data were collected by administering 240 interviews to metro users in the city of Rome in October 2017. Interviews have largely been performed through social media and e-mail, while approximately one third were carried out "face to face" in metro stations.

Four main sections compose the survey:

1. Socio-demographic: collects gender, age, level of education, employment and behavioral variables useful to detect a "green" attitude;
2. Travel reconstruction: this section aims at detailing the characteristics of the main home-based trip for both weekday and weekend by metro lines;
3. Stated preferences scenarios: using hypothetical crowdshipping service's features, it investigates the role location of delivery points (APL), remuneration, delivery booking and alternative bank crediting modes (Table 2) have in stimulating people to act as crowdshippers. Remuneration, was set considering current shipping costs in the B2C market and the rates applied by existing national crowdshipping companies; the feature "delivery booking" represents the high or low flexibility of the crowdshipper to react to an on-line request of delivery.
4. Additional behavioral statements: this section aims at discovering further service characteristics' perceptions as well as specific issues such as the willingness to deviate from the usual path (leaving the usual metro stations or moving outside them).

Table 1 presents a summary of respondents' socio-demographic characteristics. Although the sample does not perfectly reflect census data distribution for the entire population of Rome, the high number of young respondents moving for study/work represents an added value for the purpose of the study, since young people are typically more keen to use crowdshipping platforms. Indeed, some studies suggest that web surveys have high rates of technologically advanced respondents (Kwak and Radler, 2002). As it is for the green attitude (GA), it has been

measured in terms of four levels (no GA, low, medium, high), associating a weight to specific pro-environmental behavioral attitudes. These attitudes relate to the interest in environmental problems, as well as to the adoption of sustainable transport modes or the use of organic products. Each attitude has been assessed through a Likert scale during the survey: 74% of the respondents self-stated a medium level of green attitude (Figure 1, a).

Home-based trips stated by respondents and involving the use of the metro are mainly taking place in the morning peak (79%). A similar frequency for the work-to-home trips in the afternoon is due to the fact that the investigated trips are mainly commuter trips taking place during weekdays (84%). Access/egress to/from metro stations is usually performed by walking (52.9%) and the average travel time associated to the entire is of approximately 50 minutes.

Table 1. Socio-demographic characteristics of the sample

		Sample size	Sample [%]	Entire Pop [%]
Gender*	Man	105	46.7	46.7
	Woman	120	53.3	53.3
Age*	15-30	95	42.2	16.5
	31-44	67	29.8	23.0
	45-58	40	17.8	26.5
	>58	23	10.2	34.0
Level of education**	Primary school diploma	2	0.9	16.9
	Middle School diploma	12	5.3	28.0
	High school diploma	146	64.9	36.5
	University degree (any level)	55	24.4	15.1
	Post university degree	10	4.4	3.6
Professional status**	Busy	104	46.2	47.9
	Student	70	31.1	7.7
	Withdrawn from work	12	5.3	22.4
	Working student	5	2.2	-
	Housewife (no man)	21	9.3	10.5
	jobless	13	5.8	11.5
Income	< 5.000 €	73	35.3	
	€ 5,000 - € 10,000	27	13.0	
	€ 10,000 - € 20,000	66	31.9	
	€ 20,000 - € 30,000	28	13.5	
	€ 30,000 - € 40,000	11	5.3	
	€ 50,000 - € 80,000	1	0.5	
	> 80.000 €	1	0.5	

* Resident population 1st January 2017, age group 16-99 (ISTAT data – http://demo.istat.it/)
** 2011 Census, age group 16-99 (ISTAT data - http://datiopen.istat.it/)

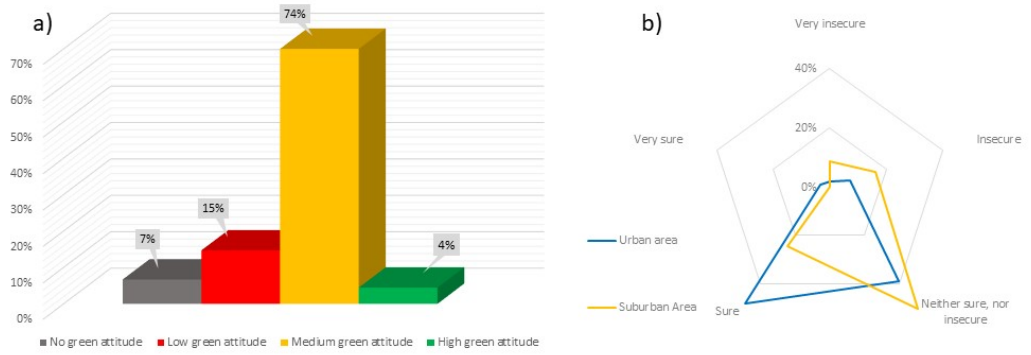

Figure 1. Green Attitude levels (a) and level of trust on the success of the service (b)

Choice alternatives for SP scenarios were constructed via a Bayesian D-Optimality efficient design developed using JMP® (by SAS) statistical software. Bayesian designs use the results of a pilot survey (i.e. utility-neutral design, see Zwerina, 1996) as an input to develop the final questionnaire and D-optimality aims at minimizing the determinant of the covariance matrix of the model coefficients and maximize the expected value of the chosen alternatives (Kessels et al., 2011).

Each respondent was given three choice exercises with three alternatives: two unlabeled linked to a crowdshipping service (i.e. option A and option B) and a "no choice" option. This last option represents the *status quo* service that does not imply the use of a crowdshipping service. The decision to include the "no choice" option increased the realism of respondents' estimated preferences (Bateman et al, 2002). However, the strategy could also lead to a serious reduction in the information gathered (Dhar, 1997). Thus, to avoid this problem, respondents who picked the "no choice" option were, subsequently, forced to express a preference between alternative A or B.

The optimal design generated using the JMP® software produced four different questionnaire blocks each including three choice's exercises for a total of twelve different attribute levels' combinations.

Table 2. Description of features and levels for the SP scenarios

Description of the features of the service	Levels
Location of APL	● Inside metro stations (+1) ● Outside metro stations/adjacent buildings (-1)
Remuneration	● 3 €/delivery (+1) ● 1 €/delivery (-1)
Delivery booking	● Real-time booking (+1) ● Off-line booking (-1)
Bank crediting modes	● Single delivery (+1) ● Every 5 deliveries (-1)

With reference to the maximum deviation from the usual path, it is interesting to note that about a half of the sample (43.1%) is not willing to modify the path if the APL is outside the metro stations; 39.2% would accept to deviate the path for a 300 meters maximum. Only 15.3% is willing to travel an additional distance of 600 meters, while the percentage of those willing to travel more than 600 meters is negligible.

Finally, the respondents were asked to express a judgment on the chances of success of the crowdshipping service both in urban and suburban areas, under the hypothesis of expanding it using APL located in the main stations of the entire metro and urban rail network of the city. In the urban case, the majority of the sample (48%) foresees a successful service while 39% are not sure. As for the suburban area, the percentage of respondents confident in a success of the service decreases to 24% (Figure 1, b).

4. Results

4.1. Econometric results

A multinomial logit model was estimated where three independent choices are represented: option A, option B, and "no choice" (as in the SP scenarios). Agents' systematic utility function is reported below, where in the no choice option a socio-demographic variable (Age) is added to the specific constant attribute:

$$V_A = \beta_1 * \text{Location of APL}_A + \beta_2 * \text{Remuneration}_A + \beta_3 * \text{Delivery booking}_A + \beta_4 * \text{Bank Credit Mode}_A$$
$$V_B = \beta_1 * \text{Location of APL}_B + \beta_2 * \text{Remuneration}_B + \beta_3 * \text{Delivery booking}_B + \beta_4 * \text{Bank Credit Mode}_B$$
$$V_{\text{no choice}} = \beta_5 * \text{Age} + \text{ASC}$$

The estimation process followed a two-stage approach based on a maximum likelihood approach:

1. the first stage estimates only the coefficients used to characterize the crowdshipping service (coefficients related to the features of Table 2). We used the Firth method for bias correction to improve estimates (Firth, 1993). The Firth method suggests that the dominant term of the asymptotic distortion of the maximum likelihood estimator can be removed by appropriate modification of the score function. To respect block balance used in the experimental design, the estimation was performed using the same number of surveys for each of the four questionnaire types;
2. the second stage tested socio-demographic (age, level of education) and attitudinal variables (green attitude) in the model. For these attributes, it was possible to use the entire sample without the equilibrium constraint previously adopted with the Firth method. However, only age, adopted as a continuous variable, proved to be statistically significant (Table 3), showing that older people are less interested in working as crowdshippers.

The sample reconstitution, i.e. the number of times the model is able to reproduce the right choice of the users, is equal to 62%, while the average modal share error is equal to 39% mainly due to the difficulty of reproducing the "no choice" option.

Table 3. MNL: parameter estimates, fit statistics and validation

		MNL			
		Coeff. (β)	Stand. Error	T-test	P-value
Attributes	Age	0.0473	0.0111	4.25	0
	Location of APL*				
	Inside metro stations	0.5940	0.0706	8.42	0
	Remuneration**				
	3 €/delivery	0.4890	0.061	8.02	0
	Delivery booking***				
	Real-time booking	0.3350	0.0683	4.90	0
	Bank credit mode****				
	Single delivery	0.5330	0.0698	7.64	0
	"no choice" [ASC]	-3.390	0.483	-7.03	0

*base level: "Outside metro stations/adjacent buildings"; **base level: "1 €/delivery"; ***base level: "Off-line booking"; ****base level: "Every 5 deliveries".

Model Fit Statistics	MNL
N. of observations (individuals)	627 (209)
Null log-likelihood	-688.83
Final log-likelihood	-489.293
Likelihood ratio test	399.074
Rho-square	0.290
Adjusted rho-square	0.281
Simulation test	
Sample reconstitution	62%
Average modal share error	39%

Explorative calibration exercises have been also conducted introducing the "not interested" option in the model: i.e. a systematic utility function for those respondents not participating to the SP experiment, since they are not interested in the crowdshipping service at all. Preliminary results showed that introducing the "not interested" option

leads other attributes as the green attitude to be statistically significant. Specifically, a higher green attitude contributes to the choice of one of the two alternatives of being a crowdshipper.

Moreover, given the presence of several features in the SP choice exercise, a question has been included in the survey to identify the possibility that the respondent focuses more carefully on a specific feature with respect to the others. Therefore, it was possible to identify four types of respondents: the "basic" interested in the bank credit mode in order to obtain an immediate gain, the "static" interested in the location of APL inside the metro stations, the "dynamic" interested in higher remuneration, the "flexible" interested in the real time booking. If the estimation process is conducted on these sub-samples, a variability of the concept of utility is founded for each class that deserves to be investigated in the future increasing the sample. Clustering techniques, such as K-means (Likas et al., 2003), could be adopted to this aim, dividing the sample on the bases of similarity criteria and improving the significance and the reliability of the final behavioral model.

4.2. Policy Implications

One can use the estimated MNL probabilities to simulate the probability of choosing each alternative assuming different service specifications and potential crowdshipper characteristics (Figure 2). As far as the characteristics of the service are concerned, all possible combinations of the investigated features are analyzed, while for the "no choice" scenarios, the age attribute is fixed. Specifically, three possible profiles assume different crowdshippers' age are considered:

- Profile 1: considers a crowdshipper aged 50 representing the average age of the population in Rome (Pop. Roma in Figure 2);
- Profile 2: assumes a young population with an average age of 25 (Young people in Figure 2);
- Profile 3: focuses on an elderly population with an average age of 65 (Old people in Figure 2).

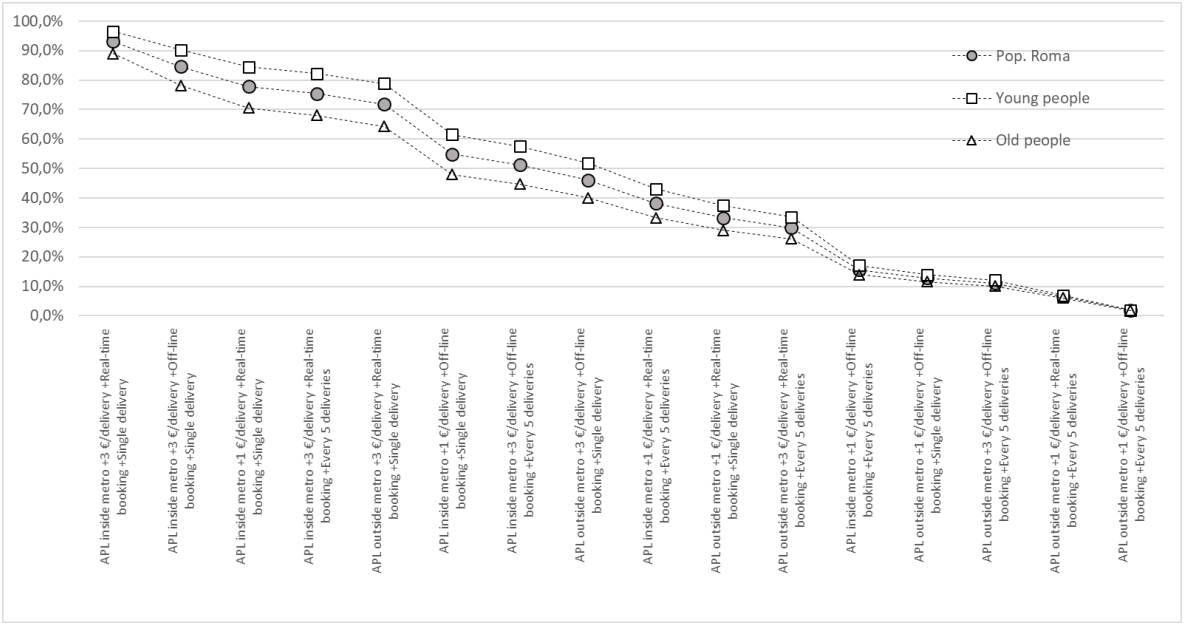

Figure 2. Probability of acting as a crowdshipper with respect to the characteristics of the service (level of service) and the characteristics of the potential crowdshipper (Age)

Figure 2 shows that the probability to act as a crowdshipper ranges from very low to very high values. Most important changes are due to the proposed service conditions (level of service). It is interesting to observe also a variability of the probability of acting as a crowdshipper as a function of individual characteristics. This variability

is small between the profiles representing the population of Rome and the young people, while it is evident with respect to the elderly people.

Crowdshipping initiatives in Rome are still few and mainly linked to the food sector by dedicated trips. This is the case of Foodora, that delivers food from restaurants to homes and Take my things/LoPortoPerTe that recently matched together, also plan to operate in Rome.

From the analysis of these existing crowdshipping companies, as well as other national and international experiences, all the operating platforms actually require an off-line booking of the service, while a remuneration is provided for each individual delivery. By fixing these features of the service, one can simulate scenarios as reported in Table 4. Applying these scenarios to the case study, one can calculate the probability of acting as a crowdshipper among Rome's metro users. These probability ranges from 86.4% to 12.8%. The lower percentage is due to the need to reach locations outside the metro stations and to the low remuneration. If delivery points are located inside the metro stations, despite the low remuneration, it is possible to reach the 54.8%.

Table 4. Possible scenarios with respect to the actual crowdshipping platform conditions

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Location of APL	Inside metro stations	Inside metro stations	Outside metro stations/adjacent buildings	Outside metro stations/adjacent buildings
Remuneration	3 €/delivery	1 €/delivery	3 €/delivery	1 €/delivery
Delivery booking	Off-line booking	Off-line booking	Off-line booking	Off-line booking
Bank crediting modes	Single delivery	Single delivery	Single delivery	Single delivery
Probability to act as a crowdshipper	*86.4%*	*54.8%*	*46.0%*	*12.8%*

If we consider that the potential demand of crowdshipping service is generated by the inhabitants located in the surrounding area of the metro stations (adopting a catchment area of 800m radius for each stop), assuming 2.62 orders per day per 100 inhabitants (B2C delivery of small packages), it is possible to obtain a first estimate of the number of orders per day for crowdshipping by metro in Rome. Then, one can compare the demand with the potential number of available crowdshippers in the different scenarios of the service.

Table 5. Comparison between crowdshipping demand and supply based on public transport in Rome

SCENARIO	Metro users*	Inhabitants**	Probability to act as a crowdshippers	Potential crowdshippers		Potential demand*** [orders/day]	Demand satisfied
SCENARIO 1	113'347	647'154	86.4%	97'932	↔	21'317	> 100%
SCENARIO 2	113'347	647'154	54.8%	62'114	↔	21'317	> 100%
SCENARIO 3	113'347	647'154	46.0%	52'140	↔	21'317	> 100%
SCENARIO 4	113'347	647'154	12.8%	14'508	↔	21'317	68%

*Users of the Rome's metro lines during the peak hour (Roma Mobilità, STATUS 2016).
**Inhabitants in the 800'meters catchment area (elaboration from census data ISTAT 2011).
***Considering an on-line daily purchase rate of 2.62% per inhabitant (elaboration of data from the following sources: Politecnico di Milano, Netcomm, BEM Research, 2016-2017).

The comparison actually results in a surplus of supply with respect to the demand at least for the first three scenarios. However, these computations do not consider the real frequency of acting as a crowdshipper, since it is assumed that each potential crowdshipper is available every day of the week. Moreover, considering that the degree of penetration of e-commerce in Italy is about a third compared to many countries in the Euro zone, future research are needed to investigate the evolution of e-commerce demand in the short-medium term, as well as the willingness to use the crowdshipping service with respect to traditional shipping services.

5. Summary and conclusions

Crowdshipping as a service to deliver goods in the last mile is progressively being deployed throughout the world and some examples are also present in Italy (e.g. Deliveroo: https://deliveroo.it/it/, Foodora: https://www.foodora.it/, Take my things/LoPortoPerTe: http://www.takemythings.com/).The highest potential impact of this innovative service is linked to e-commerce and food/groceries-related deliveries. While innovative and with a relevant potential, both economic and environmental, he success of this service depends on the way it is organized and performed. In fact some authors (e.g. Buldeo Rai et al., 2017) while acknowledging the potential improvements that can be reaped when efficiently using spare capacity also suggest that when delivering freight via the crowd one make use of dedicated trips, much, if not all of the potential economic and environmental benefits might well vanquish. As a matter of fact one can possibly argue that due to rebound effects the final situation could be characterized by worst conditions compared to the starting point.

Departing from this critical point the paper investigates with respect to the specific case of the city of Rome under which conditions people already moving from point A to point B for work/school related purposes would act as crowdshippers. More in detail the paper studies specific segments of the population that are travelling by metro. The idea is to involve people using public transport which, on average, impose lower environmental and congestion costs on society (Gori et al., 2012, 2013) and additionally, and even more important from our point of view, to deliver freight within the city in a timely and efficient manner without adding any trip to the network. We believe the most efficient crowdshipping service from all points of view is the one based on non-dedicates trips. If this is true, one has to focus on commuters using the metro rather than bus users as a main mode of transportation since the former service is typically more frequent and reliable thus making an additional stop or detour acceptable also for low compensations which are typical for last mile deliveries. Engaging a sample of metro users this paper investigates which proportion of commuters would be willing to operate as crowdshippers given different service configurations. Results, while preliminary, are encouraging, in fact there is a high confidence in the success of the service (about 48% of the sample) and the estimated number of potential crowdshippers for the case of Rome is actually higher than the potential demand.

The main weaknesses of the paper are those typical of any stated preference study, which are mainly related to the hypothetical bias issue. Moreover, additional features require to be investigated in the short-term development of the research, as the frequency the user is available to work as a crowdshipper, or if the freight type has an impact on this choice.

The main strength of the paper is the broad identification of the most relevant instruments/service characteristics to work with in order to develop a crowdshipping service that can rely on a sufficiently large base of potential crowdshippers so to be able to provide a reliable solution to a substantial number of delivery requests. The knowledge acquired will be shared with Rome Mobility Agency who has informally already manifested an interest in this research and would like to explore possible service configurations to be tested in a real life pilot study.

The joint increase in the amount of small-volume/ low-weight/ high-value parcels in the future linked both to e-commerce in general and to the development of high-end e-groceries services offered by retailers ‘ distribution chains and the concomitant opening of the C-metro line in Rome suggest investigating this freight distribution mode in great detail.

Thus, future research activities include: 1) increase the sample size to detect specific users sub-samples with specific characteristics amenable for the development of a crowdshipping service; 2) study the demand side of this specific crowdshipping so to discover if it is possible to develop a pre-business pilot study; 3) quantify the environmental effects one can obtain by the development of crowdshipping by public transport (reduction of environmental pollutions, noise and climate-change emissions); 4) verify the feasibility of the service through an economic-financial analysis; 5) define how to link the regular logistic chains with the new service and the new potential operators; 6) evaluate if the green-label associated to crowdshipping by public transport can enhance the business of the company operating in this sector; 7) work on the logistic network design, defining the optimal structure of the network and nodes location.

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