A scientometric analysis of cycling and the case study of the city of Ioannina

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Abstract. In urban areas, cycling as a sustainable mode of transport contributes to creating more liveable and vibrant urban environments. They take up less space than cars, reduce noise pollution, and create a human-scale, people-friendly atmosphere. This paper provides an environmental and sustainable scan of the literature on bicycles using established systematic literature review approach. The main issues the existing literature is dealing with according to the identified clusters can be categorized into four main categories that rely on environment-oriented, infrastructure-oriented, safety-oriented and health-oriented research fields, where the majority of research has been focused during the analysis period. Moreover, in this study, the implementation and use of cycling in the city of Ioannina is examined. The technical characteristics of the existing cycling paths in the city, the policy and the behavioral aspect of the people are presented by analyzing the responses of 102 residents of Ioannina in a structured questionnaire.

1 Introduction

Improved health, less pollution and traffic, as well as financial rewards for the individual are just a few of the noteworthy advantages of using bicycles for transportation for both individuals and communities. Despite the many benefits of bicycling that have been scientifically proven, communities struggle to encourage more people to bicycle for mobility as opposed to only for leisure. In the US, for example, federal funding for bicycling continues to decrease, and even outlier cities such as Portland, Oregon (with a 6% bicycle commute mode share) are not close to reaching the levels of commute cycling seen in cities such as Amsterdam (Netherlands), or Copenhagen (Denmark) (34% and 37% bicycle commute mode shares, respectively) [1].

Only 1 to 2% of all trips are made by bicycle globally, despite the fact that more than half of all journeys are shorter than 5 km [2]. Promoting cycling has attracted attention from different disciplines such as city and regional planning, civil engineering, public health, and psychology. However, the effectiveness of campaigns to promote cycling varies and probably depends on the particular tactics employed. The literature has identified socio-psychological factors, habit, and facilitating circumstances as pertinent elements to explain travel behaviour. Although traditional choice models have concentrated on understanding how socioeconomic factors and the relative attractiveness of each option influence transportation decisions, significant progress has been made in the last 20 years to explicitly account for attitudes and habits. Regarding biking specifically, commuters' impressions and assessments of the benefits and risks of biking have been influenced by attitudes and preconceptions about the activity [4].

The connection between bicycles and sustainability is multi-faceted and significant. Bicycles play a crucial role in promoting sustainability across various aspects, including environmental, social, and economic dimensions. By using bicycles for short trips and commutes, individuals can significantly reduce their carbon footprint, air pollution, and greenhouse gas emissions. Bicycles offer an affordable and accessible mode of transport, particularly in low-income communities where access to cars or public transportation may be limited. Promoting bicycles as a means of transport can enhance social equity by providing an affordable and sustainable mobility option for a broader segment of the population. As a sustainable transportation option, bicycles can play a part in mitigating the effects of climate change. By reducing emissions and dependence on fossil fuels, the widespread adoption of cycling can contribute to global efforts to combat climate change.

This paper provides an environmental and sustainable scan of the literature on bicycles using established systematic literature review approach. Moreover, the implementation and use of cycling in the city of Ioannina is examined. The technical characteristics of the existing cycling paths in the city and the policy are presented by analyzing the responses

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of 102 residents of Ioannina in a structured questionnaire.

2 Literature review

An extensive literature review of existing studies was carried out concurrently with a bibliometric and visualization analysis to identify relevant publications and explore the sustainable concept of the bicycle mode of transport. This method is widely accepted in the literature and in bibliometrics [5-6] and includes identification, description, analysis, interpretation and critical evaluation of the existing body of knowledge regarding a certain research area such as bicycle mode of transport.

Rapid computational methods and digital information have resulted in optimized and low-cost data collection procedures that can be used in various analyses. Therefore, bibliometricians and researchers can apply sophisticated cluster analyses without requiring technical expertise and time-consuming methods.

To appropriately select the examined literature, a comprehensive database of gathered data from Scopus [7] was developed. Documents that contain the key terms "bicycle" and "sustainable", or "sustainability" were selected for the analysis. Following this procedure, a dataset of 1,991 scientific publications was developed. The software VOS [8] was applied to examine, analyze and visualize the distribution of the most important key terms co-occurring in the keywords of the examined publications. More specifically, a smart local moving algorithm introduced by Waltman et al. [9] was employed to identify relations among scientific publications and therefore to evaluate patterns of the existing literature. A clustering technique was then applied to assign the identified key terms to groups of common characteristics.

Following the analysis, the presence of 10,970 keywords in the 1,991 publications was confirmed. The threshold of 10 occurrences was adopted and resulted in 369 key items for the analysis. The consistency of the database ensured the validation of the analysis in the context of this study. The final analysed keywords and their node size are illustrated in Figure 1. An interpretation of each cluster according to its characteristics is presented as well.

According to the analysis, the higher the keyword and the node, the larger number of articles containing the specific keyword. Thick lines indicate the co-occurrence of the keyword in the literature. Thicker lines indicate a stronger link.

Four clusters of key terms were developed according to the analysis, each of which constitutes a grouping of research activity and subsequent publication (set of related items). Table 1 presents an interpretation of each one cluster according to its characteristics, concurrently with identified key terms for each case based on the analysis.
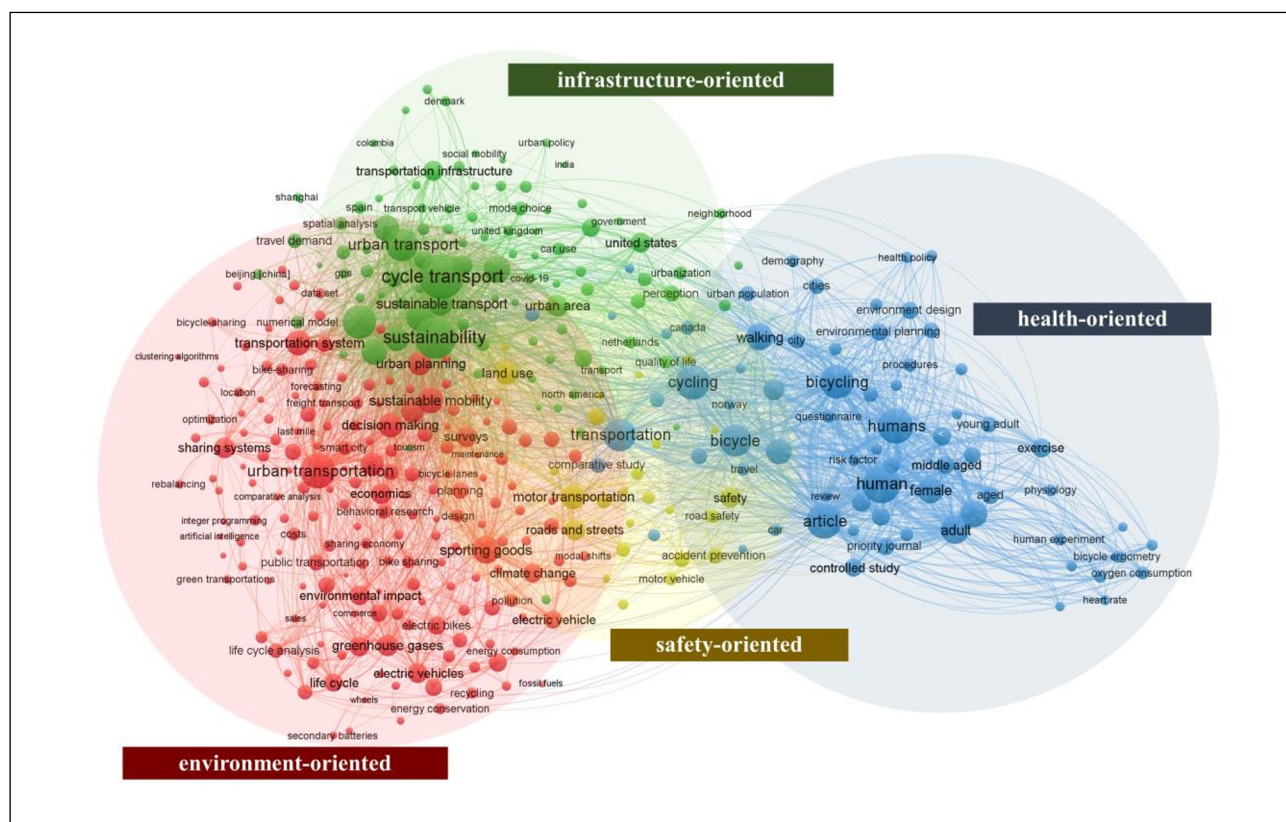

Fig. 1. Network visualization of authors' keyword occurrence.

Table 1. Interpretation of identified clusters.

Cluster/ total key items	Characteristic	Key terms
Red (178)	environment oriented	• greenhouse gas • carbon footprint • environmental impact • climate change • sharing systems
Green (96)	infrastructure oriented	• transportation infrastructure • accessibility • commuting • policy making • public transport • Covid 19
yellow (70)	safety oriented	• accident prevention • road safety
blue (25)	health oriented	• health care policy • human • exercise • active travel

The main issues the existing literature is dealing with according to the identified clusters can be categorized into four main categories that rely on environment-oriented, infrastructure-oriented, safety-oriented and health-oriented research fields. More specifically, significant key terms for each cluster were identified, focusing on climate change, carbon footprint and the sharing systems for the first case, accessibility, COVID-19 and commuting for the second case, accident prevention for the third case and finally, health care policy and the bicycle as a mode of transport for the last one cluster.

According to Figure 2, a rising trend in the publication of environment-oriented and infrastructure-oriented research fields is observed during the last years. Proposed strategies and adopted policies appeared recently in order to reduce greenhouse gas emissions by promoting a shift to low-emission mobility, concurrently with the impacts of COVID-19, explain the fact that cycling infrastructure, sharing transport systems and carbon footprint assessment are the main research fields the literature is dealing with during the last years.

On the other hand, health-oriented and safety-oriented research fields regarding cycling were examined mostly during the previous decade.
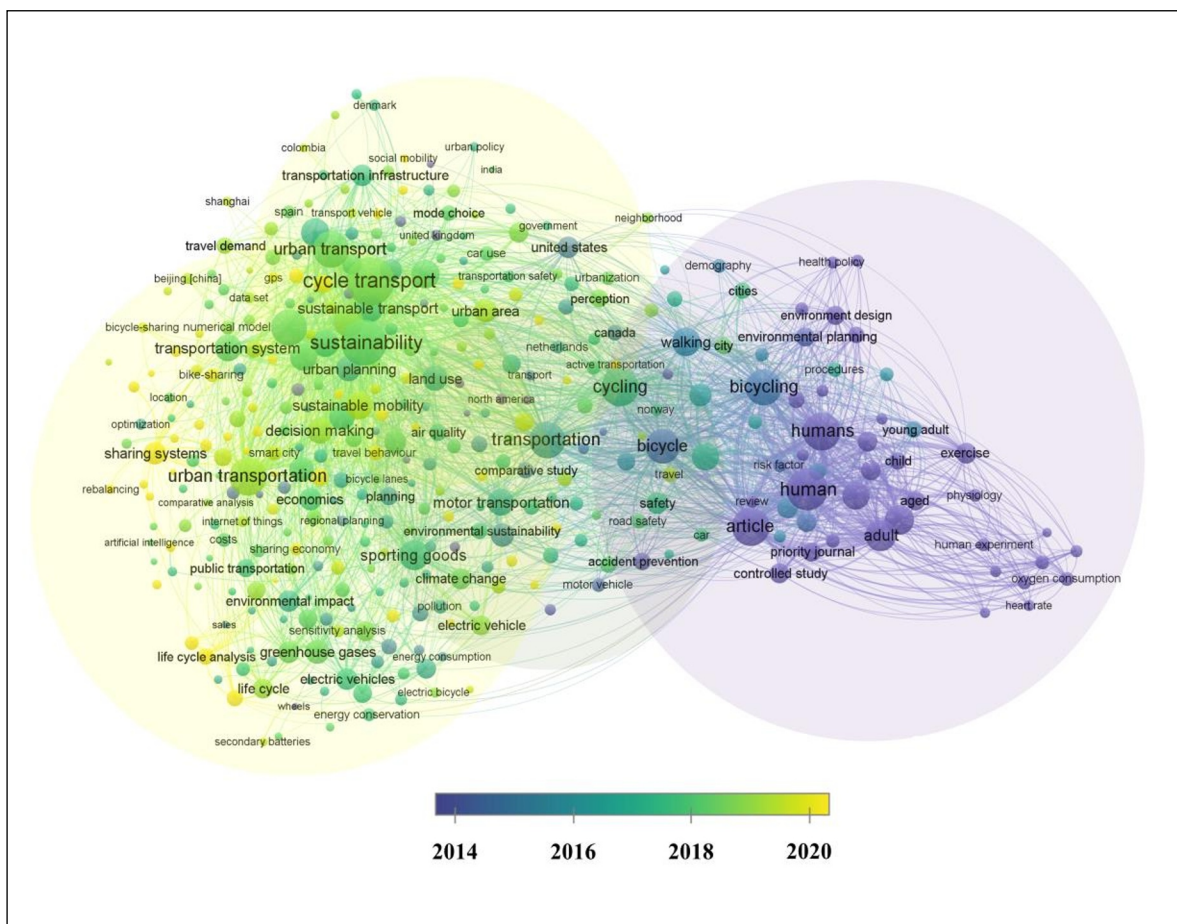
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Fig. 2. Network visualization of authors' keyword occurrence during the last decade

3 Data and methodology

3.1. Survey

A structured questionnaire survey is conducted among the residents of Ioannina, which focuses on the way people move around, the safety of the existing bicycle network, as well as on aspects of the behaviour towards cycling [10].

Consequently, a questionnaire of 20-questions was developed. The first three questions were demographic, related to gender, age, and the area of residence, in order the profile of respondents created.

Six of the questions concerned the respondents' travel habits and conditions. Participants were asked questions about their means of daily transport, how they commute, whether they own a cycling, and how they use it.

The remaining questions were about their opinion on the existing infrastructure of the cycling network in terms of safety, road surface quality, attitudinal aspects of cycling and the integration of cycling into the overall traffic network of the city.

In addition, respondents answered questions about the future development of cycling infrastructure, what factors would motivate them to buy a bicycle, to what extent various promotion policies have influenced them, and whether widespread use of bicycles would help eliminate traffic congestion problems in the city.

3.2. Study area

The research of this study was conducted in the city of Ioannina. Ioannina is the capital and largest city of Epirus, an administrative region in north-western Greece. It is a major urban center and an economic, cultural and educational hub within the region.

According to the 2021 census, the municipality had 113,978 inhabitants.

In Ioannina, private car ownership is widespread, and the city has an extensive road network. The city's traffic system has several problems. One of the main factors is the low participation of citizens in the use of public transport, which is due to the way that public transport is structured and operated. The routes intersect with almost all bus routes and there are delays in the passengers arriving at their destination. Public transport on the periphery of the city center has many problems also, as the number of routes is very low. In addition, the main roads lack geometric features such as for example sidewalks of small width, pedestrian crossings are sparse and curb ramps and blind guides are largely absent. Another point is that the light traffic network is absent from the city center and, combined with the failure to develop an appropriate road plan, this creates major traffic problems. Some of the main traffic problems in the city are: the city center is an attraction for commuters, parking spaces are scarce in relation to the volume of vehicles, lack of completion of the peripheral ring road, poor traffic organization and lack of road safety at junctions.

In the Figure 3 the existing cycling network infrastructure in the city of Ioannina is presented. The network is of particular concern. The distance of the cycle paths from the urban landscape, the lack of connectivity of the cycle path sections and the poor quality of some sections of the route have discouraged people from using bicycles.

A vision of an integrated network for cycling and walking has gathered wide support and it is developed in the Sustainable Urban Mobility Plan of the city of Ioannina,and formed a paradigm shift within city transport policy.
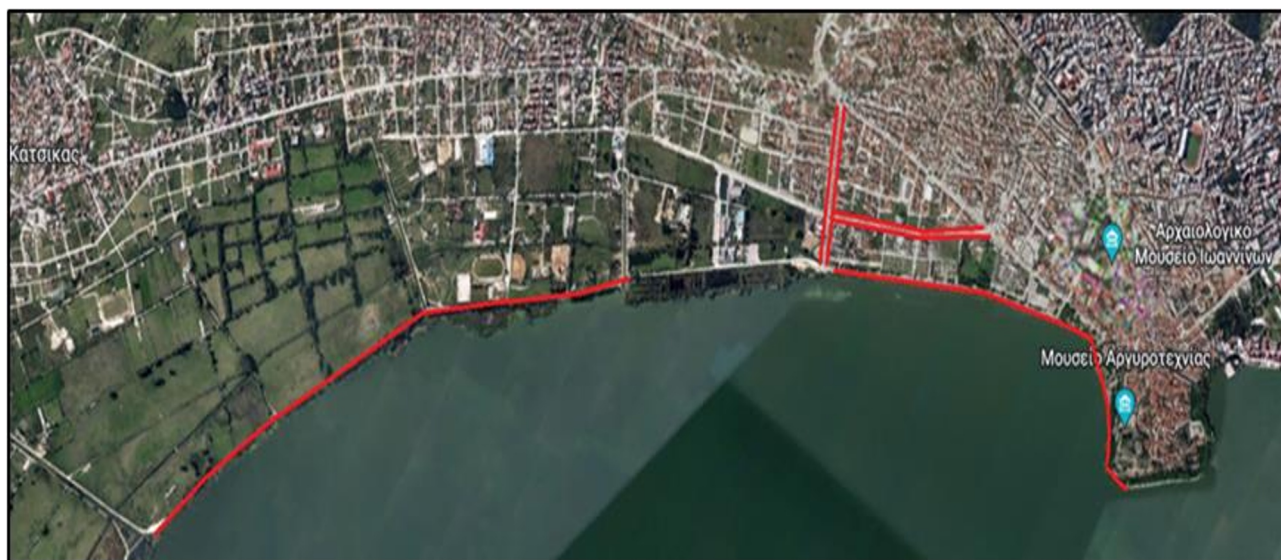

Fig. 3. The existing cycling network infrastructure in the city of Ioannina.

Fig. 4. The beginning of a part of cycling infrastructure lane.

Fig. 5. Cycling infrastructure lane near a pedestrian network.

Fig. 6. A cycling infrastructure lane near a road lane infrastructure.

3.3. Sample characteristics

Only residents of Ioannina and students living in the city took part in the questionnaire, as they are part of the local community. The survey was conducted based on the place of residence of the citizens, i.e. whether they live in the urban area or in the suburbs of the city. Table 2 illustrates the demographic attributes of the respondents in this study. In total, 102 individuals, citizens of Ioannina, were surveyed, of which 53 were men and 49 were women. The largest proportion of respondents falls within the age group of 18-50, followed by the age groups of >50 and the group <18.

Table 2. Demographic characteristics of respondents (N=102).

Demographics	Characteristic	Percentage %
Gender	Male	52
	Female	48
Age	<18	15.7
	18-50	49
	>50	35.3
Residential area	Urban	68.6
	Peri-urban	31.4

4 Results

According to the survey, in Ioannina, the main means of transport is the private car at 43.1%, followed by walking (26.5%), public transport (15.7%), and finally cycling (14.7%). Based on the above statistics, cycling is the last in preference, which should be of concern to those responsible for the effort to integrate cycling into the everyday life of citizens. It can be observed that sustainable means of transport (cycling, walking, public transport) have an overall preference of 56.9% over the car, which shows the shift of citizens to sustainable mobility compared to the past when the private car was the only choice.

All the respondents (97.1%) declared that there are many traffic and congestion problems in the city. A large percentage of 83.3% responded positively in the owning of a bicycle, while only 16.7% did not. This result shows the potential for residents to the transition to sustainable mobility. Residents of Ioannina, when asked how regularly they use the bicycle, 44.6% answered rarely, 26.1% often, 16.3% daily, while 13% never. These results are not particularly encouraging, as the majority use bicycles infrequently. This fact should certainly be of concern to those responsible for the creation of the SUMP. Bearing in mind, from a previous question, that 83.3% of citizens own a bicycle but only 42.4% use it frequently or daily, it reveals the lack and the poor quality of the infrastructure as well as the poor cycling awareness. The majority of citizens responded for sport/recreation (60.9%). The next selected use was commuting to work (23%) and commuting to school (11.5%), while the other uses are below 5%. Based on the characteristics of the existing cycle paths the existing network does not serve to meet basic needs of everyday life.

According to the questionnaire, 23.8% use bicycles on cycle paths, 27.4% on roads, 8.3% on pedestrian streets and 40.5% on all of the above.

Citizens were asked about the safety offered by the road network of Ioannina to cyclists, with the results being discouraging. The majority with a cumulative

percentage of 77.3% considers the safety of the cycling network to be below average (5/10). This result confirms the belief that the citizens of Ioannina are moving away from cycling because cycle paths do not have a developed network in the urban area and access to basic needs is necessarily through the road network, which is unsafe. Thus, the shift to sustainable mobility by bicycle is taken away as long as the level of safety on the road network remains so low and no integrated bicycle network is built within different urban land uses.

In Ioannina, new roundabouts were constructed on central arteries of the urban area, which replaced traffic lights, and reduce traffic congestion during peak hours. 44.1% of the respondents answered that the roundabouts increase the feeling of safety for cyclists compared to the previous situation, 39.2% perceived no difference, while 16.7% felt a decrease in the feeling of safety. A large proportion of cyclists are happy with the roundabouts, but the fact that cumulatively 55.9% did not notice any difference or felt unsafe should be of concern to decision makers.

Concerning the feeling of safety, 38.5% of the respondents feel that the cycle network provides marginally above average safety, 27.1% fairly to very safe, and 34.4% moderate to not at all. The fact that the largest percentage responded that the bike lanes are marginally safe should not be particularly pleasing to those in charge, considering that these are dedicated bike lanes. In particular, since cyclists do not come into contact with the motorized path, the insecurity results from the poor quality of technical features such as the rolling surface, signage, accessibility, transitions, etc.

The majority of citizens want new cycle paths to be built, which indicates that the frequency of cycling will increase. The citizens who answered that they would use bicycles every day are 25.5%, 40.2% often, 21.6% rarely and 12.7% never.

The main traffic problem in the city is caused by the accumulation of vehicles in the urban fabric during peak hours, as the city center is an attraction for commuters. Cycle paths can absorb a significant proportion of the traffic to ease the congestion.

In the question whether residents are willing to use bicycles more than cars in urban areas, 70.6% answered positively, while 29.4% answered negatively. This answer initially reveals the magnitude of the traffic problem, because there is a fairly high percentage of citizens who are willing to leave the car for travel within the city and use an alternative mode of transport such as cycling.

42.2% of citizens want cycling to be promoted. The possibility of sharing bicycle and any type of workshops to increase citizens' awareness about cycling are some of these actions. Although 16.7% of respondents do not own a bicycle, a great part of the respondents (42.2%) are interested in promoting cycling through actions such as sharing bicycles, which means that it is an action that will further increase citizens' mobility through cycling since there will not be the limitation from private bicycles, in terms of parking space, fear of theft, etc. However, the percentage that answered negatively is 57.8% and this signals that there is no familiarity, by citizens, with such actions.

The question that concludes the questionnaire is the citizens' opinion on how much they think that the cycle paths will solve the traffic problems of the city. 17.8% of the respondents think that it will completely solve the traffic problem, 40.6% think it will solve it quite a bit, 22.8% think it will solve it marginally, while 18.8% do not think it is the solution. These results are quite promising, and this is a key step towards sustainable mobility and especially cycling, as the residents of Ioannina envision a more sustainable city, which will be conducive to travel and will not inconvenience citizens with traffic problems.

4 Discussion-Conclusion

The systematic review of existing studies, carried out and presented in this paper, is an appraisal of the available research on factors that are associated with the sustainability and the bicycling. During the last years, a rising trend in the publication of environment-oriented and infrastructure-oriented research fields is observed, due to the transition to a more sustainable transport mode.

Shifting to a sustainable, ecological-friendly mobility mode is one of different policy measures implemented in the city of Ioannina. The condition of the constructed cycle infrastructure plays significant role in the adoption of the transition to a cycling mobility. According to the questionnaire survey, the residents of Ioannina are willing to use bicycles more regularly in the urban area compared to cars, but the combination of the lack of the necessary facilities and the fact that the existing cycling network does not offer the required feeling of safety to cyclists, distracts citizens from sustainable mobility. The Municipal Authority intends to address this fact through the integrated strategic plan for sustainable urban mobility. It is planned to create new cycle paths in the short and long term, with the aim of the transition to sustainable mobility. This situation will benefit society as a whole in many areas as cycling will solve several traffic problems, improve the health of citizens through exercise, reduce pollutants to the environment, reduce household savings by reducing car maintenance costs.

In a more holistic point of view, the increasing use of cycling can be influenced by various factors and criteria that can contribute to the growth of bicycling as a mode of transportation.

- Infrastructure: The presence of well-designed and safe cycling infrastructure can significantly increase the appeal of bicycling as a viable transportation option. Cyclists are more likely to choose cycling when they feel confident about their safety and have convenient routes to their destinations.

- Urban Planning: Cities and towns that incorporate cycling-friendly urban planning, such as mixed-use development, shorter travel distances, and access to essential services, can encourage more people to choose bicycles for short trips rather than cars.

- Safety Measures: Ensuring the safety of cyclists on the road is crucial. Implementing traffic calming measures, educating both motorists and cyclists about road safety, and enforcing traffic laws can reduce the risks associated with cycling and boost its popularity.

- Public Awareness and Education: Raising public awareness about the benefits of bicycling, including its positive impact on personal health, the environment, and traffic congestion, can influence more people to adopt cycling as a mode of transportation.

- Bicycle Sharing Programs: Implementing bicycle-sharing schemes in urban areas can make cycling more accessible to people who don't own bikes or need them for occasional use.

- Incentives and Policies: Governments and organizations can offer incentives, such as tax benefits for bike commuters or employer-sponsored bicycle programs, to encourage more people to choose cycling over other modes of transportation.

- Health and Environmental Concerns: Growing concerns about public health and environmental issues can lead individuals to opt for bicycling as a sustainable and healthier alternative to driving.

- Integration with Public Transport: Improving the integration of bicycles with public transport systems, such as allowing bicycles on buses and trains, can extend the reach of cycling and make it a more attractive option for longer trips.

- Supportive Culture: Developing a positive and supportive cycling culture within communities can foster a sense of community and encourage more people to embrace cycling.

- Economic Considerations: Bicycling can save individuals and society money in terms of reduced infrastructure costs, lower healthcare expenses (due to improved public health), and less environmental damage.

References

1. D. Piatkowski, M.Bopp, J. Urban Plann. Dev. **147**(**2**): 04021019 (2021)

2. Department for Transport. (2018). Analysis from the National Travel Survey. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_____data/file/674568/analysis-from-the-national-travel-survey.pdf.

3. O.C. Doğru, Th.L. Webb, and P. Norman.. Transp. Res. F: Traffic Psychol. **81**: 144-157 (2021).

4. M. Lizana, A. Tudela, and A. Tapia. Transp. Res. F: Traffic Psychol. **82**: 70-83 (2021)

5. B.B. Badassa, B. Sun, L. Qiao, Sustainability, **12**, 2033, (2020).

6. Y.-M Guo, Z.-L Huang, J.;Guo, H. Li, Z-R. Guo, M.J. Nkeli, Sustainability, 1**1**, 3606, (2019).

7. Scopus. Available online: https://www.scopus.com/ (accessed on 01 June 2023).

8. VOSviewer. Available online: http://www. https://www.vosviewer.com/ (accessed on 01 June 2023).

9. L. Waltman, N.J. Van Eck, & E.C.M. Noyons, J.Informetr. **4**(**4**), 629–635 (2010).

10. A.Tsompikos, Diploma Thesis, Civil Engineering Department AUTh, (2023)