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Factors influencing greenways use: Definition of a method for estimation in the Italian context

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ABSTRACT

The aim of this research is to assess the relationships between the number of users detected along some Italian greenways and the characteristics of the territory crossed in order to define a model capable of estimating the number of potential users of a greenway before it is realized.

We have gathered monthly users data of 7 Italian greenways. For each greenway, we also analyzed the variables influencing its use (characteristics of the greenways, population, landscape, climate and season).

Using the most significant variables, we have developed three different linear regression models (I: all 13 counters; II: sub sample of 10 mountain counters; III: sub sample of 9 homogeneous mountain counters) having as the dependent variable the monthly users number, in order to assess the combination more able to describe the studied phenomenon.

The three models have a significant χ^2, meaning that the regressors are jointly significantly different from zero, thus the set of our explanatory variables plays a role in estimating greenways monthly potential users.

The use of a greenway is influenced mainly by the population level of education, the tourists number, the richness of historical and architectural resources, the degree of accessibility of the trail and by the month of the year. The population aged under 15 and over 64, the degree of urbanization influence negatively the use.

Although additional researches are needed, the model defined may have potential application in the forecasting studies to estimate existing or proposed greenways use. However, because different regions have different climates, socio-demographic characteristics and landscapes, further research are needed to extend, test and validate the model.

1. Introduction

The issue of non-motorized mobility in the last decades has seen increasing attention at the international level. In Italy, we assisted at the creation of hundreds of kilometers of trails dedicated to cycling and walking, many of which meet the greenway definition of the European Greenways Association: "*Communication routes reserved exclusively for non-motorized journeys, developed in an integrated manner which enhances both the environment and quality of life of the surrounding area. These routes should meet satisfactory standards of width, gradient, and surface condition to ensure that they are both user-friendly and low-risk for users of all abilities. In this respect, canal towpaths and disused railway lines are a highly suitable resource for the development of greenways*" (EGWA, 2002).

More generally, greenways can be planned at different scales and for multiple purposes (ecological, recreational, cultural, non-motorized mobility) (Fabos, 1995).

There is a significant literature on greenway planning and design from all around the world. Various methodologies and studies on greenway planning have been conducted in Italy (Rovelli et al., 2004; Senes et al., 2010; Toccolini et al., 2006). However, it is surprising that, despite the increasing interest in non-motorized transport (at social, political, and academic level), little attention has been paid to cycling and walking compared with other modes of transportation (Heinen et al., 2010). This is a great gap for two reasons. Firstly, because the characteristics and determinants of non-motorized transport are very specific. For example, the weather as well as physical effort greatly influence non-motorized transport when compared to car and public transport use (Heinen et al., 2010). Secondly, because in the modern society cycling and walking represent an important part of multimodal travel behavior, and combine with other modes of transport in daily life

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Table 1
Classification of the variables found in the literature.

Category	Variable	References
Socio-economic variables, related to social, economic and demographic characteristics of the population and/or the users of the trails	Age	Dill and Voros, 2007; Furuseth and Altman, 1991; Handy et al., 2010; Hunt and Abraham, 2007; Moudon et al., 2005; Parkin et al., 2008; Turner et al., 1997; Wardman et al., 2007; Zacharias, 2005.
	Income	Dill and Carr, 2003; Dill and Voros, 2007; Furuseth and Altman, 1991; Guo et al., 2007; Parkin et al., 2008; Plaut, 2005; Schwanen and Mokhtarian, 2005; Stinson and Bhat, 2003; Turner et al., 1997; Zacharias, 2005.
	Education level	Furuseth and Altman, 1991; Handy et al., 2010.
	Gender	Böcker et al., 2015; Cervero and Duncan, 2003; Dill and Voros, 2007; Furuseth and Altman, 1991; Garrard et al., 2008; Moudon et al., 2005; Parkin et al., 2008; Plaut, 2005; Rietveld and Daniel, 2004; Rodríguez and Joo, 2004; Ryley, 2006; Scheiner, 2010; Wardman et al., 2007.
Environmental and land-use variables, related to the physical characteristics of the environment near the greenway	Land use	Cervero and Duncan, 2003; Clayton and Musselwhite, 2013; Coutts, 2008; Dill and Voros, 2007; Jones et al., 2010; McCahill and Garrick, 2008; Milakis and Athanasopoulos, 2014; Pikora et al., 2003; Pucher and Buehler, 2006; Rodríguez and Joo, 2004; Turner et al., 1997.
	Population density	Baltes, 1996; Boarnet et al., 2008; Chatman, 2009; Dill and Voros, 2007; Greenwald and Boarnet, 2001; Guo et al., 2007; McCahill and Garrick, 2008; Parkin et al., 2008; Turner et al., 1997; Zahran et al., 2008.
	Proximity to downtown	Bush, 2011; Coutts, 2008; Coutts, 2009; Dill and Voros, 2007; Milakis and Athanasopoulos, 2014.
	Scenery and natural areas	Chon and Shafer, 2009; Coutts, 2008; Milakis and Athanasopoulos, 2014; Pettengill et al., 2012; Shafer et al., 2000.
	Gradient	Cervero and Duncan, 2003; Hunt and Abraham, 2007; Milakis and Athanasopoulos, 2014; Moudon et al., 2005; Parkin et al., 2008; Rietveld and Daniel, 2004; Rodríguez and Joo, 2004; Stinson and Bhat, 2003.
Weather	Rain	Böcker et al., 2015; Dill and Carr, 2003; Nankervis, 1999; Niemeier, 1996; Parkin et al., 2008; Spencer et al., 2013.
	Temperature	Baltes, 1996; Bergström and Magnussen, 2003; Böcker et al., 2015; Bush, 2011; Nankervis, 1999; Niemeier, 1996; Parkin et al., 2008; Ploner and Brandenburg, 2003; Spencer et al., 2013.
	Wind	Böcker et al., 2015; Helbich et al., 2014; Spencer et al., 2013.
Temporal variables	Time of day	Bush, 2011; FHWA, 1999; Niemeier, 1996.
	Season	Stinson and Bhat, 2004; Niemeier, 1996; Ploner and Brandenburg, 2003; Guo et al., 2007.
Accessibility variables	Parking	Stinson and Bhat, 2003.
	Street connectivity	Bhat et al., 2005; Dill and Voros, 2007; Milakis and Athanasopoulos, 2014.
	Proximity to a freeway	Dill and Voros, 2007.
	Proximity to metro/railway station	Milakis and Athanasopoulos, 2014.
Alternative mobility	Household automobile availability	Dill and Carr, 2003; Dill and Voros, 2007; Guo et al., 2007; Parkin et al., 2008; Plaut, 2005; Pucher and Buehler, 2006; Scheiner, 2010; Stinson and Bhat, 2003, 2004.
	Trip distance, travel time	Hunt and Abraham, 2007; Parkin et al., 2007; Stinson and Bhat, 2003, 2004; Timperio et al., 2006.
	Cost of other means of transportation	Pucher and Buehler, 2006; Rietveld and Daniel, 2004.
Traffic variables	Motor vehicle volume	McCahill and Garrick, 2008; Stinson and Bhat, 2003.
	Traffic speed	Milakis and Athanasopoulos, 2014.
Psychological variables		Dill and Voros, 2007; Gatersleben and Appleton, 2007; Rietveld and Daniel, 2004; Stinson and Bhat, 2004.
Variables related to the infrastructures (trails, bike-paths and greenways) themselves	Proximity to bicycle network	Krizek and Johnson, 2006.
	Amount of infrastructures nearby	Dill and Carr, 2003; Jones et al., 2010; Moudon et al., 2005; Pucher and Buehler, 2006
	Pavement	Stinson and Bhat, 2003.
	Facility type	Dill and Gliebe, 2008; FHWA, 1999; Hunt and Abraham, 2007; Stinson and Bhat, 2003
	Continuity of cycling facilities	Stinson and Bhat, 2003.

(Olafsson et al., 2016).

In relation to greenway planning, there is a notable lack of specific literature on 'greenway users' and on the factors influencing their choices (Bush, 2011). Only a few studies are available (Bush, 2011; Coutts, 2008; Coutts, 2009; Coutts and Miles, 2011; Eizaguirre-Iribar et al., 2016; Mundet and Coenders, 2010; Pettengill et al., 2012; Price et al., 2012; Reed et al., 2011; Shafer et al., 2000) in the last 15 years, following the pioneering study for Indianapolis (Lindsey, 1999).

The growing interest and social demand for greenways, often collides with the scarcity of public funds putting a problem of choice among different alternative uses of public money. Consequently, it emerges an increasing need to evaluate each project in terms of its potential benefits (not only economic) and costs for local communities and its capacity to be attractive for users. In this sense, the preliminary evaluation of the number and characteristics of users potentially interested in a new infrastructure should be a crucial phase in the planning and design processes, and a necessary step to perform a cost-benefit analysis of the project. Furthermore, a correct estimation of potential users could be useful also to improve or to extend existing infrastructures.

Different methodologies could be adopted for the estimation of non-motorized users (Porter et al., 1999), falling within two broad categories: aggregated or individual analysis. While the individual analysis is mainly devoted to analyze relationships between personal characteristics of users with the different mobility options, aggregated studies try to find statistically significant quantitative relationships among infrastructures' characteristics, territorial and socio-economic features of the area in which they are placed and the number of users. The two approaches, that are not mutually excludable, present both advantages and disadvantages. Individual analysis tend to be more precise, but they are also complicated and onerous to be implemented due to the difficulties in collecting data. Aggregated studies are more easy and immediate to be implemented and more adaptable to different contexts; their effectiveness depends on the dimension of utilized dataset, the correct modeling of factors involved in greenways use and the statistical fitness of the estimation model.

Due to its positive properties, particularly the transferability of methodology among different territorial contexts, we decided to perform an aggregated analysis aiming to quantitatively assess the relationships between the number of users detected along some Italian greenways and the characteristics of the territory crossed (in terms of population and territorial characteristics). The final output of this process should be the definition of a statistical model capable of preventively estimating the potential users of a greenway before it is completed. Representing one of the first attempts of this kind in Italy, our study wants to be an opportunity for the development of these provisional models in greenways planning and design and, more generally, for widening knowledge on factors influencing non-motorized mobility in Italian rural areas.

In this article, the relationships between the number of users detected along some Italian greenways and the characteristics of the territory crossed is analyzed in order to build a predictive model for the number of users in the Italian greenways. Particularly, Section 2 summarizes the main literature about greenways functions and determinants of their utilization. Section 3, describes the 13 considered greenways and the collected data. Section 4 explains the methodology used in the analysis and the considered variables. Section 5 describes the main results, considering all the counters (model I), and only the counters in the mountain area (model II and III), and provides for their discussion. Finally, we discuss about the limit of the study and draw some conclusions.

2. State of the art

In order to achieve the research aim and recognizing the lack of a specific literature (Bush, 2011), we referred to the wider literature on non-motorized transport in general. This literature refers more specifically to cycling (as mode of transport) and commuting (as reason of transport). We know that greenways are multi-user (cyclists, pedestrians, skaters, horseback riders, etc.) and multi-purpose (commuting, leisure and recreation, tourism, physical activity, etc.) trails and they are likely to be influenced by different factors. However, there are also many similarities as greenways are also used for commuting, especially in urban and sub-urban contexts (Bush, 2011; Mundet and Coenders, 2010; Pettengill et al., 2012; Price et al., 2012; Shafer et al., 2000).

In this context, we reviewed the findings that have emerged from previous research, in relation to three topics:

- factors influencing greenways use;
- area of influence of the greenway corridor;
- method/technique to be used to estimate the potential users of a greenway.

In relation to the first topic, the literature revealed a wide range of factors influencing greenway and trail use (we found at least 26 variables widely used), that can be subdivided in 9 categories (Table 1).

The first category is related to social, economic and demographic characteristics of the population and/or the users of the trails. This category includes variables as age (in general the most users are in the age 20–60), income (that generally has a positive effect on cycling and outdoor recreation), education level (generally associated in a positive way to non-motorized mobility, especially cycling) and gender. This last variable has an unclear relationship with cycling and walking: although most research concludes that men cycle more than women, some others underline different behaviors in relation to the nationality, the age and the purpose of the trip. All these relationships between the variables mentioned above are subject to slight modifications if the trip is made alone or with friends, family, children, etc. (Pooley et al., 2011).

The second category is related to the physical characteristics of the environment near the greenway. The land use of the surrounding area is one of the most cited variables: the proximity of residential areas mixed with services and natural/cultural resources that can attract recreation/touristic users (mixture of land-uses and functions) has a positive influence on cycling and outdoor recreation; land use seems to have more influence on long distance commuting (Maoh and Tang, 2012). Another variable is the population density: generally, the more people living around the trail, the more it will be; nevertheless, greenways sections not in highly populated areas but that connect these with natural land-uses show an increase in the number of users (Coutts, 2008). Other variables include proximity to downtown (usually related with the previous two ones), scenery and natural areas (frequently cited as an important greenway characteristic by the users), gradient (with a big negative effect on non-motorized travel, especially on commuting).

The third category is related to the weather conditions that vary from day to day and can affect greenways use; they are usually coupled to the data coming from the automatic counters to determine correlations. Leisure trips appear to be more weather sensitive respect to commute ones (Helbich et al., 2014). The most cited variables are rain, with a negative impact on non-motorized travels, and temperature, with not too hot and not too cold (17–30 °C) preferred, influencing commuters less than other cyclists). The effect of wind is less investigated, with no significant effect or an inhibitory one.

The fourth category is related to the time of the day, daylight is widely preferred (personal security issues arise at night) and season, with summer seeing higher use than winter (related to the weather, the daylight and the non-working time).

The fifth category is related to accessibility variables, the ease of access to the greenways and its interconnection with the broader infrastructural network: greater ease of access and interconnection, increased use of the greenways.

The sixth category is related to the possibility of choice of other means of transport; these variables are particularly important for commuting. The most cited variables include household automobile availability (that negatively affect non-motorized mobility), trip distance/travel time (one of the most important factors, related with the land use), and cost of other means of transportation (including public transports).

The last three categories are related to traffic variables, that affect the perceived safety of travel, psychological variables, that affect the travel behavior and mode choice (attitudes, social norms, altruistic and ecological beliefs, perceived behavioral barriers, habits), and the infrastructures-related variables (with a positive effect of proximity to bicycle network and amount of bicycle paths and multi-use trails nearby).

For a general literary review on the determinants of the non-motorized mobility it is possible to see Bhat et al. (2005), Ewing and Cervero (2010), FHWA (1999), Ginger et al. (2011) and Griswold et al. (2011), Heinen et al. (2010), Rietveld and Daniel (2004), Turner et al. (1997).

In relation to the second topic, we found different thresholds for the area of influence of the greenway corridor (obviously greater for cyclists than walkers), ranging from 350 to 400 m to 1.6 km to 8 km (Coutts, 2009; Griswold et al., 2011; Krizek et al., 2007; Lindsey, 1999;

Milakis and Athanasopoulos, 2014; Scheiner, 2010). Most cycling trips are up below 15 km (Heinen et al., 2011), similar to the distance travelled by users to get to the trail (Price et al., 2012).

In our study, there was also an interest in capturing the influence of the attractions in the surrounding of the greenway. The optimal maximum distance of the possible destinations is a variable depending on types of users, climate, and hills, varying between 1 and 3.5 km for walkers and joggers and 6 to 14 km for cyclists (Lusk, 2002; Millward et al., 2013; Scheiner, 2010).

In relation to the third topic (method/technique to be used to estimate the potential users of a greenway) different solutions have been previously adopted to face this issue, such as aggregate-level methods, attitudinal surveys, discrete choice models and regional travel models (Porter et al., 1999). Several authors (Barnes and Krizek, 2005; Betz et al., 2003; Bhat et al., 2005; Krizek et al., 2007; Hankey et al., 2012; Lindsey et al., 2006, 2007; McDonald et al., 2007; Parkin et al., 2008; Rodríguez and Joo, 2004; Turner et al., 1997) have addressed the issue over the past 15 years, highlighting the main factors that influence the use of greenways and proposing some methods and models for its estimation based on the collection of available users data for similar paths or surveys of the population potentially affected. Unfortunately, these methods/models are often applicable only in similar contexts and require baseline data usually not available in Italy.

Making particular reference to aggregated studies, we chose do adopt a quantitative approach estimating the effect of factors potentially affecting the utilization rate of non-motorized infrastructures. In this context, regression is one of the most used statistical instruments for modeling the relationship between the greenways/trails users and the different variables (Baltes, 1996; Dill and Carr, 2003; Hankey et al., 2012; Lindsey et al., 2007; Ploner and Brandenburg, 2003). In a recent review, Ewing and Cervero (2010) analyzed more than 60 papers noting 16 methods/techniques of analysis: more than 50% of the studies used a regression technique.

3. Data and methods

3.1. Greenway traffic counts

In order to develop a model for the estimation of the potential users of a greenway, we gathered data on users from 13 automatic counters along 7 greenways in Northern Italy (Table 2; Fig. 1). The counters were located mainly in the countryside, near small towns, and the data were generally available over a period of 4 years (2006–2009) for the greenways in Trentino Alto-Adige, and over a period of 3 years (2007–2009) for the greenways in Lombardy (Fig. 2).

All the greenways considered run mainly in rural areas, crossing the large Po valley or mountain valleys, along streams or disused railways lines, and they connect a wide variety of land uses, including agricultural, natural, residential and industrial. They have a mild average slope and are mainly used for tourist-recreational purposes, for walking, cycling or skating. Their choice was determined by the limited availability in Italy of systematic data on greenways and trails users, and with the objective of analyzing greenways with heterogeneous characteristics.

The automatic counters allow for the detection of the users 24 h a day, 365 days a year, recording the users passages at fixed points of the track, but cannot distinguish the different types of users (cyclists, pedestrians, skaters, equestrian, etc.) neither the number of users from the number of passages (i.e. return trips).

The automatic counters record the passages in a specific point along the trail and do not allow the estimation of the real users of the relative trail segment. Procedures to extend point-source data to a segment (i.e. taking into account average distances and times travelled) should be defined in order to estimate users across trails segments.

Data collected by permanent automatic counters are increasingly used for research purposes despite their limitations (El Esawey et al., 2013; El Esawey et al., 2015; Fournier et al., 2017; Lumsdon et al., 2004).

The data collected by each counter were aggregated on a monthly basis, thus creating a dataset of 337 observations used for the development of the model. This number could have been higher if we had not been obliged to discard 140 monthly observations (29%), due to the climatic conditions of some mountain areas that prevent the use of trails in winter months and faults the automatic counters. As a consequence, the number of monthly observations for each counter used in the model varies from a minimum of 12 for the counter C10 to a maximum of 45 observations for the counter C6.

Analysis of the collected data shows that trail traffic varies temporally and spatially in systematic ways. The monthly mean traffic for the different locations in the period 2006–2009 varies from a minimum of 57 passages detected in January by the counter C1 along the Mantova-Peschiera greenway to a maximum of more than 85,000 passages registered in August by the counter C13 along the Valle dei Laghi greenway, with significant differences across locations. The monthly mean traffic across all locations ranges from 1042 passages in January to 25,977 in August, with a total average value of 13,600 passages per month, while the median monthly traffic varies from 868 passages in January to 16,389 in August (Fig. 3).

In both cases, the data show clearly the seasonality of trail use; most users can be seen from April to September, with a peak in the spring months for greenways in Lombardy (located in lowland areas) and in the summer for greenways in Trentino-Alto Adige (located in mountain

Table 2
Description of the 7 greenays considered in the study.

Greenway	Region	Length	Brief description
Valle dell'Adige	Trentino-Alto Adige	100 km	It's the main greenway of the Trentino Alto-Adige. It develops in the wide and flat bottom valley of the Adige river, that crosses all region from north to south, at an average altitude of 250 m. It develops in a mainly rural landscape (cultivation of cereals, orchards and vineyards), crossing some important and populated cities such as Trento and Rovereto.
Val Rendena	Trentino-Alto Adige	23 km	It's located in the bottom of Rendena Valley, at an average altitude of 700 m, in a mountain landscape protected by natural parks. It crosses a touristic area, with the main town of Pinzolo.
Valsugana	Trentino-Alto Adige	50 km	It's located in the wide Valsugana valley, a lateral one of the Adige valley, at an average altitude of 350 m. It crosses a rural landscape with orchards and vineyards, touching some touristic towns and the lakes Caldonazzo and Levico.
Val di Fiemme	Trentino-Alto Adige	36 km	It develops in the Fiemme valley, along the disused railway Ora-Predazzo, in a mountain landscape at an average altitude of 900 m. It crosses an important touristic area, with the main towns of Cavalese and Predazzo.
Valle dei Laghi	Trentino-Alto Adige	15 km	It's located in the wide bottom valley of the Sarca river, at the north end of Lake Garda, surrounded by vineyards and orchards. In the south part it crosses the important touristic area formed by the towns of Arco and Riva del Garda.
Mantova-Peschiera	Lombardy	45 km	It's located in the main plain of the north Italy, along the Mincio river, in a rural landscape with extended cultivation of cereals. It connects the Lake Garda with the city of Mantova.
Mantova-Bagnolo San Vito	Lombardy	11 km	It's located in the main plain of the north Italy, along the Mincio river, in a rural and low populated area. It doesn't cross relevant towns.

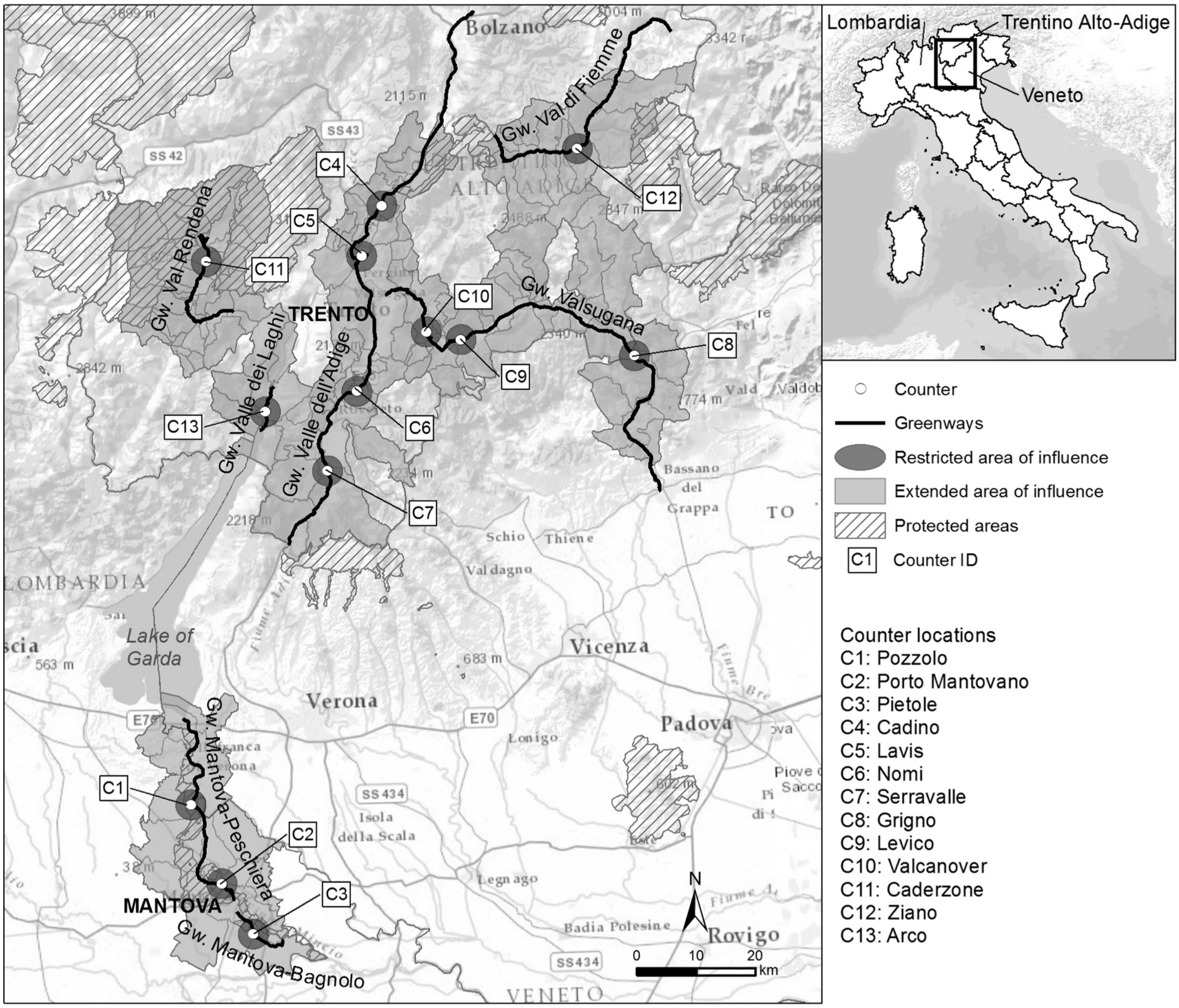

Fig. 1. The study area and the location of the greenways.

valleys) (Fig. 4).

The annual mean traffic in the considered period varies from a minimum of 30,000 passages detected by the counter C3 along the Mantova-Bagnolo *S. Vito* greenway to a maximum of > 350,000 passages registered by the counter C13, with no significant increases or decreases during the different years for almost all counters and a median annual traffic of nearly 100,000. Differences in traffic levels reflect variations in both trail and neighborhood characteristics and are maintained over time; some trails consistently received greater use. In particular, the Valle dei Laghi greenway presents a number of passages significantly higher than the other greenways, due to the presence of the Garda Lake, an important tourist attraction.

3.2. Model specification

Variables potentially influencing the traffic dynamics on Italian greenways have been statistically tested using the Ordinary Least Squares (OLS) method of regression analysis. In selecting the final specification of the model, we adopted the following strategy. Firstly, we performed a correlation analysis in order to exclude correlation between explanatory variables. Secondly, we modeled a specification that considers the effect of all the categories of determinants and their specific proxies. Then we simplified it by putting emphasis on both theoretical consideration and the robustness of the different determinants.

The result is a model specification (Model I) tested on the whole sample of 337 observations (all the 13 counters).

As previously highlighted, the greenways are located in two quite different geographical contexts. In fact, 10 counters are in the Alpine Region, while 3 counters are situated in the Po Valley, the main Italian flatland. For this reason, in a second step we tested final specification only on the sub-sample of the 10 counters located in the mountain area (Model II).

In a last step (Model III), we excluded from the Model II the observations belonging to counter C13. In fact this counter seems to distinguish itself as an outlier because of its location in the middle of a famous tourist town, recording a number of users that is significantly higher than the other counters (Fig. 2).

Following Lindsey et al. (2007), the dependent variable is converted in a logarithmic form in order to normalize the distribution, respecting OLS assumptions.

Given a log-linear form of the model:

$$Ln\ U = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + e \qquad (1)$$

where U is the monthly number of greenways users, the expected value of U can be predicted as:

$$E(U \mid x_1, x_2 \ldots) = \widehat{U} = exp(\widehat{\beta}_0 + \widehat{\beta}_1 x_1 + \widehat{\beta}_2 x_2 + \ldots + \widehat{\beta}_n x_n)\ exp(\widehat{\sigma}^2/2) \qquad (2)$$

where $\widehat{\sigma}^2$ is the unbiased estimator of σ^2, the root mean square error of the regression (Wooldridge, 2003).

In the log-linear functional form the $\widehat{\beta}_n$ coefficient represents the estimated variation of the natural logarithm of users corresponding to a

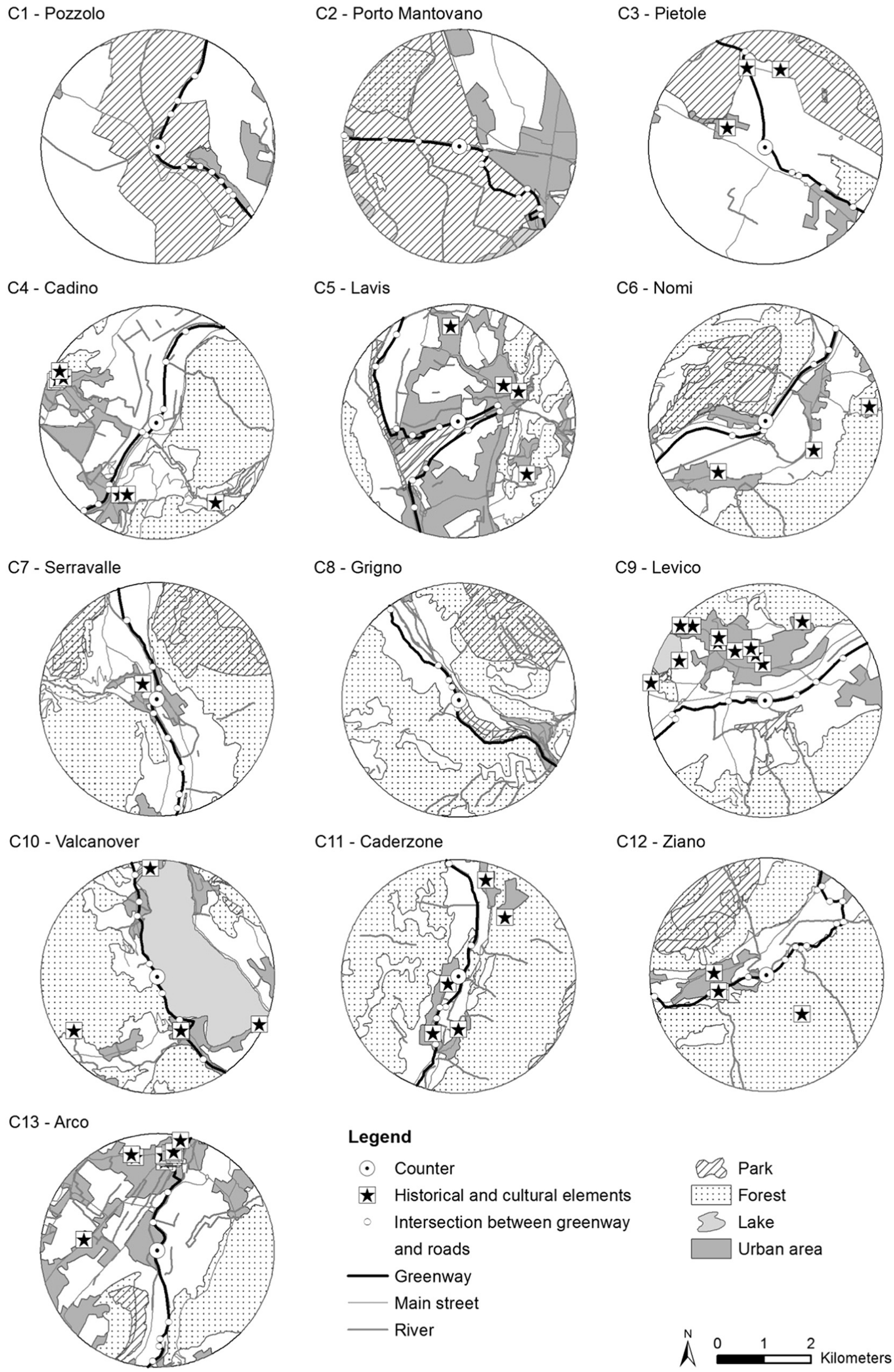

Fig. 2. Land use and elements of interest in the "restricted" buffer area around the counters.

one-unit increase in the covariate x_n, from which the estimated marginal effect $\frac{\widehat{\Delta U/U}}{\Delta x_n}$ of the variable x_n on U, that has to be read as a percent increase of the users consequential to one unit increase of x_n (all other factors held constant), is expressed by the formula (Wooldridge, 2003):

$$\frac{\widehat{\Delta U/U}}{\Delta x_n} = \%\widehat{\Delta U} = (e^{\widehat{\beta}_n} - 1) \times 100 \tag{3}$$

The above mentioned marginal effect is also called the *semi-elasticity* of U with respect to x_n and its value is constant along the log-linear

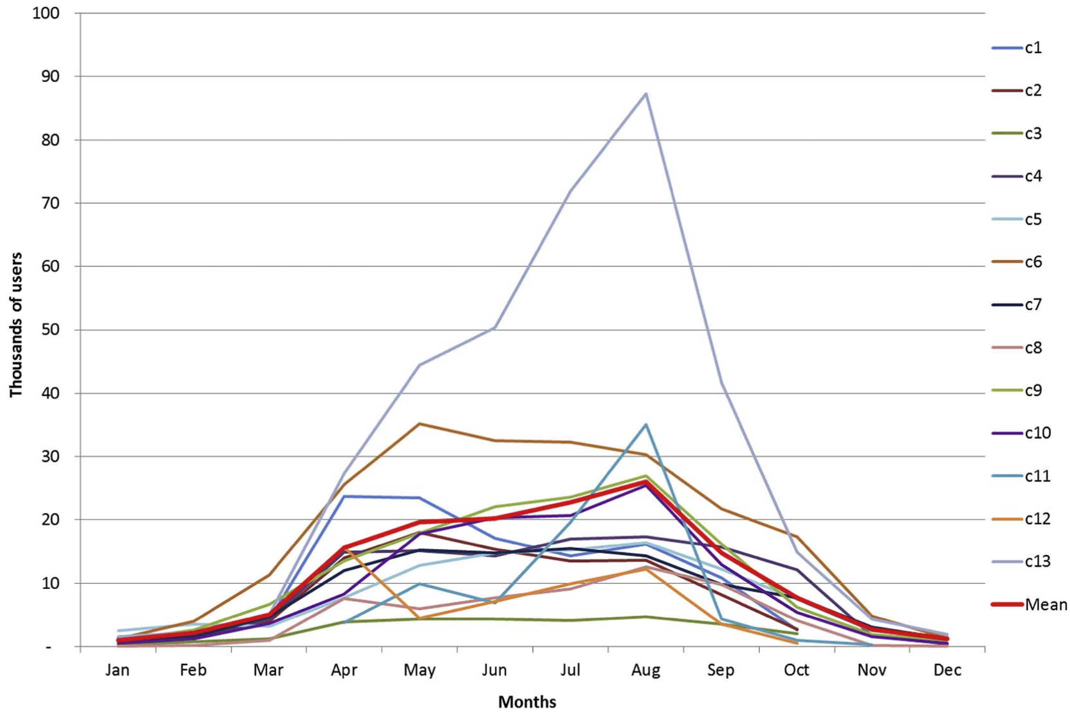

Fig. 3. Monthly mean passages registered by the automatic counters.

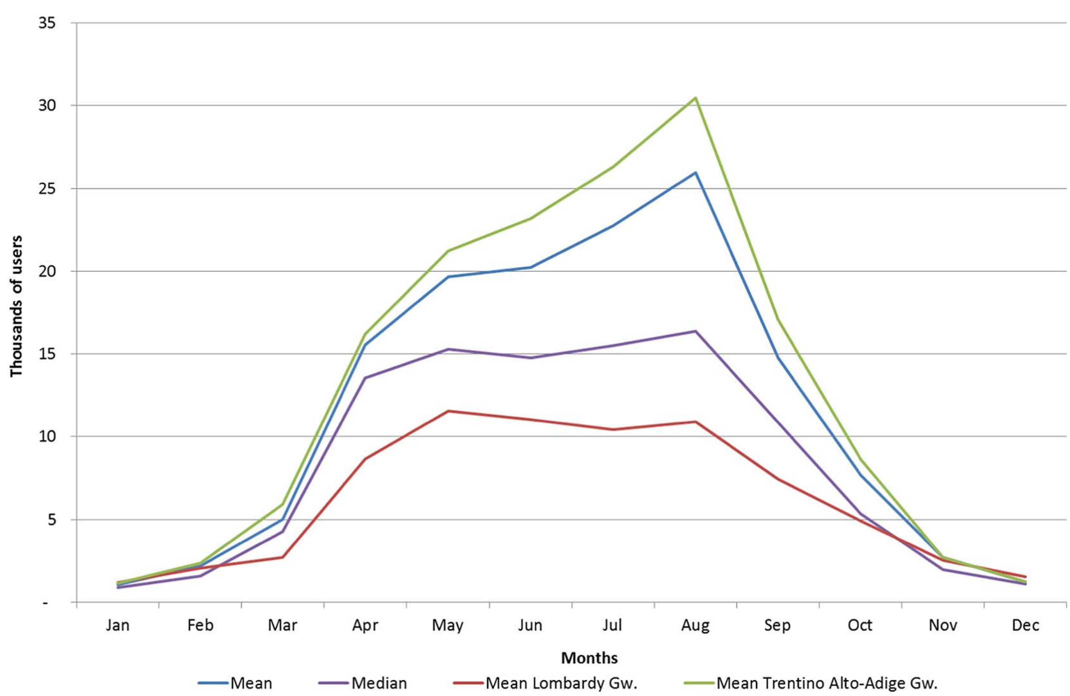

Fig. 4. Monthly mean and median passages registered by the counters by geographical area.

function (Wooldridge, 2003). Undoubtedly, this fact represents an advantage since it makes possible to interpret the effect of a covariate x_n independently from the starting point. On the other hand, a one unit change in an explanatory variable x_n has different weight according to the absolute value (on sample average) of the variable itself. For some variables it could represent a considerable variation, but in other cases a very small one.

For such a reason, we compute the point *elasticity* of U with respect to the x_n covariates at the mean values of x_n. The estimated elasticity $\hat{\varepsilon}_{U,x_n} = \left(\frac{d\widehat{U}}{U} / \frac{dx_n}{\bar{x}_n}\right)$ is the percentage change in the dependent variable (U) caused by a 1% change in an explanatory variable. In a log-linear model the value of elasticity changes as the values of the explanatory variables change, but at a certain point it allows to make a correct comparison among the marginal effects. The elasticity of U with respect to a covariate x_n is computed as follows. Starting from (Baltes, 1996):

$$U = exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + e) \tag{4}$$

Differentiating to get the marginal effect

$$\frac{dU}{dx_n} = \beta_n \cdot exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + e) = \beta_n U \tag{5}$$

Table 3
Description of the variables considered in the study.

Variable names	Definition	Area of influence	Hypothetical effect
Dependent variable			
Users	The monthly traffic of each counter	–	
Socio-demographic variables			
Density	Population density (inhabitants per sq. km of land area)	Extended	Positive
%young	% of the population aged < 15 years	Extended	Negative
%old	% of the population aged > 64 years	Extended	Negative
Education	% of the population having an education level ISCED 3 or upper	Extended	Positive
Income	Per capita Gross Domestic Product (€)	Extended	Positive
Tourism	Annual number of overnight stays in tourist accommodations per sq. km of land area	Extended	Positive
Accessibility variables			
Road density	Length of roads per sq. km of land area (km)	Extended	Positive
Intersections	Number of intersections between greenways and roads	Restricted	Positive
Railways	Number of railway stations	Extended	Positive
Highways	Number of highways toll-booths	Extended	Positive
Landscape variables			
Parks_small	% of total land area covered by protected areas	Restricted	Positive
Parks_large	% of total land area covered by protected areas	Extended	Positive
Forests_small	% of total land area covered by woodlands	Restricted	Positive
Forests_large	% of total land area covered by woodlands	Extended	Positive
Lakes_small	% of total land area covered by lakes	Restricted	Positive
Lakes_large	% of total land area covered by lakes	Extended	Positive
Rivers_small	Length of rivers per sq. km of land area	Restricted	Positive
Rivers_large	Length of rivers per sq. km of land area	Extended	Positive
Urban_small	% of total land area covered by urbanized areas	Restricted	Positive
Urban_large	% of total land area covered by urbanized areas	Extended	Positive
Elements of interest	Number of elements of historical and cultural interest	Restricted	Positive
Orography	Standard deviation of elevations	Restricted	Negative
Bicycle trails	Presence of other bicycle trails in the study area (yes/no)	Extended	Negative
Temporal variables			
Holiday	% of holidays in the month	–	Positive

and

$$\beta_n = \frac{dU}{dx_n} \cdot \frac{1}{U} \tag{6}$$

As a consequence of (Bhat et al., 2005) and (Boarnet et al., 2008), the estimated elasticity of U with respect to x_n (calculated at x_n mean value $\bar{x}_n$) is computed as:

$$\hat{\varepsilon}_{U,x_n} = \left(\frac{\widehat{dU}}{U} / \frac{dx_n}{\bar{x}_n}\right) = \left(\frac{\widehat{dU}}{dx_n} \cdot \frac{\bar{x}_n}{U}\right) = \beta_n \bar{x}_n \tag{7}$$

3.3. Measures of socio-demographic characteristics of potential users and geographical characteristics of the area

The data gathered from the automatic counters have been related with the main variables potentially influencing the greenways use, based on the available literature. We identified 24 variables, divided into four categories:

- socio-demographic characteristics of the potential users, both residents and tourists: population density, age, level of education and income, number of tourists;
- accessibility of the greenway: presence of roads and railways nearby, intersections between the greenway and the road network;
- landscape characteristics of the area: topography, land use, historical, cultural and natural resources, presence of other greenways;
- time and climatic variables: month of the year, holidays per month.

The variables were chosen with the dual aim of characterizing both the greenways themselves and the surroundings of the counters. To this end, given that few previous studies have examined the distances at which specific variables influence bicycle and pedestrian traffic, two different areas of influence for each counter have been defined:

- an "extended" area of influence, in order to consider the area of origin of the possible daily users detected by the counter and to describe the environmental and infrastructural context in which the greenway is located (Fig. 1);
- a "restricted" area of influence, in order to describe the characteristics of the surroundings of each counter (Fig. 2).

These areas of influence were determined using a Geographical Information System (GIS) and taking into account the level of detail of the data available for the calculation of the variables (Toccolini et al., 2004). The "restricted" area of influence was defined by a circular buffer of 2.5 km around the counter location (which is equivalent to a 30 min travel walking or 10 min travel cycling). We used a walking speed of 5 km/h and a cycling one of 15 km/h, trying to mediate the different speeds in urban and rural areas found in the literature (Eizaguirre-Iribar et al., 2016; Foth et al., 2013; Millward et al., 2013). The 30 min limit is consistent with a similar Spanish study (Eizaguirre-Iribar et al., 2016).

The extended area of influence was defined by the boundaries of the municipalities within the area of intersection of a 16 km circular buffer around the counter and a linear buffer of 6 km along the greenway. This is because the statistical data used for the calculation of the socio-demographic variables are only available at the municipal level. The municipalities were included in the extended area of influence if:

- > 50% of the municipal land area or all the residential area falls within the area of intersection;
- > 50% of the municipal territory has a difference of < 1000 m respect to the counter elevation.

As a result, the extended area of influence is not centered on the counter location (as a geometric buffer) and may exclude areas close to the counter (but not populated or with a too high difference in height) and include more distant areas (but populated or more accessible considering the difference in height).We think this approach can adequately represent the origin of most potential users who reach the

Table 4
Most significant statistical values for the variables considered in the study.

Variables	Mean	Std. dev.	Minimum	Maximum
Dependent variable				
Users	13,657	17,634	57	162,297
Socio-demographic variables				
Density	216.63	120.39	38.80	443.11
%young	14.39	1.34	11.20	16.24
%old	20.34	1.83	18.18	25.24
Education	32.50	3.83	25.17	38.66
Income	14,013	1226	10,946	15,887
Tourism	3239	3752	216.24	12,306
Accessibility variables				
Road density	0.751	0.190	0.293	1.072
Intersections	1.486	0.381	0.880	2.072
Railways	3.887	3.689	0	11
Highways	1.181	1.086	0	3
Landscape variables				
Parks_small	15.46	18.77	0	65.45
Parks_large	17.99	11.53	3.57	59.53
Forests_small	33.42	21.31	0	69.39
Forests_large	43.23	22.11	0.59	65.27
Lakes_small	1.675	5.084	0	26.77
Lakes_large	1.640	2.101	0.082	6.183
Rivers_small	0.854	0.395	0.186	1.569
Rivers_large	0.541	0.185	0.315	0.924
Urban_small	11.79	6.049	3.941	21.21
Urban_large	6.665	3.649	1.647	14.85
Elements of interest	5.42	5.72	0	17
Orography	170.46	108.68	2.52	370.69
Cycle trails	0.365	0.482	0	1
Temporal variables				
Holiday	30.64	3.17	25.81	40.00

greenway by walking, by bicycle or by car.

In Table 3, the variables considered in this study are summarized, with the indication of the area of influence to which they have been calculated and the expected effect on monthly users. Some variables were evaluated for both areas of influence. Table 4 shows the most significant statistical values for each variable (mean, standard deviation, minimum and maximum value).

The variables used to describe the socio-demographic characteristics of potential users were calculated for the extended area of influence, and include population density, age, level of education, income and the overnight stays of tourists. Age was measured with two proxies: the percentage of population less than age 15 and the percentage of population greater than age 64. Education was defined as the percentage of population having an ISCED (International Standard Classification of Education) education level 3, corresponding to an "Upper secondary education" (UNESO, 2012) or higher. Income was defined as the per-capita Gross Domestic Product (GDP). The number of overnight stays was included to measure the presence of tourism and was defined as the annual number of overnight stays in tourist accommodation per square kilometer of area. The population density, age, education and income were calculated using the last census (2011) data from the Italian National Institute of Statistics - ISTAT while the number of overnight touristic stays was gathered from the Provincial Tourist Offices because a national database doesn't exist. The expected effect is positive for all the variables, with the exception of the percentage of the population under 15 and over 64 years old, that, according to the literature, is expected to have a negative effect on the number of users.

The variables used to describe the greenways accessibility are: the number of highways tollbooths and railway stations, the road network density and the number of intersections between roads and greenways. These variables were calculated for the extended area of influence, except for the intersection between roads and greenways, using GIS and the cartographic data available on the National Cartographic Portal of the Italian Ministry of Environment. The expected effect on the number of greenway users is positive for all the variables.

The variables used to describe the landscape characteristics of the area crossed by the greenways include the orography, the presence of protected areas, urban areas, forests, water bodies and rivers, the number of elements of historical and cultural interest (churches, museums, historic buildings, etc.) and the presence of other pedestrian and bicycle paths. The orography was calculated as the standard deviation of the elevations in the restricted area of influence. The presence of protected areas, urban areas, forests and water bodies was defined as the percentage of the area covered by these land uses. The presence of rivers was defined as the extension of the rivers per square kilometer of the area of influence. The presence of other pedestrian and bicycle paths was represented by a dummy variable that takes the value 0 (no other paths) or 1 (presence of other paths). Almost all of the landscape variables were calculated using GIS, both for the extended and restricted area of influence, starting from cartographic data available on the National Cartographic Portal and from the Italian Touring Club (TCI) data for the tourist attractions. The expected effect on the number of greenway users is positive, with the exception of the variables related to the topography and the presence of other greenways.

Finally, monthly dummy variables were included to check the effect of seasons and the percentage of non-working days for each month was calculated in order to take into account the effect of public holidays. We expect a positive effect on the number of users from all these last variables.

4. Results and discussion

Table 5 displays the regression results of the three models in which we controlled for monthly fixed effects with the use of specific dummies, while Table 6 shows for all variables for each specification the estimated point elasticity and the corresponding absolute users variation caused by a 1% increase of the explanatory variable.

In Table 5, we report the estimated coefficients, and the respective *p*-value for each model. For comparability and symmetry, we chose to include in the final specification the same set of variables for all the three models. The criterion adopted for the final specification is to include a variable only if it results to be significantly different from zero in at least one model (p-value < 0.1).

All the three models have a significant χ^2, meaning that all the regressors are jointly significantly different from zero, thus the set of our explanatory variables plays a role in estimating greenways monthly potential users.

Particularly in Model I, which has been tested on the whole sample, accounts for about 80% of the variation in monthly use of the considered greenways. This is an outcome in line with Lindsey et al., 2007 results. The restriction of the analysis to the sub-samples increases the adjusted R-squared, but to a small extent. In fact, in Model II the overall explanatory power reaches 81%, while in Model III it rises to 82%.

Examining in depth to the different categories of determinants, almost all proxies related to socio-demographic characteristics of potential users appears to be strongly significant. Indeed, only the income, that is usually considered an important variable (Lindsey et al., 2006, 2007), does not present any effect in all the three explained models, while the others are generally significant at the 1 or 5% level.

In line with the a-priori expectations, the percentages of younger and older people are negatively and significantly correlated to the fruition of greenways. The tourism intensity and the level of education show a positive effect. Contrary both to Lindsey et al. (2007) and our expectations, population density coefficient takes a negative value. This is probably due to a different influence of the population density on urban (Lindsey et al., 2007) and rural greenways (the present study). Making reference to the Model I, the elasticity coefficient of demographic variables is very high, as well as one for education (9.79). By contrast, the percentage variation in users corresponding to a 1% variation of the tourism intensity is very limited. However, if we impose an

Table 5
Regression results of the three models used.

	Model I		Model II		Model III	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Temporal variables						
January	− 0.2828791	0.267	− 0.2701101	0.305	− 0.1745205	0.517
February	0.5621449	0.018	0.4779576	0.063	0.6710171	0.010
March	1.559288	0.000	1.526959	0.000	1,742,953	0.000
April	2.750626	0.000	2.692144	0.000	2.718508	0.000
May	2.99123	0.000	2.971842	0.000	2,965,159	0.000
June	3.056132	0.000	3.08846	0.000	3.0727	0.000
July	3.180259	0.000	3.289552	0.000	3.263584	0.000
August	3.356938	0.000	3.50448	0.000	3.488594	0.000
September	2.756585	0.000	2.845388	0.000	2.847208	0.000
October	1.918765	0.000	1.99794	0.000	2,145,008	0.000
November	0.7455168	0.001	0.7504362	0.001	0.7592061	0.002
Socio-demographic variables						
Population density	− 0.0154728	0.000	− 0.0230691	0.002	− 0.0214335	0.003
%young	− 0.7045987	0.000	− 2.528816	0.002	− 1.960272	0.010
%old	− 0.5348318	0.000	− 1.694303	0.017	− 1.601141	0.022
Education	0.2873542	0.000	0.2828231	0.000	0.2443862	0.000
Tourism	0.0000501	0.013	0.0000139	0.728	− 0.0001317	0.027
Accessibility variables						
Road density	4.03832	0.000	4.95718	0.057	5.768171	0.060
Landscape variables						
Orography	− 0.0030615	0.000	− 0.0068234	0.000	− 0.0052962	0.002
Elements of interest	0.0380183	0.003	0.0471008	0.004	0.0314481	0.182
Intercept	18.77017	0.001	70.6318	0.005	605,573	0.011
Nr. of observations	337		263		219	
Adjusted R-squared	0.80		0.81		0.82	
F-statistic	71.9		58.1		64.3	

increase to the tourism variable, equal to its standard deviation (3752), we cause a users growth of 20.7%. Notably, the absolute value of socio-demographic variables coefficients and elasticity, as well the population density one, increases in model II and III, whereas tourism either is not significant (model II) or turns to be slightly negative (model III).

This result leads to an interesting consideration: the demographic structure of society plays a stronger role in mountainous areas than in the less hilly ones, probably due to the greater physical effort needed not only to face hilly bike trails, but also to approach them along substantial gradients. However, despite the growing interest in bicycle tourism in Italy, this factor does not yet have a significant impact on the number of users. In the light of this, more research is needed to evaluate the relative incidence of resident and tourist greenways users in the different pathways (counters do not distinguish between them!).

Accessibility plays an important role in all the three presented models, but only if we refer to the road density proxy, calculated on the extended area of influence. Instead, the other proxies, such as intersections, railways and highways, either do not capture the effect or are not important. Users elasticity with respect to accessibility does not significantly vary across the different models.

With regards to the landscape variables we find a negative correlation with the orography and a positive correlation with the presence of elements of historical and cultural interest. An increase of the orography variable, equal to its standard deviation, leads to a 28.3% decrease in the potential users. The marginal effect of an additional element of interest is 3.9%.

In our analysis we have not found any effect of the other landscape and natural characteristics, but we are conscious of the difficulties to model landscape attractiveness with quantitative proxies such as lakes, rivers and forests. Moreover at a landscape level (medium scale) detailed information about vegetation and other landscape elements is available only for few regions in Italy. Further research is needed to investigate this issue.

Other important elements, such as surface characteristics and views

Table 6
Estimated variables elasticity at the mean values.

	Model I		Model II		Model III	
	Estimated elasticity at mean values	Absolute annual users variation	Estimated elasticity at mean values	Absolute annual users variation	Estimated elasticity at mean values	Absolute annual users variation
Socio-demographic variables						
Population density	3.30	4353	4.28	6661	3.94	5018
%young	9.64	12,735	31.58	49,167	25.56	32,566
%old	10.31	13,615	28.22	43,934	26.82	34,176
Education	9.79	12,928	9.61	14,963	8.29	10,559
Tourism	0.16	214	0.05	76	0.23	296
Accessibility variables						
Road density	3.08	4064	3.57	5551	4.18	5325
Landscape variables						
Orography	0.52	687	1.47	2287	1.21	1546
Elements of interest[a]	3.88	5117	4.82	7509	3.19	4071

[a] Marginal effect at the mean values.

Table 7
Actual and estimated traffic using regression models.

Counter	Annual actual traffic (mean 2007–2009)	Model I		Model III	
		Annual estimated traffic (mean 2007–2009)	% error	Annual estimated traffic (mean 2007–2009)	% error
C_1	102,921	92,086	− 10.5%		
C_2	89,711	145,463	62.1%		
C_3	27,376	34,910	27.5%		
C_4	81,166	109,758	35.2%	103,442	27.4%
C_5	98,481	128,459	30.4%	148,409	50.7%
C_6	217,160	229,471	5.7%	266,940	22.9%
C_7	68,462	87,781	28.2%	81,018	18.3%
C_8	44,046	31,884	− 27.6%	32,770	− 25.6%
C_9	121,964	159,767	31.0%	146,354	20.0%
C_10	118,276	222,322	88.0%	127,613	7.9%
C_11	45,937	35,700	− 22.3%	27,505	− 40.1%
C_12	40,784	37,414	− 8.3%	33,295	− 18.4%
C_13	396,762	274,479	− 30.8%		

Mean of percent error (absolute value).

from the trails, have to be considered in a smaller buffer at the design level (micro scale). Therefore, they can be partly modified in the design phase (Sharma, 2015).

Finally, the bicycle trails variable does not show any significant effect and the holidays variable has not been included in the model, because its effect is largely captured by the month fixed effects.

In order to perform a models validation, we computed by mean of (Barnes and Krizek, 2005), the annual estimation of users for each counter and, then, we compared those values with the annual actual traffic. Both the actual and the estimated traffic are expressed as a mean of 3 years (2007, 2008 and 2009). For each year and counter, the number of actual and estimated users is referred only to the available months.

Table 7 displays, for each counter, the percentage error occurred in both model I and model III.

We can observe that in Model I the annual expected value considerably diverges from the actual value for only two counters (C_2 and C_10), while the average percent error, expressed in absolute value, is 31.4%. Model III, performed on a restricted group of counters located in a more homogeneous area, shows an average absolute error of 25.7%, confirming that model III performs better than model I and so supporting the assumption that the investigated phenomenon could develop in different ways depending on the territorial location (for example in the mountains or the plain). In model III only the counter C_5 users have been estimated with an error upper than 50%.

All results considered, the present study adds to previous findings by confirming that trail use is a function of socio-demographic and environmental characteristics. Particularly the potential users are negatively affected by population density and positively by the presence of amenities indicating that greenways are mainly considered for leisure activities and their appeal largely depends on the quality of landscape and a low incidence of urbanized area. Also the positive role exerted by education and tourism intensity that are both generally linked with a social demand for environment seems to confirm this interpretation.

Having estimated the elasticities of these factors provide policy makers and greenways planners/designers with an instrument to forecast the number of potential users for future greenways projects, improving the effectiveness of public funds spent in such investments. In fact, territories with a high (low) level of the variables positively (negatively) related with the number of users are probably more suitable for a new greenway infrastructure.

However, we are aware that quantitative modeling of complex phenomena, like this, is not always straightforward and many factors, especially those that are hardly quantifiable, can be neglected in a statistical aggregated model. Nevertheless, if the predictive capacity of the model is statistically acceptable, this method could represent a good compromise between estimation precision, on the one hand, and time/costs savings of estimation and adaptability to different territorial contexts, on the other hand. In any case, such a quantitative analysis could be efficiently complemented by a qualitative one, focused on a deepened investigation of the personal characteristics of users and their specific needs.

As anticipated, our study represents a first step in the investigation of a phenomenon that is quite recent and further and more solid considerations could emerge when data about a larger number of routes is available (in Italy, the attention to the non-motorized mobility has emerged only in the last decade). In this study, we used data obtained from 13 automatic counters in 4 years, along 7 different greenways, in two Italian regions with a total of over 4 million counts, which constitute the most comprehensive data set currently available.

Moreover, in contrast to previous research, the present study focused on rural areas, both in the plains than in the mountain zones, extending the results of previous research that are almost exclusively referred to metropolitan areas.

We tested new proxies for measuring the landscape and the accessibility characteristics of the greenways, extending the area of analysis with respect to most previous studies, in order to consider the influence of the trail surroundings as a whole. Our results show that some of these proxies, such as the orography, the road density and the presence of historical and cultural elements, are significantly correlated with the greenway use, defining an original predictive model for estimating bicycle and pedestrian traffic on Italian trails.

Our analysis also confirms the need for additional research to improve the model and overcome some limitations due to the availability of data, the calculation methodology or the specific Italian situation.

Pointing our attention to the different factors potentially affecting the utilization of greenways we should remember that some of them – such as territorial, climate and socio-economic ones – are exogenous and not modifiable (at least in the short period), while others, related to the technical characteristics of the route, to the presence of services dedicated to users or the implementation of marketing campaigns, are potentially modifiable. This property makes an estimation of the effect of these last factors useful not only for an ex-ante evaluation of future projects, but also to improve existing greenways. Unfortunately, many of these factors are not quantifiable, or data about them are not, or hardly, available. Given the preliminary nature of our study, we didn't considered them. However, being aware of their potential impact, we underline the need of further research in this field.

Returning to factors included in the analysis, we remember that our proxies were constructed using the statistical and geographic data available throughout the country, in order to investigate variables that could be calculated for other study areas. The census data, used to measure the socio-demographic characteristics are updated on a 10-year basis and available only at municipal level. Geographic data used to measure the landscape features and the accessibility are considered constant over time. The statistical data related to tourism are updated on annual basis but they are always available at municipal level. The use of temporally and spatially more detailed and updated data could improve the model and the research results.

Such as Lindsey et al. (2006, 2007), we tested by means of an OLS regression model the relationship between the number of greenways users and some socio-demographic, accessibility and landscape variables, referred to the territory in which the greenways lie. Greenway users are proxies based on the number of transits recorded by the electronic counters (the dependent variable Users). Therefore this analytic approach is clearly quantitative.

Electronic counters made available to us 10,000 daily observations (4.5 million single transits) over 13 greenways, over some years, over all seasons, aggregated in > 300 monthly observations. The huge dimension of dataset, we believe, is a strong point of our analysis, because it gives a complete statistical universe and a statistical robustness to our model.

On the other hand we recognize that electronic counters don't reveal user preferences, but it is likewise undeniable that it is impossible to cover a similar statistical population with interviews of users. In any case, given the quantitative approach of the analysis, we think that this lack is widely compensated by the dataset dimension advantages.

Another important decision that could have influenced the results concerns the area unit used to construct variables. We decided to test two areas of influence: a restricted and an extended one, in order to characterize both the greenways themselves and the surroundings of the counters. Further research on the effects of using different areas of influence, together with the testing of new proxies to measure the same theoretical constructs, would be useful to develop a robust model that can be used to inform management decisions.

Despite the limitations and the need of additional research to validate the results, the models defined may have practical application in forecasting studies to estimate greenway use at specific locations on existing or proposed trails. Although there is uncertainty in the estimates and they don't represent the number of real users but only the number of passages for each segment, planners may use the results in feasibility studies for new greenways, for the evaluation and choice among alternative projects to finance and implement, or as input into cost-benefit analysis aimed to optimize the allocation of resources.

Finally, because different regions have different climates, socio-demographic characteristics and landscapes, further research is needed to extend, test and validate the model before it may be used in other geographical areas.

5. Conclusions

The present study has confirmed in the Italian context examined, a significant correlation between the greenway use and the socio-demographic and landscape characteristics of the trail surroundings, its accessibility and the temporal variables. In particular, all the proxies used for modeling the socio-demographic variables appears to be significant, except income, as well as the greenway traffic appears correlated with the road density, the orography and the presence of elements of historical and cultural interest. Those proxies, together with the temporal control variables, explained > 80% of the variation in monthly greenway use.

The model defined may have potential application in the forecasting studies to estimate existing or proposed greenways use. However, because different regions have different climates, socio-demographic characteristics and landscapes, and in the present study weren't considered the characteristics of the greenways and the individual behavior, further research are needed to validate and extend the model.

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