

Exploring the influence of socio-economic aspects on the use of electric scooters using machine learning applications: A case study in the city of Palermo

Tiziana Campisi^a, Emre Kuşkan^b, M. Yasin Çodur^c, Dilum Dissanayake^{d,*}

^a Faculty of Engineering and Architecture, Kore University of Enna, 94100 Enna, Italy

^b Faculty of Engineering and Architecture, Erzurum Technical University, Erzurum, Turkey

^c College of Engineering and Technology, American University of the Middle East, Egaila 54200, Kuwait

^d School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham B15 2TT, United Kingdom

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ABSTRACT

Most European countries have been committed to reducing their carbon footprint, combating climate change, and reducing the air pollution typical in large cities over the past decade. Among current solutions that can be adopted are the replacement of fuel-powered means of transport with electric ones, as well as the introduction of car sharing, bike sharing and electric scooters.

The post-pandemic phase was characterized by a greater propensity to use these means of transport as they were perceived as a healthier choice (for a greater possibility of implementing social distancing) and cheaper (for the diffusion of shared services). The study of modal choice depends on socio-economic structures. The present work analyses data related to socio-economic factors (work, income and other) to examine the tendency to use electric scooters in the metropolis of Palermo, Sicily, through machine learning algorithms.

The comparison of different algorithms allowed us to underline how the multilayer perceptron algorithm obtained the best classification among the minimal sequential optimization algorithms. The findings also highlight middle-income and freelancer people as being more likely to use micro-mobility than others. Contrary to what was thought, these findings revealed that micro-mobility is not just a preferred mode of transport for low-income people or students. These trends will be able to encourage continuous monitoring of the relevant factors and will be able to help political decision-makers to increase and improve the diffusion of micro-mobility and to direct marketing campaigns to the groups identified here.

1. Introduction

The availability of different types of transport in urban areas makes it possible to offer various choice options to transport users depending on the user requirements such as their travel purpose and the distance to be travelled. However, there are still some problems that exist not only with the evolution of infrastructures but also with the lack of equity among the users. Equity in transport mode choices is fundamental, so that different genders and ethnicities are properly considered and reflected so that the ethnicity, diversity and inclusion aspects (EDI) in current society can be fully addressed (Creger, Espino, & Sanchez, 2018). But urban mobility planners have focused their strategies on private vehicle displacement in the 20th century. The resulting transportation system has had a devastating impact on disadvantaged and/or

low-income communities that include not only ethnic minorities but also people with disabilities and weaker segments of the population such as the elderly and young people who have been left out of the decision-making process and suffered from poor public transport services (Cohen et al., 2017; Raptopoulou, Basbas, Stamatiadis, & Nikiforiadis, 2021).

Public transport must continue to be the fairest form of mobility together with the development of shared mobility with reference to cycling and micro-mobility. The spread of shared e-scooter services has occurred over the past few years in different parts of the world. This modal choice ensures convenient and fast travel for short distances and is often connected to other modes of transportation to ensure first/last mile trips. Recent research has critically highlighted the evolution of these transportation systems by focusing on several case studies

* Corresponding author.

E-mail address: d.dissanayake@bham.ac.uk (D. Dissanayake).

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implemented in urban settings, particularly in Europe (Bösehans, Bell, Thorpe, Liao, et al., 2023; Bösehans, Bell, Thorpe, & Dissanayake, 2023; Bösehans, Kavta, Bell, & Dissanayake, 2023; Campisi, Akgün-Tanbay, Md Nahiduzzaman, & Dissanayake, 2021).

Several studies have shown that private and shared transport systems can help cities with environmental issues such as reducing air pollution, reducing inequalities in access to transport, promoting cost savings and improving the resilience of mobility. Decarbonizing urban transportation is one of the central goals of global, national and city climate plans. Some actions have been implemented recently to reduce vehicular traffic and encourage sustainable mobility options including e-scooters.

In general, urban dwellers perceive an increasing awareness of the car-centric mobility burdens related to pollution, noise and inefficient use of limited space, coupled with the problem of possible contagions and respect for social distancing. Some forms of mobility have suffered a strong decline, such as local public transport, while other forms such as cycling and micro-mobility have undergone some level of growth. The recent pandemic has greatly altered travel habits inducing many users to opt for different forms of mobility including scooters and travelling by bicycle and walking for short distances. The pandemic forced the imposition of multiple restrictions including social distancing that increased the use of forms of micro-mobility. E-scooters also partially reduced urban road congestion problems due to the number of private vehicles that have been growing in numbers post lockdown (Esztergár-Kiss & Lopez Lizarraga, 2021).

Different studies describe the spread of e-scooters in metropolitan areas (Che, Lum, & Wong, 2021; Liu, Jafari, Shim, & Paley, 2022). The main advantages of electric micro-mobility are its flexibility and speed, while the main disadvantages are potential conflicts with other road users leading to safety issues as well as parking problems (Almannaa et al., 2021; Liao & Correia, 2022; Moran, Laa, & Emberger, 2020).

Several countries have enacted laws to regulate the use of e-scooters, especially in spaces shared by pedestrians and users of active mobility devices (such as bicycles), but unfortunately there are still no uniform laws or 100% regulation of the issue (Latinopoulos, Patrier, & Sivakumar, 2021; Shokouhyar, Shokouhyar, Sobhani, & Gorizi, 2021). These include cost of renting, availability of shared cars at a location/hub, “not having a place where you can leave your car, not having a shared car in your neighbourhood,” and lack of knowledge about using electric cars (Gaglione, 2020).

Shared electric mobility is characterized by several features common to other modes of transportation such as electric car sharing, e-bike sharing, and e-scooter sharing. It is evident that the above modes of transportation have different travel capacities, but it is also clear that they are generally used for short trips. The users who use these transportation services most are male, of adult age around 40–50 years and with relatively high income and education (Bösehans, Bell, Thorpe, Liao, et al., 2023).

National and local governments have promoted a series of actions to support the diffusion of e-scooters, but these actions are still not sufficient to increase consumer preferences towards micro-mobility. In Italy the presence of non-monetary but psychosocial disincentive factors emerges and a reduced offer of services also emerges which limit the possibilities that electric scooters can be used by a greater percentage of the population (Mitropoulos, Stavropoulou, Tzouras, Karolemeas, & Kepaptsoglou, 2023). Several studies explore how participatory planning can influence the propensity of some users to use micro-mobility in the metropolis of Palermo. In the same city, the propensity to rent such means of transport was investigated, as well as sharing and ownership (Campisi, Akgün, Ticali, & Tesoriere, 2020; Dias, Arsenio, & Ribeiro, 2021). Several correlations between the variables were also analysed, including socio-economic variables relating to the propensity to hire and the perception of safety during the use of micro-mobility in Palermo through the distribution of questionnaires to a target of users registered with an association dedicated to micro-mobility. In the same city, the environmental aspect linked to this mode of transport was studied in

accordance with (Scorrano & Danielis, 2021). A study conducted in the city of Braga underlined the importance of the use of shared e-scooters as an alternative modal solution in the post-pandemic phase and several companies of this service have adopted special rates for people who use them for the first time (Dias, Ribeiro, & Arsenio, 2023).

A study conducted in the city of Belgrade compared different scenarios, analysing the availability and capacity of some road services and infrastructures, and paying attention to road geometries with lanes dedicated to electric scooters or the sharing of the existing infrastructure with cyclists, pedestrians and motor vehicles (Glavić, Trpković, Mileković, & Jevremović, 2021). In particular, results from multinomial logistic regression showed that mode of travel before and during COVID-19, and trip length, had an effect on users' propensity to use electric scooters in bike lanes (Carrese, Giacchetti, Nigro, Algeri, & Ceccarelli, 2021).

This research study focuses on the role of those new mobility services to initiate a more sustainable transport system by reducing greenhouse gas emissions, providing a reliable and equitable transport service and improving the human experience. Scooter transportation is crucial today due to its role in addressing urban mobility challenges, reducing traffic congestion, and promoting sustainable transportation options. Scooters offer a convenient and eco-friendly mode of transportation, particularly in densely populated urban areas where traditional transportation systems may be congested. They provide a flexible and cost-effective solution for short-distance trips, contributing to reducing carbon emissions and improving air quality. Additionally, scooters help enhance first and last-mile connectivity, complementing existing public transportation networks and reducing reliance on personal vehicles, thus promoting a more sustainable and efficient urban transportation system (Boarnet, 2013; Zhang, Zhao, Chen, & Zhang, 2021). For all these reasons, this study focused on investigating scooter use in detail. In particular, the research investigated some socio-demographic and economic aspects by characterizing a sample of population subjected to an online survey from which it was possible to define different classes and analyse them through a sequential algorithm, as explained in the following paragraphs.

2. Background

The recent scientific literature focused on the sustainability of transport generally analyses 3 main points: the demand for transport, the users and the offer, which splits into infrastructures and services. This also occurs for the analysis of micro-mobility. There is currently no uniform distribution of literature reviews and of micro-mobility services as the most sustainable solution in Europe. A study conducted by (Nikiforiadis et al., 2020) analysed and compared more than 300 scientific articles defining a bibliometric network of literature through the analysis of citations and co-citations of authors, articles, journals and countries. Much of the research points out that this mode of transport is characterized by low carbon emissions and is a developing modal choice.

The co-citation analysis allowed for classification of the literature into four research themes addressing respectively the categories of advantages, technology, policy and behavior of mode choice.

Different conflicting judgments on the concept of sustainability of electric scooters have emerged from different scientific works and many of them highlight the lack of services or infrastructures that can stimulate the demand to use them (Sung, 2023). Furthermore, a scientometric analysis was applied to examine nearly 500 articles published between 1991 and 2020. The results show a proliferation of research in the field of motorized micro-mobility since 2012, demonstrating that there is a greater propensity for micro vehicles (Abduljabbar, Liyanage, & Dia, 2021). Attractiveness depends on e-scooters qualifying as a “flexible, sustainable, affordable, on-demand transportation alternative” and reducing reliance on the use of private vehicles for short-distance travel (McQueen, Abou-Zeid, MacArthur, & Clifton, 2021; O'hern &

Estgfaeller, 2020).

In general, the term micro-mobility refers to means of transport such as bicycles, scooters, skateboards, segways and hoverboards which can be powered by electric motor or human traction, and which can be rented or privately owned or shared. Their diffusion has occurred in recent years also because they are part of the modal solutions that can generate the least negative impact on health and quality of life, especially if congestion, emissions and air quality are considered (Shaheen, Cohen, Chan, & Bansal, 2020). The integration of electric scooters with other transport systems in urban areas must consider some problems related to the fair allocation of road space. A study conducted by Laa and Leth (2020) shows that this perception also depends on whether a private or shared vehicle is used and the idea that electric scooter drivers could be additional users of cycling infrastructures, often reducing space for pedestrians.

The recent pandemic crisis has increased the propensity to use these means of transport but has also highlighted the strong lack of legislation and infrastructure in many European and non-European contexts. On the contrary, the investment of various companies in the diffusion of shared services and the technological evolution and the reduction of the digital divide in the 18–50 population group have exemplified the booking of scooter sharing services. In general, these services are introduced by private operators and are implemented as a floating system within public spaces. To date, the offer of services is often not well calibrated, i.e., it only minimally considers the characteristics of local users and the management of public spaces and infrastructures.

Another evident criticality is linked to the recent legislation which does not exhaustively regulate the micro-mobility sector. In general, the concept of sustainability is related to the lower environmental impact, namely, pollutants. The reduction of impacts on society, the environment and the economy can be achieved by ensuring better multimodality and combination/integration of public transport and micro-mobility systems.

Another critical issue is connected to the rapid development of these services in contexts where local administrations have often not been able to immediately manage them in the best way. To improve services and make these services more sustainable, further studies and investigations on the advantages and limits of the integration of micro-mobility and public transport will have to be promoted (Tiwari, 2019).

Finally, a further critical issue is related to safety. Recent studies show that although the use of scooters generates numerous benefits from an environmental (emissions and pollutants), social and economic (vehicle operating costs and time savings) point of view, these are minor when compared to safety issues (Félix, Orozco-Fontalvo, & Moura, 2023).

Demand analysis is essential to improve services, therefore demographic data, land use characteristics, connectivity and urban planning actions play a fundamental role in the creation of high-performing services. In general, the use of e-scooters during peak hours has been studied in addition to all time periods by comparing a few cities in the United States. A series of political and social strategies can incentivize and change users' modal choices by leaning towards micro-mobility services, also providing a more sustainable transport solution and a valid alternative for first and last mile journeys (Sperling, 2018).

When the studies in the literature are examined, other sustainable transportation modes have also been examined in a significant number of studies on e-scooter use. Studies focusing only on e-scooter transportation type are more limited. However, in studies on e-scooter transportation, transportation infrastructure, emission and safety criteria are generally at the forefront. In this study, the socio-demographic structure in the preference of e-scooter use is examined in more detail. In addition, the use of machine learning methods instead of traditional methods in the study also ensures the timeliness of the study. Today, machine learning methods are frequently used in every field and produce successful results.

3. Sample selection and survey definition

The economic aspects of sustainable mobility can be analysed and measured from seven different perspectives shown in Fig. 1.

The outcomes of the evaluation may differ depending on the perspective chosen. This study is very much focused on “User Perspectives” and that ultimately has connections to other perspectives including “social” and “micro-economic” perspectives. While the focus of the study is about the users of micro-mobility, their views are useful to help review current guidelines and policies. On the other hand, user perspectives are very important for mobility providers for their business models and improving their services. Evaluations based on user perspective are those that generally dominate discussions and decision-making processes.

The main objective of the research is to understand the incidence of the type of work and salary on the choices related to micro-mobility in the city analysed to have a preliminary overview of the possible users of new micro-mobility services and for local governments to remodel and design spaces and infrastructures for their use.

The study was conducted through the first phase of data acquisition and a second phase of comparing the classification performance of 4 different types of data mining algorithm. In particular, the research has focused on a preliminary assessment of some variables related to user and social aspects. Participants in the online survey were recruited randomly from the data of two Facebook social pages. No stratified proportional random sampling strategy was mainly used to recruit participants.

An online questionnaire was distributed to 1150 micro-mobility users in the city of Palermo. 698 micro-mobility users (61% of the population) who were aged over 18 years and residents in Palermo participated in the survey. All these users were e-scooter owners. The small questionnaire (8–10 min to complete) was administered online to gather information based on a series of questions in 3 sections aimed at understanding the perception/situation of a target population with respect to their interest on micro-mobility.

The questionnaire is one of the most widely used methods for collecting data, given its current ease of implementation and the possibility of dissemination to a wide audience through online platforms. Good statistical processing is necessary to make the best use of data collection.



Fig. 1. Different perspectives (This study).

The first step in constructing the questionnaire is to align it to the objective of the study, that is, to investigate how certain socio-demographic parameters may influence the use of micro-mobility in Palermo. The questionnaire survey has three main sections:

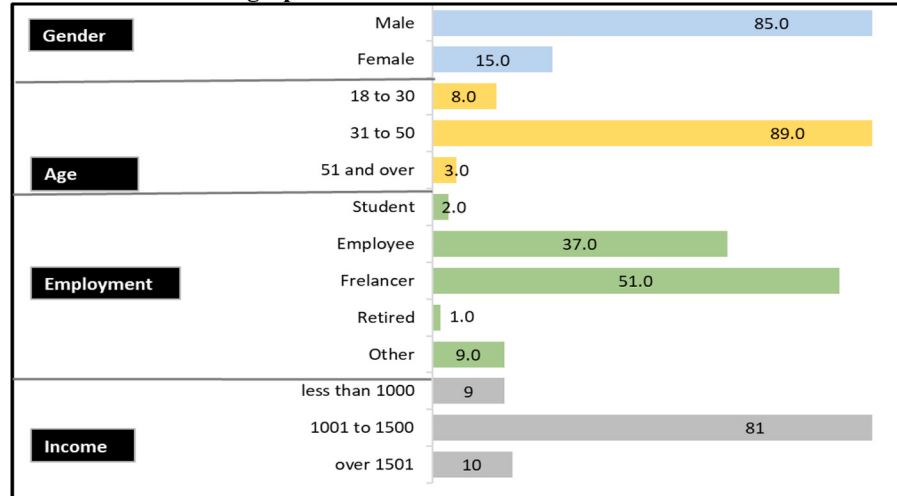
- **Section 1** socio-demographic characteristics
- **Section 2** travel habits (frequency and motivation), and
- **Section 3** perception of some of the factors that incentivize the use of micro-mobility and factors that discourage its use in the post-pandemic phase.

The sections were organized to achieve the main objective by

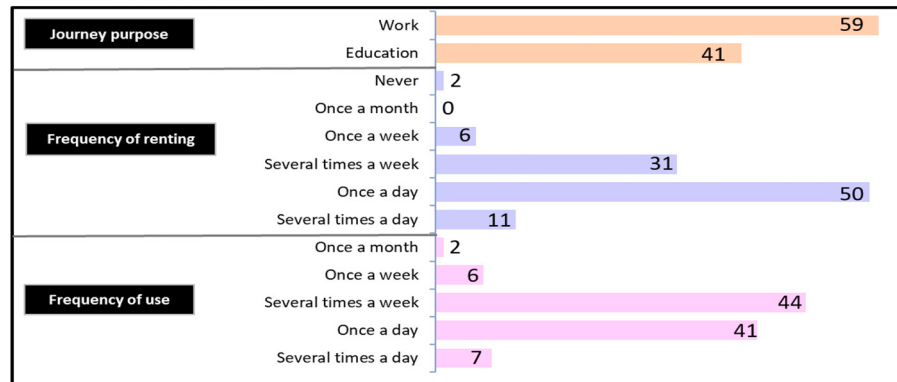
assigning a sort of importance classification to the various survey dimensions. Closed-ended items are included in the present research with single answers on a list of possible selections and Likert scale, making closed-ended answers suitable for conducting quantitative analyses. The items created are simple, short, and written in a language familiar to the target respondents so that the questionnaire passes the validation process and can therefore generate some valid responses. Fig. 2 presents the descriptive analysis of data.

This study aimed to investigate the effects of socio-demographic characteristics of individuals on e-scooter use. Since the age and gender factors of individuals in e-scooter use are generally distributed in certain classes and do not show diversity, they were not preferred in the

Section 1: Socio-demographic data



Section 2: Travel habits



Section 3: User perceptions

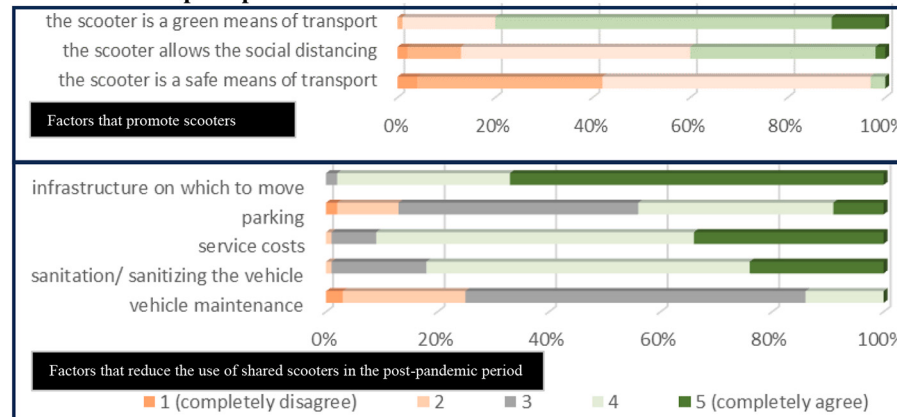


Fig. 2. Descriptive statistics (This study).

formation of the classifications in the study. However, the fact that factors such as the income status and employment status of individuals are related to each other allows the classification process to be performed more successfully. It is not correct to limit the use of e-scooters in the world to only certain groups of people. Although it is thought that the use of e-scooters is generally preferred by low-income individuals or students, this is not exactly the case. Many other people prefer e-scooters to prevent harmful gas emissions and provide healthy transportation.

The two main elements that constitute the socio-demographic structure of the individuals are categorized as employment and income. Employment status includes 5 different categories. These categories are student, employee, self-employed, retired and others. Income status includes the following 3 categories as monthly income of individuals in euros: Less than 1000, between 1001 and 1500 and more than 1500. Based on the selected socio-demographic variables of “employment” and “income”, 15 different classes were created where the categories belonging to both were evaluated together (Fig. 3).

3.1. Machine learning algorithms

In the study, machine learning algorithms were utilized to execute the classification procedure with high accuracy. For this, more than one algorithm should be used. In addition, an algorithm with the highest accuracy values and lower error rates should be recommended. A total of four different algorithms were applied in the study. These algorithms are nearest neighbour, support vector machines, naive Bayes and multilayer perceptron algorithms. These algorithms can be called both data mining and machine learning algorithms. In this study, both nomenclatures have been preferred (Comi, Polimeni, & Nuzzolo, 2022).

There are many criteria in choosing data mining in the study. Data mining looks for hidden, valid and potentially useful patterns in large data sets. It also explores previously unknown relationships between data using the fields of artificial intelligence and statistics (Kuşkan, Sahraei, Çodur, & Çodur, 2022).

3.1.1. Sequential minimal optimization (SMO)

Sequential Minimal Optimization (SMO) is often used to solve optimization problems during the training process of supporting vector machines. SMO replaces all missing values and converts categorical (nominal) attributes to binary attributes. All attributes are normalized by default. Support Vector Machines (SVM) show good generalization performance empirically on a wide variety of problems such as character recognition, face recognition, pedestrian detection, classification and text categorization. A soft-margin support vector machine is trained by solving a quadratic programming problem, which is expressed in the dual form as follows:

$$\max \sum_{i=1}^n a_i - \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n y_i y_j K(x_i x_j) a_i a_j \quad (1)$$

Subjected to: $0 \leq a_i \leq C$ for $i = 1, 2, 3, \dots, n$

$$\sum_{i=1}^n a_i y_i = 0 \quad (2)$$

Where, C is an SVM hyper parameter and $K(x_i x_j)$ is the kernel function, both supplied by the user; and the variables a_i are Lagrange multipliers (Nakanishi, Fujii, & Todo, 2020).

3.1.2. K nearest neighbour (KNN)

The K Nearest Neighbour (KNN) method is a machine learning algorithm that is frequently used in classification problems. In this method, the distribution of the data to be classified is examined with the help of a graph. Each dataset close to each other represents a class. The characteristics of each class have been determined and are different from each other. By looking at the status of the newly added data to the dataset, the class to which it is closest can be determined. The performance of the algorithm is affected by the number of k nearest neighbours in the dataset, the threshold value, the similarity measure, and a sufficient number of normal behaviours (Pham, Tien Bui, Prakash, Nguyen, & Dholakia, 2017).

Thus, the k observations with the closest distance are selected to calculate the neighbours. This procedure utilizes the Euclidean distance formulated in Eq. (3) for points i and j in the distance calculation.

$$d(i, j) = \sqrt{\sum_{k=1}^p (x_{ik} - x_{jk})^2} \quad (3)$$

3.1.3. Multilayer perceptron (MP)

Artificial Neural Networks (ANN) are composed of artificial nerve cells, each of which has a unique memory and is interconnected with weighted connections, inspired by the learning ability of the human brain.

The network is designed by connecting these cells in 3 layers (input layer, intermediate layers and output layer) and in parallel at each layer. ANN is classified according to many different criteria such as the architecture of the network, the learning algorithm, and the connection types between its neurons. In this context, multilayer perceptron is one of the most used and preferred network structures (Kuşkan, Çodur, & Atalay, 2021). In this network structure, the data processing process, that is, the training of the network, is renewed to obtain the desired output with minimum error from the information given to it as input. Classification via MP is usually symbolized by the formulation in eq. (4). Here ω denotes the vector of weights, x denotes the vector of inputs, b deviations, and ϕ nonlinear activation function.

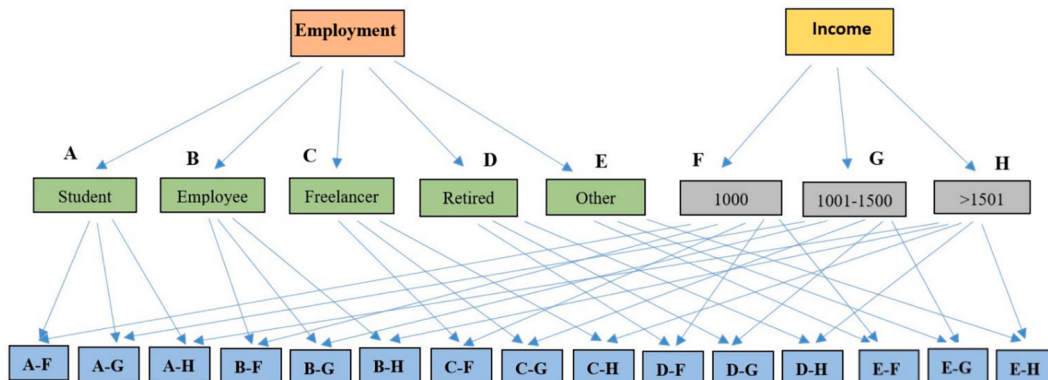


Fig. 3. Classes that consist of the socio-demographic structure of individuals (This study).

$$y = \varphi \left(\sum_{i=1}^n \omega_i x_i + b \right) = \varphi (w^T x + b) \quad (4)$$

3.1.4. Naive Bayes (NB)

The Naive Bayes is successfully used not only on numeric data, but also on non-numeric textual data. Today, with the Naive Bayes algorithm, it can be determined with great accuracy whether the content of many e-mails and messages are sent by people or whether they are advertising or fraudulent messages sent in bulk. Probability is used when calculating with the Naive Bayes algorithm (Murphy, 2006). $P(A/B)$; The possibility that event A occurs when event B occurs, $P(B/A)$; It is the possibility that event B will happen when event A occurs. The method is defined as eq. (5).

$$P(A/B) = [P(B/A) \times P(A)] / P(B) \quad (5)$$

3.2. Performance and error scales analysis

When data mining algorithms are tested on an application, it is requested to know which algorithm has better success. Many concepts can be used for evaluation and comparison of algorithms. The most commonly used of these concepts are precision, recall and F-measure. Confusion matrix is used to calculate these concepts. The confusion matrix is given in Fig. 4 (Kristiyanti, Umam, Wahyudi, Amin, & Marlinda, 2018).

The calculation of the concepts of precision, recall, F-measure calculated using the confusion matrix is given in Eq. 6-7-8-9.

$$Precision = \frac{TP}{TP + FP} \quad (6)$$

$$Recall = \frac{TP}{TP + FN} \quad (7)$$

$$F - measure = \frac{2 \times Recall \times Precision}{Recall + Precision} \quad (8)$$

Accuracy criteria are not sufficient to determine the performance of an algorithm. For this, it is necessary to examine the error criteria. Because if some data sets are not suitable for algorithms, there may be inconsistency between performance values and error criteria.

For this reason, it is necessary to calculate the values of mean square error (MSE), root mean square error (RMSE) and Kappa statistical, which are error measures. MAE measures the average magnitude of the errors in a set of forecasts, without considering their direction (Zhou, 2016).

RMSE is a quadratic rating rule which measures the average degree of the error (Chicco, Warrens, & Jurman, 2021). The Kappa is a form of the correlation coefficient. Like these coefficients, it can vary from -1 to

+1, where 0 symbolizes the quantity of agreement that can be expected from arbitrary chance, and 1 signifies an excellent agreement between the raters. Although the Kappa value is an error criterion, it has high values in algorithms that perform well. These values are given in eqs. 9, 10, 11 below.

$$MAE = \frac{1}{N} \sum_{i=1}^N (x_{f,i} - x_{o,i}) \quad (9)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_{f,i} - x_{o,i})^2} \quad (10)$$

$$K = \frac{p_o - p_e}{1 - p_e} \quad (11)$$

Where $x_{f,i}$ and $x_{o,i}$ are the i th expectation and observation, respectively.

4. Results

More than one data mining algorithm is preferred to classify the data with high accuracy. In this way, better results can be obtained by using the data of the best classification algorithm. Accuracy values and error scales should be examined to determine the algorithm that makes the best classification. The higher the precision, recall, F-measure and roc field values of an algorithm, the better the performance. However, MAE and RMSE values, which are error values, should be low and Kappa statistical values should be high. If there is disproportion in these results, the dataset may not be suitable for that algorithm. For this reason, it is necessary to examine both the accuracy values and error scales of the algorithms.

The accuracy values obtained in each algorithm using Weka software for the 15 classes created according to the socio-demographic structure of the individuals are presented in Fig. 5.

When the results are examined, the MP algorithm has the highest value with 0.80 in terms of f-measure. Similarly, the recall and precision values of the MP algorithm are higher than other algorithms. Among these three criteria are the f-measure; since it is the harmonic mean of the concepts of recall and precision, it is the most decisive factor in the success of an algorithm. On the other hand, SMO and NB algorithms have close results for the current dataset. Although these algorithms have given relatively successful results, the KNN algorithm is the algorithm that gives the most unsuccessful results with an f-measure value of 0.59. In cases where the f-measure value of an algorithm is below 0.7, it can be interpreted as being not suitable for the current dataset. In machine learning, the success of algorithms is determined not only by accuracy values but also by error criteria. In an algorithm, these two results are expected to be compatible with each other. If the accuracy value and error criteria of an algorithm are incompatible, it can be said that it is not a suitable algorithm for the current data set. The error scales of the algorithms are shown in Fig. 6.

When the error scales of the algorithms are examined, it is the MP algorithm that has the lowest MAE and RMSE values. Similarly, the Kappa statistical value of this algorithm is high. Although the concept of Kappa statistics is an error criterion, unlike the concepts of MAE and RMSE, the higher it is, the more successful results are obtained. The MP algorithm has the best values in terms of both accuracy values and error scales. Although the accuracy values of the SMO algorithm are better than the NB algorithm, the error scales did not give good results. On the other hand, the KNN algorithm has worse results than other algorithms in terms of both accuracy values and error scales. Thus, it has been determined that the most suitable algorithm for the data set is the MP algorithm.

	Predicted 0	Predicted 1
Actual 0	TN	FP
Actual 1	FN	TP

Fig. 4. Confusion matrix.

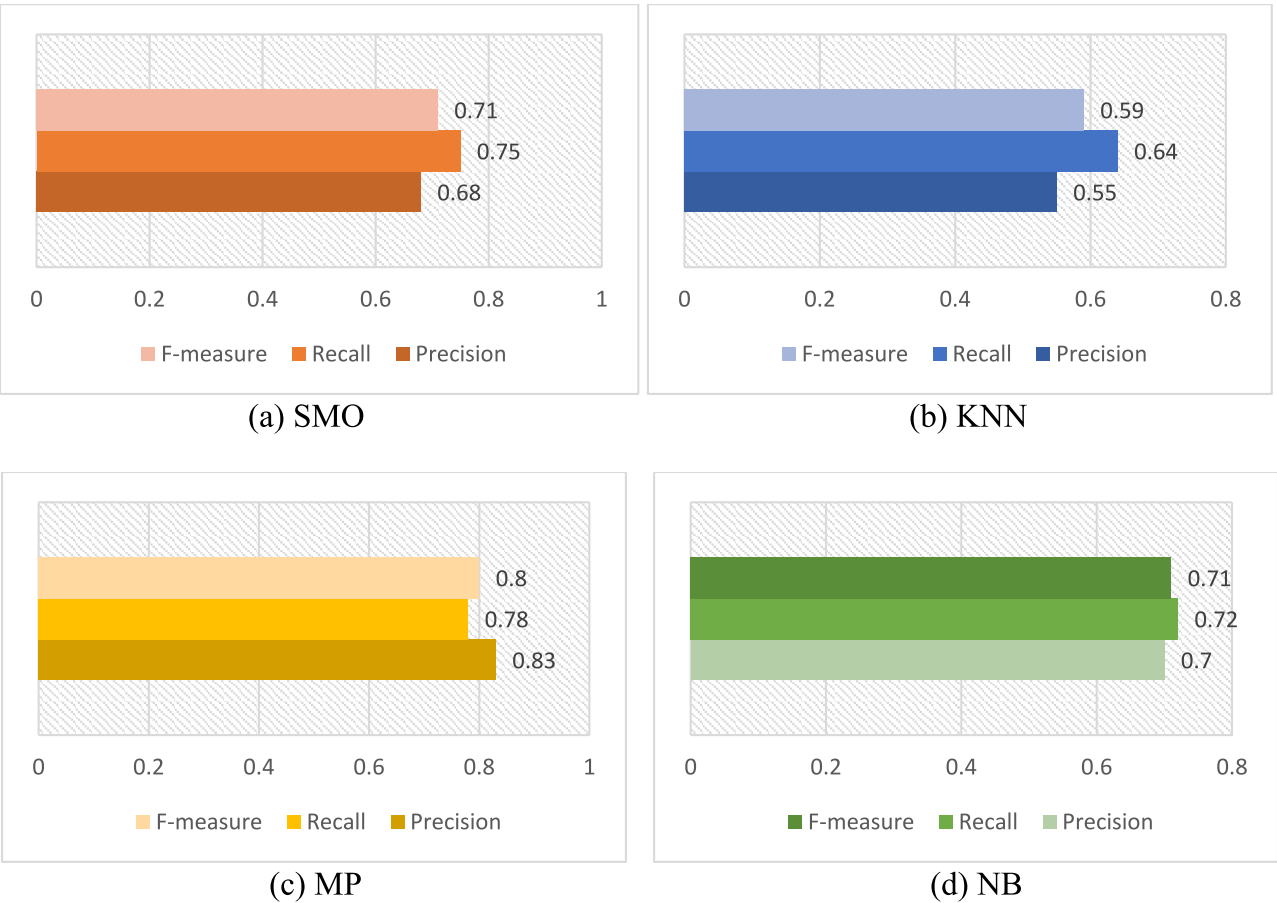


Fig. 5. Accuracy values of the algorithms (This study).

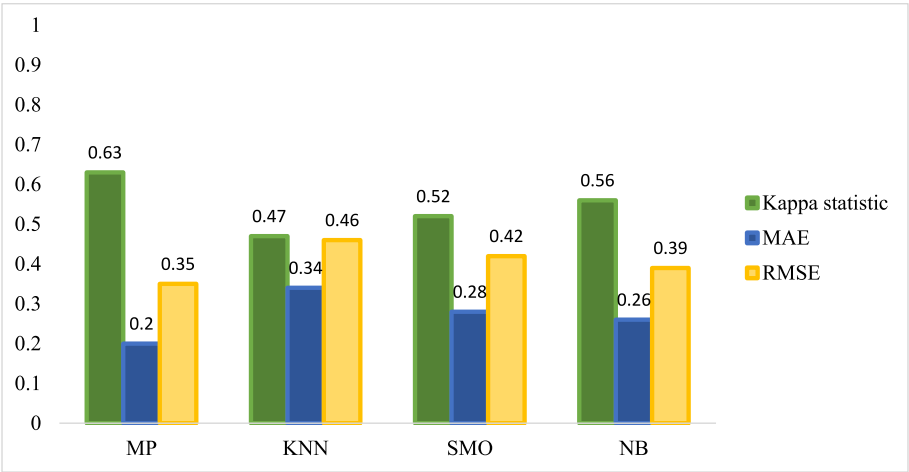


Fig. 6. Error scales of the algorithms (This study).

Table 1
The weightings based on the MP algorithm.

Classes	A-F	A-G	A-H	B-F	B-G	B-H	C-F	C-G
Weights	−0.14	0.07	0.03	0.06	0.20	−0.07	0.24	0.36
Classes	C-H	D-F	D-G	D-H	E-F	E-G	E-H	
Weights	0.23	0.18	0.23	−0.03	0.11	0.21	−0.07	

5. Discussion

Since the MP algorithm shows the best performance among the algorithms used in the study, the results obtained with this algorithm are taken into consideration. The weighting of the classes according to this algorithm is given in Table 1.

According to this algorithm, the class with the highest weight value of individuals travelling by e-scooter was determined as the class of freelancer with middle-income (C-G). This may be due to the fact that self-employed individuals do not have to wear formal dress or that there are no strict limits on the hours of entry to work (Pourfalamatoun, Ahmed, & Miller, 2023). C-G was followed by C-H (freelancer with high-income) and C-F (freelancer with low-income). This is because individuals travelling by scooter in formal attire may experience some difficulties. Another remarkable point in the analysis results is that high-income individuals also prefer the use of e-scooters. This situation may also cause the use of scooters to increase as it will show that the use of scooters in society is not a deficiency. In addition to these three freelancer categories, it is also observed that individuals who are middle income employees (B-G) and middle income (D-G) retired are also shown to use e-scooters for their journeys.

Also, it has been determined that the income status of the students does not affect the use of scooters much. It has been observed that they do not prefer the use of scooters even if they are middle or low income. The segment with the lowest use of e-scooters is retired individuals. The lower use of e-scooters by these individuals may be due to their age.

The increasing prevalence of micro-mobility in the world has led to an increase in studies on this subject. Compared to analysis methods based only on observations, innovative methods produce more advanced and comprehensive results. In this context, in this study, the analysis by using algorithms of data mining makes the study innovative. In addition, more useful findings have been revealed thanks to the advantages of data mining.

The reason for examining the socio-demographic structure of individuals in this study is to determine whether there is a relationship between the use of scooters and the income status and employment of individuals. Overall, creating a more environmentally friendly transportation system, reducing air and noise pollution can be achieved using scooters. Considering the socio-demographic structure of the individuals in the city of Palermo, it is not possible to increase the scooter use of the elderly individuals, but the use of scooters can be increased in the younger individuals. As an example, studies can be carried out to encourage students to use scooters. Increasing the number of scooters that can be rented, especially on the roadside, can increase their use by students for transportation between home and school. This will provide a more livable environment for future generations, as well as promote the spread of micro-mobility.

6. Conclusions

The present work analysed two socio-economic variables to examine individuals' preference for micro-mobility; that is, considering the type of work and other socio-economic factors related to income levels. The widespread use of micro-mobility in recent years has allowed various studies to be carried out in this field. Particularly, thanks to data mining methods, micro-mobility can be studied more effectively because algorithms used in data mining facilitate high accuracy classification. In this study, the data of the survey study including the use of e-scooter in the city of Palermo, Sicily, were examined. Accordingly, a total of 15 different classes were created, including the employment and income status of individuals. Classification performances of each algorithm were examined using SMO, KNN, MP and NB algorithms. In the results obtained, it has been revealed that the MP algorithm gives the best results in terms of both performance values and error criteria.

According to the analysis made with the MP algorithm, middle-income and freelancer individuals prefer to travel by scooter more

often than other individuals. Another important result obtained from the analysis is that the income status of individuals does not have a significant effect on scooter use. This reveals that there is no major obstacle to the increase in the use of scooters. However, the rate of use of scooters by students is quite low. It may be helpful for policy makers to implement practices that encourage students to use scooters. In this way, it can enable young people to reduce their use of vehicles in the future. It is possible that this situation will allow the increase of micro-mobility. In addition, future studies on this subject are recommended by the authors to examine how much micro-mobility reduces traffic congestion and air pollution with data mining algorithms.

CRedit authorship contribution statement

Tiziana Campisi: Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft. **Emre Kuşkan:** Formal analysis, Investigation, Methodology, Writing – original draft. **M. Yasin Çodur:** Writing – review & editing. **Dilum Dissanayake:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data used to support the findings of this study have not been made available due to data privacy.

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