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Cycling into Sustainability: Lessons from the Netherlands for Slovenia's E-Bike Adoption

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Abstract: This study investigates whether Slovenia can learn from the Netherlands to enhance its bicycle commuting culture and how e-bikes can improve cycling performance among its residents. The research utilises secondary data from the Statistical Office of the Republic of Slovenia and Statista, covering variables such as bicycle sales, gross domestic product, and urbanisation rates from 1997 to 2024. The data are analysed using Vector Auto Regression (VAR). The results reveal that urbanisation positively influences both traditional and e-bike demand, highlighting the importance of improved cycling infrastructure. However, GDP negatively impacts bike demand, suggesting affordability issues that could hinder adoption without financial support. These findings indicate that e-bikes play a transformative role, particularly in overcoming Slovenia's hilly terrain and long-distance commuting barriers, with evidence of substitution effects between traditional bicycles and e-bikes. Lessons from the Netherlands emphasise the integration of cycling with public transport, financial incentives, and cultural promotion of cycling. Slovenia's growing e-bike market signals a promising shift towards sustainable mobility, but strategic investments in infrastructure and policies are crucial.

Keywords: cycling culture; e-bikes; policy incentives; sustainable mobility; urbanisation

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1. Introduction

The phenomenon of bicycle commuting and its sustainable demand among populations remains relatively underexplored within academic research [1–3]. This shortfall is surprising given the globally recognised need for sustainable transportation options amidst growing environmental concerns and urbanisation pressures and cycling tourism [4]. This research article aims to shed light on the dynamics of bicycle use, focusing on Slovenia, a country with a rich cycling tradition that faces modern challenges. The emphasis of the discussion is centred on the acquisition of bicycles as opposed to the bicycle-sharing system, which has been extensively studied among scholars [5].

The motivation behind this study is rooted in the pressing need to combat the increasing reliance on automobiles, which has become prominent since the 1970s. This has not only contributed to environmental degradation but has also sparked a plethora of social and health-related issues. Furthermore, this research is endorsed by the relevant ministries in Slovenia to support the attainment of the 2030 strategic goals for emission reduction. Consequently, the findings possess significant implications for policymaking in Slovenia. Additionally, certain raw comparative secondary data are valuable in this context. The government seeks the best world examples of how to achieve the goals of neutral emissions using bikes, and the Netherlands started early in integrating bikes into daily commuting, among other countries like Denmark and Belgium [6,7]. In this study,

the chosen country is the most appropriate point of comparison, particularly because Slovenians also demonstrate a strong affinity for cycling [8].

The primary goal of this study is to contribute to the existing literature by providing a comprehensive analysis of the factors influencing bicycle commuting and sustainable demand in Slovenia as an old–new entrepreneurial opportunity in Slovenia. To achieve this, the research is guided by specific objectives: firstly, to assess the historical and current numbers of bicycle sales in Slovenia and worldwide; secondly, to identify the barriers to and enablers of increased bicycle use; and thirdly, to analyse the impact of e-bicycles on traditional bicycle demand and urbanisation. Through qualitative and quantitative methodologies, including structured interviews and time series econometrics, the study aims to provide a holistic understanding of Slovenia's cycling culture transmitted to its developed counterparts.

1.1. Development of the Research Question

When exploring ways for Slovenia to bolster its cycling culture, it is beneficial to assess its cycling landscape compared to countries known for their strong cycling cultures, such as the Netherlands. This nation has effectively integrated cycling into its transportation systems, resulting in widespread bicycle usage, well-established cycling infrastructure, and supportive policy frameworks. In the Netherlands, cycling is deeply ingrained in the culture, with nearly 27% of all trips made by bicycle. This achievement can be attributed to many factors, including a flat terrain, extensive cycling infrastructure, and robust political support for cycling initiatives. Dutch cities are designed with cyclists in mind, featuring extensive networks of dedicated bike lanes, secure parking facilities, and traffic calming measures that prioritise cyclists over cars [9].

The cycling analysis in the Netherlands aims to examine and evaluate exemplary practices within the EU. Our objective is to pinpoint the crucial factors contributing to the success of cycling as a primary mode of transport in the Netherlands and promote the exchange of best practices among different nations. Ultimately, our overarching goal is to advocate for cycling as a crucial aspect of sustainable urban transport in Slovenia.

The number of residents in the Netherlands who choose to cycle to work is steadily increasing, with a 17% increase in cycling to work compared to the previous year. Workers cited practicality and health benefits as reasons for choosing cycling. Employers played a significant role in making cycling more accessible. Despite the popularity of cycling, car trips to and from work also increased, but traffic levels during peak hours were still lower than before the pandemic. Public transport usage increased sharply due to the lifting of coronavirus restrictions [10]. The Netherlands and other countries offer financial incentives for cycling to work, including tax breaks and bike purchase schemes [11].

We analysed studies by Heinen et al. and Abduljabbar et al. [12,13] on the impact of work-related factors on cycling to work. The studies surveyed employees and residents in four Dutch municipalities. The results show that employer-provided cycling facilities and workplace relationships are critical factors in cycling decisions. Employees' attitudes and expectations and the presence of cycling infrastructure at the workplace also influence cycling behaviour. These insights can help employers and policymakers promote cycling among employees for sustainable mobility and improved health [14,15].

The research question for this study can be summarised as follows: Can Slovenia draw lessons from the Netherlands to enhance its bicycle commuting culture and empower its residents to adopt this habit? Furthermore, can e-bikes contribute to improved biking performance among Slovenian residents?

The questions for the Interview are presented in Appendix A.

1.2. Structure of the Paper

The structure of this scientific article is methodically designed to guide the reader through the research process and findings. It begins with an introduction, which sets the context of the study and outlines its significance, objectives, and structure. Following this,

a comprehensive literature review highlights the gaps in existing research and positions this study within the broader academic discourse on sustainable transportation. The subsequent section, data and methods, details the research approach, including the data sources, such as the Slovenian Statistical Office, and the analytical techniques employed, such as qualitative and summary statistical analysis.

The results section presents the findings from the data analysis, revealing notable trends in the adoption of e-bicycles and the decline in traditional bicycle demand. These findings serve as a basis for the discussion section, where the research implications are explored in depth. This includes an examination of potential policy interventions to promote cycling and a comparative analysis of successful cycling initiatives in a European Union (EU) country. Finally, the conclusion synthesises the critical insights of the study, offering recommendations for future research and policymaking.

2. Literature Review

Slovenia has committed to a sustainable future by adopting a national strategy to achieve zero emissions by 2030, which aligns with the broader EU goals for carbon neutrality. The Slovenian government acknowledges the pressing need to move away from fossil fuel-based transportation, which is significantly contributing to greenhouse gas emissions and urban air pollution. Promoting sustainable mobility options, such as cycling, is considered a crucial part of this strategy. E-bikes, in particular, are viewed as a transformative solution that supports both environmental and economic objectives by reducing car dependency, easing urban congestion, and lowering carbon emissions. In pursuit of the zero emissions goal, Slovenia is investing in green infrastructure, including cycling paths and incentives for electric vehicles. Nonetheless, cultural perceptions of cycling and inadequate infrastructure hinder widespread adoption. Encouraging the transition to sustainable commuting requires governmental support and entrepreneurial innovation, especially in the burgeoning e-bike market. This study delves into how Slovenia can further promote e-bikes as a viable alternative to traditional transport, fostering sustainable urban mobility. By drawing on successful strategies from cycling-centric countries like the Netherlands, Slovenia can expedite its journey towards achieving its zero emissions target by 2030.

Indeed, the anticipated trajectory in the consumer market within Slovenia indicates a rising inclination towards both traditional bicycles and electric bikes (e-bikes), a trend that mirrors broader global shifts. So, the demand and commerce could benefit from an economic perspective. This surge in demand is not only reflective of an evolving consumer preference but also speaks to an acknowledgement of the ability of e-bikes to bridge the gap between conventional cycling and the necessity for more accessible, eco-friendly commuting alternatives. Consequently, this trend is poised to redefine mobility patterns within the region, proposing a cyclic transformation in the transportation paradigm that harmonises technological advancements with environmental stewardship and urban mobility needs. This paradigm shift is expected to have far-reaching implications on the market dynamics of personal transportation urban planning and public health, thereby compelling a holistic reconsideration of mobility infrastructure and its role in fostering sustainable urban environments.

The convergence of bicycles and commerce has gained greater importance due to the growing focus on sustainable transportation worldwide. The sustainable impact of bicycles, especially in urban areas, is wide-ranging and includes the direct sale of bikes and accessories and the broader economic influence of cycling infrastructure on local businesses and urban economies.

2.1. Slovenian Bicycle Market

Bicycles significantly contribute to the global economy through the sale of bicycles and related accessories. The demand for bicycles has increased due to a growing interest in health, fitness, and eco-friendly transportation options. The market is expected to continue expanding, especially with the increasing popularity of e-bikes for commuting and leisure.

Research from Mordor Intelligence in 2024 [16] shows that the global bicycle market was valued at 100 billion euros in 2023 and is projected to reach 241 billion euros by 2032, with a compound annual growth rate (CAGR) of 10.6%. The Asia Pacific region held the largest market share in 2023 at 44.44%, driven by increased health consciousness, urbanisation, and environmental concerns. The market growth is also fuelled by the rising popularity of cycling for commuting, exercise, and sports, leading manufacturers to offer a wide range of bike categories, including mountain, road, and hybrid bikes [17].

The bicycle market in Slovenia has experienced consistent growth driven by evolving customer preferences, market dynamics, local conditions, and macroeconomic influences. There has been a notable shift in consumer preferences towards sustainable transportation, resulting in heightened bicycle demand. E-commerce trends and the increasing popularity of e-bicycles have also played a role in driving this growth. Slovenia's robust cycling infrastructure, stable economic growth, and government initiatives could further propel the market forward. According to Statista [18], bicycle commerce in Slovenia is expected to generate 178 million euros in revenue in 2024, with steady growth projected at a CAGR of 0.16% from 2024 to 2029. This growth is anticipated to result in a market volume of 180 million euros by 2029. Regarding unit sales, the market is predicted to reach 240,600 bicycles by 2029, reflecting a rising demand for bicycles in Slovenia. The volume-weighted average bicycle price is projected to be 670 euros in 2024, indicating the range of prices across different types and brands available. Slovenia's growing focus on sustainable transportation has fuelled the popularity of e-bicycles, contributing to expanding the country's bicycle market.

2.2. Bicycle Market

E-bikes are becoming increasingly popular due to their convenience and positive environmental impact, which are further accelerated by government incentives [19]. Improving cycling infrastructure, such as dedicated bike lanes and paths, also contributes to the market's growth (Table 1).

Table 1. Revenue comparison of e-bikes sold in Slovenia and the Netherlands in euros.

Year	Revenue SI	Per Inhabitant [1]	CI	Revenue NL	Per Inhabitant [2]	CI
2015	3,000,000	1.43	/	511,000,000	30.06	/
2016	17,000,000	8.09	565.73	538,000,000	31.65	105.29
2017	30,000,000	14.29	176.64	569,000,000	33.47	105.75
2018	37,000,000	17.61	123.23	818,000,000	48.12	143.77
2019	40,000,000	19.05	108.17	868,000,000	51.06	106.11
2020	58,000,000	27.62	144.99	1,238,000,000	68.78	134.70
2021	76,000,000	36.19	131.03	1,151,000,000	63.94	92.96
2022	91,000,000	43.33	119.73	1,201,000,000	66.72	97.00
2023	100,000,000	47.62	109.90	1,159,000,000	64.38	96.49
2024 [3]	102,000,000	48.57	101.99	1,124,000,000	62.44	96.99

Notes: [1] The population is 2.1 million inhabitants; [2] The population was 17 million in 2019 and 18 million in 2020–2024; [3] The predicted data are NL—Netherlands, SI—Slovenia, CI—chain index; Source: Statista [20].

The data highlight significant growth in e-bike sales revenue in Slovenia (SI) and the Netherlands (NL) from 2015 to 2024, showcasing the rising popularity of e-bikes. Slovenia's revenue experienced exponential growth, from 3 million euros in 2015 to a projected 102 million in 2024, marking a 34-fold increase. This reflects a rising per capita revenue from 1.43 euro in 2015 to 48.57 euros in 2024. The chain index (CI) indicates fluctuating annual growth rates, with a sharp rise in 2020, likely influenced by the COVID-19 pandemic. In Slovenia, government subsidies in 2024 stimulate demand. The data underscore the

ongoing global shift toward sustainable mobility solutions, where some problems regarding e-garbage remain [21].

Similarly, the Netherlands, a mature e-bike market, saw steady revenue increases, peaking at 1.238 billion euros in 2020 before stabilising at slightly lower levels in subsequent years. Per capita revenue rose from 30.06 in 2015 to a predicted 62.44 in 2024, reflecting sustained consumer interest. The pandemic likely contributed to a revenue spike in 2020 as people embraced sustainable and individual transport solutions. In the Netherlands, a long-standing cycling culture further supported this boom.

However, some challenges include the availability of alternative transport options and the higher cost of e-bikes compared to traditional scooters or motorbikes. The market is divided by technology, type, end-user, design, and distribution channel, with conventional bikes dominating but e-bikes experiencing rapid growth. In addition to direct sales, the presence of bike-friendly infrastructure can significantly boost local commerce [22]. Cities investing in cycling infrastructure often experience increased foot traffic in business districts, as cyclists are likelier to patronise local shops, cafes, and restaurants than motorists [23]. This trend has been observed in cities worldwide, where establishing bike lanes and parking facilities has rejuvenated sustainable areas. For instance, a study in New York City revealed that streets with protected bike lanes experienced a 49% increase in retail sales, whereas other streets in the same neighbourhoods only saw a 3% increase [24]. These data highlight the economic benefits of accommodating cyclists in terms of sales and cultivating vibrant and economically resilient communities [25].

Furthermore, the bike industry encompasses physical products and various services. This includes bike repair and maintenance businesses, bike-sharing programs, and organised cycling excursions, all contributing to the economy by providing jobs and generating revenue. The rise in popularity of e-bikes has increased demand for specialised repair services and broadened the market for bike components and batteries, creating new opportunities for businesses operating within the bicycle sector [26]. Incorporating bicycles into the realm of commerce substantially impacts the gig economy [27], especially with the emergence of bike-based delivery services. Companies such as Uber Eats, DoorDash, and Deliveroo have leveraged the effectiveness of bicycles in navigating bustling urban areas, enabling swifter and more eco-friendly delivery options [28]. This transition not only diminishes the carbon footprint of delivery services but also generates economic prospects for cyclists who can take on roles as couriers [29].

Bicycle Commuting in Slovenia

Bicycle commuting is widely acknowledged as a sustainable form of transportation, providing many environmental, social, and health advantages. Research indicates that cycling can significantly lower carbon emissions, alleviate traffic congestion, and enhance public health by promoting physical activity [30]. For instance, a study carried out in Denmark, a country celebrated for its cycling culture, revealed that cycling reduces the incidence of cardiovascular disease and diabetes, leading to reduced healthcare costs and improved public health outcomes [31–34].

Despite its numerous benefits, bicycle commuting is not widely embraced in many parts of the world, including Slovenia. One of the primary obstacles highlighted in the literature is inadequate cycling infrastructure. Studies have demonstrated that having safe and convenient cycling infrastructure, such as dedicated bike lanes, metro connections, and secure parking facilities, is essential for promoting bicycle usage [35–37]. Slovenia's progress in developing cycling infrastructure has been uneven, with significant disparities between urban and rural areas. While cities like Ljubljana have made remarkable efforts to encourage cycling by implementing bike-sharing programs and expanding cycling networks, other regions have not kept pace, which hampers the potential for widespread bicycle commuting [38–40].

Another challenge is the social perception of cycling. Jurak et al. [41] found that a growing body of literature reports the health benefits of active commuting to school. Their

study in Slovenia investigated barriers and determinants of active commuting in children living within 3 km of school. They found that household poverty, education of the mother, and parental encouragement for physical activity were not associated with the commuting mode. Distance to school, concern about being late, and conformist family barriers were the main reasons for not choosing active commuting. The study suggested that parents from all social strata who drive their children to school in a walking or cycling range are a promising target population for active commuting interventions. In many countries, cycling is still seen as a mode of transport for those who cannot afford a car rather than as a viable and sustainable alternative to motorised transport. This perception can discourage people from cycling, particularly in countries like Slovenia, where car ownership is often associated with social status [42,43]. Addressing these social barriers is essential for promoting bicycle commuting and shifting cultural attitudes towards cycling.

The emergence of e-bikes has added a new dimension to bicycle commuting, addressing some of the challenges associated with traditional cycling. E-bikes, equipped with an electric motor for assistance, make cycling more accessible to a broader range of people, especially those who may find traditional cycling physically demanding. This is especially significant in regions with hilly terrain, like Slovenia, where the physical effort required for cycling can be a deterrent [44]. Additionally, e-bikes have the potential to expand the reach of bicycle commuting, making it a more feasible option for longer commutes. This is crucial in the context of urban sprawl, where distances between home and work can be considerable. By reducing the effort needed to cycle longer distances, e-bikes can help make cycling more appealing for commuting, reducing the reliance on cars and promoting more sustainable urban mobility [45]. However, the growing popularity of e-bikes also brings new challenges. One concern is the potential impact of e-bikes on the demand for traditional bicycles. Some researchers argue that the increasing popularity of e-bikes could lead to a decline in the use of traditional bicycles as people choose the convenience of electric assistance. This shift could have implications for cycling culture and commuting safety, as e-bikes may attract a different demographic of users, including those who would not otherwise consider cycling [46]. E-bikes often travel faster than traditional bicycles, raising safety issues, especially on mixed-use cycling paths where various cyclists coexist. It is crucial to design cycling infrastructure that meets the requirements of both traditional cyclists and e-bike users in order to foster safe and inclusive cycling environments [47].

Slovenia boasts a rich cycling heritage, with bicycles traditionally playing a pivotal role in transportation across urban and rural areas. Nonetheless, similar to many nations, Slovenia has witnessed a transition towards car-focused transport since the 1970s, propelled by economic development, higher car ownership, and urban expansion. This change has led to notable environmental and societal impacts, such as heightened traffic congestion, air pollution, and decreased public health [48]. Despite these challenges, cycling remains an integral part of Slovenian culture, while bicycles are still commonly used for short trips and recreational purposes. In recent years, there has been a renewed interest in promoting cycling as a sustainable mode of transportation, driven by growing environmental awareness and the need to reduce carbon emissions. This has led to the development of new cycling initiatives, including the expansion of cycling infrastructure, the introduction of bike-sharing schemes, and campaigns to raise awareness of the benefits of cycling [49–52]. The widespread acceptance of cycling as a significant mode of transportation in urban areas remains low, especially among commuters. Studies indicate that a significant obstacle to more people commuting by bicycle in Slovenia is the perception of cycling as unsafe, particularly in densely populated urban areas with heavy traffic. Romania, Poland, and Slovenia have the highest cyclist fatality rates [53]. Overcoming this challenge entails creating safer cycling infrastructure and fostering a cultural change that promotes cycling as a practical and appealing transportation option [54,55].

The studies in Table 2 explore various aspects of bicycle commuting and related patterns. Heinen et al. [56] provide a literature review emphasising the complexity of factors influencing cycling frequency. Surveys by Sears et al. [57] highlight weather and

training as key to year-round cycling, while Heinen et al. [58] examine daily decisions influenced by work, weather, and commute characteristics. Liang et al. [59] analyse French commuting rhythms, linking long commutes to emissions, and Te Velde et al. [60] explore European commuting patterns, noting demographic and cycling trends. Ilenič et al. [61] use citizen sensors in Ljubljana to study PM2.5 exposure risks for cyclists, and Jonkeren et al. [62] investigate Dutch bicycle–train users, identifying them as young, educated professionals integrating cycling with public transport.

Table 2. Review of the literature on daily commuting.

Authors	Methods	Influencing
Heinen et al. [56]	Literature review	This paper examines the factors influencing bicycle commuting frequency, emphasising the need for a deeper understanding beyond traditional motorised transport studies.
Sears et al. [57]	Survey	A study in northern communities showed that warmer, dry weather boosts bicycle commuting. While distance and gender matter, training cyclists for cold conditions and promoting multimodal commuting can support year-round biking.
Heinen et al. [58]	Survey	This study examines daily bicycle commuting decisions among 633 part-time cyclists, revealing that weather, commute, and work factors significantly influence mode choice, with occasional cyclists more swayed by weather and frequent cyclists deterred by practical barriers.
Liang et al. [59]	Survey	This study analyses French commuting patterns using 2019 survey data, identifying four travel rhythms influenced by trip distance, time, and frequency, with long-distance commutes significantly impacting transport emissions.
Te Velde et al. [60]	Survey	This study, part of the 2010 ENERGY project, explores commuting patterns among children and parents across eight European countries, highlighting demographic influences, marked national differences in cycling rates, and an inverse association between parental cycling to work and overweight status.
Ilenič et al. [61]	Case study sampling protocol	This study in Ljubljana used citizen-deployed sensors to assess PM2.5 exposure, showing higher risks for cyclists, seasonal and diurnal pollution patterns, and minimal health risks, emphasizing the value of integrating sensor data into air quality policies.
Jonkeren et al. [62]	Survey	This study examines bicycle–train users in the Netherlands, revealing they are typically young, highly educated commuters who integrate cycling with train travel, favouring large city stations and shared bicycles for activity-end trips.

Source: Authors' compilations.

3. Materials and Methods

To gain insights into the critical aspects of daily commuting for employees in the Netherlands, we conducted two interviews with key stakeholders in sustainable mobility. The interviews took place on the MS Teams platform and involved representatives from the Dutch Cycling Embassy, the Ministry of Infrastructure and Water Management, and the Dutch Cycling Association. The questions for the interview are available in Figure A1.

The secondary data were sourced from SURS, covering annual quantity on bicycle imports to Slovenia from 1997 to 2024, reflecting the absence of significant domestic production since the closure of the Rog factory [63].

Additionally, bicycle (BIK) and e-bicycle (e_BIK) sales revenue data for Slovenia were obtained from Statista. To complete the dataset for the Vector Auto Regression (VAR) model, gross domestic product (GDP) and urbanisation (URB) rates were also extracted from Statista. The analysis focuses on evaluating their impact on the bicycle market, particularly on bicycle demand. The VAR model spans the time range from 2015 to 2029, using annual data frequency with the observed and the predicted values by Statista. Therefore, the data vector for the VAR is as follows:

$$_{2015=100}^{SI}[e\_BIK\ BIK\ GDP\ URB\ ]_{t}^{T=15}, \quad (1)$$

where T is the number of observations, and SI is the symbol for Slovenia. The base year is 2015 (2015 = 100) and the isolated data were further recalculated to a base index.

4. Results

The empirical evidence gathered reflects a robust methodology, utilising both primary and secondary data to ensure the accuracy and reliability of the findings. The statistical overview thus complements the qualitative insights. By integrating these quantitative findings with qualitative observations, this report provides valuable implications for formulating strategies that align with market trends.

4.1. Qualitative Analysis

4.1.1. Interview—Dutch Cycling Embassy

On 30 January 2024, an in-depth interview took place with a representative from the Dutch Cycling Embassy to explore the intricacies of daily commuting patterns for employees in the Netherlands. This scholarly conversation unveiled several crucial aspects, with the following key points: national policies and infrastructure measures are designed to bolster cycling, encompassing cycling network development; convenient vehicle parking options; and effective traffic management. The Netherlands is emerging as a global leader in cycling, boasting high bicycle ownership and extensive cycling infrastructure. Cycling infrastructure plays a pivotal role in promoting cycling to work, with a comprehensive network of paths being critical for safe and comfortable cycling. There is a notable emphasis on integrating cycling with public transportation, the rising popularity of e-bikes for extended range, and the utilisation of cycling superhighways for longer distances. In addition to infrastructure, raising awareness, marketing, and promoting cycling as a lifestyle, which brings myriad benefits to physical and mental health, is paramount. Various services for bike maintenance, such as maintenance stations at railway stations and bike shops, as well as the option to rent electric bikes, need to be readily available. The national government of the Netherlands offers a range of financial incentives and benefits for cycling to work, including reimbursement per kilometre and bike leasing schemes. Employers have varying approaches to promoting cycling in the workplace, ranging from providing showers and other facilities to offering financial incentives for employees completing their journeys. Despite the successes in promoting cycling, the Netherlands faces challenges due to high car ownership rates, necessitating further measures to encourage sustainable modes of transportation.

The Netherlands has dedicated much time to evolving into an exemplary bicycle-friendly country. Establishing a cycling culture among its population has been pivotal to this transformation. The country's approach emphasises promoting cycling as a primary mode of transport, encompassing political measures, infrastructure improvements, and policies to enhance traffic safety. Pricing policies related to car parking and transit traffic restrictions in urban areas also play a crucial role. With 27% of all trips made by bike, the Netherlands leads the world in promoting cycling. One of the key factors contributing to its success is the high-quality cycling infrastructure accessible to people from all walks of life. The Dutch national government offers various benefits and incentives for cycling to work, including reimbursement per kilometre and bike leasing schemes. While these initiatives have been successful, there is still room for the improvement and coordination of benefits with other modes of transport. Opportunities for enhancement include launching better promotional campaigns for cycling, forging closer partnerships with employers to provide cycling benefits, and further expanding cycling infrastructure, particularly in areas with high car ownership rates.

4.1.2. Interview—Ministry of Infrastructure and Water Management of the Netherlands

On 7 March 2024, representatives from the Dutch administration engaged in an enlightening discourse, unveiling several pivotal themes of discussion. This dialogue, marked by meticulous preparation and a notably controlled atmosphere devoid of controversy,

primarily revolved around public policies concerning housing investments to augment sustainable commuting, with a particular emphasis on cycling.

The governmental strategies delineated encompass a comprehensive approach towards enhancing cyclist and pedestrian safety, underscored by initiatives to avert crossings, establish cycling highways, and enforce a vehicular speed limit of 30 km/h within urban precincts. These measures dovetail with broader objectives to cultivate a cycling culture through education, starting from educational institutions. This is further supported by infrastructural provisions such as bike parking facilities, showers, changing amenities, and commuting incentives bolstered by state-endorsed schemes and subsidies. Additionally, the augmentation of cycling path throughput and adapting public transportation infrastructures, including the assurance of regular and timely train services, are vital for incentivising the modal shift from automobiles to bicycles.

The transition of the Netherlands into a reputed cycling sanctuary was not serendipitous but the result of strategic foresight, the seamless integration of cycling paths within urban layouts, and the decentralisation of vehicle parking to peripheral urban zones. The overarching strategy for supplanting vehicular dominance with sustainable mobility paradigms encapsulates three core facets: the development of a robust cycling infrastructure, the establishment of an extensive network of cycling routes, and the implementation of persuasive measures aimed at altering commuting perceptions, engaging multiple stakeholders from various sectors, including the corporate sphere.

The exchange illuminated by the interview is particularly noteworthy for the diverse insights provided by the interviewees. A consensus emerged on the criticality of meticulous planning in formulating sustainable mobility policies, configuring infrastructural elements, and the seamless interconnection of transportation modalities. Moreover, the imperative to curtail urban vehicular speeds to 30 km/h was accentuated to ensure safety and promote cycling as a preferable mode of transportation over driving, mainly when time-efficiency is considered. While financial incentives were recognised as marginally influential, it was acknowledged that within the microcosm of corporate entities, employers play a pivotal role by offering enhanced commuting compensations to employees who opt for cycling, thereby underscoring the multi-faceted approach required to foster a cycling-centric mobility culture.

4.1.3. Interview—Fietserbond

The interview with the Head of International Relations at Fietserbond took place on the MS Teams platform from 14:30 to 15:15 on Thursday, 7 March 2024. Focusing on the local, provincial, and national levels, cycling continues to be a popular mode of transportation, with around a quarter of commutes being made by bike. This trend dates back to the 1950s and 1960s. The Netherlands has made significant strides in promoting cycling, exemplified by the high cycling rate, particularly for short distances up to 7.5 km, and the existence of more than 37,000 km of separate cycling paths. Building a safe and comprehensive cycling infrastructure, including separate cycling paths and combined modes of transport, is crucial for promoting cycling. Additionally, providing amenities such as bike parking spaces, showers, changing rooms, road markings, and service points for bicycle repairs is essential. Furthermore, developing a cycling culture involves promoting sustainable practices and offering specific incentives for commuters who cycle to work, including financial allowances or travel expense reimbursements, fostering employer support for cycling among employees. The Netherlands has made significant strides in promoting cycling as a sustainable mode of transportation. However, there is still untapped potential for further growth, particularly in reducing reliance on car traffic. Our political leaders must prioritise the development of sustainable transport options and encourage the integration of cycling and public transportation.

The country's long history of high cycling rates and ongoing infrastructure development sets a commendable example for promoting cycling as commuting. A key takeaway from our discussion is the pivotal role of dedicated cycling infrastructure in successful

cycling promotion, the advantages for both employers and employees and the availability of convenient bike parking facilities. Moreover, we must underscore the importance of an integrated approach to mobility that combines cycling with other sustainable modes of transport, such as public transit.

To drive further advancements, it is imperative to continue comprehensively developing cycling infrastructure, considering safety, directness, attractiveness, and consistency. Additionally, offering supplementary services like repair stations and tyre inflators and expanding incentives for cyclists through tax breaks and subsidies for bike purchases or rentals can be highly beneficial. Raising awareness about the benefits of cycling and promoting sustainable transportation practices are also vital. By implementing these measures, the Netherlands can uphold its prominent position in promoting cycling for commuting and contribute to alleviating traffic congestion, enhancing air quality, and improving the overall well-being of its residents.

4.2. Quantitative Analysis of the Bikes Sold in Slovenia

In addition to the qualitative analysis, the study further presents the summary statistics concerning the bicycle market in Slovenia (Table 3).

Slovenia has witnessed a discernible increase in the importation and sales of bicycles in recent years, an evolution reflective of escalating interest in cycling as a form of leisure and a sustainable transportation alternative. This phenomenon manifests a consistent demand for traditional bicycles and, more prominently in recent times, a marked increase in the importation of e-bikes, signifying a transformative shift in consumer inclinations towards more contemporary and efficient commuting modalities.

An analysis of data reveals that the acquisition of traditional bicycles has maintained a robust trajectory since 1997, with periodic fluctuations correlating with broader market dynamics. In 1997, Slovenia's bicycle imports numbered 41,440 units, demonstrating a steady ascension, peaking notably in the late 1990s and early 2000s. For instance, 1998 witnessed a spike in imports to 51,703 units. This ascending trend underscores a resilient bicycle market, propelled by factors including Slovenia's scenic geographies, an augmented emphasis on health and fitness, and governmental initiatives advocating for cycling as an eco-conscious mode of transportation.

Nonetheless, the most striking trend within the Slovenian market pertains to the exponential growth in the importation of e-bikes. While categorical data on e-bike imports became discernible only in recent years, the growth trajectory underscores a broader global phenomenon where consumers increasingly favour electric bikes over their traditional counterparts. Enticed by the array of advantages e-bikes offer, such as diminished physical exertion, capacity for longer distances, and compatibility with Slovenia's diverse topography, including its hilly terrains, consumers increasingly favour electric bikes over their traditional counterparts.

Table 3. Bikes and e-bikes imported to Slovenia 1997–2024.

Year	No. of Bikes	CI	No. of E-Bikes	CI	Sum	CI
1997	41,440				41,440	
1998	51,703	125			51,703	125
1999	40,069	77			40,069	77
2000	48,719	122			48,719	122
2001	44,456	91			44,456	91
2002	72,329	163			72,329	163
2003	109,068	151			109,068	151
2004	142,871	131			142,871	131
2005	82,757	58			82,757	58
2006	87,184	105			87,184	105
2007	87,183	100			87,183	100

Table 3. *Cont.*

Year	No. of Bikes	CI	No. of E-Bikes	CI	Sum	CI
2008	109,600	126			109,600	126
2009	83,881	77			83,881	77
2010	84,198	100			84,198	100
2011	65,547	78			65,547	78
2012	64,998	99			64,998	99
2013	69,305	107			69,305	107
2014	67,481	97			67,481	97
2015	74,655	111			74,655	111
2016	73,484	98			73,484	98
2017	80,996	110	1446		82,442	112
2018	81,546	101	5131	355	86,677	105
2019	86,924	107	7639	149	94,563	109
2020	83,437	96	10,492	137	93,929	99
2021	82,598	99	16,351	156	98,949	105
2022	83,690	101	18,663	114	102,353	103
2023	62,295	74	16,003	86	78,298	76
2024 [1]	39,140	63	11,551	72	50,691	65

Notes: [1] The data for 2024 are for the first half of the year. CI—chain index; gray colour—data not available; Source: Slovenian Statistical Office (SURS) [64].

The data delineate that e-bike imports were initially negligible, with a significant uptick observed in more recent periods. This pattern intimates that the adoption of e-bikes in Slovenia constitutes a relatively recent development, potentially spurred by advances in battery technology [65], diminishing costs, and heightened environmental consciousness among consumers. Subsidies introduced in 2024 further corroborate this trend [66,67].

The era spanning 1997 to 2016 was characterised by a dominion of traditional bicycles, with importation peaking in 2004 at 142,871 units, indicative of a potent demand during that epoch (Figure 1). However, the market paradigm commenced a significant transformation in 2017 when the introduction and ascendancy of e-bikes became evident. E-bike imports, initially modest at 1446 units in 2017, soared to 18,663 units by 2022, illustrating a more than tenfold increase within a mere five-year span. This surge parallels the global trend towards electric mobility, propelled by technological advancements, urban commuting predicaments, and a pronounced emphasis on sustainable transport solutions. Conversely, traditional bike imports have fluctuated, displaying a general downward trend from 87,184 units in 2006 to 62,295 units in 2023. This decline in traditional bike imports, juxtaposed with the burgeoning e-bike sector, suggests a market transition whereby consumers increasingly gravitate towards e-bikes over conventional models. This shift is likely attributed to the added convenience, ease of use, and versatility of e-bikes for varying commuting demands, including traversing longer distances and navigating the hilly terrains characteristic of Slovenia. Despite this, the chain indices predominantly indicate more years of growth than decline. Overall, the base indices, calculated through a specified equation, reveal a rise from 1997 to 2022 of almost 150% (base index is 247), illustrating the substantial growth and transformation within Slovenia's bicycle market.

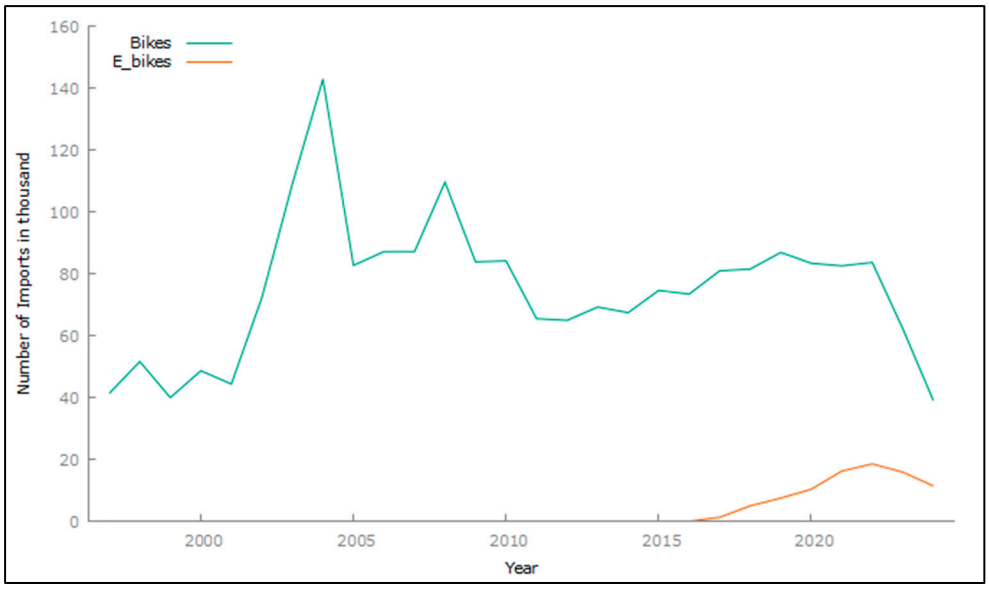

Figure 1. Trends in bike and e-bike imports in Slovenia (1997–2024).

The graph depicts the import trends of traditional bikes and e-bikes in Slovenia from 1997 to 2024. It highlights the consistent demand for traditional bikes, marked by noticeable peaks and declines over the years. Conversely, there has been a substantial surge in e-bike imports since 2017, indicating a rising preference for electric mobility. This trend emphasises the growing popularity of e-bikes as a sustainable and efficient transportation option in Slovenia. It is worth noting that Statista [68] offers more profound insights into bike sales in Slovenia. The data reveal that commuter bicycles and kids' bikes, which are more aligned with sustainable daily transportation, represent only 50.00% of the total sales. In contrast, other types of bicycles, such as mountain bikes, make up another half. In 2023, the sales percentages were as follows: commuter bicycles 29.00%, kids' bicycles 21.90%, mountain bicycles 36.00%, other bicycles 2.30%, performance bicycles 8.80%, and utility bicycles 2.00%. This suggests a significant market share for non-commuter bicycles despite their possible double environmental impact [69].

The bicycle market in Slovenia is experiencing a dual trend: a sustained demand for traditional bicycles, accompanied by urbanization and GDP growth. On the other hand, there is a significant rise in e-bike imports (Figure 2).

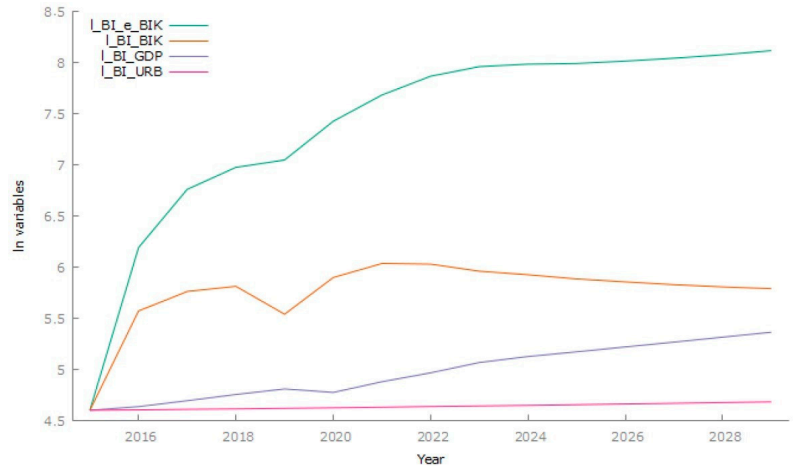

Figure 2. Characteristics of the data isolated from Statista.

The graph illustrates the trends of four variables—e-bike imports, traditional bike imports, GDP, and urbanisation rate—from 2015 to 2029. E-bike imports show a steep and consistent increase, indicating rising popularity. Traditional bike imports initially grow but stabilise and decline slightly after 2020. GDP follows a steady upward trend, while the urbanisation rate remains almost flat. These patterns highlight the growing dominance of e-bikes in Slovenia's bicycle market.

For a deeper analysis of bicycle market in Slovenia, the vector VAR is employed. According to the research question the dependent variable is bikes sold, and the independent variables are e-bikes, real GDP and urbanisation:

$$BIK_t = -7890.45 - \underset{(0.31)}{0.94 \cdot BIK_{t-1}} + \underset{(0.59)}{0.12 \cdot e\_BIK_{t-1}} - \underset{(0.08)}{8.33 \cdot GDP_{t-1}} + \underset{(0.27)}{168.40 \cdot URB_{t-1}} + \varepsilon, \quad (2)$$

where p values are in parenthesis, and ε is a random walk.

The VAR model examines the interdependence between traditional bicycle demand, e-bike demand, GDP, and urbanisation rate. The equation suggests that traditional bicycle demand is negatively influenced by its own lag (coefficient: -0.94), indicating declining momentum. E-bike demand has a minor positive but insignificant impact (0.12), showing limited substitution effects. GDP negatively impacts bicycle demand (-8.33). Urbanisation positively influences demand (168.40). The high standard errors highlight variability, warranting cautious interpretation of relationships. A Durbin–Watson (D–W) statistic of 2.97 indicates a potential issue with negative autocorrelation in the residuals of the VAR model. This suggests that the errors from one period may negatively influence the errors in subsequent periods, highlighting potential model misspecification or omitted variables that need further investigation or adjustment. Therefore, on the other hand, e-bikes have a more significant effect. The results is as follows:

$$e\_BIK_t = -76,891.3 - \underset{(0.02)}{3.71 \cdot BIK_{t-1}} + \underset{(0.31)}{0.42 \cdot e\_BIK_{t-1}} - \underset{(0.00)}{45.92 \cdot GDP_{t-1}} + \underset{(0.02)}{877.26 \cdot URB_{t-1}} + \varepsilon, \quad (3)$$

where p values are in parenthesis, and ε is a random walk.

The VAR equation for e-bike demand reveals that traditional bike demand (has a significant negative impact (-3.71), indicating a substitution effect as consumers shift towards e-bikes. Previous e-bike demand has a minor positive but insignificant impact (0.42). GDP significantly reduces e-bike demand (-45.92), suggesting affordability concerns. Urbanisation strongly promotes e-bike demand (877.26), highlighting the role of urban planning in encouraging e-bike adoption. These results suggest that urbanisation positively drives e-bike popularity, while economic constraints and substitution effects shape the market dynamics.

5. Discussion

The results show that the answer to the research question is the opposite: it is not regular bikes that impact e-bikes, but vice versa. The VAR results provide insights into how Slovenia can draw lessons from the Netherlands to enhance its bicycle commuting culture. The significant influence of urbanisation on traditional bicycle demand suggests that improving urban infrastructure, such as bike lanes and parking facilities, could strongly promote cycling. Slovenia could emulate the Netherlands' approach by integrating cycling infrastructure with public transit systems to encourage multimodal commuting.

E-bikes show a clear potential to enhance biking performance, as they exhibit growing demand and substitution effects with traditional bikes. This highlights their role in overcoming barriers like long distances or hilly terrains, common in Slovenia. However, the GDP's negative impact on both bike and e-bike demand suggests affordability challenges, emphasizing the need for subsidies or financial incentives to make e-bikes accessible.

The discussion highlights the significant growth in e-bike sales in Slovenia, contrasting it with a more moderate increase in traditional bicycle sales. The data analysis reveals that while Slovenia has a long-standing cycling tradition, the recent surge in e-bike imports

marks a transformative shift in consumer behaviour driven by technological advancements, urbanisation challenges, and increasing environmental awareness. The comparison with the Netherlands, known for its thriving cycling culture, suggests that Slovenia can further enhance its cycling infrastructure and policies to sustain this growth in e-bike use. The findings underscore the potential of e-bikes to serve as a critical component of sustainable urban mobility, offering a practical solution to reduce car dependency and address urban congestion. Additionally, the discussion identifies the need for targeted policy interventions, such as subsidies and investments in cycling infrastructure, to support the continued rise in e-bike adoption.

The data from 1997 to 2024 illustrate notable trends in bicycle and e-bike sales in Slovenia, indicating a significant shift in consumer behaviour over the years. The information reveals a consistent demand for traditional bicycles, with noteworthy peaks, such as in 2004 when imports reached 142,871 units. However, starting from 2017, there has been a substantial increase in the import of e-bikes, with the numbers rising from 1446 units in 2017 to 18,663 units by 2022. This steep incline reflects the growing popularity of electric mobility, driven by advances in e-bike technology, urban commuting challenges, and heightened environmental awareness. The data suggest that e-bikes complement and possibly replace traditional bicycles, especially in urban areas where convenience, speed, and versatility are crucial [70]. This trend corresponds with the global shift towards sustainable transportation solutions. It emphasizes the importance of Slovenia continuing to invest in cycling infrastructure and supportive policies to sustain and further enhance these positive trends in the bicycle market.

The research question for this study can be summarised as follows: Can Slovenia draw lessons from the Netherlands to enhance its bicycle commuting culture and empower its residents to adopt this habit? Furthermore, can e-bikes contribute to improved biking performance among Slovenian residents? Best practices are transferable from the Netherlands to Slovenia, utilising comprehensive policy strategies and considering the existing habits of the residents. Despite the strong car preference, Slovenians have a notable inclination towards cycling. Thus, implementing transferable practices and introducing new aspects in infrastructure and economic and social habits could revolutionise daily commuting and travel patterns. Moreover, this study's quantitative aspect confirms these directions' significance.

6. Conclusions

The study highlights the role of cycling as a sustainable, and efficient mode of transportation, drawing lessons from the Netherlands' success in fostering a strong cycling culture. Over the years, the Netherlands has become a global leader in cycling by implementing supportive policies, offering work-related cycling incentives, and actively engaging citizens in promoting cycling as a lifestyle. Key factors driving this success include high-quality infrastructure, integrated transport systems, and widespread awareness of cycling's benefits. Despite this progress, potential remains, particularly in further reducing car dependency and expanding cycling adoption.

The findings suggest that the Netherlands' approach can serve as a valuable model for countries aiming to develop sustainable mobility systems. By enhancing infrastructure, providing additional services and benefits for cyclists, and promoting cycling's advantages, nations can replicate these successes to alleviate traffic congestion, reduce emissions, and improve public health.

In contrast, Slovenia demonstrates a rising trend in e-bike sales. Descriptive statistics reveal exponential growth in e-bike imports in Slovenia, contrasting with a decline in traditional bicycle demand. VAR analysis underscores urbanisation as a positive driver for cycling demand, while GDP negatively impacts affordability. These findings suggest that Slovenia can enhance its cycling culture by adopting targeted measures, including financial incentives, urban planning, and public awareness campaigns, to sustain e-bike adoption and promote sustainable commuting.

6.1. Implications

This study indicates that both countries must intensify their efforts to address transportation issues. This study's direct policy implications suggest that Slovenia should focus on expanding cycling private–public investments to meet the rising demand for e-bikes and traditional bicycles. Furthermore, implementing financial incentives such as subsidies for e-bike purchases and tax breaks for cycling commuters could significantly bolster the adoption of cycling. Policymakers should also emphasise the integration of cycling with public transportation to establish a seamless and sustainable urban mobility network. Some other measures that could reduce car dependency among Slovenians are funded studies on cycling behaviour, urban mobility, and e-bike technology to support evidence-based policymaking; encouraging partnerships with businesses to promote cycling through workplace incentives, such as bike leasing programs and rewards for commuting by bike; and implementing programs to educate citizens about the environmental, health, and economic benefits of cycling, fostering a cultural shift towards sustainable commuting habits.

On the scientific front, the study underscores the necessity for further research into the factors influencing the adoption of e-bikes and the impact of cycling on urban mobility in Slovenia. This includes evaluating the effectiveness of different policy interventions in increasing cycling rates and reducing car dependency. Additionally, gaining insights into the demographic and behavioural variances between traditional bike and e-bike users could offer valuable information for implementing targeted strategies to promote sustainable transportation. Comparative studies with countries like the Netherlands (Figure A2) could also uncover best practices and innovative approaches to cycling infrastructure and policy, contributing to the broader discussion on sustainable urban transportation solutions.

6.2. Limitations and Further Research

Further research could expand the scope of research to include higher-frequency data, such as monthly or quarterly sales figures, would enable a more precise analysis of trends and seasonal variations in bike and e-bike purchases. This increased granularity would enhance the ability to detect short-term impacts of policy changes or economic shocks on cycling demand. Additionally, incorporating data from a broader range of nations, particularly those with established cycling cultures like Denmark and Belgium, would allow for comparative analyses that could reveal best practices applicable to Slovenia.

It is important to note that the study's limitations include its reliance on annual data, which may obscure short-term fluctuations and limit the depth of insights. Moreover, the analysis primarily focuses on Slovenia, and while comparisons with the Netherlands are informative, the results may not be fully generalisable to other contexts. Future studies should consider a more comprehensive set of countries to enhance the external validity of the findings and draw more comprehensive conclusions about the global trends and drivers of bicycle and e-bike adoption in diverse economic and cultural environments.

In order to bolster the research findings, it is essential to conduct further studies like survey. Our recent survey in Slovenia reveals preliminary insights into why people choose not to commute by bike, citing reasons such as excessive traffic, inadequate cycling infrastructure, proximity of the workplace, and the availability of flexible working hours.

6.3. Highlighted Results

1. Urbanisation positively impacts both traditional bike and e-bike demand;
2. E-bike imports and sales in Slovenia have grown exponentially since 2017;
3. GDP negatively influences bicycle demand;
4. E-bikes are increasingly replacing traditional bicycles.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Novo Mesto (protocol code UNM 49/2024), and the date of approval was 24 April 2024.

Informed Consent Statement: Not applicable.

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Appendix A

Interview regarding cycling practices in Netherlands

Welcome to our interview on cycling practices in Netherlands. We thank you for your participation, as your knowledge and insights are important to our research. We are a research group, that actively participates in the CRP 2023 project, which focuses on improving sustainable daily transportation to work in Slovenia. We would like to point out that we are focused on daily bicycle users (i.e., those that commuting to work) and not tourists. Our aim is to carry out a comparative analysis of the best practices in the European Union and to develop plans for urban areas and beyond in our country.

This interview will take up to 45 minutes max. and will be audio recorded to ensure the accuracy of our reflections and inferences. Any information shared will only be used for scientific purposes. Your participation is voluntary and you have the right to withdraw at any point.

So, if you are ready, we can start with the first question.

1. How does the Netherlands promote cycling as the primary means of transportation to work?
2. How would you rate the success of the Dutch policy to promote cycling?
3. How would you rate the success of the development of cycling infrastructures as one of the factors in promoting cycling to work?
4. What practices do you think could be transferred to the other environments (e.g. Slovenian) to encourage greater use of cycling as a way of transportation to work?
5. Do you think that the choice of cycling as a way of transportation to work, depends to a large extent on appropriate infrastructure and accessibility, as well as the provision of parking spaces?
6. How do you set up bicycle service points and bicycle tire filling stations in the Netherlands?
7. Do you have any special reliefs available (e.g. tax reliefs, some sort of financing) in the Netherlands for people who choose to cycle to work? If so, could you please give an example.
8. Your question: Please ask yourself a free-form question about cycling practices in the Netherlands and answer it.

Thank you for your cooperation, and as a whole team we wish you successful further work.

Figure A1. Questions for the interview. Source: own source [71].

Appendix B

Figure A2. Source: authors' compilation made by Canva.

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