Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 60 (2022) 60–67

Transportation Research Procedia

www.elsevier.com/locate/procedia

XXV International Conference Living and Walking in Cities - New scenarios for safe mobility in urban areas (LWC 2021), 9-10 September 2021, Brescia, Italy

The transformation of urban spaces as a cycling motivator: the case of Cagliari, Italy

Francesco Piras[a*], Beatrice Scappini[a], Italo Meloni[a]

[a]*Università degli Studi di Cagliari, via San Giorgio 12, Cagliari 09124, Italy*

Abstract

Recently walking and cycling, known as active mobility, have attracted the attention of both citizens and policymakers. Many new pedestrian areas and cycle paths have been created or extended in various cities across Europe and monetary incentives have been offered to support and encourage citizens to use active mobility. Starting from this context, the aim of the current paper is to evaluate the impact that interventions of re-functionalization of the street space have in boosting cycling mobility in the city of Cagliari (Italy). Employing data collected in three distinct cross-sectional surveys (2014, 2019 and 2020), we constructed a logit model that simulates individuals' probability to cycle/not cycle for one purpose or another. Model results indicate a general increase in the probability to cycle over time and that individuals living in those areas where cycling facilities are provided were more likely to use the bicycle than the rest of the city's residents. Furthermore, our findings show that measures developed to improve cycling infrastructure should be implemented jointly with interventions of urban regeneration, that modify the environment in terms of both safety and livability. Finally, our results stress the importance of the longitudinal assessment of policies and strategies.

Keywords: street space; cycling infrastructure; cycling mobility; logit model; scale factor

1. Introduction

The urban street represents the main place for a city's social life and interaction, is used by citizens to carry out their economic and social activities and recognized by them as a public and democratic place (Ascolese, 2017). However, with the increase in automobile use - paradigm of 20th century urban development - the idea of the street has progressively been equated to the two-dimensional surface built for cars on the move and parked (Global Designing Cities Initiative, 2016). This change of perspective has, over the years, contributed to relegating non-

* Corresponding author. Tel.: +39-0706756405; fax: +39-0706756401
E-mail address: francesco.piras@unica.it

10.1016/j.trpro.2021.12.009

motorized users, *e.g.* pedestrians and cyclists, to the margins of the urban street space and has generated dangerous levels of vehicle congestion, unsustainable for citizens' health as well as for the environment, resulting in a decline in cities' livability, functionality and aesthetics.

Hence, nowadays urban planners and policymakers in many European cities must face the challenge of balancing the demand for increasing personal mobility and economic growth with the need to respect the environment and provide an acceptable quality of life for all citizens (Directorate General for Environment, 2004). Furthermore, because of the recent Covid-19 pandemic, the cultural movement for rethinking the design of spaces and structures that shape urban streets have received an additional impulse to restore the right balance between individuals and functions that use public spaces and vehicular mobility. This new approach is based on the fact that urban streets today represent the greatest public good that cities have, and for which it is possible to build a new model of urban mobility, highly sustainable and focused on active mobility.

Regarding cycling mobility, the topic of the current paper, some studies indicate that the growth of bicycle usage is correlated with the implementation of initiatives designed to transform public spaces to accommodate dedicated infrastructure (Heesch *et al.*, 2016; Zahabi *et al.*, 2016; Hong *et al.*, 2019; Félix *et al.*, 2020; Yang *et al.*, 2021). For example, Zahabi *et al.* (2016) observed, for the city of Montreal, an increase in the modal share in favor of cycling, passing from 2.8% to 5.3% in urban areas and from 1.4% to 3.0% in suburban neighborhoods, thanks to the installation of cycling facilities over time. Analyzing the case of the city of Lisbon, which over the years has developed its network of cycle paths and bike sharing services, Felix *et al.* (2020) indicated that these kinds of "hard" measures put in place by the administration to promote cycling can have a major impact on the growth of bicycle modal share in a starter cycling city.

However, creating cycling infrastructure may not be sufficient to increase the number of individuals practicing this activity, as the success of such measures strongly depends on their design. As suggested by previous research, the creation of a dense and well-connected network of cycle paths or lanes in urban areas should be preferred (Habib *et al.*, 2014; Félix *et al.*, 2020; Yang *et al.*, 2021). Also, the distance from home to the closest cycling infrastructure has been found to have a positive impact on the probability of an individual choosing to use the bicycle as the main mode of transportation (Rodriguez-Valencia *et al.*, 2019).

Natural and built environment characteristics can be facilitators of cycling mobility as well (Wang *et al.*, 2016; Félix *et al.*, 2020). Indeed, the urban fabric and topography, land use and location of activities are considered to be some of the most important factors influencing active mobility (Habib *et al.*, 2014). For example, the presence of high-quality open spaces, such as large parks and gardens, public squares together with tree-lined streets and boulevards is linked with the increase in walking and cycling levels (Wang *et al.*, 2016). Another kind of open space to be found in many Mediterranean cities are port waterfronts and beach promenades (Félix *et al.*, 2020).

From the above overview it is clear that in recent years the number of research studies investigating which factors can boost cycling mobility has dramatically increased and it is safe to assume that "*planners know what to do to promote cycling in the real world*" (Nello-Deakin, 2020). What is less well known is if and how the creation of new cycling infrastructure and, in general, the transformation of urban spaces can effectively encourage more individuals to use the bicycle. In fact, papers addressing this topic are in many cases exploratory in nature and do not employ an appropriate methodology to analyze the evolution of individuals' preferences over time. Some researchers based their findings on counting users of new bicycle lanes (Heesch *et al.*, 2016; Hong *et al.*, 2019), but by so doing they did not account for the fact that many cyclists utilizing the new infrastructure used to cycle before its creation. Others (Zahabi *et al.*, 2016; Yang *et al.*, 2021) did not compare, from a modeling standpoint, the impact of the different factors influencing the use of the bike over time. More specifically, there has been little quantitative analysis, from an econometric standpoint, of the effect on the propensity to cycle of living in a neighborhood before and after that cycling infrastructure was created. Instead, this kind of assessment should become the rule, as it allows us to understand if the measures put in place are working well and which areas of the city still need interventions.

Motivated by the above discussion, the object of the current paper is to explore, from a modeling point of view, the relationship between bikeway provision and cycling mobility over time in Cagliari a medium-sized city in Italy. Driven by the need to reduce motorized transport, local administrators in the city of Cagliari have started in the last few years to implement different policies and infrastructure interventions regarding active mobility. Through the specification and estimation of a binary logit model we provide a systematic before-after evaluation of the effects of these policies on the choice to cycle for both utilitarian and recreational purposes. Data drawn from surveys conducted by the University of Cagliari in 2014, 2019 and 2020 are used for this purpose. The use of 2020 data (October-December) also gave us the opportunity to analyze people's travel behavior after the restrictions imposed to reduce the spread of COVID-19 and verify whether this has actually led to a cycling renaissance, as postulated by some recent studies (Scorrano and Danielis, 2021).

This study aims to contribute to urban planning research by reporting a case study of the effect of the evolution of physical and built environment on cycling over time. More specifically, we provide evidence on the effectiveness of interventions aimed at encouraging the use of the bike, which is a topic little investigated in the literature. Furthermore, we show a methodology that can be easily employed by urban planners to evaluate ex-post the impact of policies carried out to promote cycling and improve cyclability.

The remainder of the paper is organized as follows. In Section 2 we provide a description of the study context, how we collected the data and the methodology employed. In Section 3 we report and discuss modeling results, while key conclusions are drawn in Section 4.

2. Methodology

2.1. Study context

Capital of Sardinia and main gateway to the Mediterranean Sea, Cagliari is an Italian municipality located on the southern coast of the island. With about 155,000 inhabitants it is the most populous city of Sardinia. Currently the urban area counts three main pedestrian areas located in the city's historic districts Marina, Villanova and Castello and six restricted traffic zones (ZTL), with a ratio of 0.58 m^2 pedestrian areas and 7.40 m^2 ZTL per inhabitant. With regard to cycling infrastructure, the city has a discontinuous and fragmented cycle network of about 70 km while a bike sharing service has been operating since 2014 (3.9 bikes per 1,000 inhabitants), with the recent addition of 40 e-bikes. Public parks and green spaces, together with the port waterfront and the Poetto beach area provide a lot of space for active mobility within the city, with a ratio of 54.9 m^2 of green areas per inhabitant (Legambiente, 2020).

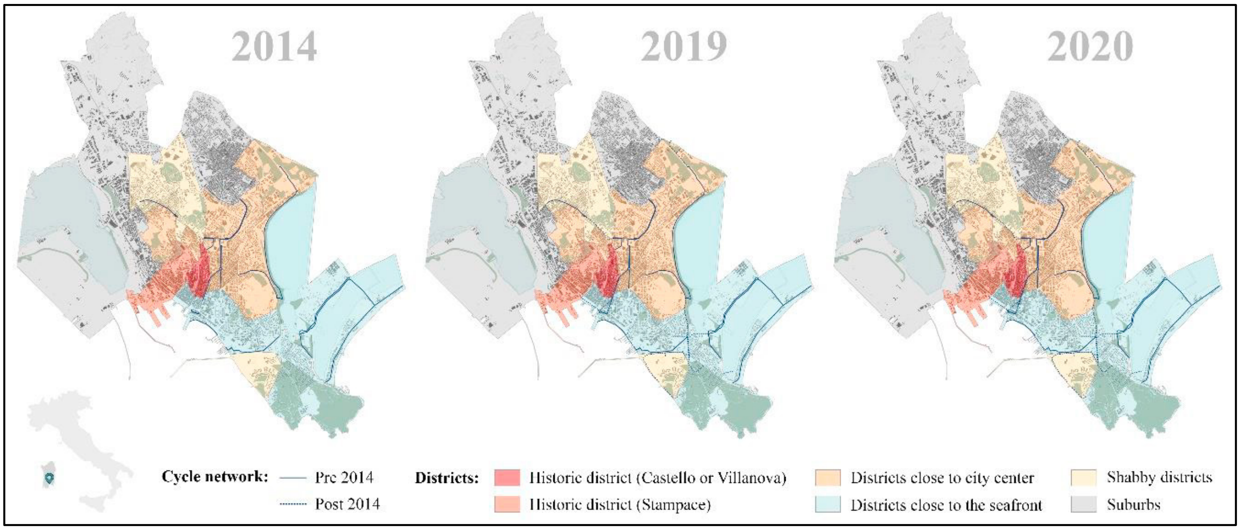

Fig. 1. Cycle network in Cagliari in 2014, 2019 and 2020 (source: elaboration of the Research Centre for Mobility Models at the University of Cagliari).

Some hurdles still need to be crossed in the transition towards sustainable, zero-emission mobility in the city, such as the high motorization rate, with 65 cars per 100 inhabitants, and the insufficient supply of local public transport in terms of electric mobility. Nevertheless, the creation of cycle paths and shared mobility services, with new e-bikes and electric kick scooters around the city, has led to a renewed interest in active mobility. In particular, during the last decade, Cagliari has been involved in a number of active mobility infrastructure projects (Figure 1):

- 2010: start of the pedestrianization process of Villanova and Castello districts;
- 2011-2015: regeneration of the Poetto beach seafront, with a new promenade consisting of bike and pedestrian paths, 30 km/h zones and a public transport system serving the whole area;
- 2014-2017: creation of the pedestrian mall between via Garibaldi, via Manno and corso Vittorio Emanuele II, providing a 1.5 km dedicated area for walking and cycling;
- 2015-2019: implementation of the city's cycle network with the construction of 13.88 km of segregated cycle paths and cycle lanes in addition to the previously existing 26.51 km.

2.2. Data collection and analysis

The data employed in the current study are drawn from three different surveys developed and conducted over the years by the Research Centre for Mobility Models (CRiMM) at the University of Cagliari:

- "Bici Mi Piaci", conducted in 2014 within the program agreement for urban development and cycling, pedestrian and commuter mobility in the metropolitan area of Cagliari (survey wave A).
- "Svoltiamo", conducted in 2019 as a part of broader program aimed at promoting more sustainable travel behavior among individuals working in the municipality of Cagliari (survey wave B).
- "Svoltiamo COVID", conducted between October and December 2020 for the purpose of understanding how travel behavior in the municipality of Cagliari had changed after COVID pandemic restrictions (survey wave C). Note that during this period the main restrictions in Sardinia were the closure of bars and restaurants at 18:00, nighttime curfew from 22:00 and a reduction of public transport occupancy rate by 50%.

For each survey, potential participants were recruited by sending emails to staff at the University of Cagliari, the Regional Government of Sardinia and Cagliari town hall employees. Note that the three surveys were conducted for different scopes. For this reason, some of the questions included in the three questionnaires were different depending on the scope of the survey. In survey wave A we focused on perceptions of cycling benefits and barriers; in survey waves B and C we developed questions focusing on attitudes toward the use of the car and sustainable mobility in general. Furthermore, in survey wave C we asked some questions concerning COVID-19 pandemic. In order to build a logit model, which is one of the aim of the study, we need only the information common to the three surveys: 1) individual and household characteristics, such as gender, age, household composition and car ownership; 2) if they chose to cycle for one purpose or another at least once in the last year; 3) home address.

Given the aim of the current study, we only considered individuals actually living in the city of Cagliari. Descriptive statistics for the socio-demographic variables are shown in Table 1. The number of observations totaled 2,953, of which 796 were drawn from survey wave A, 1,440 from survey wave B and 717 from survey wave C.

Table 1. Data description.

	Wave A (2014)		Wave B (2019)		Wave C (2020)	
	N	%	N	%	N	%
Total	796	26.95%	1440	48.76%	717	24.29%
Age (AVG)	48.63		47.42		47.93	
# of male individuals	369	46.36%	707	49.10%	365	50.91%
# of individuals with a bachelor's degree or higher level of education	523	65.70%	969	67.29%	527	73.50%
# of individuals with children in the household	378	47.49%	636	44.17%	323	45.05%
# of household members (AVG)	2.75		2.61		2.61	
# of individuals holding a driving license	780	97.99%	1401	97.29%	697	97.21%
# of cars in the household (AVG)	1.68		1.53		1.55	
# of individuals who use the bicycle for any purpose	383	48.12%	820	56.94%	427	59.55%

It is important to highlight here that having three separate datasets can be challenging in terms of comparability. In our specific case, we had to address three different kinds of problems: 1) the different number of individuals in each dataset, 2) the different distribution of some exogenous variables across waves, 3) the representativeness of the sample with respect to the general population in terms of socio-demographic and neighborhood characteristics across waves.

Concerning the first issue, as indicated by Ortúzar and Willumsen (2011), having different sample dimensions in different temporal waves should not be seen as a problem on the condition that the target of the survey is the same across waves, as in our application. As for the second, there is no reason to believe that cause-effect mechanisms can be influenced by the different distribution of socio-economic characteristics in the datasets over time. In fact, as indicated by Solon *et al.* (2015), because our sampling approach was unweighted, an unweighted estimation of the model, as in our specific case, does not lead to inconsistent parameters nor does it modify causal relationships. To solve the third issue, namely correct the deviation between the marginal proportion in our dataset from the active population of the city of Cagliari for some socio-demographic and neighborhood characteristics, a weight w_q is computed for each observation q in the sample, using the raking technique (Kalton and Flores-Cervantes, 2003).

2.3. Modeling methodology

This research involves modeling the choice to cycle/not to cycle for one purpose or another over three different temporal waves. To this end, a binary logit model with the inclusion of a scale parameter is employed here. The inclusion of scale parameters, which reflect the variance of unobserved factors in each wave, is necessary as estimated parameters from different data sources are not directly comparable unless the relative scale differences (*i.e.* variance differences) are isolated (Mark and Swait, 2004). In particular, when investigating changes in choice preferences over time, what may appear as a change in systematic preferences could be attributed only to scale changes in the discrete choice model (Habib *et al.*, 2014).

As in typical discrete choice models, we define $U_{q_t}^t$ as the utility that each individual q_t associates with cycling in the first (t = A), second (t = B) and third wave (t = C) respectively. The discrete choice model can be specified as:

$$U_{q_t}^t = \theta^t\left(ASC + \boldsymbol{\beta}^t \boldsymbol{x}_{q_t}^t + \varepsilon_{q_t}^t\right) \tag{1}$$

Where $\boldsymbol{x}_q^t$ is a vector of explanatory variables, $\boldsymbol{\beta}^t$ is a vector of coefficients associated with the explanatory variables and ASC are the alternative constants, $\boldsymbol{\varepsilon}^t$ are the independently and identically distributed (i.i.d.) Gumbel error terms for each wave and θ^t is the scale parameter. In our specific case, the scale parameter θ^A is normalized to one, while we estimate θ^B and θ^C: in this way we ensure that we are estimating the relative error variance of one dataset with respect to another (Mark and Swait, 2004).

Because we assumed that $\boldsymbol{\varepsilon}^t$ is i.i.d. Gumbel a logit model is obtained. Then, the probability that decision-maker q chooses to cycle is given by:

$$P_{q_t}^t = \frac{\exp\left(\theta^t\left(ASC + \boldsymbol{\beta}^t \boldsymbol{x}_{q_t}^t\right)\right)}{1 + \exp\left(\theta^t\left(ASC + \boldsymbol{\beta}^t \boldsymbol{x}_{q_t}^t\right)\right)} \tag{2}$$

The choice model was estimated using *PythonBiogeme* software (Bierlaire, 2016).

The predicted share of people who choose to cycle at wave t in Cagliari in each temporal wave can be obtained by summing over all respondents Q_t the probability of choosing to use the bicycle $P_{q_t}^t$ for individual q:

$$S(cycling)^t = \sum_{q_t=1}^{Q_t} w_{q_t} \cdot P_{q_t}^t \tag{3}$$

As stated in Section 2.2, to correct the bias due to the non-representativeness of the dataset for certain categories, each probability $P_{q_t}^t$ is weighted by the weight w_{q_t}, which is computed for each observation q of the sample. In particular, each weight reflects the representativity of observation q in the population of Cagliari in terms of gender, age category and neighborhood type at time t. Multiplying each choice probability by its weight ensures that the aggregate predicted share is not affected by the over-representation or under-representation of some categories in the sample respect to the population (see Glerum *et al.*, 2013 for more details).

3. Model results

Model results are illustrated in Table 2. Before arriving at the final specification, we tested the impact of different socio-demographic and built-environment variables, both alone or in interaction.

Concerning socio-economic characteristics, compared to males, females are less likely to cycle. At the same time model results indicate that as age increases so the utility associated with the choice to cycle decreases. We also tested the effect of other individual and household factors (level of education, car ownership, income, presence of children) but, surprisingly, none of these turned out to be statistically significant.

With regard to built-environment characteristics, the existence of a bike lane or path within 250m of home has a positive and statistically relevant impact on cycling utility only for waves B and C, while there was no evidence that the presence of a cycle lane affects the choice to use the bike in wave A. One explanation for this difference is that in 2014 (wave A) the cycle network in the city of Cagliari suffered from a low level of continuity and connectivity, with some bike lanes leading nowhere. As a consequence, living in proximity of a cycle lane was not a sufficient condition for riding a bicycle. Since 2015, as illustrated in Section 2.1, the existing network has been expanded and completed and as found in previous research (Félix *et al.*, 2020), these interventions have led more people to take up cycling. Furthermore, the estimate of the interaction term between the presence of cycle lanes and the dummy variable gender indicates that females benefit more than males from the provision of dedicated space for cycling.

In all three waves A, B and C the coefficients indicate that individuals who reported living in a neighborhood close to the seafront are more likely to cycle compared to individuals living in other areas of Cagliari. This can be attributed to the fact that this area is one of the city's most attractive, both in terms of entertainment locations and natural beauty spots such as the Poetto beach and the Molentargius park. Furthermore, the existence of an extensive cycle network that since 2013/2014 directly connects all the commercial activities along the seafront should be considered a bonus that can positively influence individuals' proclivity for cycling.

Table 2. Model results.

	Wave A		Wave B		Wave C	
	Coeff.	R T stat	Coeff.	R T stat	Coeff.	R T stat
Constant	0.528	1.71*	0.528	1.71*	0.528	1.71*
Gender (male = 1, female = 0)	0.692	4.65***	0.692	4.65***	0.692	4.65***
Age (continuous variable)	-0.155	-2.13**	-0.155	-2.13**	-0.155	-2.13***
Live in a neighborhood close to the seafront (yes = 1, no = 0)	0.379	2.85***	0.379	2.85***	0.379	2.85**
Live in the historic district of Stampace (yes = 1, no =0)	-0.386	-2.27**	-0.386	-2.27**	-0.386	-2.27**
Live in the historic district of Castello or Villanova (yes = 1, no = 0)	-0.456	-2.45**	0.348	1.80*	0.348	1.80*
Live in a shabby neighborhood (yes = 1, no = 0)	-0.694	-2.63**	--	--	--	--
Presence of a cycle lane/path within 250m of home (yes = 1, no = 0)	--	--	0.267	2.02**	0.267	2.02**
Presence of a cycle lane/path within 250m of home (yes = 1, no = 0) × Gender (male = 1, female = 0)	--	--	-0.203	-1.26	-0.203	-1.26
Scale factor (t test against one)	1.00	n/a	0.973	0.09	1.23	0.59
Goodness of fit measures						
Null log-likelihood	-2,046.864					
Final log-likelihood	-1,956.210					
ρ^2 adj.	0.038					

Note: "--" in a cell indicates that the variable in the corresponding row does not have a significant impact on the utility of the alternative in the corresponding column. "n/a" not applicable.

**** Significant at 99% confidence interval; ** significant at 95% of confidence; * significant at 90% of confidence.*

Coefficients with identical values across waves represent coefficients that were combined during estimation because their values were not statistically different among waves.

The utility of wave A is negatively correlated with living in a shabby neighborhood, while the parameter associated with this variable turned out not to be statically significant in waves B and C. This is likely the result of improvements in these areas over the last few years. In fact, in 2014 almost no cycling infrastructure existed in these neighborhoods, the main reason for the negative sign of the parameter in wave A. However, since 2017 some new bike lanes have been created that connect with the city's main cycle network, so that in 2019-2020 cycling utility of individuals living in these areas does not differ from that of individuals living in other areas close to the city center.

The effect of living in the historic districts of Castello and Villanova was statistically significant for all three waves but with opposite signs. In particular, this parameter was negative in wave A, but positive in waves B and C. This is not surprising, as at the time waves B and C were conducted some streets in the two districts became car free, access only being permitted for pedestrians and cyclists. Instead, the coefficient associated with the historic Stampace district indicates that residents in this area of the city are less likely to use the bicycle in all three waves. This is for two reasons. The first is that the presence of steep slopes makes cycling hard. Second, no infrastructure interventions have been implemented over the years, such that the area of Stampace remained poorly served by cycle lanes at the time of the second/third survey wave.

With regard to scale parameters, they were not statistically different from one, suggesting that the three datasets have the same variance of unobserved effects.

Finally, we computed the weighted choice probability for each wave t. In particular, the percentage of individuals who cycle with any frequency and for any reason in Cagliari is 51.0% for the first wave (2014), 56.4% for the second one conducted in 2019 (+ 10.6%) and 57.5% for the third one conducted in 2020 (+12.7% compared to the first wave and +1.9% to the second).

4. Conclusions

Does urban transformation that reduces spaces for private vehicles help to increase individuals' propensity to cycle? The current paper attempted to answer this question from a modeling perspective in the city of Cagliari (Italy), where various infrastructure facilities dedicated to active mobility have been designed and built over the years. The data used were drawn from the responses to three cross-sectional surveys conducted in 2014, 2019 and 2020 respectively.

Modeling results indicate a general cycling probability increase in the city as a whole, confirming the effectiveness of the actions undertaken by local administrators. However, it is important to point out here that this greater propensity of residents to cycle differed from one neighborhood to another. In fact, we found that individuals living in those areas where infrastructure interventions had been put in place or those with homes close to the seafront, which boasts a dense network of cycle lanes, were more likely to cycle compared to the rest of the citizens in Cagliari. This finding strengthens the concept of "if you build it, they will come" applied to cycling infrastructure and should be seen as additional proof of the importance of bringing out actions and policies that limit the space dedicated to private vehicles in favor of active mobility. Furthermore, the development of an extensive cycling network can also incentivize the use of e-kick scooters, which has been legally allowed in Cagliari since 2020. E-kick scooters, in addition to active mobility, can be a green travel solution able to convince people to get out of their cars.

The other significant finding to emerge from this study concerns cycling behavior following the imposition of COVID-19 restrictions. In our specific context, the probability of using the bicycle passed from 56.4% to 57.5%, an increase of 1.9%. This is certainly lower than the 10.6% increase observed between 2014 and 2019 and seems to be in contrast to the trend observed in other European cities. However, two considerations should be borne in mind here. The first is that behavior change is a slow process and the shock caused by the COVID-19 pandemic for many individuals may not be enough to elicit people's willingness to cycle. The second is that the municipality of Cagliari, unlike other cities, did not introduce any specific measure to expand its cycling network between the 2019 and 2020 survey waves, which is, as discussed before, a crucial aspect when promoting cycling mobility.

From a policy perspective, the findings of this study have a number of important implications. First, measures and strategies aimed at improving cycling infrastructure should be implemented jointly with interventions of urban regeneration, where a greater portion of public road space is dedicated to both active mobility and social interaction. In fact, we observed that in Cagliari, in addition to the presence of cycle lanes, neighborhoods environment is crucial to yield an increasing number of people start up cycling. Riding along cycle lanes and/or itineraries placed in a high-quality urban environment in terms of both safety and livability not only contributes to enhancing the physical, but also the mental well-being. Second, our results stress the importance of the ex-post assessment of policies and strategies, as it offers to policy makers the opportunity to 1) evaluate the positive and negative effects generated by the implementation of policies aimed at increasing cyclability and 2) improve the quality of future interventions.

The current research, however, is not without limitations. First, our sample was not representative of the whole active population in Cagliari, though it can be considered as representative of the workers in the service sector, which in Cagliari accounts for 86.5% of the entire working population. Furthermore, conducting a web based survey can lead to biased data as it could be difficult to reach certain categories of individuals. Second, we considered the choice to cycle both for utilitarian and recreational purposes. Instead, it would be important to distinguish between these two purposes so as to verify if the implemented interventions reduced individuals' use of the car or just increased cycling for sport. Third, we did not investigate whether different types of infrastructure, such as off-street bike lanes, buffered bike lanes, pedestrian/cycling areas have a different or similar marginal effect on the propensity to cycle. Future research should address these limitations so as to confirm our results and permit the implementation of more effective pro-cycling policies.

References

Ascolese, M., 2017. Camminando a testa in giù: vagare, girovagare, divagare. Una metodologia di lettura dello spazio della strada. Doctoral dissertation, University of Napoli Federico II, Napoli, Italy. <http://www.fedoa.unina.it/12149>

Bierlaire, M., 2016. PythonBiogeme: a short introduction. Report TRANSP-OR 160706, Series on Biogeme. Transport and Mobility Laboratory, School of Architecture, Civil and Environmental Engineering, Ecole Polytechnique Fédérale de Lausanne, Switzerland.

Directorate General for Environment - European Commission, 2004. Reclaiming city streets for people. Chaos or quality life?. < https://op.europa.eu/en/publication-detail/-/publication/94a8a003-be86-467a-9a85-63a5d52bf7ae>

Félix, R., Cambra, P., & Moura, F., 2020. Build it and give 'em bikes, and they will come: The effects of cycling infrastructure and bike-sharing system in Lisbon. *Case studies on transport policy*, 8(2), 672-682.

Glerum, A., Stankovikj, L., Thémans, M., & Bierlaire, M., 2014. Forecasting the demand for electric vehicles: accounting for attitudes and perceptions. *Transportation Science*, 48(4), 483-499.

Global Designing Cities Initiative., 2016. *Global street design guide*. Island Press.

Habib, K. M. N., Swait, J., & Salem, S., 2014. Using repeated cross-sectional travel surveys to enhance forecasting robustness: Accounting for changing mode preferences. *Transportation Research Part A: Policy and Practice*, 67, 110-126.

Habib, K. N., Mann, J., Mahmoud, M., & Weiss, A., 2014. Synopsis of bicycle demand in the City of Toronto: Investigating the effects of perception, consciousness and comfortability on the purpose of biking and bike ownership. *Transportation research part A: policy and practice*, 70, 67-80.

Heesch, K. C., James, B., Washington, T. L., Zuniga, K., & Burke, M., 2016. Evaluation of the Veloway 1: A natural experiment of new bicycle infrastructure in Brisbane, Australia. *Journal of Transport & Health*, *3*(3), 366-376.

Hong, J., McArthur, D. P., & Livingston, M., 2020. The evaluation of large cycling infrastructure investments in Glasgow using crowdsourced cycle data. *Transportation*, *47*(6), 2859-2872.

Kalton, G., & Flores-Cervantes, I., 2003. Weighting methods. *Journal of official statistics*, 19(2), 81.

Legambiente, 2020. Ecosistema urbano. Rapporto sulle performance ambientali delle città. <https://www.legambiente.it/rapporti-in-evidenza/ecosistema-urbano>

Mark, T. L., & Swait, J., 2004. Using stated preference and revealed preference modeling to evaluate prescribing decisions. *Health economics*, *13*(6), 563-573.

Nello-Deakin, S., 2020. Environmental determinants of cycling: Not seeing the forest for the trees?. *Journal of transport geography*, 85, 102704.

Ortúzar, J. de D., & Willumsen, L. G., 2011. *Modelling transport*. John wiley & sons.

Rodriguez-Valencia, A., Rosas-Satizábal, D., Gordo, D., & Ochoa, A., 2019. Impact of household proximity to the cycling network on bicycle ridership: The case of Bogotá. *Journal of Transport Geography*, 79, 102480.

Scorrano, M., & Danielis, R., 2021. Active mobility in an Italian city: Mode choice determinants and attitudes before and during the Covid-19 emergency. *Research in Transportation Economics*, 101031.

Solon, G., Haider, S. J., & Wooldridge, J. M., 2015. What are we weighting for?. *Journal of Human resources*, 50(2), 301-316.

Wang, Y., Chau, C. K., Ng, W. Y., & Leung, T. M., 2016. A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods. *Cities*, 50, 1-15.

Yang, Q., Cai, J., Feng, T., Liu, Z., & Timmermans, H., 2021. Bikeway Provision and Bicycle Commuting: City-Level Empirical Findings from the US. *Sustainability*, 13(6), 1-15.

Zahabi, S. A. H., Chang, A., Miranda-Moreno, L. F., & Patterson, Z., 2016. Exploring the link between the neighborhood typologies, bicycle infrastructure and commuting cycling over time and the potential impact on commuter GHG emissions. *Transportation research part D: transport and environment*, 47, 89-103.