

Bivariate Analysis of the Influencing Factors of the Upcoming Personal Mobility Vehicles (PMVs) in Palermo

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Abstract. The micro-mobility sector is spreading in the Italian and European urban context. The use of micro-mobility vehicles is often adopted to reach areas with particular transit restrictions or to avoid the problem of parking and congestion on the roads. Although personal mobility vehicles (PMV) are characterized by a growing technology, they still have problems related to driving safety in shared road spaces, not only for the inadequacy of infrastructure but also for some regulatory deficiencies and user behaviour. The Italian legislation is very recent and regulates the operational characteristics of the various vehicles and limits their use to certain age groups and in some areas of the cities. The present work focuses on the analysis of the attitudes and perceptions of a sample of users using micro-mobility in the centre of Palermo, one of the metropolises of Southern Italy. The results were obtained by administering questionnaires to a sample of specific users and the data were studied through a bivariate statistical analysis that highlights the significance of the comparison between two variables. The sample was chosen in collaboration with an association of citizens that promotes group activities by moving with means of micro-mobility in Palermo. Several correlations between the variables were addressed and among these some socio-economic ones were related to the propensity to rent and the perception of safety during the use of PMVs in Palermo. From this comparison, conclusions and notes useful for further research steps emerge.

Keywords: Micro mobility · PMV · Bivariate analysis · New mobility users

1 Introduction

Three factors that characterize the success of mobility in an urban context are related to

- the regulation of the society promoting standards for sustainable and resilient mobility.
- industry and its innovative, low-impact processes.
- citizens defined as users of goods and services who have to implement policies and strategies to protect the environment and the city.

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The development of mobility is part of this approach, adopting various forms of transport that may not favor motor vehicles, in order to reduce noise and environmental impact and thus traffic congestion.

Micro-mobility is one of the types of means of transport that provide a potential reduction in congestion. It is often believed that this transport system can replace or complement walking. Unfortunately, it is not yet clear how these electrically powered devices can contribute to the reduction of greenhouse gas emissions [1].

At present, the macro-category of PMVs generally includes electric bicycles, scooters and mopeds to which other vehicles used mainly for recreational purposes (e.g. segways, hoverboards and monowheels) have also been attached for less than a decade, the latter being governed by regulations are still under development for many countries. Among the problems that characterize the PMVs there are the safe parking areas, especially for shared vehicles. In fact, shared micromobility vehicles parked in public have spaces spread in some states of America and Europe and allow users who do not want to buy these vehicles to use them and park them in well-defined areas [2]. Unfortunately, there are now numerous acts of vandalism that cause these vehicles to be thrown into rivers and oceans.

Another negative aspect of sharing is linked to the location of the areas for the acquisition and return of the vehicles, which are only available in certain designated areas, usually central areas and therefore exclude suburban areas or often even areas with multimodal exchange areas. Among the countries where regulation is still difficult to implement is China, where there has been a high increase in sales and use of PMV [3].

The available literature suggests that performance, effort expectations, social influence, perceived risk and policy measures have a positive impact on users' intentions to drive PMV on the road. However, there are some after-effects due to accidents that users have on board these vehicles and that generate health problems caused by the posture and mechanics of the vehicle make the user more exposed to direct impact with the infrastructure, other people or vehicles. For instance, Yarmohammadi et al. [4] describe patients with facial injuries after the use of standing electric scooters and in this case the severity of the injuries highlights this important emerging health risk and policy implications. Users are satisfied to use PMV but the problem of accident risk makes them desist from using them [5]. In addition, there are four adjustment variables: gender, age, level of education and experience while observing others driving PMV on the road. Segways offer older users the opportunity to increase their range of mobility and can also be useful as a training tool. In terms of the physical discomfort caused by these means of transport, no statistically significant differences have been found between the average lower body muscle effort caused by walking and the use of a Segway. The systematic use of a segway can be an interesting option for developing physical training programmes to prevent falls [6].

With the increasing popularity of hoverboards in recent years, several centres have noted orthopedic injuries associated with cyclists. The use of appropriate protective devices, such as wrist protectors, as well as adult supervision, can help mitigate injuries associated with the use of this device [7].

Often the correlation between micromobility sharing and APPs means that they can only be used with a smartphone, connected to a credit card. The literature also finds

that, in terms of safety, casual users sharing vehicles are less likely to wear helmets than owners who use them regularly [8]. An analysis and improvement in infrastructure planning design phases that also consider costs and safety in an integrated manner can mitigate the possible impacts, especially for cyclists and users of PMVs. In particular, the use of IBIM (building information model for Infrastructures) models can help the integrated vision of these aspects and the choice of the best design scheme to be adopted both in the design phase and in the redevelopment of an infrastructure [9].

In addition, the use of technology such as GPS or ITS systems can improve the knowledge of the transport habits of users and control the real time conditions of the transport system. In fact, for a greater control of the sharing service or for the control of the flows from own vehicles or the interaction of the flows of PMV with the other modes of transport, it is useful to develop systems that take into account the interaction and implementation of the dedicated technical platforms [10–12]. Moreover, the perception of the transport service from the perspective of Mobility as a service can facilitate the transport choices of users [13, 14].

Municipal administrators therefore play a key role in the authorisation or prohibition of operators and in defining the conditions under which the service can be provided. The spread of sharing mobility (especially cars and bikes) in different European cities and did not allow different population groups to move easily, considering the need to travel and the motivation to move [15, 16].

Shared micromobility vehicles, starting from the definition of a comprehensive national regulation, will have to circulate according to regulatory standards that define where they can be used (e.g. roads, cycle paths, sidewalks, pedestrian areas,), at what speed (e.g. 30 km/h), after what training, at what age and according to what safety standards (e.g. helmet, lights, direction indicators, etc.). Often devices, such as a helmet, to improve safety when using these vehicles have caused stronger pain and more adequate problems than those used in road cycling [17].

For example, electric scooters have become very popular but with regulatory defects compared to those with “classic” power supply and this poses additional safety problems that require special attention. Looking at possible future developments, micromobility is not necessarily limited to personal mobility, but could also become the way to manage personal deliveries and includes a shared fleet of delivery shuttles or autonomous delivery shuttles for drones that could be made available for occasional (short-term) rental via a smartphone to send or receive small packages within designated areas. Cities have reacted strongly to the advent of shared micro-mobility in different ways, ranging from total prohibition to total openness, with many nuances in between. Some have adapted their policy over time to developments in the sector, although this also includes public reaction. The following paragraphs show how Italy has only recently enacted legislation on the use of micromobility, which in some respects is not yet exhaustive as described in paragraph 2. Moreover, the methodology applied for the acquisition of data related to this research has been considered in a metropolitan context of Southern Italy as reported in paragraph 3. The data were statistically analyzed through a bivariate analysis in order to understand the correlation between the variables and their significance. These results were discussed in the last part of the work, providing ideas for the next stages of research.

2 PMV and Italian Rules

The use of PMV in Italy has recently grown both because of a wide range of choices at lower prices and because they are means that allow unlicensed people to move. Users choose this mode of transfer both to avoid using the private vehicle that tends to congestion on most roads during rush hour, being often only one person on board, and to move in a restricted traffic zone (ZTL in Italy).

After the first road accidents, the Italian government stopped using some electric means of transport, such as segways, hoverboards and so on. Until mid-2019, in fact, Italian law was unable to identify these types of transport. Therefore, the Italian national government decided to make a provisional and experimental decree to observe the behaviour of users after a proposed regulation. In July 2019, a decree (No 162, dated 12 July 2019) was issued by the Italian Ministry of Transport to define electric vehicles, including segways, hoverboards, etc., and how they can be used in urban areas. It states that for the following two years (2020–2021) all electric vehicles can legally circulate in urban areas, but with certain restrictions as follows:

- bicycles and hoverboard seat and gear wheels are excluded;
- hoverboard, monowheel, segway and similar can circulate only on pedestrian area, with a specific limit of speed (6 km/h).
- the users have to put helmet and specific high visibility clothing
- all municipalities have to adopt a specific regulatory to allow electric vehicle circulation.

This decree also authorized the owners of segways, hoverboards and monowheels in Italy, which are self-balanced devices, as well as scooters which are non-self-balanced vehicles and for which energy is supplied. Moreover, municipalities are required to authorise the circulation of these devices on an experimental basis, as well as to provide parking spaces, exclusively in urban areas and only on certain stretches of road. In addition, the rule stipulates that the devices may only be operated by adults or minors with a driving license, which is required in Italy when mopeds and microcars are to be driven. Since 1st March 2020, the new rules on the circulation of electric scooters have come into force, establishing new restrictions and new penalties, for example on the use of PMV by minors who must not be accompanied by more than two, on the devices to be adopted (night lighting, high visibility reflective vests or braces) and the transport of other people, objects or animals is prohibited. For rental services, a specific request will be made to the Municipality where, in addition to the number of licenses that can be activated and the maximum number of devices put into circulation, the obligation of insurance coverage for the performance of the service must be provided. Table 1 below shows the changes made in terms of characterization and use of the vehicles.

Table 1. Main characteristics of the principal PMV in Italy.

From 30th December 2019				
	e-scooter	Segway	Monowheel	Hoverboard
	Equivalent to electric scooters		Recognized as "self-balanced" devices	Equivalent to electric mopeds
Max Power (MP) and speed (MSp)	MP = 0.5 kW MSp = 20 km/ h			
Transport	No transport of passengers No transport of things No trailer			No transport of passengers No transport of things No trailer
Action area	City area Cycle paths on the road, MSp = 30 km/h		Pedestrian and cycle paths; own cycle paths and on a reserved lane; "Zone 30"	Areas defined by Municipality; Pedestrian and cycle paths
Protection device	High-visibility retro-reflective vest. Braces in the evening and at night on the road or on the cycle path			
After 1st March 2020				
Novelties	Road MSp = 25 km/ h; Pedestrian MSp = 6 km/ h. Without lights ban on use in dark hours and bad weather conditions		Play areas the private road of one's own home, as well as on the dock	

3 Methodology

The analysis was conducted by defining an interview format, inviting an industry association to respond. The non-profit association "micro electric mobility Palermo" is composed of about 380 units, today is the only one present in the city.

A total of 133 interviews were collected that is more than 30% of the members of the association. The analysis has been carried out in a context in which many limited traffic areas have recently been established that drastically reduce the presence of vehicles, especially in the historical centre. Several areas in the common area allow an easy use of this mode of transport, amplified by the fact that in the historic centre there are no steep slopes or roads with impervious geometry. The variables taken into consideration and examined through the dissemination of the questionnaire in question are respectively

- socio-demographic attributes
- suitability for the micromobility transport system
- perception of use and environment

With regard to the socio-demographic variables, the following table shows the attributes investigated (Table 2).

Table 2. Socio-economic variable implemented by interview format

	Variable	Possible reply	Variable	Possible reply
Socio-economic	Gender	Male Female	Driver license ownership	Yes only for moped Yes for car and moped No
	Age	<18 18–27 28–45 46–65 >65	Car ownership	Yes No
	Job	Employee Freelance University student Undergraduate-high school student Unemployed	Residence in Palermo	Yes No
	PMV ownership	Yes No	Transport mode ownership (multiple reply)	Car Classic bike/ electric bicycle Scooter/ moped Hoverboard Segway Monowheel

The above variables have been statistically analyzed by evaluating their values in percentage form. In regards to transport attitude, the Table 3 below shows the attributes investigated.

Through Likert's scales, an assessment was made in the second and third sections of the interview.

The values used in the above scale were between 1 and 5 and they relate to the maximum disagreement or agreement respectively. The Likert scale allows for simple data processing and is obtained by measuring opinions and attitudes [18]. It is widely used because it is easy to construct.

The following Table 4 summarizes the attributes under investigation.

A bi-dimensional or bivariate analysis is in general useful to study the influence of different variables as for example in our work considering micro-mobility.

Table 3. Investigated variable related to transport attitude

	Variable	Possible reply	Variable	Possible reply
Transport attitude	Main reason of travel	H-S (home-school) H-W (home-work) H-L (home-leisure)	Average distances daily traveled (km)	<1 1–3 4–6 >6
	Accident experience	Yes No	Micro-mobility APP confidence	Yes No
	Use frequency	Daily basis Several times a week Several times a month Less than once a month	Ownership period	<1month 2–7 months 8–12 months >1 year

Table 4. Investigated variable related to user mode and road perception

	Variable	Possible reply
Mode and Infrastructure Perception	Safety on board	Likert Scale 1 = completely 2 = disagree partially disagree 3 = I can't evaluate 4 = partially in agreement 5 = totally agree
	Economic savings	
	Time savings	
	Willingness to join in groups with the same means of transport	
	Infrastructures safety view	
	Propensity to micro-mobility sharing/rent	
	Propensity to recommend the use of micro mobility	

For the analysis it is necessary to consider a contingency table with columns r rows c.

The $\chi 2$ test procedure may be

- generalized to verify the independence between two
- categorical variables X and Y

In this context the null and void hypotheses are

- H0: the two categorical variables are independent (there is no relationship between the two variables)
- H1: the two categorical variables are dependent (there is a relationship between the two variables)

The test is based the equation below

$$x^2 = \sum_{allcells} (f_{ob} - f_{aw})^2 / f_{aw} \quad (1)$$

The $\chi 2$ statistic is obtained by calculating for each cell of the contingency table the difference squared between the observed frequency (f_{ob}) and expected frequency (f_{aw}), divided by f_{aw}, and then adding the result obtained for each cell. The decision rule is to reject H0 if the value observed of the statistic χ^2 is greater than the critical value χ^2 of the distribution $\chi 2$ with $(r - 1) \times (c - 1)$ as the degree of freedom

4 Study Area of the Research

The analysis focuses on a sample of resident and non-resident users of the metropolis of Palermo located in southern Italy. The users interviewed share the membership of a non-profit association focused on micro-mobility issues. This association as of today is the only one based in Palermo (Fig. 1).



Fig. 1. Source(s) `Micromobilità Palermo - Monopattini elettrici' no profit association

For PMV users, after the fines and the chaos over the rules, the city council approved a resolution that was then transformed into an ordinance of the traffic office to authorize the testing of new means of the so-called electric micro-mobility. This measure is similar to the one issued for tests already started in cities such as Milan, Turin and Pesaro.

This municipal ordinance allowed PMV users to circulate in pedestrian areas, without exceeding 6 kilometres per hour, on cycle paths, while scooters and hover-boards can only be used in pedestrian areas. Vehicles authorized for experimental circulation can be parked in the spaces reserved for bicycles and motor vehicles, ensuring reduced interference with cars and pedestrians. From an infrastructural point of view, since 2010 many cycle paths have been designed in Palermo to connect the

historic centre and the Mondello seaside area with other peripheral areas. From the point of view of transport offer, in the city of Palermo there is the possibility to buy a single ticket for public transport and tram.

In Palermo there is not yet a shared PMV service but only a bike sharing service. The bike sharing service is integrated with the bike sharing service and has been managed by a private company (AMIGO spa) for a few years.

From the point of view of context, the city of Palermo, which has over 600,000 inhabitants and a large percentage of tourists, has undergone a transformation in mobility during the last decade with the growth of numerous day and night limited traffic areas and the presence of many common areas. In particular, the infrastructures of the historical centre such as Via Maqueda, Via Ruggero Settimo and a part of the area called "Cassaro" are located in limited traffic areas, with a low slope and wide surrounding spaces are suitable for the use of these vehicles as described in Fig. 2.

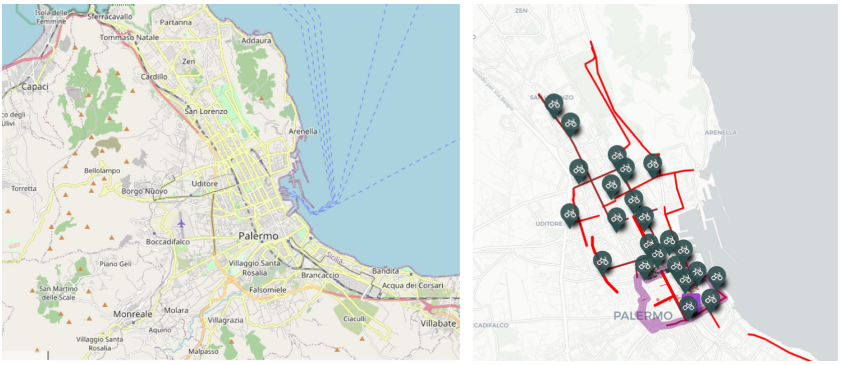

Fig. 2. Palermo maps and Palermo cycle routes (red lines) and restricted traffic area (purple line). (Color figure online) Source: Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org

This research was focused on an interview format administered during the period between 16th of January and 28th of February 2020, with the method of face-to-face interviews. The main purpose of the questionnaire is to acquire information on users with particular reference to socio-demographic data, travel habits and sensations perceived during travel with PMV means. The data were then statistically processed and through a bivariate analysis they were compared in pairs in order to understand the dependency or independence between them.

5 Interview Results and Discussion

The acquired data show that there is gender heterogeneity and in the age group, in fact, there was a higher percentage of male users (68%) than women (32%). As far as the first section is concerned, it was recorded that the sample interviewed is almost entirely resident in Palermo (97%). More than 20% of the sample is between 18 and 27 years of

age, while the highest percentage was recorded as 62% of the sample between 28 and 45 years of age, while the <18 and >65 bands recorded a value equal to and equal to 5%. As far as employment is concerned, a good percentage of respondents are employees and freelancers (32 and 40% of the sample respectively)The motivations for the daily commute by PMV were evaluated in terms of home-work, home-study and home-leisure reasons. It was recorded that the displacement with means of micro-mobility occurs mainly for work (60%) and to follow free time (37%) and school (3%).

As far as the possession of the driving license is concerned, 75% replied that they have one for driving a car, while 15% did not have one. The remaining percentage, on the other hand, concerned only the user of the motorbike with this driving license. About 65% of the sample had a car. Some of the interviewees stated that they rent PMVs in shops for short periods, as there is not yet a shared micromobility service in Palermo. As regards the main mode of transport used daily, the private vehicle (40%) is in first place followed by the assisted bicycle (25%), the scooter (20%) and single wheel (10%). Only 5% use the hoverboard in Palermo.

The second part of the interview investigated the interviewees' experience with PMV means and found that more than 40% of the sample has a small micromobility means that is between 2 and 7 months. In addition, more than 60% of the sample uses micromobility for travel over 6 km (medium distance) and a total of 35% for journeys under 3 km (short distance). As far as the accident aspect is concerned, 18% have already had an accident with the vehicle since they bought it, mostly caused by wet road conditions or poor maintenance. For better mobility, over 90% use dedicated apps, especially with scooters. With regard to the sensations experienced while driving micromobility vehicles in Palermo, the following Likert scale judgements were given in the table below (Table 5).

Table 5. Perception distribution considering Likert scale

	Variable	Distribution of the answers given by the sample according to the Likert scale				
		1	2	3	4	5
Mode and Infrastructure Perception	Safety on board	10%	15%	45%	15%	15%
	Economic savings	5%	12%	63%	12%	8%
	Time savings	2%	1%	7%	55%	35%
	Willingness to join in groups with the same means of transport	12%	3%	55%	25%	5%
	Infrastructures characteristic	1%	0%	29%	58%	12%
	Propensity to micro-mobility sharing/rent	1%	1%	6%	43%	49%
	Propensity to recommend the use of micro mobility	0%	5%	5%	35%	55%

After the statistical analysis, the chi square was evaluated by comparing the following pairs of values in the first section:

- socio-demographic variable (age)
- socio-demographic variable (work)
- rationale for the move

with the variables of the third section

- safety on board
- economic savings
- propensity to micro-mobility sharing/rent

These combinations have been taken into account to understand how much the driving of the micro-mobility vehicle, the petrol saving or wear and tear of a motorized vehicle and the propensity to use non-engineered vehicles varies according to the type of user and the motivation for the journey. These assessments have shown that the following Table 6 shows that.

Table 6. Results of chi square analysis

		$p < .05$	$p < .01$	$p < .10$	Degree of freedom	Result
Age	Propensity to micro-mobility sharing/rent	$\chi2 = 38.022$			16	Significant
	Economic savings	$\chi2 = 52.665$				
	Safety on board	$\chi2 = 48.4678$				
Job	Propensity to micro-mobility sharing/rent	$\chi2 = 33.6527$			16	Significant
	Economic savings	$\chi2 = 47.6266$				
	Safety on board	$\chi2 = 36.1799$				
Moving reason	Propensity to micro-mobility sharing/rent	$\chi2 = 10.3307$			8	Not significant
	Economic savings	$\chi2 = 27.4644$				Significant
	Safety on board	$\chi2 = 42.6707$				Significant

The degrees of freedom, calculated considering (number of rows-1)*(number of columns-1) show a value of 16 and 8 respectively. A contingency table with a maximum number of rows and columns of 5 was used for the chi-square evaluation.

The calculation was carried out through 3 steps, the first of which consists in evaluating the variables and the relative ranges to be considered; the second step focuses on the distribution of the values according to the rows and columns whose total value is equal to 100% of the interviewed sample (i.e. 133) and finally it was possible to evaluate the significance of the results obtained through a calculation function on excel sheet. The correlations analyzed allow us to understand how, as the degrees of

freedom vary, for the variables acquired there can be dependence or independence between them.

The calculation of the $\chi 2$ statistics allows us to identify how much the observed data deviate from those we have estimated in the independence hypothesis. If the value is low, the real and theoretical values are very similar; if the value is high, they deviate from each other. And if reality is very close to theory ($\chi 2$ low), since the theoretical hypothesis is that the two variables are independent from each other, we will conclude that the two variables do not influence each other. Whereas if the $\chi 2$ is high, it is not possible to say that the variables are independent, but they influence each other. The data obtained from these correlations with multi degrees of freedom reflect what is described in the literature in terms of the relationship between degrees of freedom and p-value [19].

6 Discussion and Conclusions

This work shows a description of the diffusion of micro mobility in Palermo with some references to the typical users. From a survey it was possible to define the typical user using micro mobility in Palermo in 2020. The common users is mostly a man, employee or freelance worker and aged between 28 and 45 years and who has had a PMV for less than a year. The bivariate analysis has shown that some of the variables investigated are closely connected

In particular, the age of the user and the type of work influence the perception of safe driving while on board the PMV, the economy of using this vehicle instead of others and the propensity to use shared or rented vehicles. The survey, however, did not reveal any significant between motivation to travel and propensity to rent or share the vehicle.

On the other hand, the motivation of the displacement has registered a significant correlation with both the security and the economy aspects. The sample is PMV users and for a more in-depth investigation it could be useful to investigate other sub-categories such as rejecters or those who have not yet used these means for the first time but tend to do so.

The limitations of this analysis lie in the smallness of the sample but this in turn depends on the recent legislation that protects the use of these means of transport. However, this work is a first step of analysis for all to understand at the present time the propensity to use micromobility in Palermo to obtain results that may be useful to calibrate a service of micromobility rental obtain results useful for local authorities in order to limit and/or guarantee the use of micromobility in the historical centre of the city of Palermo characterized by a growing expansion of the ZTL areas.

These results is going to provide, for example, a basis for companies to optimize their rental services. This work foresees an increase in the interviewed population and the application of multi-variable Logit models to study the probability of modal choice in the urban context of Palermo.

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