



The impact of individual behavioural change in daily transportation on carbon footprint: An applied study on bicycle use in the case of Iğdır

Günlük ulaşımında bireysel davranış değişiminin karbon ayak izi üzerindeki etkisi: Iğdır örneğinde bisiklet kullanımına ilişkin uygulamalı bir çalışma

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Abstract

This study presents the impact of behavioural changes in individual transportation preferences on the carbon footprint through a self-observational case study. From a theoretical perspective, the motivational underpinnings of individual action are explained within the framework of the Theory of Planned Behaviour and the Value-Belief-Norm Theory. The study focuses on a public employee living in Iğdır Province, Türkiye, who, over a period of approximately two months, switched from private cars to bicycles. This transition is analysed using quantitative data regarding environmental, economic, air pollution, and health aspects. As a result, the participant's weekly cycling distance of 145.52 km led to the prevention of approximately 21.43 kg of CO₂ e emissions and the saving of 7,999 litres of fuel. Moreover, their physical activity level met World Health Organization standards. Overall, the study highlights the potential for low-carbon transportation practices at the individual level to contribute to collective climate goals, while also emphasizing the shortcomings of local governments and providing policy recommendations.

Öz

Bu çalışma, bireysel ulaşım tercihlerindeki davranışsal değişimlerin karbon ayak izi üzerindeki etkisini öz-gözlemsel bir vaka analizi aracılığıyla sunmaktadır. Teorik olarak, Planlı Davranış Teorisi ve Değer-İnanç-Norm Kuramı çerçevesinde bireysel eylemin motivasyonel temelleri açıklanmaktadır. Araştırma, Türkiye'nin Iğdır ilinde yaşayan bir kamu çalışanının yaklaşık iki ay boyunca özel araç kullanımını bırakarak bisiklete geçişini ele almakta ve bu geçişi nicel verilerle destekleyerek çevresel, ekonomik, hava kirliliği ve sağlık açısından analiz etmektedir. Katılımcının haftalık 145,52 km'lik bisiklet kullanımı sonucunda yaklaşık 21,43 kg CO₂ e salımı engellenmiş ve 7,999 litre yakıt tasarrufu sağlanmıştır. Ayrıca fiziksel aktivite düzeyi Dünya Sağlık Örgütü standartlarına uygun hâle gelmiştir. Bu bağlamda çalışma, bireysel düzeydeki düşük karbonlu ulaşım uygulamalarının kolektif iklim hedeflerine katkı potansiyelini vurgularken, yerel yönetimlerin eksikliklerine dikkat çekmekte ve politika önerileri sunmaktadır.

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1. Introduction

The climate crisis, with its multidimensional impacts, is one of the biggest challenges threatening the Sustainable Development Goals at the global level (Abbass et al., 2022; WMO, 2023). Increasing concentrations of greenhouse gases in the atmosphere are raising global average temperatures. This, in turn, disrupts ecosystem balance and directly affects socioeconomic structures. Rising temperatures have led to a decrease in biodiversity, while environmental problems such as declining agricultural production, habitat loss, and water scarcity have accelerated (Anukwonke et al., 2022; Dixit et al., 2022; Saleem et al., 2024). These developments threaten human health and can cause numerous health problems, ranging from respiratory diseases to infectious diseases. Furthermore, they exacerbate social inequalities by complicating access to fundamental rights such as housing, education, and healthcare, while also deepening the impacts on vulnerable groups, particularly in urban areas (Chong, 2018; Reckien et al., 2017).

These multidimensional impacts are increasingly visible, especially through urbanization processes, where transportation—an integral component of urban life—emerges as both a driver of and a potential solution to the climate crisis. Cities are expanding rapidly, and in this process, the transportation sector has become not only a major source of emissions but also one of the fundamental challenges affecting urban life. Against this backdrop, transforming the transportation sector, which is responsible for approximately 23% of global carbon emissions, is regarded as a priority objective of climate policies (IPCC, 2023). According to the European Federation for Transport and Environment, transportation represents one of the largest sources of emissions in Europe, with the sector alone projected to account for 10% of global emissions by 2050 (Sun et al., 2022). Therefore, reducing emissions in the transportation sector is of critical importance in addressing the climate crisis.

Road transport, in particular, accounts for approximately 70% of transportation-related emissions (IPCC, 2023). The majority of these emissions originate from individual cars (Ritchie, 2020); that is, from individual transportation choices. Thus, transportation is not only an economic activity but also a sector that must be reconsidered within the framework of environmental sustainability. With the onset of rapid urbanization in the last century, the widespread use of private cars for short-distance urban travel (Muneer et al., 2011) has not only increased emissions (Yang et al., 2024) but also undermined the goals of sustainable urban transportation. Transportation policies shaped under the pressures of urban growth have often favoured infrastructure investments prioritizing private vehicles, while environmentally friendly alternatives, such as public transport, cycling, and walking, have been overlooked. As urban transportation systems continue to evolve (Yang et al., 2024), reducing motor vehicle use in short-distance travel or discouraging private car dependency (Garus et al., 2024) holds significant potential for lowering the overall carbon footprint.

This development shows a similar pattern in Türkiye. In 2017, the transportation sector accounted for 84.7 metric tons of carbon dioxide (CO₂), representing 16% of total greenhouse gas emissions nationwide (Güzel & Alp, 2020). Meanwhile, the environmental impacts of urban transportation practices have become increasingly evident. Data from the Turkish Statistical Institute reveal that individual car ownership has risen markedly in recent years, a trend particularly

concentrated in major cities. The number of registered vehicles increased by 10.1% in December 2022 compared to the same month of the previous year, reaching 1,269,912 (TÜİK, 2023). Moreover, shuttle services continue to constitute an important mode of transportation for daily commuting, such as to schools and workplaces. However, these vehicles frequently lead to substantial fossil fuel consumption, even over short distances (de Nazelle et al., 2010), thereby contributing to the rise in urban carbon emissions.

Therefore, research on the environmental impacts of urban transportation systems, particularly in recent years, has highlighted the role of individual transportation choices in addressing the climate crisis. The transportation sector, responsible for approximately one-quarter of energy-related greenhouse gas emissions, has become one of the defining contributors to the global carbon footprint. In this context, the expansion of low-carbon transportation modes has become central to sustainable development policies. Beckx et al. (2013) emphasized that reducing individual car use for short-distance trips is essential for cities to achieve their carbon neutrality targets, while the International Energy Agency (IEA) notes that, under the Net Zero Emissions by 2050 scenario, CO₂ emissions from the transportation sector must decline by more than 3% annually by 2030 (IEA, 2023). In this regard, cycling stands out with its low infrastructure costs, zero direct emissions, and positive health effects (Buehler & Pucher, 2021). Mueller et al. (2018) demonstrates that promoting active transport in European cities could prevent more than 10,000 premature deaths per year, with health benefits being as substantial as the climate benefits.

Similarly, studies from various countries highlight the impact of transportation choices on the carbon footprint at both the university and city levels. For instance, in Brazil, Barros et al. (2018) found that university employees, due to their predominant reliance on private cars, contribute to high emissions, whereas students who use public transportation have much lower per capita emissions. In Canada, Mathez et al. (2013) investigated the influence of vehicle types used for university transportation on carbon emissions, examining seasonal variability in emissions throughout the year through travel surveys. Nevertheless, such technical assessments may be insufficient to capture the psychological and behavioural dynamics underlying individual decision-making.

At this point, theoretical approaches that explain the role of psychological factors—such as individuals' attitudes, perceptions of social norms, and perceived behavioural control—in the transition to environmentally friendly modes of transportation come to the forefront. Research conducted within the framework of Ajzen's (1991) Theory of Planned Behaviour (TPB) and the Value–Belief–Norm (VBN) Theory (Steg & Vlek, 2009; Stern, 2000) indicates that individual values, norms, and behavioural control are key determinants in the adoption of active transportation choices, such as cycling. For example, Bamberg et al. (2003) demonstrated that interventions aimed at changing transportation behaviour are effective only when they align with individuals' environmental attitudes and sensitivity to social norms. Donald et al. (2014) emphasized that increases in public transportation and cycling use are driven more by normative orientations and habitual behaviour than by cost–benefit analyses of alternatives. Klöckner & Matthies (2004) noted that in Germany, sustainable transportation behaviours are associated not only with environmental awareness but also with the level of social acceptance and perceived self-efficacy.

On the other hand, macro-scale modelling studies also demonstrate the impact of public and active transportation on carbon footprints. In the United States, Ercan et al. (2016) examined the role of public transportation in reducing CO₂ emissions, using system dynamics modelling, and estimated that a 25% increase in public transportation could lower CO₂ emissions by 61.3 million tons by 2050. Li et al. (2015) in a study of university students in Shanghai, conducted a comparative analysis of the effects of transportation, nutrition, and academic activities on the annual carbon footprint and highlighted the importance of awareness campaigns. Using a lifecycle approach, Guangnian et al. (2023) demonstrated that public-use bicycles require an average of seven months of operation to reach carbon balance, and that emissions may increase again if this period is not exceeded. Jing et al. (2022), analysing data from 30 cities in China, showed that the development of public transportation reduces energy consumption and direct carbon emissions.

Finally, Schwanen et al. (2012) argue that changes in individual behaviour can only be achieved through collective habit transformations, and therefore habits must be reproduced not only at the individual level but also within social, cultural, and spatial contexts.

In this context, promoting and supporting sustainability-oriented behavioural changes at the individual level is crucial (Klaniecki et al., 2019). This is precisely where the present study is situated. The study aims to analyse the impact of individual transformations in urban short-distance transportation on carbon footprints. Yang et al. (2024) define transportation accessibility as the extent to which individuals can easily reach essential destinations such as workplaces, educational institutions, and shopping areas. In other words, a well-planned and interconnected transportation system facilitates efficient decision-making by reducing travel time and costs. This, in turn, enhances transportation efficiency and contributes to lower carbon emissions over the same distance.

Within this framework, the study aims to address the question of whether the transformation in individual transportation preferences reduces the urban carbon footprint. Specifically, the consequences of choosing bicycles instead of private vehicles are examined through a case study supported by quantitative data. The study offers a unique contribution because it focuses on one of Türkiye's worst-performing cities in terms of air pollution, explores its long-standing cycling culture (discussed in detail below), represents a pioneering investigation in this field, and utilizes numerical data to support the micro-scale environmental impacts of changes in individuals' transportation behaviour. The findings, obtained by calculating carbon footprints, are expected to contribute both to revising the city's approach to bicycle transportation and to provide a clearer and more concrete understanding of the relationship between individual preferences and sustainable development goals.

2. Conceptual Framework

2.1. Transportation and Carbon Footprint

The carbon footprint is an environmental indicator that quantifies greenhouse gas (GHG) emissions resulting from human activities as carbon dioxide equivalent (CO₂ e). This indicator measures the total emissions caused directly or indirectly by an individual, institution, or product

(Ferreira et al., 2023; Wiedmann & Minx, 2008). Consequently, the carbon footprint has become a crucial metric, particularly in the development of sustainability policies.

Consequently, the transportation sector stands out as one of the largest contributors to both global emissions (Fan et al., 2023) and the carbon footprint. In particular, road transport powered by fossil fuels is responsible for approximately 70% of total transportation-related emissions (IPCC, 2023). This high proportion is because diesel- and gasoline-powered vehicles emit not only CO₂, but also pollutants harmful to both the environment and human health, such as nitrogen oxides (NO_x) and particulate matter (PM₁₀). As a result, the environmental impact of road transportation is further exacerbated (Breuer et al., 2020; Haakman et al., 2020; WHO, 2025).

Against this backdrop, active modes of transportation—such as walking and cycling—are central to sustainable transport strategies. The benefits of active transportation include low economic costs, minimal parking requirements, and the absence of direct emissions. In particular, using bicycles for short-distance urban trips can play a significant role in reducing carbon emissions.

The high frequency of short-distance trips in European cities serves as a concrete indicator of the potential to reduce emissions. For instance, 44% of urban trips in the Netherlands, 37% in Denmark, 41% in Germany, and 30% in the UK are shorter than 2.5 kilometres. Similarly, 60% of weekday journeys in Sydney are under 5 kilometres (Xia et al., 2013). These figures highlight the opportunity to promote active transportation over short distances. However, despite this potential, the continued prevalence of private motor vehicle use for short trips hinders efforts to lower transport-related emissions (de Nazelle et al., 2010; He et al., 2022; Neves & Brand, 2019). A striking example of this is observed in the UK: although one-quarter of trips are made on foot, they account for only 3% of the total distance travelled. The preference for motor vehicles—even for distances as short as 1–2 miles—indicates that prevailing social habits are misaligned with environmental goals (UK Parliament, 2019). Indeed, considering that diesel vehicles emit approximately 2.68 kg of CO₂ per liter (Pilkington, 2022), while cycling reduces an individual's transport-related carbon footprint to nearly zero (Wood, 2023), it becomes clear how critical are personal transportation choices.

Karjalainen & Juhola (2019) argue that urban transportation constitutes a strategic priority in the effort to reduce greenhouse gas emissions. Similarly, Kuss and Nicholas (2022) emphasize that a transition to fossil fuel-free transportation systems is essential for Europe to meet its climate objectives. In light of this, changes in individual transport preferences can be understood not only as an environmental necessity but also as part of a broader social paradigm shift.

When evaluated globally, transportation sector emissions increased by an average of 1.7% annually between 1990 and 2022—faster than in other sectors—according to the International Energy Agency (IEA, 2023). In countries such as the United States, the transportation sector accounts for 28% of total greenhouse gas emissions, intensifying environmental pressures in parallel with the rising rates of vehicle ownership (Ercan et al., 2016). This upward trend represents one of the key structural challenges to achieving carbon neutrality or net-zero targets. Yet these targets are crucial for mitigating the catastrophic effects of the climate crisis, limiting global temperature rise to 1.5°C, and ensuring a liveable planet for future generations. Therefore, the transportation sector must be

addressed both as a major contributor to the climate crisis and as a critical leverage point in the transition toward sustainability.

2.2. Sustainable Transportation and Individual Behaviour Change

Sustainable transportation refers to a holistic approach that not only minimizes environmental impacts but also incorporates multidimensional objectives such as social equity, economic accessibility, and public health (Jelti et al., 2023). Recognized as one of the core components of sustainable development since the 1992 Rio Conference, the concept has become increasingly associated with the transportation sector, particularly within the framework of the United Nations Sustainable Development Goals (SDGs) introduced in 2015 (United Nations, 2025). In light of these considerations, bicycle transportation emerges as a key pillar of sustainable mobility due to its low carbon emissions, minimal infrastructure costs, positive health impacts, and efficient use of urban space (Ballo et al., 2023; Karanikola et al., 2018).

Empirical studies on the impact of cycling on carbon emissions demonstrate that significant environmental benefits can be achieved even at the individual level. For instance, Brand et al. (2021) found that individuals who cycle have 84% lower lifetime CO₂ emissions from transportation compared to non-cyclists. Each additional cycling trip reduces lifecycle CO₂ emissions by 14%, while trips that replace car journeys reduce emissions by as much as 62%. Similarly, daily bicycle use in Copenhagen has been shown to prevent approximately 90,000 tons of CO₂ emissions annually (NYC Global Partners, 2013).

However, the promotion of bicycle transportation is not solely dependent on infrastructure investments. Insights from behavioural economics and social psychology suggest that transportation choices are influenced not only by rational cost-benefit analyses but also by habits, social norms, perceived safety, and symbolic meanings (Stern, 2000; Wang et al., 2022). Given these factors, the absence of safe cycling infrastructure, high levels of motorized traffic, unfavourable weather conditions, and feelings of social exclusion are among the key barriers to bicycle use (Heinen et al., 2010; Marincek, 2023).

In this context, public policies have the potential to significantly influence individual transportation behaviour. In particular, local governments in Northern European countries implement a range of measures to promote cycling, including tax incentives, awareness campaigns, integrated infrastructure investments, and institutional support mechanisms. The Netherlands—where bicycle usage exceeds 27%, the highest rate in Europe—attributes its success to a longstanding planning vision, culturally oriented strategies, and strong societal acceptance (Buehler & Pucher, 2021).

The concept of sustainable or active transportation encompasses modes of mobility that encourage physical activity and move beyond the reliance on single-occupancy vehicles (SOVs) (Mundorf et al., 2018). These modes are strategically significant for reducing greenhouse gas emissions, enhancing public health, and improving overall quality of life. However, car-centric transportation policies that gained prominence in the post-World War II era have led to several structural challenges, including traffic congestion, air pollution, suburban sprawl, and inefficient land

use. To address these issues, urban strategies such as mixed-use development, the expansion of green spaces, the integration of transportation networks, and improved pedestrian and bicycle infrastructure are increasingly being adopted (Mosca et al., 2024).

Social and cultural factors also play a critical role in shaping active transportation behaviours. Transforming these factors often involves a long-term and complex process. Nevertheless, many local governments and public institutions are developing holistic strategies aimed at promoting active transportation and enhancing public health. Safe, accessible, and integrated public transit systems—along with pedestrian and bicycle infrastructure—are fundamental to supporting healthy lifestyles, particularly for vulnerable groups such as children, the elderly, and low-income populations. The design of transportation systems and urban space plays a decisive role in ensuring environmental sustainability, fostering social inclusion, and improving quality of life. In contrast, automobile-oriented transportation policies have the potential to weaken social bonds and exacerbate social exclusion (Mundorf et al., 2018).

Walking and cycling are not only direct forms of mobility but also sustainable modes that can be effectively integrated with public transportation systems. In the United States, for instance, cycling is predominantly used for recreational purposes, whereas in regions such as Europe and China, it serves as a core component of daily transport. However, concerns regarding traffic safety and personal security—particularly for women, children, and the elderly—pose significant barriers to the widespread adoption of pedestrian and bicycle transportation (Mundorf et al., 2018). Changes in transportation preferences are often closely tied to transformations in individuals' life circumstances. A study conducted in London found that factors such as changes in employment or residence, health status, family structure, modifications in transport infrastructure, cost fluctuations, and rising environmental awareness are influential determinants of car ownership and usage (Rees, 2022).

Sustainable mobility is regarded as a priority policy domain in addressing the climate crisis, primarily due to the detrimental effects of greenhouse gas emissions from the transport sector on environmental quality and public health. In Europe, road transport alone accounts for approximately 72% of transport-related emissions and contributes to 25% of total energy-related emissions (Mosca et al., 2024). Accordingly, the promotion of cycling requires both structural interventions—such as road pricing mechanisms, dedicated cycling infrastructure, and pedestrianization initiatives—and behavioural strategies, including awareness campaigns and self-regulatory incentive schemes.

Encouraging individuals to adopt environmentally friendly transportation choices requires enhancing their environmental awareness through persuasive, non-coercive strategies (Whillans et al., 2021). Contemporary transportation systems face multifaceted challenges—such as traffic congestion, greenhouse gas emissions, air pollution, and road accidents—which must be addressed through comprehensive strategies at both the infrastructural (supply-side) and behavioural (demand-side) levels. In this context, increasing individuals' awareness of their environmental impact and guiding them toward sustainable alternatives—such as public transport, cycling, and walking—constitutes a critical dimension of behavioural change aimed at reducing the reliance on single-occupancy motor vehicles (Anagnostopoulou et al., 2020).

In the conceptual analysis of individual behavioural change, TPB is among the most widely applied models (Ajzen, 1991). According to TPB, behavioural intention is shaped by three key components: individual attitudes, subjective norms, and perceived behavioural control. Accordingly, shifts in individuals' preferences for sustainable transportation can be explained by factors such as pro-environmental attitudes and physical accessibility. Furthermore, VBN theory posits that sustainable behaviour stems from a normative sense of obligation grounded in environmental values (Stern, 2000). Within this framework, the internalization of cycling as a social norm serves as a critical indicator of behavioural transformation toward sustainable mobility.

3. The Development of Bicycle Culture in Iğdır: Historical and Contemporary Perspectives

In Iğdır, bicycles constitute not only a mode of transportation but also a significant element of urban culture and social life. The widespread adoption of bicycles in Iğdır began in the 1950s. İbrahim Baydar, born in 1939, established the region's first bicycle shop under the name "*Baydar Ticaret*," initiating bicycle rental and repair services. This enterprise laid the groundwork for the development of bicycle culture in Iğdır. Baydar fulfilled the city's bicycle-related needs by operating from the same shop for 55 years, thereby contributing to the integration of bicycles as an indispensable component of everyday life during this period (Cyclist Türkiye, 2018).



Figure 1. First bicycle shop in Iğdır

Resource: (Cyclist Türkiye, 2018)

The prevalence of bicycle culture and usage in Iğdır is supported not only by individual preferences but also by local institutional structures. In this city, which hosts the Provincial Representative of the Turkish Bicycle Federation, the cycling lifestyle has become a social norm.

Ekrem Baydar, former Provincial Representative of the Iğdır Bicycle Federation, commented on the city as follows:

“We use bicycles for transportation. In fact, it also contributes to our health by providing some physical exercise. Approximately 80 percent of the population uses bicycles. Bicycles are the primary means of transportation for commuting between home and work.” (Eroğlu, 2012).



Figure 2. Pinocchio bicycle trials in Iğdır in the 1960s

Resource: (Cyclist Türkiye, 2018)

Baydar also asserts that Iğdır has a 62-year history of bicycle use. On average, 2,000 bicycles are sold annually in the city, positioning it as the city with the highest number of bicycles in Türkiye (40,000 bicycles) relative to its population density (Eroğlu, 2012).

Similarly, Erdal Ünver, an official of Ünver Bicycle with 50 years of experience in the bicycle industry, attributes the high prevalence of bicycle ownership in Iğdır to the following reasons:

“We continue our father’s profession. We sell between 1,000 and 2,000 bicycles annually. Each household owns 2-3 bicycles. Residents of Iğdır enjoy cycling. They commute between home and work across the flat plains. They also travel to their fields and perform irrigation tasks. Some even commute from villages to the city by bicycle. Primarily, it is beneficial for their health and is cost-effective. Even car owners use bicycles due to high fuel prices and lack of parking spaces, bicycles do not face such issues.” (Yeşil Iğdır, 2019).

The city's existing bicycle culture has not yet reached the desired level. In this context, considering the current developments in bicycle transportation, it can be observed that despite the absence of an urban bicycle transportation network, the Iğdır Municipality has established bicycle parking facilities at selected locations throughout the city, as shown in Figure 3, to promote bicycle use and provide citizens with environmentally friendly transportation alternatives. These facilities were installed in areas with high bicycle usage to offer cyclists safer and more organized parking opportunities. Municipal officials stated that this initiative was implemented to encourage bicycle transportation (Aras, 2024).



Figure 3. Bicycle parking facilities in the city centre of Iğdır

Resource: (Aras, 2024).

Despite cycling being an essential component of urban transportation, only approximately 3.9 km of bicycle paths have been constructed outside the city centre (Figures 4 and 5). However, findings from the figures and observations show that these paths are not actively used and do not serve their intended purpose. In particular, photos taken from different points show that the paths are blocked by garbage bins and covered with gravel. This prevents safe cycling and can also damage bicycle wheels. In addition, there are no signs to ensure safe travel for cyclists.



Figure 4. Separated bicycle lane 1

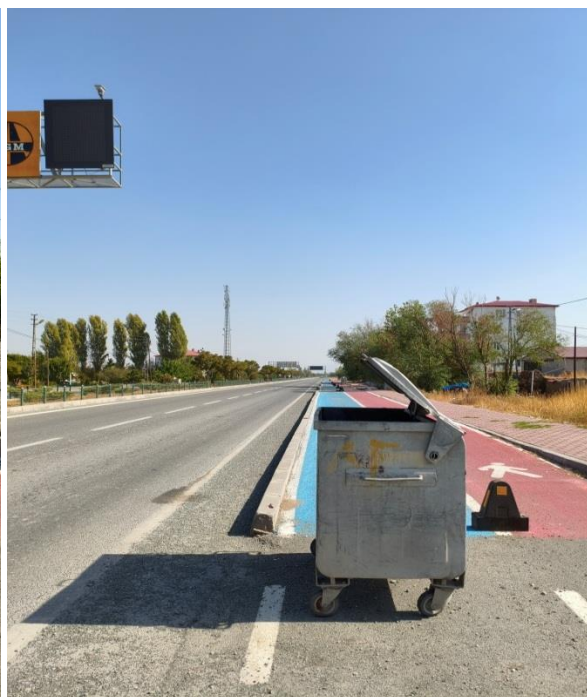


Figure 5. Separated bicycle lane 2

In addition, on significant days, cycling events are organized in the city, often announced with slogans such as “Ride a bike for health.” Tours are held with the participation of provincial institution directors and a limited number of citizens, often accompanied by police escorts.

4. Method

4.1. Research Design

This study is a single-case study research based on a mixed-methods approach, incorporating both qualitative and quantitative data, which examines the effects of behavioural change in individual transport preferences on carbon footprint. The research is based on a change made by the researcher in his own transportation habits and, in this respect, provides a personal case study. The transition process from private car use to bicycle use is systematically documented, and the environmental effects of this transformation are discussed in light of quantitative data. Over the course of approximately two months, the researcher conducted systematic daily observations of both car and bicycle commutes. Each trip was recorded for key parameters, such as route, frequency, duration, and fuel consumption (for car trips). This approach enabled detailed and structured documentation of the transition process, ensuring that both qualitative experiences and quantitative data were reliably integrated into the analysis.

The research aims to reveal the impact that individual behavioural change can have on the context of sustainable transportation. The findings are supported by environmental behaviour theories and situated within a theoretical framework. Within this framework, the case analysis conducted at a micro scale aims to contribute to the social and environmental sciences literature by demonstrating that environmental effects can be identified even with a limited number of observations.

Additionally, the main limitation of this study is that it is based on introspective data from a single participant, which restricts the generalizability of the results. Moreover, the study period covers only a two-month timeframe, potentially overlooking the effects of seasonal conditions (e.g., reduced bicycle use during winter). Therefore, the findings should be considered preliminary observations regarding the potential effects of micro-level behavioural change. Furthermore, as this topic is being addressed for the first time in Iğdır, it has not been possible to draw directly from scientific sources. For this reason, the data presented in the section on bicycle culture, in particular in Iğdır, has been obtained from newspapers.

4.2. Participant Profile and Selection Criteria

The participant examined in this study is a 38-year-old male employed in the public sector, residing in the province of Iğdır, located in eastern Türkiye. This region is characterized by low population density and widespread use of motor vehicles. The participant commutes between his home and workplace, covering a total round-trip distance of 7,276 km (Figure 6). Formerly, he travelled this route five days a week using a private vehicle (a 1.3-litre diesel engine with an observed average urban fuel consumption of 5.5 litres per 100 kilometres). For the past two months, however, he has exclusively used a bicycle for this commute, five days a week.



Figure 6. Home-Workplace transportation route map

Resource: (Google Earth, 2025)

The participant was selected through purposive (non-random) sampling. This method is commonly used in qualitative research that seeks to analyze specific behaviours in depth, rather than generalize findings (Patton, 2014; Yıldırım & Şimşek, 2021). Within this context, the behavioural changes observed at the individual level are considered to offer valuable insights into the potential for broader social transformation.

4.3. Data Collection Process

The data used in this study were collected based on the participants' self-report. These data include numerical information such as daily commuting distances, private vehicle usage frequency, and fuel consumption. The participant's explicit consent was obtained, and the data collection process was conducted in accordance with principles of personal data protection and research ethics. The recorded distances were verified using the Google Earth application. Vehicle fuel consumption was calculated based on the technical specifications of the diesel-powered car and the observed average urban fuel consumption (5.5 litres per 100 km). Fuel prices were set at 47.36 Turkish Lira (TL) per litre, based on the average diesel prices from Turkish Petroleum between 01 March 2025 and 25 May 2025.

Although the calculations in the study were based directly on carbon emissions, these values were interpreted as equivalent to the carbon footprint since they were derived on an individual scale. Therefore, the term “*carbon footprint*” is used consistently throughout the study.

4.4. Data Analysis and Carbon Footprint Calculation

To evaluate the environmental implications of the participant's behavioural shift from private vehicle use to cycling, a standard carbon footprint calculation methodology was employed. The total carbon emissions from private vehicle use were estimated using the following general formula (Wolff, 2025):

$$CF = FC \times EF$$

Where:

CF = Carbon footprint (kg CO₂ e)

FC = Fuel consumption (litres)

EF = Emission factor (kg CO₂ e per litre of fuel)

The emission factor EF for diesel was adopted as 2.68 kg CO₂ e per litre, based on international reporting standards (Al-Quds University, 2023).

Since cycling generates no direct tailpipe emissions, the bicycle's carbon footprint during the study period was considered negligible.

$$CF_{\text{bike}} = 0 \text{ kg CO}_2\text{e}$$

Thus, the environmental benefit (emissions reduction) resulting from the modal shift can be represented as:

$$\Delta CF = CF_{\text{car}} - CF_{\text{bike}} = CF_{\text{car}}$$

Where ΔCF is the net carbon footprint reduction.

To determine fuel consumption FC , the formula below was applied:

$$FC = \left(\frac{C}{100} \right) \times D$$

Where:

C = Vehicle fuel consumption rate (litres per 100 km)

D = Distance travelled (km)

Indirect emissions related to bicycle production, maintenance, and infrastructure were excluded from the scope of this study.

4.4.1. Pre-Transition Period: Carbon Footprint from Private Vehicle Use

In the pre-transition period, the participant used a diesel-powered private vehicle with an average urban fuel consumption of $C=5.5$ L/100 km. The daily commuting distance (round-trip) was $D=7.276$ km/day, resulting in the following monthly travel:

Step 1: Monthly travel distance

$$D_{\text{month}} = 7.276 \text{ km/day} \times 20 \text{ days} = 145.52 \text{ km/month}$$

Step 2: Monthly Fuel Consumption

$$FC_{\text{month}} = \left(\frac{5.5}{100} \right) \times 145.52 = 7.999 \text{ litres/month}$$

Step 3: Monthly Carbon Footprint

$$CF_{\text{month}} = 7.999 \times 2.68 = 21.43 \text{ kg CO}_2\text{e/month}$$

Step 4: Annual Estimation

$$CF_{\text{year}} = 21.43 \times 12 = 257.18 \text{ kg CO}_2\text{e/year}$$

Table 1. Carbon footprint from individual transportation – pre-transition period (Private vehicle use)

Time Period	Distance (km)	Fuel Consumption (L)	Carbon Footprint (kg CO ₂ e)
Daily	7.276	0.4002	1.0725
Weekly	36.38	2.001	5.362
Monthly	145.52	7.999	21.43
Annual	1,746.24	95.99	257.18

These values provide a concrete quantification of carbon emissions resulting from regular commuting via private car. The observed reduction in emissions following the transition to cycling is as significant as the total emissions before the transition due to the absence of direct emissions from bicycle use.

4.4.2. Post-Transition Period: Carbon Footprint from Bicycle Use

In the post-transition period, the participant traveled the same distance (145.52 km/month) using a bicycle. Given that bicycles generate no direct carbon emissions, they are an environmentally friendly mode of transport.

Carbon Footprint = 0 kg CO₂ e/month

Table 2. Post-Transition period: Carbon footprint from bicycle use

Time Period	Distance (km)	Carbon Footprint (kg CO ₂ e)
Daily	7.276	0
Weekly	36.38	0
Monthly	145.52	0
Annual	1,746.24	0

Table 3. Reduction in carbon footprint due to modal shift to bicycle use

Time Period	Carbon Footprint Reduction (kg CO ₂ e)
Daily	1.0725
Weekly	5.362
Monthly	21.43
Annual	257.18

Table 4. Economic and environmental savings from the shift to bicycle use (Diesel price: 47.36 TL/L)

Time Period	Fuel Saved (L)	Emission Reduction (kg CO ₂ e)	Cost Savings (TL)
Daily	0.4002	1.0725	18.95
Weekly	2.001	5.362	94.75
Monthly	7.999	21.43	378.90
Annual	95.99	257.18	4,544.34

4.5. Research Area

Located in the easternmost part of Türkiye, Iğdır Province exhibits geographical and climatic conditions conducive to cycling. As shown in the topographic map (Figure 7) obtained from Google Earth, the region has flat terrain. In addition, it features a compact urban structure, low population density, and favourable weather conditions. In fact, it contrasts with the harsh climate of Eastern Anatolia. The Aras Plain, situated between high mountains and plateaus, possesses a unique climate unlike that of any other region. Summers are hot and dry, while winters are cold and humid. Iğdır, which has a microclimatic structure, is characterized by an alluvial geological formation. According to meteorological measurements taken in Iğdır, the lowest recorded temperature to date is -20°C, while the highest is +40°C. The heaviest rainfall occurs in spring and autumn (Iğdır İl Özel İdaresi, 2025). These spatial characteristics, combined with short average commuting distances, highlight the potential of bicycles as an effective and sustainable means of urban transportation in the province.

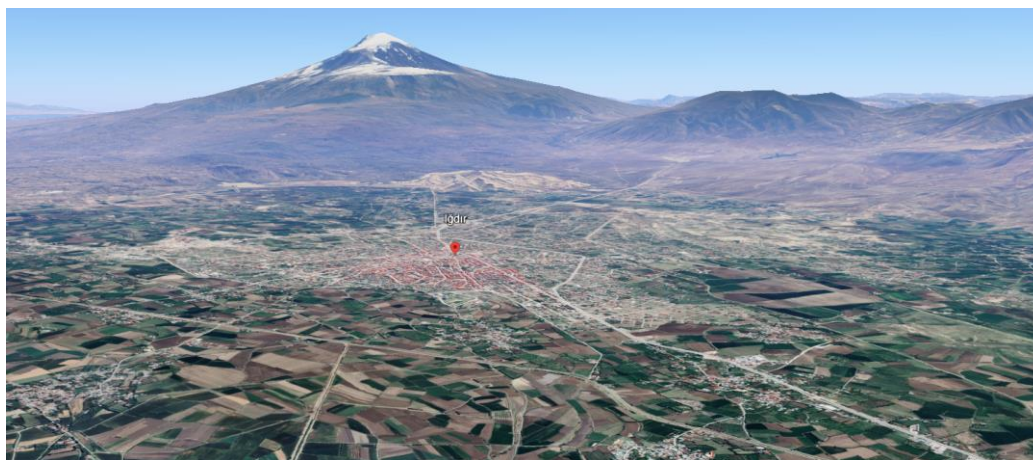


Figure 7. Physical map of Iğdır Province
Resource: (Google Earth, 2025)

The widespread use of motor vehicles and the inadequacy of bicycle infrastructure (including bike paths and parking areas) in Iğdır both limit and make cycling risky. Furthermore, a significant portion of Iğdır's residents require short-distance transportation, for example, living an average of 3–5 km from their workplaces, schools, and public institutions. This demonstrates that cycling is an effective means of meeting urban transportation demands.



Figure 8. An overview of air pollution in Iğdır

Resource: (İklim Haber, 2022)

Iğdır province is among the cities with the most polluted air in Türkiye (Gürçam & Konuralp, 2022), and even in Europe (IQAir, 2021). Çoşkun et al. (2024) reported that winter and autumn are the seasons with the highest air pollution in Iğdır. NO_x, NO, and NO₂ are the pollutants most strongly correlated with PM₁₀ concentrations (Figure 8). Despite the polluted air, citizens frequently use bicycles for commuting to work and running errands, particularly for trips from residential neighbourhoods to the city centre. Although this situation is often overlooked, it poses a significant health risk. This situation underscores the importance of environmentally friendly transportation alternatives and necessitates considering bicycles as a strategic tool within the framework of environmental sustainability. Consequently, Iğdır province provides a suitable environment for developing pilot initiatives, behaviour change models, and local policy recommendations aimed at increasing urban bicycle use.

5. Limitations Regarding Bicycle Use in Iğdır

Although Iğdır province's flat topography and intense short-distance transportation needs exist, it exhibits significant deficiencies in infrastructure supporting bicycle use. The images captured

by the participant during daily activities, presented below, illustrate the main physical and structural challenges limiting bicycle transportation in the city.

These images reveal issues such as the absence of dedicated bicycle roads and lanes in the city centre, the predominance of motor vehicle traffic on existing roads, and irregular use of road shoulders. Furthermore, the lack of any guidance or safety signage for cyclists within the transportation infrastructure serves as a critical indicator that bicycles are yet to be institutionally recognized as a legitimate mode of transportation in the city.

Such limitations create structural barriers to the effective use of bicycles as a means of transportation and jeopardize the sustainability of individual cycling preferences. The images are shared to provide contextual understanding of the physical environment in which the individual experiences occur, forming the foundation of this study.



Figure 9. Home-Workplace bicycle route

Figure 9 illustrates the lack of bicycle infrastructure within urban transportation in Iğdır, as well as the physical barriers that limit cyclists' accessibility to existing road sections. Notably, garbage bins positioned alongside the roads constrict safe passage for cyclists by narrowing the available transportation space, thereby increasing the risk of potential accidents.



Figure 10. Home-Workplace bicycle route

The Home-Workplace Bicycle Route depicted in Figure 10 clearly highlights the physical obstacles caused by heavy-duty vehicles (trucks) frequently parked along the roadside, in addition to the absence of designated cycling lanes on urban roads. This situation hampers cyclists' ability to pass safely and constitutes a significant deterrent to bicycle use in urban transportation.

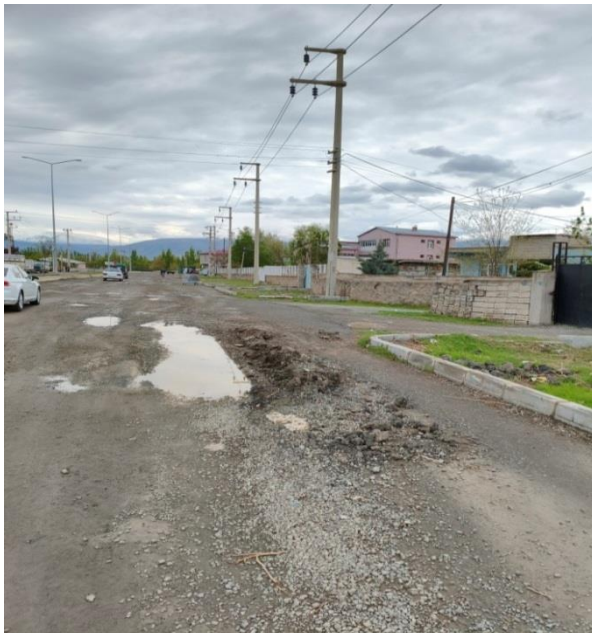


Figure 11. Home-Workplace bicycle route



Figure 12. Home-Workplace bicycle route

Moreover, one of the most significant obstacles to the widespread adoption of bicycles in Iğdır province is the institutional misalignment within the city's political and administrative structures. Specifically, the lack of coordination between central and local administrations (municipalities) complicates the planning and implementation of sustainable transportation policies from a holistic perspective. This division disrupts not only physical infrastructure projects such as bicycle path construction but also the development of environmentally friendly transportation strategies aimed at fostering a healthy, clean, and liveable environment. Due to this structural impediment, planning, awareness campaigns, and incentive mechanisms designed to encourage local residents to prefer low-carbon transportation modes such as bicycles are insufficiently developed. Nevertheless, small and medium-sized cities with flat geographical features like Iğdır represent the most suitable contexts for integrating bicycles as a transportation mode. Therefore, enhancing administrative coherence and cooperation is crucial for building a shared vision toward sustainable transportation objectives between central and local governments.

6. Findings

This research aims to reveal, through concrete data, the extent to which the transition from motor vehicle use to bicycle use in individual transportation makes a difference in terms of carbon emissions, economic costs, and health outcomes. The participant's daily home-to-work route is 3.638 km, and the 7.276 km is covered round trip. This corresponds to a weekly, monthly, and annual bicycle commuting distance of 36.38 km, 145.52 km, and 1,746.24 km, respectively.

6.1. Evaluation in Terms of Carbon Footprint

Based on an estimated fuel consumption of 5.5 litres per 100 kilometres for motor vehicles, the participant's pre-transition transportation routine resulted in a monthly consumption of approximately 8 litres of diesel fuel for this route alone, leading to 21.43 kg of CO₂ e emissions. After switching to cycling, carbon emissions from this route dropped to zero. As a result, the individual avoids 21.43 kg of CO₂ e emissions per month, equivalent to approximately 257.18 kg of CO₂ e per year (see Table 3).

Furthermore, the findings suggest that replacing daily car trips with active modes of transportation, such as cycling, can significantly reduce an individual's mobility-related carbon footprint. In urban environments, shifting to these modes of transport is widely recognized as a cost-effective strategy for reducing transportation emissions and achieving broader climate goals.

6.2. Economic Savings

Based on the average diesel price (47.36 TL per litre) reported by Turkish Petroleum between March 1 and May 25, 2025 switching from car use to cycling is estimated to result in fuel savings of approximately 18.95 TL per day, 378.90 TL per month, and 4,544.34 TL per year (see Table 4). These calculations suggest that the potential for significant economic savings, even when considering only the daily commute, can serve as a strong incentive for behavioral change. Individuals who are particularly sensitive to transportation costs or driven by financial concerns are more likely to perceive cycling as a viable and advantageous alternative.

Similar findings have been reported in other studies. For example, a study conducted by Lund University found that traveling by car can be up to six times more expensive than cycling when both private and public costs are taken into account (Gössling & Choi, 2015). Likewise, the Institute for Transportation and Development Policy (ITDP, 2022) emphasizes that increased cycling provides substantial long-term financial benefits for individuals and societies through reduced fuel, maintenance, and parking costs.

6.3. Health Benefits

During the transition from using a motor vehicle to a bicycle, the data showed that the participant cycled an average of 7.276 km per day, 36.38 km per week, 145.52 km per month, and 1,746.24 km per year. When converting weekly distance into time, this corresponds to approximately 100 minutes of moderate-intensity activity per week. According to the World Health Organization (WHO, 2024), adults are recommended to engage in at least 150 minutes of moderate-intensity aerobic activity per week. While the participant's weekly cycling time falls slightly below the 150-minute guideline, the cumulative daily and monthly activity levels indicate a substantial level of physical activity that contributes to cardiovascular health, metabolic regulation, and mental well-being (Green et al., 2021; Kusnanda Nurrafi'u et al., 2023; Oja et al., 2011).

Furthermore, this level of cycling aligns with research showing that individuals who cycle regularly (approximately 100 minutes per week) have up to a 17% lower risk of mortality compared to non-cyclists (Logan et al., 2023). The data also highlight that consistent cycling accumulates meaningful annual activity (1,746.24 km/year), reinforcing its role not only in meeting WHO physical activity thresholds but also in promoting long-term preventive health benefits.

6.4. Air Pollution and Its Implications for Cycling in Iğdır

Air pollution levels measured in Iğdır are alarming, particularly with regard to particulate matter (PM₁₀) (Argun et al., 2019). According to IQAir (2021), the city ranks among the highest in Türkiye and Europe in terms of annual average PM_{2.5} concentrations. This underscores the importance of environmentally friendly transportation alternatives and the potential of cycling to reduce urban traffic congestion and improve air quality. Although high pollution levels, particularly during winter months when particulate matter concentrations peak, may discourage outdoor activities, air pollution did not appear to constitute a significant barrier to bicycle commuting during the observation period.

6.5. Spatial Observations and Visual Findings

The visual data presented within the scope of this research clearly illustrates the inadequacy of physical infrastructure supporting bicycle transportation in the city centre of Iğdır. Although Figure 2 indicates that the route is relatively short and suitable for cycling, the subsequent visuals highlight significant spatial limitations. For instance, Figure 9 shows that roadside garbage bins obstruct safe passage. Figure 10 depicts heavy trucks parked along the cycling route. Figure 11 reveals that even sidewalks are rendered unusable. Figure 12 captures how private transport vehicles manoeuvre recklessly, posing a serious threat to the safety of cyclists. Collectively, these observations underscore

that the current urban transportation environment in Iğdır is far from meeting the criteria of safety, accessibility, and user-centred planning required for sustainable bicycle mobility.

Table 5. Summary findings

Indicators	Values
Daily Distance Covered (km)	7,276 km
Monthly Fuel Savings (litres)	7,999 litres
Monthly Reduction in Carbon Emissions	21.43 kg CO ₂ e
Annual Reduction in Carbon Emissions	257.18 kg CO ₂ e
Annual Economic Savings (TL)	4,544.34 TL
Weekly Physical Activity (km)	36.38 km
Bicycle Infrastructure Observation	Insufficient, risky, unplanned

7. Discussion and Conclusion

This research evaluates the effects of a micro-level transformation in individual transportation behaviour on the carbon footprint in a multidimensional manner. By choosing to use a bicycle instead of a private car on the home-work route, the participant prevented direct carbon emissions of 257.18 kg CO₂ e per year. This finding reveals that changes in transportation preferences at the individual level can provide tangible environmental gains in line with urban sustainability goals. This finding reveals that changes in transportation preferences at the individual level can provide tangible environmental gains in line with urban sustainability goals. These gains also contribute to improving local air quality, which is particularly relevant in Iğdır, a city with elevated levels of particulate matter and urban air pollution. Moreover, these gains provide significant contributions not only to the environment but also to economic and health-related areas.

The annual economic savings of approximately 4,544 TL indicate that cycling is not only environmentally friendly but also a viable transportation alternative in terms of economic accessibility. This presents a strategic opportunity to encourage individuals to adopt low-cost modes of transportation, particularly in countries like Türkiye, where fuel prices are relatively high compared to average income levels. Moreover, the participant's average weekly bicycle use of 36 km aligns with the physical activity recommendations of the World Health Organization and highlights the positive contributions of individual transportation choices to public health.

The findings also provide a meaningful perspective when evaluated within the framework of behavioural environmental theories. In the context of the Theory of Planned Behaviour (Ajzen, 1991), positive attitudes grounded in environmental and health awareness, along with the physical accessibility of the transportation route (perceived behavioural control), emerge as key determinants shaping the participant's transportation choice. Similarly, according to the Value-Belief-Norm Theory, bicycle use is not merely a utilitarian decision but can also be understood as the practical expression of an internalized environmental norm. This underscores the tendency of individuals with environmental values to voluntarily engage in sustainable lifestyle practices (Stern, 2000).

Indeed, as the participant began using a bicycle, positive and supportive feedback was received from other staff members at the institution where he is employed. Comments such as “*You are doing very well,*” “*I wish we could use it too,*” “*Can I take a ride by bicycle?*” and “*It is very economical and healthy*” indicate that bicycle use is valued not only at the individual level but also socially. These remarks suggest that many individuals may intend to use bicycles but are likely

constrained by inadequate infrastructure. Given that approximately 234 personnel work at the participant's institution, it is anticipated that bicycle usage rates could increase significantly if appropriate infrastructural improvements are implemented.

However, the research findings also indicate that behavioural changes at the individual level may be hindered by institutional and structural deficiencies. Despite the participant's multiple efforts to engage with central government representatives to promote bicycle use, adequate institutional support was not obtained. In this regard, even in a topographically flat city like Iğdır, where transportation distances are short, the absence of dedicated bicycle lanes, insufficient road safety measures, and the marginalization of bicycles within the local traffic culture—despite the city's longstanding bicycle tradition—pose significant barriers to the sustainability of bicycle transportation. The encroachment of vehicles onto roadsides (Figure 10), obstruction of transportation corridors by garbage bins (Figure 9), inadequate sidewalks (Figure 11), and reckless manoeuvres by motor vehicles (Figure 12) create both physical and psychological deterrents to cycling. These findings demonstrate that individual motivation alone is insufficient; structural interventions are necessary to ensure the sustainability of behavioural transformation. Furthermore, beyond infrastructural improvements, administrative and institutional coordination is essential to effectively promote bicycle transportation in cities like Iğdır.

In fact, as shown in Figures 3, 4, and 5, the city is experiencing a significant disconnect in terms of bicycle transportation. Local governments appear to be diverging from their core missions through purely cosmetic initiatives rather than prioritizing citizens' needs. For instance, instead of investing in the much-needed city centre bicycle infrastructure, a bike path was constructed along a route where bicycles were not used, which quickly became a wasteland, losing its intended function. Moreover, despite the absence of adequate bicycle infrastructure—and even in areas where people risk their lives to use bicycles—the municipality continues to establish bicycle parking areas. While the priority should be to integrate bicycles into urban transportation, that these actions are misaligned with their stated objectives illustrates how disconnected local governments are from the public.

Furthermore, despite the lack of bicycle infrastructure in the city centre, the Iğdır Governor's Office stated: "Due to the lack of existing bicycle paths in our city, bicycles are widely used in urban traffic." *Cyclists' failure to comply with the rules occasionally leads to accidents. Every cyclist has responsibilities that they must be aware of. First and foremost, it should be remembered that bicycles are a means of transport, and cyclists have responsibilities toward themselves, the environment, and traffic rules. Therefore, for their own safety and to avoid endangering the lives of others, every cyclist must wear a helmet, gloves, knee pads, and elbow pads. They must have the necessary lighting, signs, and markings to be easily recognized in traffic. They must wear clothing suitable for cycling and comply with the rules for cycling specified in Highway Traffic Law No. 2918. It is extremely important to comply with the rules and take the necessary precautions for safe cycling (Haber Türk, 2018).*

In contrast, the 2019 Bicycle Paths Regulation stipulates that "While the establishment of a dedicated bicycle path within the city is a priority, the Administration determines the type of bicycle path to be implemented by considering traffic density, physical conditions, and other characteristics of

the area where the path will be built.” *If the type of bicycle path to be implemented is specified in the implementation zoning plan, the design and construction must be carried out accordingly (Ministry of Environment Urbanization and Climate Change, 2019).* Nevertheless, local government institutions, instead of implementing the practices outlined in the regulation, continue to deviate from their designated priorities.

As a result, changes in transportation behaviour at the individual level yield multidimensional benefits encompassing environmental, economic, and health-related aspects. However, the sustainability and widespread adoption of such micro-level initiatives require the activation of institutional and structural support mechanisms that extend beyond individual willingness. In this regard, it is critically important to develop concrete policy proposals to promote bicycle transportation in small cities with topographic advantages, such as Iğdır. The following measures stand out as priorities for advancing bicycle transportation in the city:

- A comprehensive “*Bicycle Path Master Plan*” should be developed and integrated into the municipality’s investment agenda.
- Incentive regulations to encourage bicycle use—such as providing free bicycles or grants—should be implemented, particularly targeting public employees.
- The construction of bicycle lanes and parking facilities should be mandated along transportation routes serving schools and workplaces.
- Integration between bicycles and public transportation must be ensured to facilitate longer-distance travel. For example, establishing transportation transfer centres at strategic locations could enable Iğdır University students to access the Suveren campus more affordably, with lower emissions and in a more environmentally sustainable manner.
- Awareness campaigns should move beyond temporary and symbolic gestures. Instead of occasional group rides consisting of 30–40 people in peripheral or urban areas accompanied by processions, it would be more impactful if institutional representatives or socially influential individuals regularly used bicycles within the city. This would strengthen the perception of bicycles as an integral component of urban transportation and empower individuals to adopt cycling as a practical and realistic daily mode of transport.

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