An innovative approach in last mile food delivery system to reduce social and environmental impacts

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Abstract: The social and environmental sustainability of goods delivery is a challenge, especially for urban areas. In recent years, last-mile delivery of food has undergone considerable development due to innovations in ITC and the emergence of delivery service providers with a crowdsourcing approach. These approaches which on the one hand have facilitated food delivery activities, on the other hand have highlighted several issues, such as unsustainable labor times and high workloads for riders, with safety implications. This paper proposes an innovative model to improve employers' working conditions, public safety and environmental impacts, including economic aspects as well. The idea is based on using urban shared e-scooters service in defined time windows to deliver food, without affecting the level of sharing service for users. The sustainable evaluation of the framework of a conceptual model is based on the following steps: analysis of environmental impacts, study of economic effectiveness, and analysis of social impacts, by quantifying external costs. A simulation case study is proposed to evaluate the impacts of the proposed model compared with current management. Changing working conditions through defined working hours and appropriate vehicles allows for an impact on safety. The results show that a small reduction in accident risk has a large impact on overall externalities.

Keywords: Environmental and social impact; Rider labour condition; Last-mile delivery of food; E-scooter sharing.

I. INTRODUCTION

Globalization, improved logistics systems, technological innovation, digitalization, and the web market continue to lead the growth of goods delivery: products can be purchased anywhere and goods travel around the world through integrated systems. In addition, the increase in population within urban areas requires greater efforts in last-mile delivery activities, as most goods are delivered right in cities. In the view of a sustainable approach to the processes of logistics, transportation, and delivery of goods, it becomes necessary to improve the least efficient link in the supply chain, which is the last-mile logistics [1]. High demand for goods and less efficient transport processes in urban areas, due to the huge amount of people and to the high rate of delivery, generate greater externalities or external costs [2]. Air pollution, climate change, noise pollution, congestion, accidents, infrastructure wear and tear, oil dependencies are the main externalities due to urban transportation [3].

In recent years, food delivery activities has seen significant changes. The sale of food, including ready-to-eat food, for home delivery, has seen considerable development due to the emergence of delivery service providers (such as Deliveroo, Ubereats, etc.) that directly link users with vendors, via ICT systems and smartphone application. The consumer involvement in supply chains is transforming the shipping industry [4]. Therefore, today users can buy from stores or restaurants located in different places in the city and receive food at home. The increase in this demand is due to both the period of the pandemic and new social styles brought about by new innovations. Vendors have realized that this service is in demand and represents a new business opportunity, so they are quickly adapting through two main types of delivery: by personal means or as is increasingly the case by outsourcing it to a food logistics provider, as aforementioned. Food logistics providers in urban areas were born with the idea of

crowdsourcing, using riders with their own vehicles to deliver food through notices of pickup at the point of sale and delivery to specified address, via smartphone apps [5]. The vehicles most used for this activity by riders are bicycles, electric bicycles, electric scooters, and so on. These vehicles enable last-mile delivery of food in urban areas in an efficient and sustainable manner. Even the most careful vendors who use their own vehicles are modifying their fleets with electric vehicles, such as electric cargo bikes, electric cars, and electric light vehicles [6]. However, the food delivery service not only generates benefits but also causes issues: riders to have more deliveries and achieve adequate income are forced into unsustainable labour times and high workloads [7, 8, 9]. The consequence is a lower level of rider and citizen through increase accident risk. The challenge is the introduction of methods enable to increase the safety of riders and citizens with an environmentally and socially sustainable approach. Based on these assumptions, a research question was posed on the possibility of evaluating improving the working condition of riders in last-mile delivery of food with an innovative environmentally and socially sustainable method.

In urban areas, the mobility of people, in parallel with the delivery of goods, has also undergone significant innovations with the introduction of sharing vehicles systems. The sharing economy allows the same resources to be used by more than one person, increasing the efficiency of the overall system by providing a service much like a private good. Moreover, event at the economic level there is a shift from a goods economy to a service economy. A shift from purchasing items to flexibly accessing them for the time needed does, however, come along with challenges from the perspective of operations management [10].

In this paper, a framework of a conceptual model to perform the last-mile delivery of food with the use of sharing vehicles is proposed. A literature review shows few works in this area and no experience in the use of sharing vehicles for people mobility, including for food delivery. More in detail, the innovative approach is developed on the use of e-scooters free-floating sharing services in the city for people's mobility in specific time windows, in order to define exactly the working hours. The shared vehicles are located at different points in the city, which allows for quick use. In addition, such vehicles are safer as they are geolocated, have pre-set speed based on different areas of the city and are periodically maintained. The use of shared vehicles allows for increased sustainability of the last-mile delivery of food. The paper is organized into four other Section: urban micro-mobility with sharing services is described in Section 2; the methodology is explained in Section 3. A simulation case study is proposed in Section 4. Finally, Section 5 presents conclusion and future works.

II. URBAN MICRO-MOBILITY WITH SHARING SERVICES

The evolution of cities and mobility needs has led to the emergence of innovative solutions to deal with the so-called "last mile" problem, i.e., the last section of the trip between the main arrival point and the final destination. In this context, urban micro-mobility with sharing services has gained increasing popularity as a sustainable and efficient alternative. The use of shared electric bicycles and scooters, for example, allows citizens to quickly reach their destinations without having to deal with the traffic and parking problems typical of private vehicles and at the same time overcomes the limitations of public transportation [11]. Current data indicate a significant increase in the use of such sharing services in urban areas, demonstrating a shift in mindset and growing adoption [12].

In the modern era of increasingly dense and busy cities, the concept of urban micro-mobility with sharing services is emerging as a promising solution to address the "last mile" problem. This term refers to the short trip between the main arrival point, such as a train station or bus stop, and the user's final destination. Sharing services, which offer bicycles and electric scooters as shared means of transportation, represent an agile, sustainable and efficient form of urban mobility.

Current usage rates of these sharing services are steadily increasing in major urban areas around the world. Citizens are increasingly inclined to use shared bicycles and electric scooters as last-mile transportation options [13].

This can be attributed to several factors, including growing environmental awareness, traffic congestion, and difficulty in finding parking. People are looking for flexible and convenient solutions that allow them to reach their destinations quickly and easily while avoiding the inconvenience of conventional private transportation.

Urban micro-mobility with sharing services is a promising option for last mile logistic, offering

advantages in sustainability, efficiency over conventional private vehicles [14].

It is interesting to explore the topic of last-mile food deliveries [15] trying to understand how this service can be implemented with the use of the e-scooter sharing fleet [16].

The growing usage rates of shared electric bicycles and scooters are evidence of the popularity and effectiveness of these alternative means of transportation. Specifically, the graphs in Fig. 1 and 2 show the usage rates of shared bicycles and scooters in Italy [17].

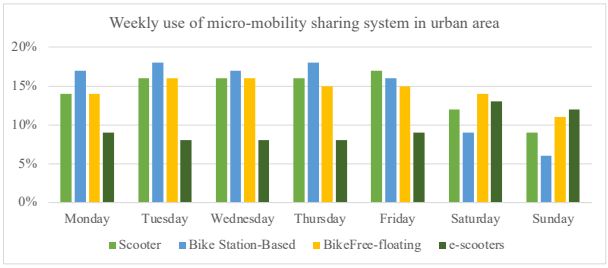

Figure 1. Italian weekly use of sharing services in urban area for different vehicles

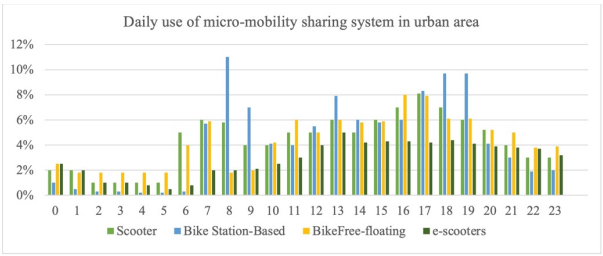

Figure 2. Italian daily use of sharing services in urban area for different vehicles

An important observation is that the rider who will use the sharing e-scooter to make deliveries will turn into a regular user, so he/she will no longer have the characteristics of the occasional user who usually uses sharing but will increase his driving aggressiveness.

This will have consequences on accidentality, if we also add that the rider who will make deliveries has high driving aggressiveness because he/she needs to optimize his/her time to increase his/her profit and efficiency.

According to the data from the local police of the municipality of Bari, in Italy, for the years 2021-2022, only 28% of the crashes occurred with electric sharing scooters, while all the others occurred with private scooters, it must be taken into account that this percentage will no longer be valid when a policy is implemented that favours the use of sharing scooters to riders. At the same time, however, the safety of the user will be protected by the safety systems that only sharing vehicles have.

Safety is a key aspect in the adoption of these sharing services, and from this point of view the shared vehicle offers advantages over the private one.

It is important to note that the e-scooters are available in two modalities, shared and private. According to the 2019 national law (L. 30.12.2018, 2018), Italian cities were allowed to start introducing e-scooter sharing services, delegating each single municipality to develop its own specific local regulation, while respecting general constraints fixed by the government. These general constraints are specified by the national ministerial decree (D.M. 04.06.2019, 2019), which provides more details about how the e-scooter sharing experimentation should be conducted:

- e-scooters must satisfy a number of technical constraints (e.g., power of at most 0.5kW and limited maximum speed of 20km/h),
- e-scooters are allowed in pedestrian zones with speed limiters to keep speed below 6 km/h, in shared bicycle-pedestrian lanes, bicycle lanes and 30 km/h zones, provided they are equipped with speed limiters to keep speed below 20 km/h [18].

In addition, sharing service providers often promote the adoption of safety equipment, such as protective helmets, to ensure an even safer riding experience, and scooters are becoming increasingly rich in useful accessories to improve safety, such as the case of the arrow to indicate lane changes, and finally, the sharing vehicle has a gps that can come in useful for safety purposes because it allows the e-scooter's trip to be tracked. The availability of dedicated infrastructure, such as bike lanes, mixed lanes with priority, and reserved lanes, helps to further improve the safety of users of these sharing services [19, 20]. The presence of dedicated infrastructure is a crucial factor in the safety and effectiveness of sharing services. Creating protected bike lanes and reserved lanes for electric scooters helps separate micro-mobility vehicles from vehicular traffic, reducing the risk of crashes [21, 22]. Implementing urban policies that promote the accessibility and safety of sharing services can encourage greater population use.

III. Methodology

In the last-mile logistics, literature proposes five categories of innovations to reduce the negative externalities generated: innovative vehicles; proximity stations; collaborative and cooperative logistics; optimization of transport management and routing; innovations in public policies and infrastructures. The food delivery business can be improved by using some of these innovations. An example is the collaborative and cooperative logistics approach, in which urban consolidation centres are implemented in many cases with shared

transportation means. The use of sharing vehicles is an economic and environmental opportunity due to the increase in both the vehicle utilization ratio and the load space saturation ratio. This makes it possible to invest in more sustainable vehicles (e.g., electric vehicles) as they payback time becomes short and to have a shorter fleet turnover rate. Last mile delivery of food is an activity with goods that are not bulky and small in size. Therefore, especially in the delivery of ready-to-eat products, a shared urban micro-mobility vehicle approach could be an opportunity. The analysis of data reported in Section 2 shows both a decrease in use of shared urban micro mobility vehicles on weekends and off-peak during the night and in times of day related to food consumption (lunch and dinner). Exactly during the periods when it is instead required to be more used by food delivery services.

The proposed approach is based on the idea of using shared urban micro-mobility vehicles, such as e-scooters, for last-mile delivery of food in time windows tied to the period of highest demand, by service provider riders. Limiting delivery service to certain time windows would increase working conditions for riders. In addition, this can further reduce the transport externalities from last-mile delivery of food without at the same time affecting the level of service provided by sharing systems for people mobility. In fact, as the data show, during the lunch and dinner hours the use of these vehicles is lower than other times of the day, so additional users do not significantly compromise the level of service provided. However, this is true considering a use for delivery over a well-defined time window. Moreover, riders of food delivery providers have different advantages: i) reduced investment, operative and maintenance costs by turning them into variable costs (there is no need to purchase vehicles, maintain and operate them because they would also be used as a service); ii) reducing the parking issue; iii) increased safety with geolocated vehicles, equipped, and frequently updated with everything required by changes in the law. The use of existing vehicles allows to reduce externalities such as emissions to build new vehicles, land use due to more parking space used, accidents with increasing of the safety condition.

The advantages for the urban micro-mobility sharing providers are related to a high number of possible additional customers (riders) in time windows with a decrease in usage by traditional customers. Then, riders could be represented directly by the food logistics providers to set up an agreement with the mobility providers of sharing services. The large number of users of the food logistics providers and the time windows required for the service could lead to the establishment of a specific seasonal ticket of vehicles use at a highly subsidized price. The idea is similar to the aggregator approach developed in other sectors [23]. There are some examples of time windows seasonal ticket with subsidized prices, for example in public transport for commuters. This also ensure economic sustainability for both riders of food delivery providers and mobility providers of sharing services. In addition, the limitation in number of vehicles in the city and the reduction in emissions also means a social benefits for citizens.

The sustainable evaluation of the framework of the conceptual model proposed is based on the follow steps:

- analysis of the environmental impact: reduction of emissions factors between the existing last-mile delivery of food approach and the proposed approach;
- study of the economic effectiveness: analysis of the actual costs for users of food delivery providers and usable seasonal ticket values based on the time windows approach, through defining the break-even point. The seasonal ticket, preferably monthly, allows for a win-win situation for both parties: sharing service companies can lower the selling price against a secure income over a longer period and can better organize the service itself; the users of food delivery providers can use a service in the time windows they work with an agreed price;
- analysis of the social impact with the reduction of externalities factors affecting riders labour conditions and citizens welfare.

The sustainable assessment of environmental, economic, and social aspects is carried out with the analysis of data and relevant peculiarities of the analysed context. In Fig. 3, a framework of the sustainable conceptual model proposed is shown.

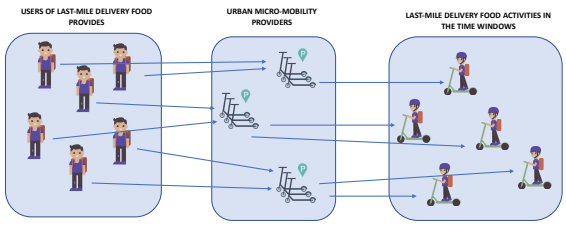

Figure 3. Daily use of sharing services in urban area with time windows

IV. SIMULATION CASE STUDY

The simulation case study is performed considering two scenarios: the first is related to the use of personal e-scooters by the riders of food delivery providers and the second with the use of sharing e-scooters approach of micro-mobility providers service in two time windows (hours 12-3 pm and 7-9 pm). Moreover, the number of riders of the food delivery providers is equal to 300, considering them as an aggregator; investment cost per rider for the purchase of urban vehicle, such as e-scooters, is about 500 €, considering a useful life of 5 years. The annual insurance and maintenance costs considered are respectively equal to 60 € and 40 €. The battery capacity is about 187 Wh (7800 mAh and 24 V) for 30 km, useful for one day; the electricity price is 0,40 €/kWh, and a daily recharge is assumed. This means an amount equal to 0,075 €/day. In a work period of 300 days per year, the amount for electricity is equal to 22,5 €. An agreement between the food logistics providers and the mobility providers of sharing services is achievable. The manufacture of each e-scooter needs energy and material resources that generate externalities. In this work, it is assumed that these externalities fall into the air pollution and climate change categories, with respectively 70 € and 46 € per vehicle. In the two scenarios analysed, the external cost related to the use of e-scooters considers only the additional values, excluding the common external costs. So, air pollution, climate change, and noise pollution are not considered. While land use, congestion and accidents have different values between the two scenarios: based on the recent review of the scientific literature on the transport external costs in urban areas [24], an estimation of the differences is reported in Table 1.

TABLE I. ADDITIONAL EXTERNAL COSTS

External cost	E-scooter [€/km]
Land use	0,108
Congestion	0,0012
Accidents	0,142

The additional cost for land use is due to the supplementary number of personal e-scooters parked in the urban area in the time windows, compared to the use of only shared e-scooters, which are already present as a service with an existing number of vehicles. The difference with regarding congestion is very small, since even by increasing the number of parked e-scooters present in urban areas, they have a minor impact on the transportation system. The type of vehicle and its use result in a high hazard also expressed by the data, as mentioned in Section 2. Therefore, the external cost of accident is very high. In this simulation case study, an average annual overall reduction of 5 percent was assumed, given by the increase of working condition due to limit the working time, e-scooters equipped with additional safety devices and correct operating speeds according to urban areas set in the sharing vehicles.

A. Environmental sustainability

The environmental aspects are linked to the use of personal e-scooters for the last-mile delivery of food. In the proposed method the reduction in the number of new vehicles is equal to 300 units. Considering the useful life of vehicles and additional external costs (air pollution and climate change) related to the new e-scooters manufacturing, the saving is about 6.960 € per year. It is a good result for the environmental sustainability of the last-mile delivery of food in urban areas and to reduce the footprint of riders involved by food delivery providers.

B. Economic sustainability

The analysis of economic aspects aims to define the value of the monthly seasonal ticket with time windows in which the proposed method is cost-effective or not. Considering the insurance and maintenance costs, the energy cost and the amortization of the investment cost to purchase the vehicle (based on the useful life and a zero final value), the annual cost of a private e-scooter is equal to 222,50 €. It should be noted that a main part of this value (about 72%) is a fixed cost so even in the case of not using the private vehicle, this annul amount is still addressed. Comparing the service over 12 months per year, the use of shared e-scooters turns out to be economic sustainable if the monthly seasonal ticket with time windows has a price of about 18,50 €. The agreement to ensure a cost-effective value, between the urban micro-mobility sharing company and the food delivery providers as a representative of its riders, is based on the identified price of monthly seasonal ticket. If the months in which the service is used are shorter this value will be higher. Below this value, it will always be convenient to use shared e-scooters compared to the personal e-scooter. Above the value it will be more convenient to use the personal e-scooter. In addition, a further advantage with the use of shared vehicles (understood as a service) it the transformation of all costs from partially fixed to

variable: for example, if as a result of an event for a few months it is decided not to make deliveries, this cost is not addressed, unlike the case where the e-scooter is owned.

C. *Social sustainability*

The social external costs identified in comparing the two scenarios are related to decrease in factors classified as land use, congestion and accidents. Considering the number of vehicles, the work period per year and the average daily distance travelled the saving external cost is about 678.240 € per year. The findings are more related to the significant value due to accidents. In fact, in the case study, a 5% reduction coefficient was considered resulting in a high external cost. This highlights a significant impact by this factor on social costs. Limiting working hours with the idea of time windows improves working conditions and reduces the risks of accidents. Therefore, it is very important to establish proper working conditions, improve infrastructure and safety devices especially for this type of urban micro-mobility vehicles in order to affect the social impact.

V. CONCLUSION

In this paper, an innovative and sustainable framework of a conceptual model for last-mile delivery of food with e-scooters sharing is proposed. The novel approach is based on the use of e-scooters sharing by the riders of food delivery in defined time windows, so the level of service for the traditional users is not affected. A comparative analysis model on the environmental, economic and social sustainability is adopted to evaluate if the proposed approach achieves best values than the use of private e-scooters and improve the working conditions. The assessment uses external costs to evaluate the differences in social and environmental impacts through analysis of air pollution, climate change, land use, congestion and accidents. In addition, a cost analysis approach is adopted to identify the economic value where the proposed approach become cost-effective.

A simulation case study is carried out to assess the possible increase in sustainability with the adoption of the proposed model compared to the actual condition. The findings highlight how a group of riders able to form an aggregator can improve performance from environmental, economic and social perspectives by using shared e-scooters in detailed time windows. The main impact is related to accidents, so increasing the working conditions of riders significantly affects the results.

The proposed framework for the conceptual model is a preliminary discussion for future developments and insights. The innovative approach on an important social topic related to the riders' working conditions and last mile food delivery activities in urban area is addressed with new solutions of operations management. As the results show, these issues affect not only riders but also safety of citizens. Therefore, the public role becomes a significant activity in regulating and resolving these issues. The law already provides this opportunity for municipalities, and the social aspects are responsibility of public authorities. Moreover, in this light, the representative role of the riders aggregator in bargaining activity with mobility providers could be assigned to a public entity. This facilitates agreement for a cost-effective price of vehicles sharing use in defined time windows and regulates last mile delivery of food in the urban area. In the next step, a real case study applied to an Italian city will be developed.

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