PUBLIC HEALTH

HEALTH AND ECONOMIC BENEFITS OF CYCLING AND SATISFACTION WITH THE CYCLING ENVIRONMENT IN SKOPJE

Jansun Bukovetz[1], Kristina Shuntova[2], Aneta Kostova[1], Mihail Kochubovski[3], Igor Spiroski[3]

[1] *Institute of Public Health of the Republic of North Macedonia, Skopje, Republic of North Macedonia*
[2] *Private Health Institution "D-r Trajkovski", Skopje, Republic of North Macedonia*
[3] *Institute of Public Health of the Republic of North Macedonia; Faculty of Medicine, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia*

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***Correspondence:** Jansun Bukovetz, Institute of Public Health of the Republic of North Macedonia, Skopje.

E-mail: cansun-97@hotmail.com

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Abstract

Walking and cycling provide numerous environmental, health, and societal benefits, improving urban life quality and saving infrastructure costs. These benefits also lead to substantial healthcare cost savings. The aim of this study was to assess the health and economic benefits of cycling and satisfaction with the cycling environment in Skopje. Materials and methods: This study utilized the Health Economic Assessment Tool (HEAT) to quantify the societal economic value of reduced premature mortality due to cycling in Skopje, North Macedonia. A survey of 1,169 participants aged 20-64 was conducted from April to November 2022, with data analyzed using the HEAT model and statistical analysis performed using the chi-square test ($p < 0.05$), with effect size measured by Cramér's V. Results: The total benefit derived from cycling activities of the 1,169 participants for one year was US$471,150 and US$4,955,982 for 10 years. Over ten years, continuing cycling habits would result in nearly 12 prevented premature deaths. The most frequently used route for cycling was in urban zones. Most participants were dissatisfied with the bike lanes in their municipalities ($p < 0.001$). To enhance safety, participants suggested more bike lanes, increased authority intervention on illegal parking, and reduced vehicle speed limits where motor and bicycle traffic intersect. Conclusion: Shifting to active mobility can reduce negative impacts on vulnerable groups, enhancing public health, environmental sustainability, and social well-being. Improving infrastructure and safety should be a priority to make cycling a viable option in Skopje.

ЈАВНО ЗДРАВЈЕ

ЗДРАВСТВЕНО-ЕКОНОМСКИ ПРИДОБИВКИ ОД ВОЗЕЊЕТО ВЕЛОСИПЕД И ЗАДОВОЛСТВО ОД ВЕЛОСИПЕДСКАТА ИНФРАСТРУКТУРА ВО СКОПЈЕ

Џансун Буковец[1], Кристина Шунтова[2], Анета Костова[1], Михаил Кочубовски[3], Игор Спироски[3]

[1] *Институт за јавно здравје на Република Северна Македонија, Скопје, Република Северна Македонија*
[2] *Приватна здравствена установа „Д-р Трајковски", Скопје, Република Северна Македонија*
[3] *Институт за јавно здравје на Република Северна Македонија, Скопје; Медицински факултет, Универзитет „Св. Кирил и Методиј" во Скопје, Република Северна Македонија*

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***Кореспонденција:** Џансун Буковец, Институт за јавно здравје на Република Северна Македонија, Скопје, Република Северна Македонија. E-mail: cansun-97@hotmail.com

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Печатарски права: ©2025 Џансун Буковец, Кристина Шунтова, Анета Костова, Михаил Кочубовски, Игор Спироски. Оваа статија е со отворен пристап дистрибуирана под условите на нелокализирана лиценца, која овозможува неограничена употреба, дистрибуција и репродукција на било кој медиум, доколку се цитираа торигиналниот(ите) автор(и) и изворот.

Конкурентски интереси: Авторот изјавува дека нема конкурентски интереси.

Извадок

Пешачењето и возењето велосипед нудат бројни еколошки, здравствени и општествени придобивки, подобрувајќи го квалитетот на животот во урбаните средини и намалувајќи ги трошоците за инфраструктура. Овие придобивки исто така водат до значајни заштеди во трошоците за здравствена заштита. Целта на ова истражување беше да се проценат здравствените и економските придобивки од возењето велосипед и задоволството од велосипедската инфраструктура во Скопје. Материјали и методи: Во ова истражување се користеше Health Economic Assessment Tool (HEAT) за квантитативно да ја процени економската вредност од намалувањето на предвремената смртност поради возење велосипед во Скопје, Република Северна Македонија. Анкетата беше спроведена кај 1169 испитаници на возраст од 20-64 години од април до ноември 2022 година, а податоците беа анализирани со HEAT алатката, додека статистичката анализа беше извршена со тест на χ^2 ($p < 0,05$), со мерка на ефектот преку Cramér's V. Резултати: Вкупниот бенефит од возењето велосипед на 1169 учесници за една година изнесуваше 471.150 USD, а за 10 години 4.955.982 USD. Продолжувањето на навиките за возењето велосипед во период од десет години ќе резултира со речиси 12 спречени предвремени смртни случаи. Најчесто користениот пат за возењето велосипед беше во урбаните зони. Повеќето учесници не беа задоволни од велосипедските патеки во нивните општини ($p < 0,001$). За да се зголеми безбедноста, жителите предложија повеќе велосипедски патеки, зголемена интервенција на властите за нелегално паркирање и ограничување на брзината на местата каде што се пресекуваат моторниот и велосипедскиот сообраќај. Заклучок: Ориентирањето кон активната мобилност може да ги намали негативните ефекти врз ранливите групи, подобрувајќи го јавното здравје, одржливоста на животната средина и социјалната благосостојба. Подобрувањето на инфраструктурата и безбедноста треба да биде приоритет за да се направи велосипедизмот одржлива опција во Скопје.

Introduction

Skopje is the capital of North Macedonia and covers an area of 1,818 km² with a population of 526,502. The topography of the city is generally flat having gentle slopes from 0.1 to 0.7 degrees, and its continental climate makes it highly suitable for cycling. Short trips (up to 5 km) are a significant part of the urban travel, with cycling being the highest speed mode of transport in such distances. Therefore, Skopje can certainly have a large role to play in becoming a cyclist-friendly city[1]. The total length of the Skopje bicycle network in 2018 was 96 km, the breakdown of which included 15 km of separated bicycle tracks/lanes, 45.5 km of mixed bicycle/pedestrian tracks/lanes, 11.8 km of combined pedestrian-bicycle tracks/lanes, and 20.8 km of recreational roller and bike tracks along the bank. By 2023, the network expanded to 117 km, marking an increase of 21 km over five years (Grad Skopje, 2021)[2]. Comparatively, Belgrade[3] has a 65 km long network of bicycle lanes, Zagreb 270 km[4], Ljubljana 300 km[5] and Copenhagen[6] 546 km long bicycle paths. In larger cities, alternative travel modes such as walking and cycling are more accessible, while smaller cities often lack public transport options. Although walking and cycling may be more time-consuming for longer distances, they are largely unaffected by traffic congestion, unlike driving and public transport. Mid-sized cities generally offer better infrastructure for walking and cycling, which is reflected in higher satisfaction among residents. The findings stress the importance of community planning focused on ensuring safety and comfort for walking and cycling, particularly in areas with limited public transport[7]. Investing in cycling networks can increase cycling rates and has a positive impact on public health by raising physical activity. Despite the fact that it is more expensive to build new cycling paths than to run advertising campaigns, it substantially enhances the safety and attractiveness leading to cycling being an attractive and practical alternative[8]. Health benefits include improvements in quality of life, reductions in all-cause and cardiovascular mortality, and decreased incidence of anxiety, depression, hypertension, hip fractures, and metabolic disorders, such as type 2 diabetes and dementia. In addition to health and environmental benefits, active transport also provides important societal benefits. It is a cheap, space-saving solution for short distances that can alleviate gridlock and improve the robustness of transport infrastructure. Active transport improves urban life quality and results in infrastructure savings[9]. These health benefits also translate into substantial cost savings for healthcare systems. The first attempt to provide estimates for the health and economic advantages of cycling in the Republic of North Macedonia was performed in 2011[10] and for walking in 2021[11]. Economic assessments have become a standard practice in transport planning and public health evaluations. The mean annual benefit for North Macedonia was €45,000 with a sample of 24 people for the mean trip length of 8.64 km back in 2011[11]. Eleven years later, we conducted a follow-up study to assess the health and economic benefits of cycling in Skopje, expanding the analysis to a larger population sample. Additionally, we examined the influence of various cycling environment

factors on cycling behavior. The aim of this study was to assess the health and economic benefits of cycling and satisfaction from the cycling environment in Skopje.

Materials and methods

The Health Economic Assessment Tool (HEAT) is a quantitative tool that has been developed by the London School of Hygiene and Tropical Medicine. It is based on the principles of HEAT for cycling, first published in 2007 and upgraded in 2023. The tool aims to incorporate societal economic value of reduced premature mortality due to cycling and walking into economic appraisals of transport and urban planning interventions. The HEAT model applies a comparative risk assessment approach to calculate the health effects of regular cycling and/or walking in different exposure levels and their variation in specific population over a defined period at national and local level. It also calculates the number of premature deaths in those specific populations over a period by multiplying the mortality rate by the population size and the given period. The tool offers the following impacts to consider in the assessment: physical activity, air pollution, crash risk, and carbon emissions. The study was conducted from April to November 2022 in Skopje, Republic of North Macedonia. We carried out a population survey including 1,169 participants who completed a 35-question questionnaire; the population was aged 20-64 years. As HEAT requires long-term average input on active travel and is affected by several factors such as seasons, time of day, or weather, the tool offers temporal and spatial adjustments. The default setting for the tool is 0%, and we kept that value for the whole study. The physical inactivity-related risks are defined in HEAT by the use of all-cause mortality rates dependent on the age range and selected mode. The default value in our study was 381, the number of deaths over 100,000 inhabitants within the given age range, according to country-level data from the WHO Global Health Observatory. To monetize mortality impacts from physical activity, air pollution and crashes, HEAT uses the Value of statistical life (VSL) that is available in US dollars based on market exchange rates, international dollars, adjusted for purchasing power parity and local currency. Our estimates were done in US dollars based on market exchange rates; the default value of VSL for US dollars was 420,000. HEAT provides economic discounting or inflating for the year in which the assessment is done; again, we used the default discount rate, which for the year 2022 was 5%. The average cycling speed is 14 km/h and provides both default and editable values if the user likes to specify his own. Furthermore, data for average daily travelers, including the count per location, per day, and the distance travelled (in kilometers), were inputted for the assessment.

The analysis was made by utilizing IBM® SPSS® Modeler 16.0. The Chi-square two-sample test was used to determine the association between two groups. A value of $p<0.05$ was used to determine statistical significance. Cramér's V is an effect size measurement for the chi-square test of independence. It measures how strongly two categorical fields are associated (Table 1).

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Table 1. Interpretation of effect size

Effect size (ES)	Interpretation
ES ≤ 0.2	The result is weak. Although the result is statistically significant, the fields are only weakly associated.
0.2 < ES ≤ 0.6	The result is moderate. The fields are moderately associated.
ES > 0.6	The result is strong. The fields are strongly associated.

Results

A total of 1,169 participants (age range 20-64) responded to the questionnaire, in accordance with HEAT-Cycling criteria. The mean age was 37.8 years and the largest percentage (36%) of participants was in the age-range group of 31-40 years. In total, 52.7% of participants were male, 46.8% were female, and 0.5% did not specify the gender. 92.6% of participants declared its ethnicity as Macedonian, other ethnic groups were Albanians, Turks, Serbs, Vlachs, Roma and Bosnians. In addition, 78.1% of participants completed high school, 21.4 secondary and 0.5% elementary school. 85% of participants were categorized as employed; the remaining 15% were students, freelancers, unemployed or retired. In total, 78.5% of participants belonged to the "middle-income household", 13.3% to the "high-income household" and 8.2% to the "low-income household". According to the place of residence, the largest number of participants were from the municipality Aerodrom (25.2%), followed by Karposh (25%) and Centar (18%). Other municipalities included Kisela Voda (11%), Gazi Baba (8.2%), and Gjorche Petrov (8%). Fewer participants were from Butel (2%), Chair (1.7%), Shuto Orizari (0.4%), and Saraj (0.5%).

In Skopje, 1.8% of the population aged 15-79 (the working-age population according to the International Labor Organization and the State Statistical Office, the 2021 census)[12], defined as the working-age population, and used a bicycle as a mode of transportation, representing 4% or 7,759 of individuals who used any form of transportation. On the other hand, in Macedonia, 0.9% or 14,093 of the working-age population used a bicycle, accounting for 2.3% of those who used any form of transportation.

Table 2. Number of residents who used a bicycle for commuting

Municipality	Number of residents who used a bicycle to commute to work or school	Percentage of cyclists by municipality	Percentage of the population aged 15-79, defined as the working-age population, who used a bicycle to commute to work or school
Aerodrom	1,943	25	3.1
Butel	229	3	0.8
Gazi Baba	534	6.9	0.9
Gjorche Petrov	719	9.2	2
Karposh	1,707	22	3.4
Kisela Voda	940	12.1	1.9

Saraj	61	0.8	0.2
Centar	962	12.5	2.7
Chair	602	7.7	1.3
Shuto Orizari	62	0.8	0.3

In the green zone, participants from Aerodrom most often cycled, followed by participants from Karposh. In the urban zone, participants from Karposh most often cycled, followed by participants from Aerodrom. In the industrial zone, participants from Gazi Baba most often cycled, followed by participants from Karposh. In the suburbs, participants from Aerodrom most often cycled, followed by participants from Karposh. In general, the suburbs were the least liked area for cycling (Table 3).

Table 3. The most frequently used route for cycling for all municipalities

	Aerodrom (n)	Butel (n)	Gazi Baba (n)	Gazi Baba (n)	Karposh (n)	Kisela Voda (n)	Saraj (n)	Centar (n)	Chair (n)	Shuto Orizari (n)
Green zone (parks, green spaces, quays, etc.)	207	8	51	53	175	72	3	122	13	2
Urban zone	230	23	73	68	248	105	3	182	15	3
Industrial zone	12	0	14	5	13	10	2	11	1	0
Suburbs of Skopje	59	5	33	25	37	32	3	45	2	3

All analyses revealed a significant relationship between the identified factors.

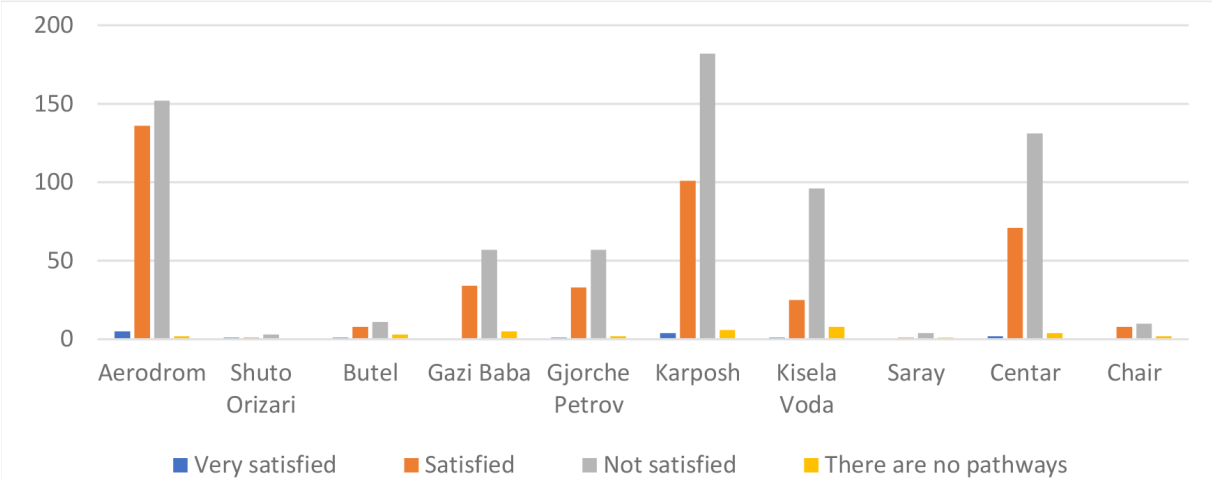
Table 4. Statistical analysis of determinants influencing cycling factors in accordance with the place of residence

Variables	Chi-square	Degree of freedom	*p*-value	Cramér's V
The most common physical obstacles when cycling on a bike lane	148.389	90	0.001	
Satisfaction with bike lanes	76.651	27	0.001	
Appropriately marked and protected construction works on the bike pathways	19.177	9	0.024	0.128
Affect your feeling of safety while cycling	83.049	54	0.007	0.109
Reasons if improved would motivate you to ride a bike	165.343	9	0.001	

When asked, the citizens of Skopje if they were satisfied with the bike lanes in the city, the majority of them gave a negative response. There was a difference between satisfaction with bike lanes in Skopje in relation to place of residence. The most satisfied with the cycling paths were

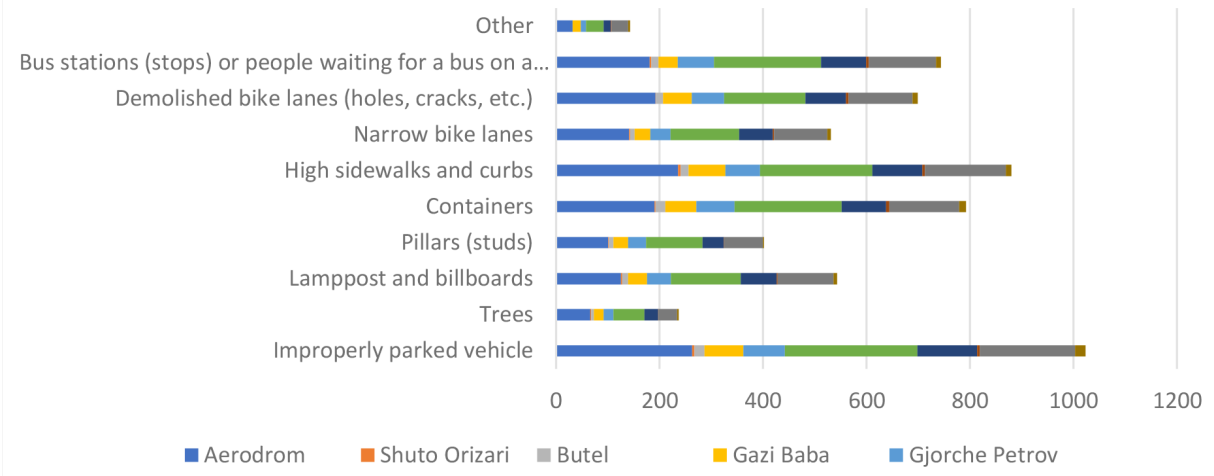
participants from Aerodrom, and the least satisfied were those from Karposh municipality. Participants from municipality of Kisela Voda answered there were no bike lanes in their place of residence (Figure 1).

Figure 1. Level of satisfaction of bike lanes for all municipalities



When asked *"What was the most common physical obstacle when cycling on a bike lane?"*, most participants from Aerodrom and Karposh answered "Improperly parked vehicles". High sidewalks and curbs were the option most participants from Shuto Orizari chose. Participants from Butel complained on improperly parked vehicles as well as containers. Overall, the most common obstacle reported by participants was improperly parked vehicles (up to 87%), followed by high walks and curbs (75%), containers (67%), bus stops or people waiting for the bus (63%) (Figure 2).

Figure 2. Level of satisfaction of bike lanes for all municipalities



A significant number of participants from the municipalities in the city of Skopje answered that construction works on the bike paths were not appropriately marked and protected. Contrary, participants from the municipality of Shuto Orizari answered that construction works on the bike paths were appropriately marked and protected. In percentage terms, 11.2%

of participants from Centar gave a positive answer for the most common physical obstacles when cycling on a bike lane for all municipalities, – followed by 9.17% of participants from Aerodrom, – 7.87% from Karposh and 5.84% from Kisela Voda.

The reasons that affected the feeling of safety when riding a bike were various depending on participants' place of residence. A significantly larger number of participants to the question *"Which of the following would affect your feeling of safety while riding a bike?" answered "More bike lanes". The most frequent suggestion of the participants from the municipality of Aerodrom was to "reduce the speed limit of vehicles"*, followed by the participants of Karposh. *"More studs on pavements"* was the most common answer given by participants from the municipalities of Karposh and Centar. Participants from the municipalities of Aerodrom and Gazi Baba suggested *"Better signalization and more traffic signs"*. Answers such as *"More bike paths," "Higher intervention rate of the authorities regarding illegally parked vehicles," and "Reducing the speed limit of vehicles where motor and bicycle traffic intersect"*, were common implications. Across all municipalities, the most common suggestion given by participants was "More bike lanes", followed by "Greater intervention by authorities regarding illegally parked vehicles", and the third option was *"Reducing the speed limit of vehicles where motor and bicycle traffic intersect"* (Figure 4).

Figure 4. Factors that affect the feeling of safety whilst cycling

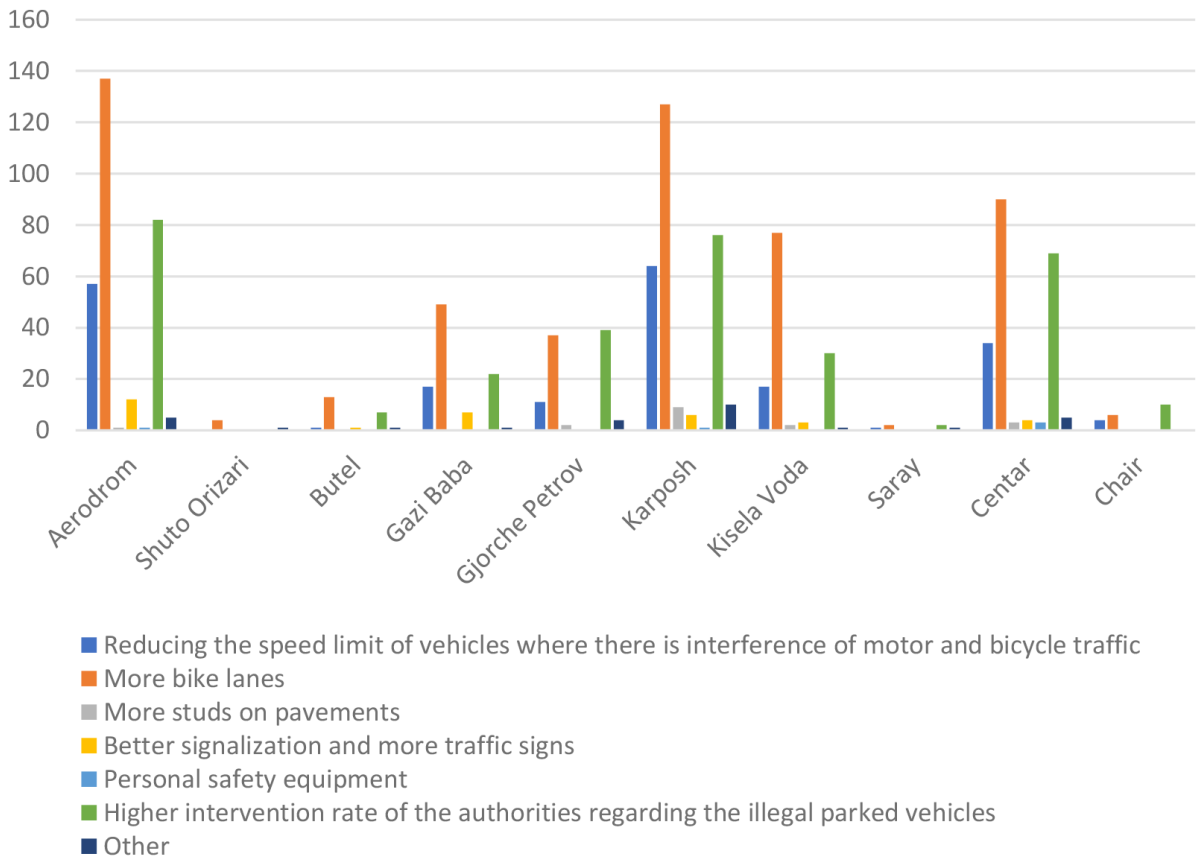


Table 5. Factors that would motivate bike riding if improved

Factor	Number of participants*
Weather	452
Air pollution	483
Traffic safety	688
Not having enough bicycle pathways	618
My colleagues or people close to me do not use bikes; therefore, I do not use it	30
Financial reasons	40
Having more time in the morning	93
Having safe parking lots for bikes	564
If I would have not been physically active enough	23
If I receive subsidies from the workplace	145

*The participants were able to choose more than one answer to this question.

Participants also reported a number of factors that would persuade them to cycle more often in general if they were enhanced. The most significant factor was reduced traffic safety issues as a key motivator identified by 688 participants. It was succeeded by the availability of bicycle pathways (618 participants) and safer bike parking options (564 participants). A total of 483 and 452 participants, respectively, mentioned air pollution and weather as significant considerations influencing their decision to cycle. Other incentives included having more time in the morning (93 participants) and receiving a workplace subsidy (145 participants). When considering financial motives and influence from coworkers or close family members, only 40 and 30 participants, respectively, considered these factors important. The least influential factor was the desire to be more physically active, identified by only 23 participants (Table 4).

Table 6 presents a summarized data of the HEAT evaluation for the distance cycled and the people that cycled that exact amount.

The total benefit derived from the cycling activities of the 1,169 surveyed people for one year was US$495,598, that being adjusted with 5% discount rate for 2022 is US$471,150. A five percent of annual discount rate is a value already suggested by the tool. It can be changed if the country in which the study is conducted has other monetary policies. It should be mentioned that along the discount rate, there is an inflation rate for the years 2024, 2025 and up. A projection over 10 years for the same sample size gives a total of an economic impact of US$4,955,982. At a discounted rate, this becomes US$3,825,166.

In terms of potentially preventable premature mortality, if those 1,169 people continue their habits of cycling over the course of ten years, there would be almost 12 prevented premature deaths. The majority of participants answered they cycled 15 km. If they were to continue cycling the same distance for the upcoming

ten years, (from 2022) there would be 5 prevented premature deaths and the total economic benefit would be US$1,520,000. With a 5 km difference in the entered data, meaning cycling 9 km, 168 people would participate, and over the course of ten years there would be 3 prevented premature deaths, with a total economic impact of US$938,000.

Table 6. Summary of the data analyzed by the HEAT

Amount of km a person cycled	Assessed population	Premature deaths prevented over one year	Premature deaths prevented over 10 years	Total economic value per 1 year (US$)	Total economic impact adjusted for 2022 (US$)	Total economic impact over 10 years (US$)	Total economic impact over 10 adjusted for 2022 (US$)
1 km	49	0.0035	0.035	1,460	1,400	14,600	11,300
2 km	70	0.015	0.15	6,310	6,010	63,100	48,700
3 km	100	0.047	0.47	19,700	18,700	197,000	152,000
4 km	113	0.077	0.77	32,500	31,000	325,000	251,000
5 km	71	0.041	0.41	17,400	16,600	174,000	134,000
6 km	42	0.017	0.17	6,970	6,640	69,700	53,800
7 km	43	0.02	0.2	8,410	8,010	84,100	64,900
8 km	17	0.0031	0.031	1,320	1,250	13,200	10,200
9 km	168	0.29	2.9	121,000	115,000	1,210,000	935,000
10 km	36	0.016	0.16	6,710	6,390	67,100	51,800
11 km	29	0.013	0.13	5,500	5,240	55,000	42,500
12 km	31	0.017	0.17	7,030	6,700	70,300	54,300
13 km	27	0.011	0.11	4,770	4,540	47,700	36,800
14 km	84	0.14	1.4	58,500	55,700	585,000	451,000
15 km	273	0.47	4.7	197,000	187,000	1,970,000	1,520,000
16 km	9	0.0018	0.018	745	710	7,450	5,750
17 km	5	0.0006	0.006	253	241	2,530	1,960
19 km	2	0.000048	0.00048	20	19	202	156
				Σ=495,598	Σ=471,150	Σ=4,955,982	Σ=3,825,166

We also assessed health and economic benefits from cycling in Skopje and municipalities of Skopje. According to the 2021 census, data on transportation modes was collected for individuals aged 15 to 79 (the working population)12. However, since the HEAT tool is calibrated for the 20-64 years, we estimated the population within this age range and used these figures for the analysis, as indicated in the "Assessed Population" column. The average distance between home and workplace, school or university was 5.6 km. Based on these input data,

HEAT estimates that cycling in Skopje and its municipalities annually avert around 2.9 premature deaths valued at an economic benefit of approximately US$1,140,000. Furthermore, if the 4,593 individuals who currently cycle maintain this behavior, ten years of cycling would prevent approximately 29 premature deaths, with an approximate economic impact of US$9,250,000 over a ten-year period.

Table 7. HEAT estimation for the municipalities in Skopje in accordance with the data of the State Statistical Office

Location	Amount of km a person cycled	Assessed population	Premature deaths prevented over one year	Premature deaths prevented over 10 years	Total economic value per 1 year (US$)	Total economic impact adjusted for 2022 value (US$)	Total economic impact over 10 years (US$)	Total economic impact over 10 adjusted for 2022 (US$)
Skopje	5.6km	4593	2.9	29	1,200,000	1,140,000	12,000,000	9,250.000
Aerodrom	5.6km	1150	0.71	7.1	300,000	286,000	3,000,000	2,320,000
Butel	5.6km	135	0.084	0.84	35,200	33,500	352,000	272,000
Gazi Baba	5.6km	316	0.2	2	82,400	78,500	824,000	636,00
Gjorche Petrov	5.6km	434	0.27	2.7	113,000	108,800	1,130,000	874,000
Karposh	5.6km	1010	0.63	6.3	263,000	251,000	2,630,000	2,030,000
Kisela Voda	5.6km	596	0.37	3.7	155,000	148,000	1,550,000	1,200,000
Saraj	5.6km	35	0.022	0.22	9,130	8,690	91,300	70,500
Centar	5.6km	556	0.35	3.5	145.000	138.000	1,450,000	1,120,000
Chair	5.6km	354	0.22	2.2	92,300	87,900	923,000	713,000
Shuto Orizari	5.6km	35	0.022	2.2	9,130	8,690	91,300	70,500

Further, a hypothetical scenario about cycling behavior in North Macedonia was performed. Due to the lack of country-specific data on distances cycled, we used the 5.6 km distance from Skopje as a proxy. If the 8,484 individuals (the population among 20-64 years of the working-age population which used a bicycle) continue their cycling habit for a period of ten years, the prevented mortality would be approximately 53 premature deaths, and, hence, an estimated economic benefit of US$17,100,000.

Discussion

This cross-sectional study gave valuable findings on the health, economic, and environmental factors that influence cycling behavior and satisfaction with cycling infrastructure in the city. The mean age of participants was 37.8 years, indicating that cycling

as a mode of transport is most popular among adults in mid-career years.

Safety concerns remain a key barrier to cycling in Skopje. A desire for more bike lanes was the most-mentioned factor to influence feelings of safety among cyclists and was stated consistently across municipalities. Strong association between place of residence and factors influencing safety perceptions signal regional disparities in cycling conditions and infrastructure. The participants from both Aerodrom and Karposh also identified reduction of the speed limit for vehicles and improvement of traffic regulation as important, again suggesting that safety is a key determinant of cycling. The results thus indicate that practical barriers to cycling, such as reduction of traffic safety problems, availability of bike pathways, and safer possibilities for parking bikes, are important facilitators of more cycling. Interestingly, the relatively low percentage of participants who identified increased physical activity as a motivator may suggest that for most, cycling is more a need or a way of getting around than it is a means to improve health. This is to say that the promotion of cycling will have to be effectively addressed through environmental and infrastructural measures.

The total economic value adjusted for 2022 for one year was US$471,150, and the total economic value adjusted for 10-year as (from 2022) calculated by HEAT was US$3,825,166. These findings underscore the potential of cycling as a public health strategy, reinforcing the role of regular physical activity in reducing health risks. The use of the HEAT tool allowed for a valuable estimation of the economic impact of these health benefits, emphasizing the cost-effectiveness of cycling interventions.

‘In the fight against rising overweight and obesity levels, and unhealthy urban environments, the renaissance of active mobility (cycling and walking as a transport mode) is encouraging’ . According to a study conducted in 2011 on the traffic system in Skopje, cycling is a decreasing mode of transport. In the year of 1981, 4.2% of the total number of trips were assigned to cycling, in 2000 this percentage went much lower (1.9% of the total number of trips), and in 2010 only 1.4% of trips were attained by bike. Municipalities of Shuto Orizari and Saraj do not have bike lanes or paths at all, so they lack bike infrastructure for safe cycling. In addition, these municipalities have a higher percentage of population aged 5-19, which are deprived of safe conditions for cycling. The municipality of Chair, being the most densely populated in Skopje, has only 7.58 km long bicycle lane. Municipalities of Centar, Karposh and Aerodrom, which are municipalities with lowest unemployment rate and highest percentage of high education among the citizens, have the longest bicycle network.

We could not find any data on the average cycling distance on a national level for Macedonia. However, in our

study, the average cycling distance was 8.9 km. The average cycling distance in the Netherlands in the year of 2008 was 4.3 km[14]; this number increased to 6 km[15] just two years later, compared to Finland where the average cycling distance was 14 km in 2010[16]. In Austria, over 40% of car trips are shorter than 10 km, and in Switzerland, more than 60% of commuter distances are under 10 km. In England, more than 50% of trips are 2-3 km[9]. Considering the question *"Unrelated to the reason, how long is your average passed route/tour?"* and that a sizeable number of participants reported using the bike as a mean of recreation, it is understandable that the average cycled distance was slightly higher.

In an Australian study, the most highly reported barriers to riding a bike for transport included not wanting to ride on the road with motor vehicle traffic (56%), concern about collision with a motor vehicle (54%), and motorist aggression (53%)[17]. Another Australian study confirmed that leading barriers to riding a bike was related to riding on the road alongside motor vehicles[18]. According to Fowler *et al.*[19], the two main obstacles to cycling in urban settings are reduced traffic safety concerns and the presence of designated bike lanes. Traffic safety therefore plays a key role in the promotion of active mobility. Perceived lack of safety can have unintended consequences by discouraging physical activity entirely[20]. Safety as expected is an important issue for most bike riders and non-bike riders. In our study, out of 1,169 people, 46.3% answered they would feel safer if there were more bike lanes, while in the study by Engber *et al.*[21] out of 799, 16% answered that more or better cycle paths would make them feel safer.

According to Gössling *et al.*, the most important thing for the cyclists is the clear separation of bicyclists from other forms of traffic. Mixed traffic, particularly when cyclists and motorists share lanes, is generally felt to be the least safe. A main road scenario without a cycle path was rated as "safe" or "rather safe" by just 11%[22] of cyclists. Cycling tracks are perceived as safer than cycling lanes, which in turn are preferred over cycling on the street. Physical separations from the car lane, a greater lane width, and a coloured surface contribute most to a high subjective safety of cycling lanes. On narrower cycling lanes, people experience extensive buffer designs as rather constraining and as impairing their safety. Combining several safety features (i.e. a sufficient demarcation of the left buffer and a coloured surface) is not necessarily beneficial for subjective safety. Our findings are mostly in line with findings on the factors benefitting or impairing objective safety[23].

In our study, among 1,169 participants, there was only 1 prevented premature death over the course of one year and 11 premature deaths prevented over the course of a decade. Cycling increases life expectancy by 0.025 years per year of regular cycling, which corresponds to only 3 hours of cycling per week, or 2,592 km cycled per year[24]. A study conducted in Australia reported a health economic benefit of $1,12 Australian Dollars[25] per kilometer of cycling, due to both the mortality and morbidity decrease resulting from a more active lifestyle. The estimated global cost of physical inactivity to the pub-

lic health care systems for the period 2020-2030 is approximately US$300 billion (or US$27 billion annually) if physical inactivity is not reduced[26]. A scenario-based study done in 17 counties across 5 continents suggests that if only 8% of the world car trips are replaced with bike trips, 18,589 annual premature deaths could be prevented by 2050 in the same population[27].

Authorities frequently cite insufficient resources as a rationale for underinvesting in active mobility infrastructure. However, numerous scientific studies suggest that investments in active mobility not only offer substantial health benefits but also yield significant economic returns. HEAT estimated that the New York City Bike share system could prevent an additional 2 to 3 premature deaths and increase its annual economic benefit from US$18,800,000 to US$28,300,000 due to increased use of bikes[28]. Deenihan *et al.*[29] made a HEAT assessment for Dublin, Ireland, and estimated that over a decade, the economic benefits of cycling the financial benefits infrastructure were in the range between €26,695,000 and €141,222,000 with a 5% discount rate, averaging between €2,669,000 and €14,122,000 annually with its maximised benefits above the seventh year. In comparison, our study estimated financial health benefits of US$3,439,168 (converted from US$3,825,166) over a decade. The public funding of the bicycle infrastructure is often deficient, which is why, Denmark made a comparative analysis of the car versus bike costs. It has shown that a kilometer of cycling costs €0.08 when all factors are taken into account, whereas a kilometer of driving a car costs €0.50. If taking into account social expenses only, every kilometer traveled by bicycle contributes to society €0.16, but every kilometer traveled by automobile incurs expenditures €0.15[24]. Skyannis *et al.* in 2019 HEAT's assessment revealed that for 5,000 cyclists riding 1,830 meters per day, 5 days a week, over 10 years, the economic benefit would be €7,800,000[30]. In our study, only 5.9% of participants reported cycling 2 km, and almost all of them cycled 5 times a week. The total economic benefit for these people was around US$6 000 for 1 year, and in a 10-year projection, that number would amount to approximately US$48,000.

Nowadays, 0.83 million (0.43–1.47) deaths are attributable to low physical activity[31]. It was estimated that in 2021, due to low physical activity, 386 deaths occurred[32]. Gharibzadeh *et al.* conducted a study in Tehran, the capital city of Iran, using HEAT of both walking and cycling modes, and found that switching from non-cycling to cycling for commuting could reduce mortality rates by 18%. If the cycling modal share increases from 1.72% to 2.5%, 5%, or 10%, it could save between 3.39 and 17.93 lives annually and generate economic benefits of €26.7 million to €141.2 million over ten years, with an initial investment of €12 million[33], resulting in highly favorable benefit-cost ratios ranging from 2.22:1 to 11.77:1.

This study has some limitations. Firstly, the reliance on Skopje-specific data to estimate the national impact of cycling introduces potential inaccuracies, as cycling behavior may vary in different regions of North Macedonia. Additionally, assumptions about the average cycling distance and the 5% discount rate may not fully reflect the local economic

conditions, warranting further sensitivity analysis. Furthermore, due to the limitation of the HEAT for the age range 20-64 years, we were unable to calculate the cycling benefits for the entire population that reported cycling at present.

Conclusion

Physical activity benefits are the dominant effects from cycling from a public health perspective. It is from monumental importance that the government, non-profitable organizations, international funds etc. invest in, firstly, quality bike lanes and paths which would be safe enough not only for the cyclists, but also for the pedestrians and motor vehicles, and secondly, policies implemented to promote cycling. Shifting to active mobility can reduce negative impacts on vulnerable groups while enhancing public health, environmental sustainability, and social well-being. Improvements in infrastructure and safety should be paramount in order to make cycling an attractive and viable option in Skopje. It is important to invest in bike lanes, reduce traffic speed in high-traffic areas, and provide a safe place for bicycle parking to improve safety and increase cycling. Further to this, local authorities should extend cycling subsidies, making such finance-available schemes accessible to all citizens, particularly to those from disadvantaged groups. Additionally, it is required to enforce traffic rules that protect the cyclists, to increase public awareness of cycling issues, and to discuss environmental challenges regarding air quality and weather conditions. Finally, the development of cycling-friendly urban spaces, like green pathways and recreational zones will be important in promoting a culture of cycling in the city.

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