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The role of bicycling for the resilience and sustainability of transport in urban areas in the post-COVID-19 world

Master Thesis submitted in fulfillment of the Degree

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Submitted to Prof. Dr. Sabine Sedlacek

Ana Marija Udovič

61903793

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AFFIDAVIT

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ABSTRACT

Mobility is one of the basic human needs and influences individuals' opportunities and wellbeing. At the same time, transport is one of the biggest polluters, and sources of GHG emissions contributing to climate change. In addition to current challenges, such as continuous urbanization trend, growing population, and negative externalities of transport, the COVID-19 pandemic additionally disrupted the status quo of urban mobility around the world. As such, new perspectives and approaches to mobility in cities are needed.

The purpose of this study is to explore how the COVID-19 pandemic disrupted the existing condition of transport in urban areas and what was the role of bicycling during that period of disruption. Based on this, the conclusions have been drawn on how bicycling can help prepare urban areas for future disruptions and contribute to their resilience. However, as we aim for survival and neglect or even abandon the sustainable principles in times of hardship, it is also important to discuss how transport in urban areas can become more sustainable. Bicycling as a flexible, economical, sustainable and healthy mode of transport can help lead the way into a more resilient and sustainable future of urban areas. The following thesis provides new evidence on the basis of a real-life phenomenon in the geographical context of two cities of comparable size: *the city of Graz* (Austria) and *the City of Ljubljana* (Slovenia). The results are based on the comparative case study where two research methods were used. The primary data has been collected through in-depth expert interviews with stakeholders from both cities who are involved in the planning and development of urban areas. Through document analysis, the data on state of the art of both cities before and during the COVID-19 pandemic has been collected, used for time-series analysis and for complementing the insights from the interviews.

Although life is returning back to normal as COVID-19 infections decrease, it is important that urban areas prepare for other future disruptions (e.g., supply chain disruptions, political conflicts, resource scarcities). This thesis therefore provides empirical evidence to encourage further development of urban areas and prioritization of bicycling – development that would increase their resilience as well as long-term sustainability.

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CAS – Complex Adaptive System

CBA – Cost-Benefit Analysis

CSI – Shared Cycling Infrastructure

EC – European Commission

EU – European Union

GHG – greenhouse gas

LKM - Ljubljana Cycling Network (slo., “Ljubljanska kolesarska mreža”)

MCDA - multi-criteria decision analysis

n.d. – No data available

n/a – Not applicable

SES – Social-ecological system

UN – United Nations

1 INTRODUCTION

Mobility is a basic need and influences citizens' opportunities and wellbeing. Transport, on the other hand, is one of the biggest polluters and sources of GHG emissions contributing to climate change which in turn poses a threat to mobility. The COVID-19 pandemic additionally disrupted the status quo of urban mobility around the world. Mentioned challenges in addition to continuous urbanisation trend, growing population, and negative externalities of transport require new perspectives and approaches to mobility in cities. That being the case, it is not surprising that the European Commission put cities at the forefront of the 'transition towards greater sustainability', set an ambitious goal of 100 European cities being carbon neutral by 2030 and promised to continue engaging with large and medium-sized cities in the member states to encourage them to develop their own sustainable urban mobility plans by 2030 (European Commission, 2020). Cycling, as a flexible, economical, sustainable and healthy mode of transport, could play an important role for the future resilient and sustainable mobility in urban areas. During the COVID-19 pandemic, many citizens turned to walking or cycling to avoid potential infection with the virus. Cycling proved to be useful in times of yet another disruption, hence this master thesis aims to explore the role of bicycling for the resilience as well as sustainability of transport in urban areas in the post-COVID-19 world.

1.1 Research Context

The COVID-19 pandemic severely disrupted the established processes and proved how vulnerable our socio-economic system has become. The disruption also proved how important it is to rethink the processes set in place. For a while, the topic of resilience became the centre of discussion at multiple international conferences, webinars, and research papers and was incorporated into further development plans. However, there is an urgent need to change due to multiple current and upcoming challenges imposing a threat to the well-being of present and future generations.

In the EU, passenger cars represented 82.9% of inland passenger transport in 2017 (European Commission & Eurostat, 2020). Consequential or external costs of transport affect the general public and are currently not reflected in the prices (e.g., aeroplane tickets, fuel bills) (Heinrich-Böll-Stiftung, 2021). In the EU (including the UK), calculated costs accounted for almost €716 billion in 2016 with accidents incurring the most costs, €282 billion (Heinrich-Böll-Stiftung, 2021). However, these costs are not equally shared among different transport modes.

The current state of the transportation system is very inefficient and unfair, favours expensive over cheaper modes of transport in addition to imposing large external costs. Due to the current state, people who walk, cycle or use public transport are bearing the costs of road transport (e.g., road and parking subsidies, subsidies for electric vehicles, congestion, pollution and higher risk for accidents) (Gössling et al., 2022). The results of a study by Gössling et al. (2019, p. 65) show that “each kilometre driven by car incurs an external cost of €0.11, while cycling and walking represent benefits of €0.18 and €0.37 per kilometre”. Even possessing a vehicle has poor social or economic returns for the owners. In 2018, households in the EU-27 (without the UK) spent €931 billion or appx. 13% of total household consumption on activities or items related to transport (European Commission, 2020a). This has been confirmed in the study by Gössling et al. (2022, p. 1) which found that the “total lifetime cost of car ownership (50 years) ranges between €599,082 for an Opel Corsa to €956,798 for a Mercedes GLC” for the typical German travel distance of 15,000 car kilometres per year.

Air pollution: Transport produces multiple emissions reducing the local air quality affecting the agricultural crop yields (Brlek et al., 2020), the health of people (e.g., global morbidity due to diseases and premature deaths) and the environment (Bongardt, Schmid, et al., 2011; Gössling et al., 2019). Air pollutants result in respiratory and cardiovascular diseases which in turn incurs additional expenditures for medical treatment costs or paid sick leaves from work (Brlek et al., 2020). According to Künzli et al. (2000, cited in Gössling et al., 2019) air pollution accounts for 6% of total mortality out of which half is attributed to motorized transport. In addition, air pollution also damages buildings by polluting the surfaces or encouraging corrosion processes caused by acidic substances (Brlek et al., 2020). Lastly, polluted air also affects ecosystems through ‘acidification of sol, precipitation and water’ and ‘the eutrophication of ecosystems, in addition to the loss of biodiversity (Brlek et al., 2020).

Noise: According to WHO (2011, cited in Gössling et al., 2019, p. 69), appx. “one million healthy life years are lost every year from traffic-related noise in the Western part of the EU”. Traffic noise negatively impacts the quality of life and health in cities (Bongardt, Schmid, et al., 2011; Gössling et al., 2019) and incurs higher costs for medical treatments as well as economic losses. The health of individuals exposed to traffic noise is affected by annoyance and increase in stress which has been linked to “mood changes, chronic sleep disturbance and lack of recovery from tiredness, nervousness, anxiety and phobia, cardiovascular diseases, and cognitive impairment of children” (Gössling et al., 2019, p. 69). In addition, noise pollution affects housing prices and losses in productivity due to poor concentration or fatigue (Gössling et al., 2019).

Climate Change: One of the drivers of global warming and climate change are GHG emissions with transportation being accountable for 13% of global GHG emissions and 23% of energy-related CO_2 emissions (Bongardt, Schmid, et al., 2011). In the EU (without the UK), GHG emissions from transport have been increasing over the past years and accounted for a share of 24.6% (European Commission, 2020a). In addition, road transportation contributed 71.8% of CO_2 emissions from transport in 2018 out of which CO_2 emissions from cars represented a share of 60.3% (European Commission, 2020a). Developed countries are currently still the largest contributor to GHG emissions driving climate change and associated costs. For example, the climate costs of transport in the EU accounted for appx. €140 billion in 2016 (Heinrich-Böll-Stiftung, 2021). Furthermore, the forecasts until 2030 project an 80% increase in road transport-related emissions in emerging economies such as China (Bongardt, Schmid, et al., 2011).

Congestion: Not only does congestion contribute to air and environmental pollution, but it also significantly contributes to the time people spend waiting in traffic instead of dedicating it to other activities (Bongardt, Schmid, et al., 2011). In turn, that also affects the well-being of people and drives stress (Gössling et al., 2019). In addition, vehicle owners or freight operators need to face increasing operating and fuel costs arising from congestion (Bongardt, Schmid, et al., 2011; Gössling et al., 2019).

Energy intensity and natural resource consumption: In 2018, transport accounted for a share of 31% of final energy consumption in the EU-27 out of which road transport represented 93% (European Commission, 2020a). Due to current global trends, transport activities (e.g., freight or road transportation) will require further extraction of resources and contribute to a large amount of energy consumption (Bongardt, Schmid, et al., 2011).

Habitat fragmentation and land consumption: Transport requires considerable amounts of the natural environment for necessary infrastructure (e.g., roads, parking spaces, highways) contributing to habitat loss and shrinking the space available for species or separating populations of species (Brlek et al., 2020; Bongardt, Schmid, et al., 2011). In addition to habitat degradation through pollution of soil and groundwater (Gössling et al., 2019).

Road safety and cost of accidents: Traffic accidents incur large external costs on society: material costs, such as the vehicle damage (e.g., material damage to the vehicle or other transport-related infrastructure), administrative costs (e.g., police and firefighter interventions, administrative costs by insurance companies or official offices) and medical treatments (e.g., urgent intervention, rehabilitation, long-term treatments of disabled), and immaterial costs, such as shorter lifetimes, suffering, pain and sorrow (Brlek et al., 2020). In 2018, the number of accidents involving a personal injury in the EU was 948,511 (European Commission, 2020a). Pedestrians and cyclists are especially vulnerable in a car-dominating society.

Mentioned above are just some of the challenges and issues urban areas have to face due to unsustainable development practices from the past. In addition, transport is embedded within other, larger systems (e.g., urban areas, global biosphere) and therefore influence the development of other systems in addition to being subject to shaping forces from them. **Figure 1** is a simplified depiction of how transport is subject to influences from other systems and how it in turn also reinforces them. As outlined above, the transport sector is directly or indirectly responsible for multiple challenges of today's world. In turn, those challenges also shape the development of transport. For example, different mobility patterns (i.e., car-dominated cultures) contributed to higher levels of GHG emissions which are speeding up climate change. The latter is a source of unforeseen disruptions (e.g., natural disasters) and the reason for continuous migration to cities from South to North (i.e., urbanization trends). A diverse range of forces put pressure on transport infrastructure and shape its development. This interconnectedness is reflected in **Figure 1** and aims to present the complexity of solving today's challenges.

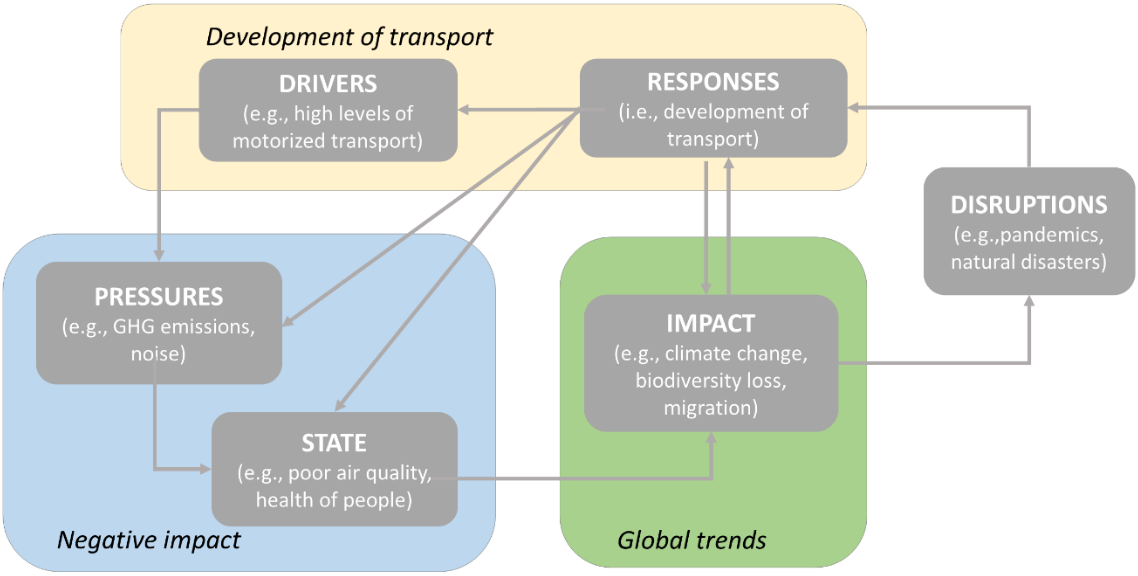


FIGURE 1: INTERCONNECTEDNESS OF GLOBAL TRENDS AND DISRUPTIONS WITH TRANSPORT AND ITS NEGATIVE EXTERNALITIES (ADAPTED AFTER EEA, 2009).

The transport system in urban areas is exposed to different types of disruptions which can be grouped into four categories according to their source and nature: internal and external factors, intentional and unintentional (see **Table 1**) and can happen on different timescales (e.g., unexpected natural disasters, daily disruptions such as traffic jams or accidents, or long-term invisible changes). Although the COVID-19 pandemic did not pose direct stress on the infrastructure, it disrupted the mobility demand and patterns (POLIS & Rupprecht Consult, 2021), for which reason it would be classified as external and unintentional disruption.

	Internal	**External**
Intentional	labour market conflicts (e.g., union strikes)	sabotages, terrorism, acts of war, pranks, political instability, demand risk, strikes, cyber attacks
Uninten-tional	human or system mistakes, accidents by users or staff, technical failures, system breakdown/failure, mechanical failures, infrastructure maintenance	natural disasters, extreme weather conditions, global warming, fuel crisis, natural resource depletion, **the COVID-19 pandemic**

TABLE 1: DIFFERENT TYPES OF DISRUPTION OF THE URBAN TRANSPORT SYSTEM (SOURCE: ADAPTED AFTER CHENG ET AL., 2021; BARRIOLA, 2021; FERNANDES ET AL., 2017; MATTSSON & JENELIUS, 2015; MARTINS ET AL., 2019).

1.2 Purpose Statement and Research Question

As outlined in the previous chapters, urban areas, and therefore transport, are subject to multiple disruptions while simultaneously also reinforcing them. Transport in urban areas needs to prepare for future uncertainties while reducing its impact on their drivers (i.e., referring to sustainability). Thus, the purpose of this study is to explore how the COVID-19 pandemic affected transport in urban areas and what was the role of bicycling during the period of disruption while also addressing the sustainability aspect of further development by exploring different dimensions of resilience and sustainability. The study aims to discover how bicycling can contribute to the resilience and sustainability of transport in urban areas in the post-COVID-19 world.

Overall research question:

What is the role of bicycling for the resilience and sustainability of transport in urban areas in the world after COVID-19?

Considering the negative externalities of transport and current global trends, the cities should prioritize active modes of transport, such as cycling, as soon as possible. The COVID-19 pandemic happened very recently, therefore there is an overall lack of empirical evidence in the literature. Some research has already been done on how the cities adapted to the pandemic and how it impacted cycling (see **Chapter 2.4**), however, there is an additional gap that this thesis aims to fill. Is it more important for the cities to adapt their built environment (i.e., infrastructure) for bicycling, as in the case of Graz, or introduce a shared-cycling scheme such as 'BicikeLJ' in Ljubljana? The answer to this question will be provided through a comparative case study where two cities of similar size will be compared and the role of cycling during the pandemic in each assessed. The results of this study could therefore be of value for local policy-makers, bike-sharing scheme operators and other stakeholders involved in the decision-making and planning of urban areas.

1.3 Conceptual Framework

The Conceptual Framework displays a 'scholarly maturity' of the researcher (Leshem & Trafford, 2007). A researcher develops "a map of theories and issues" that are related to the topic of research, giving purpose to the links among different variables (Leshem & Trafford, 2007, p. 99) and how they will help answer the research question. The conceptual framework may be derived based on the "appreciation of reading, personal experience and reflection on the theoretical positions towards the phenomena to be investigated" (Leshem & Trafford, 2007, p. 99). Other benefits of a conceptual framework are the ability to provide a comprehensive overview of the theories that guide and influence the research and providing a theoretical foundation to design and interpret the research (Leshem & Trafford, 2007). Therefore, the following section aims to explain how different theories are interconnected, how they will become operationalised in the context of transport and how these ideas evolve into the research question. A visual representation of the conceptual framework is provided in **Figure 2**.

The literature review was divided into two sections (see **Figure 2**). *Literature Review Section I* provides a summary of four topics that will guide further review of the literature and set the foundation of each topic. Theories on sustainability, resilience and complexity are the core theories important for the research topic of this thesis. Thus, *Section I* provides an overview of the most important contributions from the field. For example, 'sustainability' is a very important and popular concept. However, due to the overexploitation of its use, it became very vague. The review of the main contributions and how they diverge from one another is important as that will provide the foundation for the collection and analysis of literature included in *Section II* of the literature review and the perspectives later brought into empirical research. The fourth topic provides an overview of the most recently published literature on the impacts of the COVID-19 pandemic on transport in urban areas with a specific focus on bicycling. This section is important because it sets the thesis within a specific timeframe and provides the foundation and evidence that helped define the research question and structure of the thesis.

Literature Review Section II integrates core theories and sets the topic of 'sustainability' and 'resilience' in the context of transport in urban areas. This thesis acknowledges that multiple forces contribute to the current state of the art of transport in urban areas. That is because transport is a complex system embedded within a larger system (urban area) that evolves over time. The purpose of the first **Chapter 3.1** *Transport as a complex system* is therefore to emphasise the complexity of the topic and the need for an exhaustive analysis of all underlying drivers and elements. That is applied in the following **Chapter 3.2** *Institutions, culture and development of transport and urban areas*, which discusses the development of transport in urban areas over time, and the role of culture and institutions as two contributing "drivers" of its development. **Chapter 3.3** *Resilience and Sustainability* provides a link between the theories and reasoning on why they should be addressed in conjunction. Further two sections focus on each topic separately. **Chapter 3.4** *Sustainability of transport* provides an overview of definitions of sustainable transport and different indicators used to measure it. Similarly, **Chapter 3.5** *Resilience of transport in urban areas* provides an overview of how 'resilience' in the context of transport has been defined across literature, different characteristics of resilient transport and indicators that measure them.

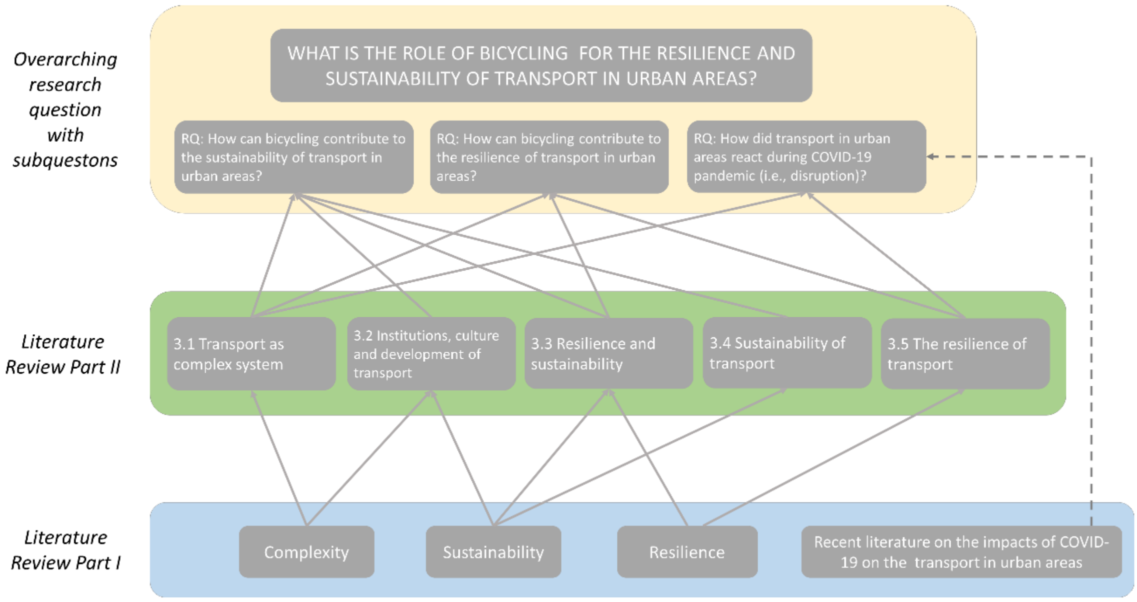


FIGURE 2: CONCEPTUAL FRAMEWORK (SOURCE: AUHTOR'S OWN) .

2 LITERATURE REVIEW – PART I

2.1 Complexity

Planning for the future requires a comprehensive assessment and understanding of our world. Complexity theories help us see the world as a 'complex system' with multiple elements and interconnections and therefore provide a better understanding of how cities developed over time and need to develop in the future. The following chapter introduces the complexity theory and applies it to the context of transport systems. The topic will be further put into the context of transport systems in urban areas in two sections of *Literature Review Part II*: Chapter 3.1 *Transport as a complex system* and Chapter 3.2 *Institutions, culture and development of transport* (see **Figure 2: Conceptual Framework**).

To better understand how 'sustainability' and 'resilience' can be achieved, it is important to understand the world as a system and what characterises it. Today systems are exposed to internal and external forces which influence their development. Within the mainstream discussion, the perception of our world being in a steady state (i.e., in one equilibrium) has been prevalent. However, due to changing conditions (e.g., changing climate, biodiversity loss) systems theory has challenged this perception and changed the way we think about our systems – rather than static we see them as dynamic.

According to Meadows & Wright (2008, p. 11), a system is "a set of interconnected elements which are organised in a way to achieve something". The components that constitute a system are different elements, interconnections among them, and the overall function or purpose of the system (Meadows & Wright, 2008). What makes those systems complex is the multiplicity of different working parts (i.e., elements) and interconnections among them to achieve a particular purpose or provide a function. As Holling (2001, p. 391) puts it, complexity results from a "smaller number of controlling processes" which creates and maintains the self-organization of the system. For this reason, Meadows & Wright (2008, p. 12) argue that systems are more than just the sum of their parts and can exhibit "adaptive, dynamic, goal-seeking, self-preserving, and sometimes evolutionary behaviour".

Complex-adaptive systems (CAS) have the ability to change or adapt (i.e., to self-organise) themselves to overcome any disruption (Holling, 2001; Folke et al., 2002; Meadows & Wright, 2008; Walker et al., 2004) which they can achieve by creating new structures or behaviours (Meadows & Wright, 2008). This self-organisation creates "systems that operate far from equilibrium and are characterised by multiple possible outcomes of management" (Folke et al., 2002, p. 16). Holling (2001, p. 394; 1986, p. 307) has proposed a model depicting this ability to self-organise which consists of four stages: exploitation (r - time of rapid growth), conservation (K), release (Ω i.e., creative destruction) and reorganization/renewal (see **Figure 3**).

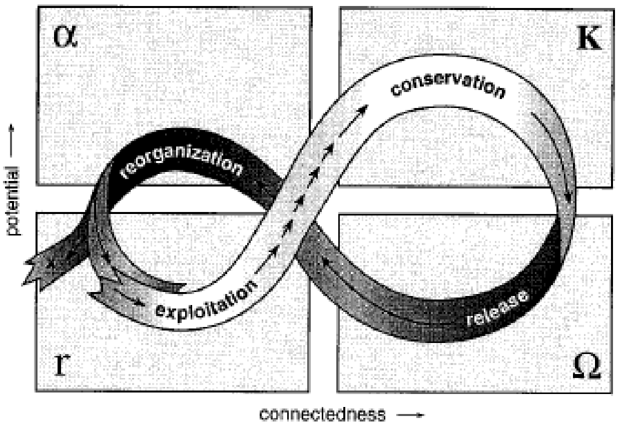


FIGURE 3: THE FOUR (ECOSYSTEM) FUNCTIONS WITHING 'COPLEX-ADAPTIVE SYSTEM' PROPOSED BY HOLLING (2001, P. 394).

To demonstrate how CAS pass through different stages of the cycle, a hypothetical situation in which the transportation system is affected by external disruption (e.g., peak oil resulting in a shortcut of oil supply and high fuel prices) will be considered.

(1) **EXPLOITATION OR GROWTH (r)**: during the phase of exploitation or growth, the city is innovating and creatively using the resources (e.g., constructing an efficient transport system, introducing new routes, building new transport infrastructure). Within a social system, the capital accumulated can either be in the form of skills, networks of human relationships and mutual trust (Holling, 2001) or built capital such as transport infrastructure, vehicles, parks and other elements of the urban landscape. This phase of capital accumulation is very slow and characterized by increasing connectedness and stability of the system (Holling, 2001).

(2) **CONSERVATION (Ω)**: During the phase of conservation, the system becomes more stable (Holling, 1986), aspires to maintain the status quo (i.e., remain within the same equilibrium) of social, political and cultural organisation, and "locks in" the resources (Walker et al., 2004). That is accomplished by increasing the connectedness between elements and increasing control which makes the system more rigid, less flexible and susceptible to disruptions (e.g., natural disasters, economic crises, wars, pandemics) (Holling, 1986; Holling, 2001; Walker et al., 2004). In the context of transport, the elements within the system become very interconnected and resources "locked in". For example, over time cities invest capital in the construction of infrastructure such as parking spaces or highways for motorized transport dependent on fossil fuels. As people heavily rely on this mode of transport, they become more vulnerable to disruptions such as hikes in oil prices or cuts in fuel supply. This makes the overall system (i.e., transport and urban area) and its elements more vulnerable. As such a disruption would affect the mobility of individuals as well as the economy.

(3) **COLLAPSE, CREATIVE DESTRUCTION OR RELEASE (K)**: All the accumulated capital in the phase of 'conservation' can be quickly "released" during times of disruption and followed by a quick reorganisation of the system (Holling, 2001). During this phase, a disruption is

introduced to the transport system (e.g., oil peak, a surge in oil prices) which initiates the 'creative destruction' of the present structure (e.g., car-dominated transport system) and processes (e.g., mobility patterns). This happens very quickly and is followed by a phase of reorganisation which offers opportunities for innovation (Holling, 2001).

(4) **REORGANISATION (α)**: During the phase of reorganisation, the transport system would undergo a reorganization of its elements and processes. This phase is important as it can lead to innovations in the next cycle (exploitation). How much a system is able to innovate also depends on "previously accumulated mutations, inventions, external invaders and capital" (Holling, 2001, p. 395) which have the possibility to be reorganised into new structures, hence creating new opportunities. In the context of transport, the system could adapt to hikes in oil prices and supply by individuals switching to active transport modes (i.e., walking or cycling), using public transport or engaging in car-sharing to split the fuel costs. However, the ability of the system to reorganize also highly depends on the 'accumulated capital'. That organisation would only be possible if the city already had effective public transport in place and the possibility to increase its capacity in the face of higher demand. Similarly, people could only switch to active modes if the safety of infrastructure would be provided (e.g., through infrastructure already in place or 'pop-up' lanes and closures of streets for other motorized traffic).

The four-phase adaptive cycle has demonstrated how organisations and functions constituting biological, ecological, and human systems evolve over time and react in times of disruption. However, to understand their reaction in times of disruption it is also important to understand how different 'four-phase adaptive cycles' are connected to each other. Holling (2001) introduces a new term – panarchy – to provide a different perspective on how systems are nested as adaptive cycles in a hierarchical manner across different time and space scales (e.g., global versus local, year versus decade). This is important because the "functioning of those cycles and the communication between them determine the sustainability of the system" (Holling, 2001, p. 396) due to the fact that systems are connected among different levels within a hierarchy and embedded within other systems (Holling, 2001; Meadows & Wright, 2008). Hence systems in a panarchy are ordered in a hierarchical structure but also "interlinked in never-ending adaptive cycles of growth, accumulation, restructuring, and renewal" (Holling, 2001, p. 392). Understanding that our system is organised as a panarchy is important because the resilience of a system at one level also depends on or influences the 'states and dynamics' above and below that level (Walker et al., 2004). During the pandemic, the ability of SES to reorganise and absorb the disruption (i.e., the spread of the virus) was also influenced by pandemic measures of local or national governments. The best example of how the transportation system reorganized is when local governments decided to promote cycling, closed the streets for motorised traffic to increase walkability and cyclability, and implemented pop-up bike lanes (see **Chapter 2.4**).

2.2 Sustainability

2.2.1 Development of 'sustainabile development' over time

Discussion on what makes development 'sustainable' is very complex and goes beyond the Brundtland Report (WCED, 1987, p. 16) definition adopted by the mainstream: "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs." For this reason, the following section provides an overview of historically important milestones contributing to the discussion on sustainable development and identifies different visualisations of sustainability and "conflicts" among them. This is important for the reader to understand how diverging perspectives contributed to the development of urban areas (see Chapter 3.2: *Institutions, culture and development of transport in urban areas*) and how sustainability is connected to resilience (see Chapter 3.2 *Resilience and Sustainability*). In addition, the core theories on 'sustainability' provide a foundation for further assessment of different definitions of 'sustainable transport' and indicators that measure it which will be presented in Chapter 3.4 *Sustainability of transport*. The interconnections among the topics and two literature review sections have also been visualised in **Figure 2: Conceptual Framework**.

In 1962, Rachel Carson published *Silent Spring* where she openly criticised the chemical industry for misinforming the public and degrading the environment through the harmful use of pesticides, which is one of the first publications giving a rise to environmentalism. In 1966, Kenneth Boulding published *The Economics of the Coming Spaceship Earth* which was one of the first publications contributing to the formulation of the discourse on circular economy. Boulding (1966, p. 9) warned about the dangers of living in an economic system that functions as an 'open system' which he termed '*cowboy economy*' where 'cowboy' symbolises "illimitable plains, and reckless, exploitative, romantic, and violent behaviour". As such, he acknowledged that the current system is open and requires a throughput of matter, energy and information to function. In such a system, throughput is to be minimized, stocks are to be maintained and success is to be measured by the "nature, extent, quality, and complexity of the total capital stock" rather than measuring growth through increasing consumption of energy and resources (Boulding, 1966, p. 9). As a contradiction to 'cowboy economy', he came up with the term *'spaceship economy'* which is an economy where "earth becomes a single spaceship, without unlimited reservoirs of anything, either for the extraction or for pollution, and which must find its place in a cyclical ecological system which is capable of continuous reproduction of material" (Boulding, 1966, p. 9). The limits of economic growth in terms of laws of thermodynamics were further popularized in 1971 with the publishing by Nicolas Georgescu-Roegen *The Entropy Law and the Economic Processes*. In the paper, he focused on the quality dimension of energy and matter consumed and produced. The economic process does not distinguish between inputs of matter and energy (i.e., low entropy), and transforms both into waste (i.e., high entropy) (Georgescu-Roegen, 1975). In other words, the economic system consumes valuable sources with low entropy (e.g., fossil fuels, materials) and at the final stage of the economic process produces valueless waste with high entropy (Georgescu-Roegen, 1975). This was important as it contradicts the narrative of indefinite economic growth being possible as that is eventually constrained by the laws of thermodynamics. A year later, in 1972, a publication by the Club of Rome *The Limits of Growth* (Donella et al., 1972) was published by a group of scientists who warned about the worrisome future of the planet due to the present patterns of population growth, food production, resource use and pollution and possible collapse of our ecosystems caused by exceeding the carrying capacity of the planet (Baker, 2006). The report was among the first to criticize the pursuit of constant economic growth and warned about the possible negative outcomes. The report and scientists, however, received a strong backlash of criticism for failing to predict the impact of technological innovations contributing to more efficient resource use and pollution reduction. This also "fueled" the rise of 'weak sustainability' where environmental protection and economic development are 'mutually compatible' (Baker, 2006). In 1972, the United Nations organized the first conference on the human environment where, for the first time, environmental issues and sustainable development were addressed on such a large international scale. Interestingly, the conference organizers symbolically organized a 200-bicycle parade across Stockholm and encouraged conference participants to move around the city and venues on bicycles (Johnson, 2012). This was followed by the first oil crisis in 1973 and the second oil crisis in 1979 which disturbed the markets and negatively affected the industrialized world highly dependent on cheap crude oil (Campbell & Laherrère, 1998). Campbell & Laherrère (1998) predicted that the sudden increases in prices are expected to be more frequent in the future and that the world needs to prepare for the post-oil economy due to decreasing reserves and fast-growing demand.

It was in 1980 when 'sustainable development' was picked by the mainstream with the publication of the *World Conservation Strategy* addressing ecological sustainability. The publication, however, neglected other present social and economic issues. This link was made in 1987 by the *Brundtland Commission Report*, which connected economy, society and environment

(WCED, 1987) (today known as *The three pillars of sustainability* or *Tripple Bottom Line Approach*) and acknowledged the fact that the stresses and problems from one of the three pillars affect the other two pillars (Baker, 2006). The report is the origin of the most widely adopted definition of sustainable development which is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 16). As such the definition recognises that the “current patterns of economic development are not generalisable” and if we wanted to generalise it to the entire population today that would destroy our ecological sources and sinks (Daly, 1990, p. 32). Human activities, such as fossil fuel extraction, agriculture industrialization, and consumption patterns, are pushing the Earth’s system out of the stable environmental state of which actions could be irreversible and catastrophic to the world (Rockström et al., 2009). The boundaries of three earth system processes have already been exceeded - climate change, rate of biodiversity loss and interference with the nitrogen cycle (Rockström et al., 2009). Although the Brundtland report further developed the definition by specifying the “distinction between different types of needs where the needs of the world’s poor are to be prioritized and limitations of the technology and social organisation to meet the needs of the present and future are to be recognised” (WCED, 1987, p. 41), the mainstream widely adopted only the first part of the definition and failed to implement the “full programme” that was conceptualized by Brundtland (Baker, 2006).

As such, the need to reduce the needs and extravagant wants of our affluent societies (Daly, 1990; Næss, 2001) and the fact that “growth is not possible nor desirable in all circumstances” went almost unnoticed (Baker, 2006, p. 21). As mentioned by Daly (1990, p. 35) if meeting the needs of the present implies that each Chinese family of three owns a car then "sustainable development is impossible”. Conflict arises also when considering the ‘level of community’ at which sustainability is to be sought which is related to the “complementarity versus substitutability of the natural and human-made capital” (Daly, 1990, p. 36). Substitutability is the assumption that natural capital can be substituted for human-made capital. This can be demonstrated through an example of importing lithium (natural capital) in return for the human-made capital (money). If one country is running short of local lithium reserves it can indeed solve this problem by importing lithium (natural capital) from another country in return for money (human-made capital). But rather than assuming that the relationship between two types of capitals is the one of substitution (i.e., a certain country substituting money for lithium), it is rather complementary as the country exporting lithium had to make exact opposite choice (i.e., replacing their lithium (natural capital) for money (human-made capital)). In conclusion “one country’s ability to substitute human-made for natural capital depends on some other country’s making the opposite (complementary) choice (Daly, 1990, p. 36). More on substitutability versus complementarity will also be discussed in **Chapter 2.2.2.**

In conclusion, although the use of the concept of 'sustainable development' has been adopted by the mainstream and incorporated into different development plans, its over exploitation turned it into another buzzword that is very vague, ambiguous and inconsistent (Gudmundsson & Höjer, 1996; Tainter, 2006). For this reason, further elaborations of 'sustainable development' started to emerge and split apart. The following section addresses two diverging perspectives on sustainable development: strong- and weak sustainability.

2.2.2 Different conceptions of sustainability

Susan Baker (2006) ordered different models of sustainable development on a ladder ranging from the weakest to the strongest and ideal model of sustainable development. Although, 'sustainability' and 'sustainable development' have been used interchangeably until now the two terms have a slightly different connotation. Therefore, it is important to also explain the difference between the two terms in addition to the differences and diverging points between weak and strong sustainability.

As explained in the previous chapter, 'sustainable development' has been popularised through Brundtland Report (WCED, 1987) which focuses on solving the environmental problems through further development in a sustainable way which at the same time pursues environmental protection as well as continued economic growth (Washington, 2015). The two things are, however, not compatible but rather mutually exclusive as 'growth' has been the "root cause of the environmental crisis" (Washington, 2015, p. 363). This implies that 'sustainable development' is an oxymoron. Although some scholars, such as Daly (1997), refer to the 'development' as qualitative change rather than quantitative growth[1], the mainstream pursues ongoing growth through 'sustainable development' (Washington, 2015). Due to this ambiguity and vagueness of the definition of 'sustainable development' the term became "self-serving" as governments and businesses were able to adopt the term without actually compromising their attachment to the

[1] Daly (1997) argues that there is a point in time at which growth in scale produces more negative environmental costs than benefits at which point "any further growth makes us poorer instead of wealthier" (1997, p. 110). For this reason, he discredits quantitative growth and further throughput of resources and calls for "redistribution, qualitative improvement in efficiency of resource use" (1997, p. 110).

economic growth (Washington, 2015). Sustainability on the other hand is a broader concept that focuses on the "long-term sustainability for all aspects of the human and natural environment", excludes the need for economic growth (i.e., GDP growth), acknowledges the problems we are currently facing, and acknowledges the ecological limits of the earth (Washington, 2015, p. 365), among others. For Washington (2015, p. 372), the term 'sustainability' implies the need to fix the negative consequences of the "endless growth myth". For this reason, the rest of the thesis refers to 'sustainability' rather than 'sustainable development'.

Weak Sustainability

Weak sustainability has diverged from environmental economics, which is an extension of neoclassical economics (prevalent in economic schools today) the objective of which is to sustain the growth of the market economy (Baker, 2006; Wilson & Wu, 2016). Baker (2000, p. 32) associates the 'weak approach to sustainability' with the *Blueprints* by David Pearce (Pearce et al. 1989) which claims that "the best way to preserve natural capital is to assign it an economic or monetary value".

According to Joumard & Gudmundsson (2010, p. 57), the weak approach perceives "natural capital as part of the total capital which consists of (a) human-made capital (e.g., knowledge, know-how), (b) productive capital (e.g., productive goods, industrial goods), (c) social capital, and (d) natural capital (e.g., natural resources, natural goods, renewable versus non-renewable resources). According to the weak sustainability approach, those types of capital are "measurable and equivalent" (Joumard & Gudmundsson, 2010, p. 57) and natural capital can be substituted by other types of capital (Baker, 2006; Gudmundsson, 2010; Holland, 1997; Kerschner & O'Neill, 2015; Spash, 2017; Vatn, 2009; Wilson & Wu, 2016). Because different types of capital are substitutable among each other, the natural capital may be consumed and "transformed" into some other capital type in order to "maintain the level of total capital assets" (Holland, 1997, p. 126; Daly, 1997, p. 50). For example, extraction and consumption of oil reserves are justified if they are used for the production of industrial goods that can be passed on to future generations (Joumard & Gudmundsson, 2010). Another perspective is that of technological advancement, as the scarcity of resources can be overcome (i.e., substituted) through technological processes (Munda, 1997) that make their production or consumption more efficient. Because of 'technical change' we have the ability to reduce the "amount of physical capital and resources required to produce the unit of output" (Stigliz, 1997, p. 1) and can therefore overcome the scarcity of resources. Similarly, Sollow (1997, p. 1) argues that "there can be some direct substitution of capital for resource inputs, when machinery reduces waste or allows us to use new types of materials that were previously unusable".

Environmental issues are also monetarized to make them comparable to economic values (Joumard & Gudmundsson, 2010) and this implies that everything, according to the weak-sustainability approach is **strongly comparable and commensurable** in monetary terms (Kerschner & O'Neill, 2015; Munda, 1997). As such, weak sustainability does not believe in the **intrinsic value** of natural capital that is that 'nature' is to be protected and preserved *per se* but sees it as 'value free' or 'value neutral' (Baker, 2006; Munda, 1997).

Strong sustainability

Strong sustainability diverges and disagrees with multiple paradigms of weak sustainability. First, it rejects the idea of **quantitative growth** (i.e., more is better) measured in material terms, calls for qualitative development with prioritization of quality of life and believes that environmental protection is a precondition for human or economic development (Baker, 2006; Kerschner & O'Neill, 2015; Martinez-Alier et al., 1998; SANZ, 2009). Especially physical stocks that are considered non-substitutable should be preserved (Neumayer, 2013).

On the contrary to weak sustainability, the strong sustainability perspective is that "human-made and natural capital are complements, and therefore have to be maintained intact because the productivity of one depends on the availability of the other" (Daly, 1997, p. 50). Daly (1997, p. 50) supports this by assuming the opposite – namely, that "accumulation of natural capital, as a near-perfect substitute of human-made capital, would be sufficient for our survival and there would be no reason to accumulate human-made capital". This, of course, is a simple provocation aimed at proving that natural- and human-made capital are indeed complementary to one another. Daly (1997, p. 51) further provokes by asking what "good is a saw-mill without forest, a fishing boat without populations of fish, a refinery without petroleum deposits?". Thus, as some (critical) natural capital is complementary, the sustainability is only attainable if that critical capital (e.g., functions of the biosphere, life support systems, oxygen, water, carbon dioxide) are maintained (Kerschner & O'Neill, 2015; Martinez-Alier et al., 1998; Neumayer, 2013; Vatn, 2009).

The strong sustainability paradigm also agreed that "if critical natural capital is to be used, then its regenerative capacity must not be exceeded so that their environmental functions remain intact" (Neumayer, 2013, p. 26). An example by Huetings and Reijnders (1998, p. 145, cited in Neumayer, 2013) is provided: “the rate of erosion of topsoil may not exceed the rate of formation of such soil due to weathering”. That is because rising consumption (i.e., increased material welfare) “cannot compensate future generations for increased environmental degradation, declining stock of directly utility-relevant renewable resources and a rising stock of pollution” (Neumayer, 2013, p. 27). As Spash (1993, p. 127, cited in Neumayer, 2013) put it: “compensation does not licence society to pollute, provided the damages created are less than the amount of compensation”. Rather future generations have the inherent right to be “free of intergenerational environmental damages” (ibid.). It also recognises that economy is a subsystem of the global ecosystem and therefore limited in its expansion (i.e., indefinite economic growth is not possible) (Munda, 1997; Neumayer, 2013). Strong sustainability rejects the idea of strong comparability (i.e., the existence of one single value used for comparison and raking of different possibilities) but accepts **weak comparability** (i.e., the ability to compare different possibilities without using one single type of value) (Martinez-Alier et al., 1998; Munda, 1997) and therefore **incommensurability** which is “the absence of a common unit of measurement across plural values, entails a rejection of monetary reductionism but also any physical reductionism, but allows for different options to be weakly comparable without actually using a single value” (Martinez-Alier et al., 1998, p. 280). It also acknowledges that the current understanding of the complexity of the natural environment is limited and that scientists, decision- or policymakers should adopt the precautionary principle (i.e., it is better to be safe than sorry) when faced with uncertainty and managing risk (Baker, 2006).

On the other hand, it is important to mention that the representatives of ‘strongly absurd sustainability’ see both approaches to sustainability mentioned above as essentially claiming the same thing. Strongly absurd sustainability, on the other hand, claims that “nature ought not to be substituted even where it can be substituted” (Holland, 1997, p. 128).

Different visualisations of weak- and strong sustainability

The purpose of the following section is to simply point to the dangers of mainstream (e.g., businesses and governments) adoption of different visualisations representing ‘sustainable development’ without any further deeper elaboration. One of the most widespread visualisations when referring to ‘sustainable development’ is the Three Pillars of Sustainability’ (see **Figure 4**) also known as the ‘Triple Bottom Line’ (Elkington, 2008) where economy, environment and society are seen as equally important pillars for the subsistence of the world (Heinrich-Böll-Stiftung, 2021; Mulia et al., 2016; SANZ, 2009) or that economic development is necessary for environmental protection (Baker, 2006). However, the risk of adopting this visualisation is the neglecting of the social and environmental pillars for the sake of economic development (economic pillar) (Mulia et al., 2016; SANZ, 2009; Wang, 2015), which is also known as the 'Mickey-Mouse effect' (see **Figure 4**). Here the separation leads to assumptions that "trade-offs can be made between the three sectors, in line with the views of weak sustainability" where natural capital can be replaced or substituted by human-made capital (Giddings et al., 2002, p. 189). This perspective underpins most global economic and political decision-making, is known as 'Business as Usual' (Elkington, 2008; Mulia et al., 2016) and offers a "technical fix approach, such as pollution control or greenhouse trading, to sustainable development issues rather than addressing the interconnections between the three pillars and underlying drivers of current problems" (Giddings et al., 2002, p. 189). The strong sustainability is in fact "consistent with the triple-bottom-line definition as it aims to achieve a balance among the three dimensions" Wu (2013, p. 1003). Still, the downside of not recognising and visualising the fact that human activity is ultimately constrained by the biosphere (i.e., the economy and society cannot exist outside of the environment) (Giddings et al., 2002; Mulia et al., 2016; Wang, 2015) might result in actions prioritizing one of the other two pillars at the cost of the environment and as such following the weak sustainability where natural capital is substitutable with other types of capital. The strong sustainability principles have been reflected by the third visualisation where society and economy are nested within the environment.

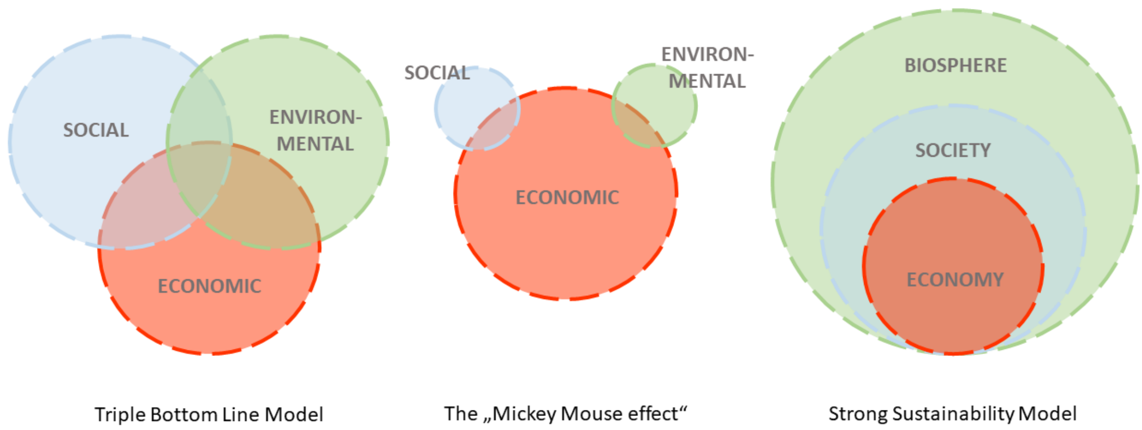


FIGURE 4: THE FOUR (ECOSYSTEM) FUNCTIONS WITHING 'COPLEX-ADAPTIVE SYSTEM' PROPOSED BY HOLLING (2001, P. 394).

2.3 Resilience

The following chapter provides an overview of different conceptualisations of resilience. This is important because those theories provide the foundation for understanding and assessment of different resilience theories in the context of the urban transport system and provide the foundation for identification of indicators of a resilient urban transport system (see Section 3.5 *Resilience of transport in urban areas*). The theories on resilience are also important for understanding on how resilience is connected to sustainability which is discussed in Chapter 3.3 *Resilience and sustainability*. The interconnections among the topics have also been presented in **Figure 2: Conceptual Framework**.

Introduction to the concept of Resilience

The word resilience, derived from the Latin word '*resilire'*, was first used in (technological) sciences such as engineering or material studies and was defined as the ability of a material to endure any pressures without breaking (Nunes et al., 2019). Since, the concept has been applied in multiple fields and disciplines such as biomedicine, geography, human ecology, social research, psychology, business and economics (Nunes et al., 2019). In order to later provide the definition of resilience in the context of transport in urban areas, it is necessary to look at its different definitions. Three main conceptualisations have been identified across the literature: *engineering resilience*, *ecological resilience* and *evolutionary* (also called *socio-ecological systems resilience*) (Nunes et al., 2019).

The prevalent definition of resilience, which was later labelled as 'engineering resilience' by C. S. Holling (1973), adopts the perspective that only one state or 'pre-existing equilibrium' is desirable (Nunes et al., 2019) and makes an assumption of 'global stability' which means that only one steady state exists and all other equilibria should be "avoided by applying safeguards" (Gunderson, 2000, p. 426). For a long time, the focus has primarily been on this stability maintaining the system in the equilibrium which Holling (1973, p. 14) defines as the "capacity of a system to return to the equilibrium after the disturbance takes place" where "the faster the system returns to equilibrium and the less it fluctuates the more stable a system is" (Holling, 1973, p. 17). The focus of engineering resilience is therefore to maintain "efficiency of function, constancy of the system, and the predictable world near a single steady-state" (Folke, 2006, p. 256).

However, in his work Holling (1973, p. 17) demonstrates that the "system can be very resilient and still fluctuate greatly (i.e., have low stability)" through an example of spruce budworm outbreaks. Furthermore, he argues that as the populations and economies continue to grow, so does the consumption of resources which affects the overall system and moves it away from equilibrium (Holling, 1973, p. 2) and, as mentioned by Gunderson (2000, p. 427), moves the system into a state of "multiple stability domains". This holds true for the current state of the world, as our system has been operating outside of the equilibrium since the start of the Anthropocene (Rockström et al., 2009) and therefore contradicts the 'engineering' narrative. This conceptualisation of resilience, where the focus is on the ability of a system to withstand different shocks and not only resist the change but to also move into another state was termed 'ecological resilience'. Contrary to engineering resilience, ecological resilience acknowledges that "multiple stability domains" exist where the "disruptions have the ability to change a system into another stable domain or regime of behaviour" (Nunes et al., 2019, p. 425). Holling (1996, p. 33) referred to this as the "magnitude of the disturbance that can be absorbed before the system changes its structure".

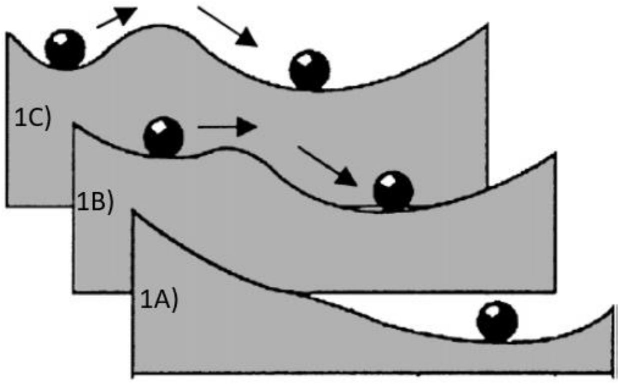
Both definitions of resilience imply that the system is 'static' and that "once the landscape is defined it remains fixed over time" (Gunderson, 2000, p. 428). In other words, while the landscape of the system will not change, the system will either: (a) always have the ability to remain within one equilibrium (engineering resilience) or (b) move between different equilibriums in the same landscape (ecological resilience). However, over time the need for another definition of resilience arose as the research proved that sometimes systems are also "dynamic and variable" (Gunderson, 2000, p. 428). The concept of resilience has been applied in the context of 'complex adaptive systems' and is defined as "the capacity to resist disruptions, self-organize, learn and adapt" (Folke et al., 2002, p. 423). Due to the negative influence that human activities have had on the biosphere since Industrial Revolution, scientists termed this new geologic era the Anthropocene (Rockström et al., 2009). While people drive the pressures on the 'planetary boundaries' and biosphere, they continue to rely on its environmental services and goods. To consider the complex landscape constituting of multiple interconnected systems and elements, the scientists began discussing resilience in the context of social-ecological systems (SES) (Folke et al., 2010; Walker et al., 2004). This perspective of resilience acknowledges that social and ecological systems are interdependent (Folke et al., 2010).

First, *social-ecological resilience* (also called 'evolutionary resilience') differs from the other two definitions of resilience in the recognition that multiple stable states exist in which an

SES can maintain its core functions (Folke, 2006). Here, the resilience of a system is related to its ability to "absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedback" (Walker et al., 2004, p. 2) or to "describe the system's capacity to adapt and respond to changing dynamics" (Nunes et al., 2019, p. 425). Secondly, from the perspective of SES, resilience might not always be perceived as a positive trait of a system if that current state is highly undesirable. For this reason, SES recognises that disturbance to the system also has an opportunity to change the status quo. This might, however, not happen if the system is highly resilient (Folke et al., 2002; Folke, 2006). In such situations, the system must also have the ability to adapt and transform itself. For this reason, the resilience of social-ecological systems (SES) is defined as follows: "(a) the magnitude of shock that the system can absorb and remain within a given state, (b) the degree to which the system is capable of self-organization, and (c) the degree to which the system can build capacity for learning and adaptation" (Folke et al., 2002, p. 7; Folke, 2006, p. 259). Thus, resilience, adaptability and transformability are the three attributes of SES resilience (Folke et al., 2010; Walker et al., 2004).

Adaptability (or 'adaptive capacity') is the "capacity of actors in the system to influence resilience" (Walker et al., 2004, p. 3) or the "ability to generate new ways of operating" (Nunes et al., 2019, p. 425). The actions, which influence the development of SES, are mainly a consequence of collective humans actions (i.e., individuals or groups managing the system) which determine the overall adaptability of the system and therefore resilience (Folke, 2006; Folke et al., 2010; Walker et al., 2004). Adaptability is therefore the ability of a whole system and its elements to "learn, combine experience and knowledge", as well as to the ability to maintain core processes within the system despite the evolving external drivers and internal activities (Folke et al., 2010, p. 3). Another attribute is **transformability**, which is the "capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable" (Walker et al., 2004, p. 3). Transformability of systems is important in situations, where it might be undesirable to maintain the 'status-quo' due to negative consequences of present economic and social structures. Even more, in some cases sustaining the 'status-quo' might intensify the current problems or result in irreversible changes in the system. For example, as planetary boundaries are interlinked exceeding a few could have an effect on the others and result in consequences that are not fully accounted for (Rockström et al., 2009). Hence, a resilient system that recognises crises as a "window of opportunity for novelty and innovation" (Folke et al., 2010, p. 7) must also possess the transformative capacity to change the current landscape (i.e., status quo) into a new, stable one (Folke, 2006, p. 262; Folke et al., 2010; Walker et al., 2004, p. 6). The SES definition of resilience, therefore, combines the interactions between "persistence, adaptability and transformability across physical and temporal boundaries" (Nunes et al., 2019, p. 425).

To further illustrate the difference between the three definitions of resilience, many authors across the literature use the 'ball in the basin' representation. In **Picture 1A)**, the slopes of the landscape represent the stability of the system where a system that is resilient will return to the basin as quickly as possible after the disruption takes place (engineering resilience) (Gunderson, 2000). **Picture 1B)** depicts a landscape with multiple basins (i.e., stability domains) where the resilience of the system is depicted through the width of the landscape (ecological resilience) (Gunderson, 2000). In the case of the second picture (**Picture 1B**)), the system can move from one basin into another while still maintaining its function. The third option (**Picture 1C)**) is the ability of a system to "remain in a stability domain, as the shape of the domain changes" (Gunderson, 2000, p. 427). This 'adaptive capacity' of a system implies that the system is constantly changing and its resilience is derived from its ability to adapt to these changes and still remain in the equilibrium (Gunderson, 2000).



PICTURE 1: BALL IN THE BASIN REPRESENTATION OF DIFFERENT TYPES OF RESILIENCE (SOURCE: GUNDERSON, 2000, P. 427).

Important to mention is also a difference between resilience and vulnerability, which are two opposing terms describing how a system reacts to a disruption. While resilience prepares the system with the capacity to react to the disruption while maintaining its function, vulnerability makes it susceptible to impacts leading to devastating consequences (Folke et al., 2002). Put differently, while increasing vulnerability reduces resilience and can therefore have devastating effects, resilience provides an opportunity for development and innovation (Folke et al., 2002, p. 13; Folke, 2006).

2.4 Recent literature on the impacts of COVID-19 on transport in urban areas

The following chapter provides a review of most recent literature on the effects the COVID-19 pandemic had on transport in urban areas with a specific focus on bicycling. This section is important because it provides an overall context of this master thesis and sets it within a specific timeframe. It also helped define the research question and structure of the thesis in addition to providing the insights on how other urban areas around the world reacted to the disruption (i.e., COVID-19 pandemic) and what role bicycling had during those times (see **Figure 2: Conceptual Framework**).

The severe impacts of the COVID-19 pandemic were not spared to any areas around the world. Transport has been one of the sectors hit the hardest by the pandemic (Gkiotsalitis & Cats, 2020; Ellen MacArthur Foundation, 2020; European Commission, 2020b). Local authorities reacted to the crisis by restricting and reducing the mobility of citizens for which reason the mobility patterns completely changed and significantly decreased during the pandemic (International Transport Forum, 2020; POLIS & Rupprecht Consult, 2021). Across European cities, the ridership has decreased by 80% since January 2020 (Serafimova, 2020) and in some countries, public transport services have been suspended completely (International Transport Forum, 2020). However, even in times of disruption people have to move to fulfil their basic needs such as shopping for groceries, getting to work or accessing medical services. As the services of public transport reduced drastically or people preferred to travel by car for the fear of catching the virus, the current disruption could waive the efforts of urban areas to become more sustainable (e.g., by increasing ridership rates on public transport and reducing the inflow of cars). On the contrary, citizens in some urban areas decided to change their travel habits due to the pandemic and opt for active modes of transport such as cycling or walking (Serafimova, 2020). The following section, therefore, provides an overview of the impact that the COVID-19 pandemic had on transport in urban areas. Specific focus has been paid to how pandemics affected bicycling.

Governments provided restrictions on the mobility of citizens in the hope to halt the spread of the virus, many companies enabled people to work from home and many individuals were afraid of catching the virus in public so they changed their mobility patterns or turned to use private vehicles or bicycles to avoid crowded spaces (POLIS & Rupprecht Consult, 2021). That significantly impacted the transport sector and resulted in a decrease in ridership on public transport by 70 – 90% in urban areas around the world (Ellen MacArthur Foundation, 2020) and by 50 – 90% at the peak of virus infections (Gkiotsalitis & Cats, 2020). Due to the impact of the pandemic, the operators of public transport had "to ensure more frequent cleaning and disinfection of vehicles and surfaces, temperature checks for staff (and for passengers in some places), improving the ventilation of facilities and vehicles, closure of waiting rooms at stations, physical distancing and 'chess board' seat marking on public transport, using face masks, maintaining hygiene, sanitation and ventilation" (Gkiotsalitis & Cats, 2020, p. 377; POLIS & Rupprecht Consult, 2021, p. 17) which resulted in higher operational costs. As the overall demand for public transport decreased, they were forced to halt or reduce the frequency of their services to cut increased operational costs (Gkiotsalitis & Cats, 2020). On the contrary, active forms of mobility such as walking and cycling have been adopted broadly. Those radical shifts in mobility patterns have resulted in a 17% reduction in global carbon emissions, cleaner air and people being more physically active (Ellen MacArthur Foundation, 2020). However, although a positive change toward higher rates of bicycling was observed there was also a negative shift in people shifting from public transport to driving in private vehicles (Heinrich-Böll-Stiftung, 2021; Pase et al., 2020). For example, in Budapest, 45% of trips are made by public transport which makes it one of the European cities with the highest rate of public transport usage and lowest motorization rates (Bucsky, 2020). However, the pandemic has resulted in a 57% decrease in urban mobility, 80% reduction in trips made by public transport and consequently higher rates of car usage (Bucsky, 2020). Another research showed that physical distancing practised during a pandemic will probably affect the mobility patterns permanently as people got used to working remotely and due to home delivery giving a boost to online retail (Ellen MacArthur Foundation, 2020). Between 40 – 60% of survey respondents in major cities around the USA, China, and Western Europe mentioned, that they will use public transport less frequently in the post-COVID-19 world and rather opt for walking, cycling or driving on their own vehicles (Bert et al., 2020). Furthermore, 80% of upper-income, 60% of middle-income and 44% of lower-income surveyed individuals in China[2] are more likely to purchase a car after the pandemic (Bert et al., 2020). On the contrary, some claim that this pandemic will not have a lasting effect as disruptions such as the 7/11 or SARS outbreak in the early 2000s, have not actually resulted in different travel patterns but rather increased innovation, security and cleaning standards (Gkiotsalitis & Cats, 2020, p.

[2] It is important to note that that could also be the result of lower ownership of cars compared to the EU and USA, cultural differences where car ownership is considered 'aspirational purchase' (i.e., 'ritual good'), and due to stricter pandemic measures compared to other regions in the world (i.e., when public transport was restricted in China only those with cars were able to move around) (Bert et al., 2020).

385). Regardless of the scenario, urban areas have to prepare for future uncertainties and disruptions and decrease their environmental impact. The question of how urban transport should develop post-COVID-19 remains present. Thus, the following section addresses how the pandemic affected bicycling and what role it played during times of uncertainty.

Impacts of the COVID-19 pandemic on bicycling

The "loss of confidence in public transit, closings of schools and recreational facilities, an urgent need to reduce traffic injuries in order to lessen burdens on the hospital, and dramatic reductions in driving" (Combs & Pardo, 2021, p. 1) have contributed to the shift in mobility patterns in cities. Therefore, cycling as an affordable, environmentally friendly, efficient, and healthy mode of transport has proven to be a good alternative to public transport and cars in urban areas during times of uncertainty (Caggiani & Camporeale, 2021; Heinrich-Böll-Stiftung, 2021; Kubaľák et al., 2021; OECD, 2020; Teixeira et al., 2021). Although the overall mobility rates decreased everywhere, cycling has experienced the lowest drop in ridership, increase the average trip duration and recovered faster compared to other modes (Combs & Pardo, 2021; Teixeira et al., 2021). According to EcoCounter, the overall bike counts in the EU increased by 8% during weekdays and by 23% on the weekends in 2020 compared to 2019 (Chapalain, 2021). The growing popularity of cycling has also been observed in the growing sales of bicycles. According to three European cycling associations (European Cyclists Federation, Cycling Industries Europe and Confederation of the European Bicycle Industry), the sales of bicycles are expected to increase by 45% per year compared to 2019 and the sales of electric bicycles are expected to increase to 10 million per year by 2024 (CIE, 2020).

Governments played an important role in the promotion of cycling during the pandemic as 95.6% of all responses took place at the city level and were driven by local government initiatives according to the research which looked at how more than 500 cities, states and countries around the world reacted to the pandemic (Combs & Pardo, 2021). Although the transport sector is very intolerant to changes (i.e., especially pedestrian and cycling projects are usually time-consuming), the governments had to react quickly, implement projects and provide new solutions (POLIS & Rupprecht Consult, 2021). They had to change the 'pace, urgency, and priority' of creating safe spaces for modes that enabled physical distancing such as walking and cycling (Combs & Pardo, 2021) and the implementation of temporary or permanent cycling measures (Heinrich-Böll-Stiftung, 2021; POLIS & Rupprecht Consult, 2021). Most of those responses were implemented in less than five months (Combs & Pardo, 2021) which displayed adaptive capacity which is one of the reactions of complex-adaptive systems in times of disruption.

As mentioned, the pandemic had a positive effect on the implementation of new transport infrastructure (Heinrich-Böll-Stiftung, 2021; OECD, 2020; POLIS & Rupprecht Consult, 2021). The research by Combs & Pardo (2021) has found that the most frequent response in cities was ‘to curb space reallocation’ which is defined as “reallocated curb space not including traffic or parking lanes to walking and cycling” (Combs & Pardo, 2021, p. 7). Other types of responses were "full-street or partial-street closures for active mobility or commerce; legal, policy, enforcement or funding changes; automation of walk signals and reallocation of non-street space such as sidewalks, parks and off-street parking to walking, cycling or outdoor commerce (e.g., gastronomy)" (Combs & Pardo, 2021, p. 7). Furthermore, the research found that almost half of the reactions, in terms of the function they provide, were to provide ‘street space for pedestrians and cyclists. Other changes involve ‘walk signal automation, speed limit reductions, signal timing adjustments, creation of new off-street recreational space, and changes to laws to expand protections of rights to pedestrians and cyclists’ and lastly ‘expanding access to bicycles’ through subsidization of shared cycling infrastructure, bicycle ownership and expansion of bicycle parking facilities (Combs & Pardo, 2021). Redistribution of street space (e.g., closing streets to motorized vehicles) and provisional bike infrastructure (e.g., pop-up bike lanes) (Bert et al., 2020; International Transport Forum, 2020; Kraus & Koch, 2021; POLIS & Rupprecht Consult, 2021) took place in multiple countries. In the cities across the EU, 2,000 km of cycling infrastructure has been announced (Kraus & Koch, 2021) and more than 150 cities around the world already implemented emergency cycling and walking infrastructure in April 2020 (International Transport Forum, 2020). Analysis by Kraus & Koch (2021) of the daily bicycle counts from 736 bicycle counters in 106 European cities combined with data on announced and completed pop-up bike lane road work projects has found that within four months on average 11.5 km of provisional pop-up bike lanes have been built. This increased cycling rates between 11 – 48% on average (Kraus & Koch, 2021). Furthermore, the research has found that this new infrastructure could generate between $1 and $7 billion in health benefits per year if citizens stick to their cycling habits acquired during the pandemic (Kraus & Koch, 2021). In the promotion of cycling, delivering safe and enjoyable cycling conditions through improved cycling infrastructure (CIE, 2020) in addition to offering different incentives such as ‘special subsidy schemes’ (Heinrich-Böll-Stiftung, 2021) were very important.

Another study by Buehler & Pucher (2021) looked at the impact pandemic had on travel behaviour around the world and compared multiple cities in the EU, Americas and Australia, and discovered a considerable increase in cycling rates from 2019 to 2020. On the contrary to some studies, the authors claim the higher rates of cycling will persist in the world post-COVID-19 due to "(a) expansion and improvement of protected cycling infrastructure" which ensured better cycling conditions for citizens, (b) higher accessibility of bicycles due to considerable growth in bicycle sales, (c) change in habits and familiarity with cycling, (d) changed the perspective of people on public transport, and (e) increase in the number of daily trips that were avoided during the pandemic (Buehler & Pucher, 2021, p. 398). Local governments have an especially important role in preserving this trend by ensuring that the on-road cycling lanes are protected, increasing the number of car-free streets, and shared streets or reducing the speed limits in some areas (Buehler & Pucher, 2021). According to another survey of 5,000 residents of major cities in the USA, China, and Western Europe, the use of privately owned bikes and e-scooters increased in all surveyed regions as bicycling provided "a way to avoid contact with others, health and convenient alternative and the opportunity to be outdoors where the risk of infection is minimal" (Bert et al., 2020, p. 2). As a result of the increased popularity of cycling during the pandemic, many cities are starting to promote cycling as their preferred mobility option in the post-COVID-19 world, investing in active mobility infrastructure, and improving its safety and accessibility (OECD, 2020).

The results of the study in the UK (Li et al., 2021) showed an increasing trend in 'London Cycle Hire' usage rates, after the initial drop caused by the local lockdown, as people were less likely to use public transport for important daily trips such as grocery shopping, exercising, or commuting to work to avoid being infected. The study by Li et al. (2021) also found that the possibility of cycling was especially important for the deprived residents as they are less able to afford other transport alternatives (e.g., private vehicles, Uber) after the use of public transport was constrained. Hence, cycling should also be considered an inclusive mode of transport contributing to the resilience of deprived areas and contributing to social equality. Although bicycling does not make up for a substantial share of trips made within the city of Budapest, it experienced the lowest reduction in usage hence proving to be the most resilient mode of transport during the pandemic. Cycling experienced a reduction of 23% in trips and bike-sharing by a 2% decrease (Bucsky, 2020). A study by Bergantino et al. (2021) in Italy compared the users' behaviour pre- and post-COVID-19 lockdown and found that people are changing their pre-pandemic habits and switching to a more sustainable and healthier lifestyle. Furthermore, the study has found that increasing the accessibility of shared-cycling infrastructure would contribute to the inclusion of the most vulnerable in the poorer areas of Italy (Bergantino et al., 2021). In Italy, the local government of the city of Milan announced plans to retrofit 22 miles of streets for pedestrians and cyclists following the summer after the pandemic (OECD, 2020). Another study by International Transport Forum (2020) mentions that the city of Milan introduced 'open streets', increased cycling infrastructure and sidewalk widening, increased the number of 30km/h zones, and introduced pedestrian zones which contributes to the goal of reducing car traffic and provision of sustainable alternatives in the city. In France, the mayor of Paris has announced that 50 kilometres, that were previously used by cars, will be repurposed and reserved for bicycles in addition to 30 pedestrians-only streets closed for traffic (OECD, 2020).

Another research explored the motivations for using the shared-cycling infrastructure during the pandemic and found that the motivations have slightly changed during the pandemic compared to previous motivations. According to a survey by Teixeira et al. (2021) conducted among the citizens, this was the case in the city of Lisbon. Before, people decided to use the system due to the service coverage and quality such as the distribution of stations, and due to personal interests and well-being such as perceived positive perception of the environmental and health benefits. However, during the pandemic, the wish to avoid public transport and maintain a social distance was a new motivator for personal interests and well-being. The users who newly joined the scheme during the pandemic emphasised the importance of social influence such as seeing others using the system or the influence within their own social circle for joining the trend (Teixeira et al., 2021). Similarly, a survey among the citizens of Thessaloniki, Greece explored the impact the pandemic had on the travellers' perception of bike-sharing systems and whether the pandemic would have a long-lasting effect on the increase of cycling in the city (Nikiforiadis et al., 2020). Although the results showed that the COVID-19 pandemic will not significantly affect the number of people using bike-sharing for their trips, more people consider bike-sharing as an attractive mobility option. Many respondents also stated that private cars are safer in terms of hygiene and the possibility of disease transmission (Nikiforiadis et al., 2020). It is also interesting that many respondents expressed their doubt about whether the current cycling infrastructure in the city is efficient for avoiding overcrowding, preserving a safe distance from other travellers and whether the operators are disinfecting the bikes regularly enough to prevent the transmission of disease (Nikiforiadis et al., 2020). However, the study on the impacts of a pandemic on the shared mobility service in Slovakia has found that in 2020 the number of bike rentals decreased by 46.25% due to lockdown measures, except for December 2020 when they recorded an increase of 56.32% (Kubaľák et al., 2021). Similarly to the case of Thessaloniki (Nikiforiadis et al., 2020), the reason related to lower usage rates was also fear of catching COVID-19 by using a bike that was previously used by an infected person. Despite those challenges, the study found that the average rental time increased from 8.97 min in 2019 to 9.96 min in 2020 (Kubaľák et al., 2021).

Impacts of the pandemic on cycling in areas outside of the EU

Cycling has also played an important role in larger urban areas in the USA. For example, a study by Teixeira & Lopes (2020) of mobility patterns in New York showed that shared-cycling infrastructure was more resilient to the effects of the pandemic compared to the subway. Cycling has experienced a 71% ridership drop compared to the 90% ridership drop on the subway. Furthermore, the time spent cycling during the pandemic increased from 13 minutes to 19 minutes per trip (Teixeira & Lopes, 2020). Another study by Pase et al. (2020) recognised bike-sharing as an important mobility alternative for citizens of New York by analysing mobility patterns during the pandemic and the effects of socio-economic factors. Furthermore, local bike-sharing ensured the mobility of 18,000 essential workers who received a free subscription to the services. That contributed to increased traffic around hospitals and health care centres (Pase et al., 2020). The results of another empirical study by Hu et al. (2021) have shown that one of the largest bike-sharing systems in Chicago - the Divvy bike-sharing system - was the most robust and resilient mobility option during the time of disruption - pandemic in the city of Chicago. It has shown the highest recovery speed and magnitude of recovery in comparison to other mobility options such as driving, walking, and public transport while public transport was affected the most and started to recover very late (Hu et al., 2021). Also according to the perspective of adults living in the USA, a study conducted in June 2020 has shown that the cycling rates did not decline during the pandemic and are expected to significantly increase in the future in the USA (Ehsani et al., 2021). Hence, shared-cycling infrastructure can significantly contribute to the resilience of urban systems in times of disruption. Although one of the researchers Jobe & Griffin (2021) found that usage rates of the shared-cycling schemes in San Antonio did decrease during the pandemic, the research has also found that was due to poor communication with potential users. Many respondents of the survey claimed to be unaware of the efforts made by the operator in controlling the spread of the disease. Hence, cycling operators should improve their communication efforts on policies and actions (Jobe & Griffin, 2021). China has been affected by the pandemic first, yet the rates of active mobility have increased after the lockdown and contributed to a 150% increase in bike-sharing rates (Bert et al., 2020; Ellen MacArthur Foundation, 2020). In the study by Saatchian et al. (2021) the results from a questionnaire in which 310 male subscribers of the shared cycling infrastructure in Mashhad in Iran were examined. The results show that the health and environmental advantages of using shared cycling infrastructure were the most favourable during the pandemic. In addition, the financial advantage such as saving time and money was also an important factor contributing to the decision to cycle more (Saatchian et al., 2021).

Lessons learned from the pandemic

Hu et al. (2021) recommend that the policymakers integrate alternative transport modes such as bicycling within an urban transport system as they are more robust and feasible for the maintenance of social distancing. Especially during times of disruptions such as pandemics, the fear of overcrowding is joined with the fear of social distancing hence cycling can offer an alternative to meet the needs of citizens in addition to offering the possibility for outdoor exercise to keep them fit, healthy and protect themselves from the virus (Hu et al., 2021). To preserve higher cycling rates and further increase the popularity of cycling, operators of shared-cycling infrastructure (SCI), municipalities or urban planners should efficiently promote the health benefits of cycling, such as physical activity, mental health, reduced transmission of the disease, and its positive environmental impact (Ehsani et al., 2021). Urban areas should adopt more supporting policies and implement infrastructures, such as separated cycling lanes and designated pathways for bicycling (Ehsani et al., 2021). The importance of SCI is supported by another study by Bergantino et al. (2021) which collected data among people living in Italy, who would use the SCI if it was available in their city, through an online survey and identified six factors influencing the use of SCI: "*facilitating conditions* (respectful of the environment, avoiding traffic congestion, cyclists, safety awareness, releasing flexibility, promoting physical activity), *psychological barriers* (boring, tiring, uncomfortable), *safety conditions* (dangerous, unsafe), *lack of infrastructure* (no bike path, non-functional bike path, bumpy road), *too demanding service* (too expensive, too much information needed), and *personal impediment* (e.g., cannot ride a bike, physical problems, unhealthy)" (Bergantino et al., 2021, p. 6). Furthermore, Nikiforiadis et al. (2020) recommend that the operators of SCI should ensure manual disinfection of bicycles or install Ultraviolet disinfection modules that would be set in stations or public spaces and that bicycle producers should use materials on which the virus survives for a shorter time. Such measures should also be effectively communicated by the operators of SCI, for the people to be assured that using bicycles is safe.

3 LITERATURE REVIEW – PART II

3.1 Transport as complex system

For sustainability and resilience of transport systems in urban areas post COVID-19, it is important to understand the complexity and dynamics within the systems. Transport is a system that is embedded within a larger system (i.e., an urban area) as well as consists of different subsystems. In the face of disturbance, that interconnectedness between different systems and subsystems can compensate for the loss of capacity within one system and to some extent reduce the vulnerability of the entire system (Mattsson & Jenelius, 2015). Because of this self-organising and adaptive capacity of the transport system, Wang (2015) even compares it to the functioning of the ecological system.

First, the transport system is embedded within the urban area which consists of multiple interconnected elements. According to Bueno et al. (2021) and Meerow et al. (2016), this was best depicted by Dicken (2011) who depicted urban areas as a system comprising of (a) *governance networks* with different actors and institutions (e.g., NGOs, businesses, governments), (b) *networked material and energy flow* being produced and consumed within the urban system, (c) urban infrastructure and form shaping the *built environment* (e.g., transportation infrastructure, buildings, roads), (d) *natural environment* (i.e., natural or ecological infrastructure representing a simplified biological and ecological processes within urban areas) and lastly (e) *socio-economic dynamics* which shape the livelihoods and capacities of citizens in an urban area (e.g., monetary capital, demographics, justice and equity) (Delgado-Ramos & Guibrunet, 2017) (see **Figure 5**). It should be noted that humans are the elements within the urban and transport system that operate and use it (e.g., use their time and energy to engage in mobility practices), hence initiating the adaptation or self-reorganisation of the status quo of mobility in an urban area (Wang, 2015). Second, the transport system consists of three main subsystems: (a) infrastructure, (b) energy and (c) vehicles, which determine its metabolism and impacts on the environment (Joumard & Gudmundsson, 2010). For each of the systems, Joumard & Gudmundsson (2010, p. 69) identify five types of activities (production, existence, use, maintenance and destruction) which add up to 13 subsystem activities (i.e., activities that determine the overall environmental impact) (see **Figure 6**).

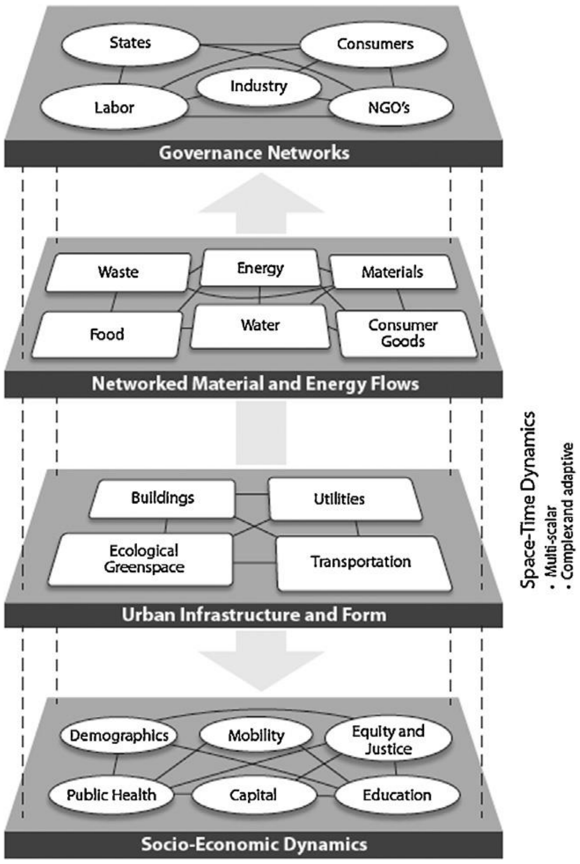


FIGURE 5: A SIMPLIFIED MODEL OF URBAN SYSTEM ADAPTED AFTER DICKEN (2011) (SOURCE: MEEROW ET AL., 2016).

Table 9. Typology of the main transport subsystems

Infra-structure	Building (1)	Energy	Final electricity production (5)	Vehicle	Production (9)
	Existence (2)		Electricity distribution (6)		Existence (10)
	Maintenance (3)		Fuel production (7)		Maintenance (11)
	Destruction (4)		Fuel distribution (8)		Destruction (12)
Traffic = infrastructure - final energy - vehicle use (13)					

FIGURE 6: MAIN TRANSPORT SUBSYSTEMS (SOURCE: JOUMARD & GUDMUNDSSON, 2010, P. 69).

As mentioned by Gudmundsson & Höjer (1996), different sectors are highly integrated with eachother, with multiple feedback loops at work and interconnections that influence their development. For example, Gudmundsson & Höjer (1996) mentioned a 'feedback loop' on travel patterns linked to the spread of cars and consequently 'spread-out' of urban structures which reduced the accessibility of different places via other modes of transport, namely public transport or active modes of mobility. This has also been discussed by Camagni et al. (2002, p. 201) who termed this phenomenon as urban sprawl: "low-density development, extending to the extreme edge of the metropolitan region and located in a random, 'leapfrog' fashion, segregated in specialised mono-functional land uses, and largely dependent on the car". In other words, as cars became more (financially) accessible and were considered a symbol of wealth i.e., 'ritual good', the number of cars on the roads increased, increasing the demand for more car infrastructure (e.g., highways, roads, parking spots) (Oosterhuis, 2016). Consequently, urban areas became more congested which is one of the reasons why people started to migrate to the outskirts of the city in pursuit of higher well-being. In addition, the "independency" that cars brought resulted in people undertaking jobs further from home thus increasing the time spent travelling. The purpose of this example is to demonstrate the complexity of our social system and connections among the elements, which Gudmundsson & Höjer (1996) recognise as one of the difficulties in scaling sustainable development. On a shorter time scale, the self-organising and adaptive capacities of transport and SES have been observed throughout the COVID-19 pandemic. As public transport was banned due to measures preventing the transmission of disease, people shifted to active modes such as walking and cycling. Many local authorities also introduced 'pop-up cycling lanes' to encourage the increased use of bicycles (POLIS & Rupprecht Consult, 2021, p. 43).

3.2 Institutions, culture and development of transport and urban areas

As outlined in **Chapter 3.1** the complexity of SES and its interrelations originates from its wide range of elements (e.g., citizens, social groups, multi-level governments, military, companies, and corporations) which in turn requires institutions for coordination and social integration (Spash, 2017). Institutions by imposing "conventions, norms, and sanctioned rules of society" (Spash, 2017; Vatn, 2017, p. 44) influence human preferences and provide "expectations, stability and meaning essential to human existence and coordination" (Vatn, 2017, p. 44). They influence and guide the development of society and its culture. Culture, on the contrary, is a crucial component of all SES processes and relations as it shapes how we think about sustainability and exchange (Hornborg, 2009). However, it also shapes the "habits, lifestyles, institutions and spatial arrangements" (te Brömmelstroet et al., 2020, p. 109) (self-reinforcing feedback loop), and changes over time.

Furthermore, as people have the internal need to understand the world in which they live and to make sense of their environment, society is organised in a hierarchical structure that shapes different classes and consumption patterns (Røpke, 1999). This means that individuals have to take part in different rituals that 'establish meanings in a social context' - a ritual in which material goods play an important role as 'ritual adjuncts' and integral "tools" to help people understand the world (Oosterhuis, 2016; Røpke, 1999). For example, in the twentieth-century cycling has been the main transport mode in most countries. Through the increase of wealth and productivity, the previous standard of living has been transformed into one of high materials tensity (Røpke, 1999; te Brömmelstroet et al., 2020). People today have to participate in new rituals and acquire goods, such as cars, to be able to discriminate (differentiate) among different classes. For example, after 1900 the working class joined the cycling trend which contributed to a 'decline in the social status of cycling' (Oosterhuis, 2016, p. 240). In Germany and Britain, the aristocracy and bourgeoisie switched from bicycling to using motorcycles and cars to differentiate themselves from the masses of working people cycling (Oosterhuis, 2016). Concurrently the acceleration of industrial capitalism also gave a rise to a new societal phenomenon of 'intensified process of individualisation' which resulted in a higher number of households, and consequently for housing and related equipment, which changed consumption patterns (Røpke, 1999). The process of becoming independent from one's closest social ties, such as family or community, contributed to new forms of self-identification. An individual was suddenly responsible for "constructing and sustaining their own self-identity" - a process in which conspicuous consumption and 'ritual adjuncts' play an important role in transferring the message to other people (Røpke, 1999, p. 410, Oosterhuis, 2016). Another phenomenon shaping the culture was the pursuit of time-saving. In hope of reducing the workload, reducing busyness and saving their time, people started to invest in 'labour-saving equipment' (Røpke, 1999). For example, car ownership promised a reduction of travel time and more flexibility yet resulted in people accepting jobs further from home, buying in shops that are not located in the vicinity of the home, or engaging in new or more leisure activities (Camagni et al., 2002; Gudmundsson & Höjer, 1996; Røpke, 1999). This is also known as the 'rebound effect'[3] which is defined as a phenomenon in which an "increase in resource or energy efficiency (usually attributed to technological advancements) does not actually result in a corresponding decrease in energy or resource use because the cost per unit falls, which in turn, increases the demand for the product and service" (Binswanger, 2001, p. 120). In turn, the need for car ownership influenced the economic and political planning decisions which made owning a car compulsory for people to have access to

[3] A typical example of the 'rebound effect' is that of increased car use due to the fuel efficiency of new, technologically advanced vehicles which made driving over a 100 km distance substantially cheaper. Due to this technological innovation people will not drive less (i.e., consume fewer resources) but drive more often and for longer distances.

crucial services (Røpke, 1999). In addition to the sensitivity of the public to the social class and status, Oosterhuis (2016, p. 241) is also of opinion that rather than a higher number of vehicles on the road it was the actions of institutions and governments (e.g., traffic policies in urban development) and their perception of motorized transportation being more 'avant-garde' that shifted the public perception on bicycling. In a world of 'global competition and commodities' where companies "need to" pursue the economic surplus (Vatn, 2017, p. 49), institutions have to "support certain values and produce and protect certain interests" (Vatn, 2017, p. 44). Consequently, that influences the development of countries and constrains the advancement of policies that could threaten those interests.

Described phenomena explain how society is gaining shape through self-reinforcing feedback loops. New consumption practices were formed by the framework, but on the other hand, also changed the framework over time through new patterns (Røpke, 1999). Mobility and transport, are part of the culture around which the society builts their urban environment (Oosterhuis, 2016; te Brömmelstroet et al., 2020). This is evident in many old European cities which were built for non-motorized transportation, with beautiful city centres where people gather in street cafés and cultural events take place. On the contrary, 'car cultures' shaped the cities where infrastructure is tailored to the needs and wants of car drivers (e.g., large streets, parking lots, and outstretched amenities) (te Brömmelstroet et al., 2020). Citizens with different cultures value different lifestyles and create their built environment around them. The previous Chapter (3.1) described the phenomena of 'diffused metropolis' (i.e, urban sprawl) where people move to the outskirts of the city for different socio-economic reasons (e.g., the pursuit of higher quality of life, rising improvement costs of housing in city or degradation of public spaces in urban areas) (Camagni et al., 2002; Oosterhuis, 2016). Consequently, the people spent more time travelling over larger distances and their levels of "busyness" remained the same. Another example of how 'cultural patterns became self-reinforcing' (te Brömmelstroet et al., 2020) is how cycling in the Netherlands produced more cycling.

The Netherlands, in addition to Denmark, is one of the best examples of how institutions and culture shape mobility and transport, and the spatial development of urban areas. In both countries, 'cyclist associations' lobbied for the rights of cyclists and promoted cycling as being part of the important national 'qualities and civil virtues' such as independence, self-control, modesty and stability (Oosterhuis, 2016, p. 243). Associations in both countries remained engaged in the planning of urban areas, the construction of cycling paths and, through their power, managed to influence the government and institutions to account for the needs of bicyclists

(Oosterhuis, 2016). Consequently, cyclists today are prioritized and protected in traffic (Oosterhuis, 2016).

Institutions are organised around specific habits and patterns which makes it increasingly costly and difficult to change (Oosterhuis, 2016; te Brömmelstroet et al., 2020), as in the case of Dutch cities where changing the mobility strategy today would require extensive investments, destructing the acquired expertise and investing in a new one. For example, in the Netherlands, all social life is adapted to cycling which can be observed in the cities and how they are organised. Smaller shopping centres are dispersed around the urban area, short-distance modes of transportation are underdeveloped, taxi services are costly, and nightlife is organised around bikeable distances (te Brömmelstroet et al., 2020). Even when discussing distances among places, the Dutch refer to 'cycling minutes' to indicate the distance (te Brömmelstroet et al., 2020). Schools also made space for parking bicycles but not for cars, which partially contributes to many children and parents travelling to school by bike. In addition, there are many bicycle lanes, parking spots and bicycles available in the cities (te Brömmelstroet et al., 2020). Consequently, all members of society (i.e., businesses, schools, universities, nightclubs) would have to adapt to this change.

Dutch and Danish societies are also very different in how needs are accounted for. According to the research on happiness (Røpke, 1999), people have absolute needs, which are independent of the situation of others, and relative needs, which are the needs that contribute to the feeling of superiority compared to others but are, however, very unstable (Røpke, 1999). The latter reflects in 'snobbiness' or 'placing yourself above the others' which the Dutch and Danish see as something negative (Oosterhuis, 2016; te Brömmelstroet et al., 2020). Contrary to car-dominated cultures, cycling in the Netherlands is not a 'ritual adjunct' (Røpke, 1999) to showcase one's status, lifestyle or identity (Oosterhuis, 2016; te Brömmelstroet et al., 2020). It is perceived as "simplistic, practical, modest, level-headed and diligent" (Oosterhuis, 2016, p. 243). Even people of high social status and wealthy enough to afford other, "luxurious" modes of transport, such as cars, decide to move by cycling. Of course, people still have the "fundamental need to relate to other people" which influences their consumption patterns (Røpke, 1999, p. 407). However, in the case of the Netherlands and Denmark, people can relate to other people and, hence, tend to cycle more to "show off their normality" (te Brömmelstroet et al., 2020, p. 111). Cycling is learned from other members of society, and social scientists would agree that cycling in the Netherlands has become normalized or part of a daily routine (Oosterhuis, 2016; te Brömmelstroet et al., 2020). Furthermore, Dutch and Danish people are aware of the positive effects that bicycling has on their mental and physical health, in addition to enhancing sociability in public life (i.e., through enhanced interactions because of the need for eye contact while cycling) (Oosterhuis, 2016; te Brömmelstroet et al., 2020) contradicting the global trend of individualisation (Røpke, 1999).

This chapter aimed to address the complexity of the SES and how it relates to its development by highlighting the role of culture and institutions. For sustainable development to be successful, the underlining drivers of societal development need to be addressed. Changing the habits and values of citizens is very complex and requires the involvement of institutions on different levels, such as governments, schools, businesses, and civil organisations (Oosterhuis, 2016; te Brömmelstroet et al., 2020), and is overall a long-term “project”.

3.3 Resilience and sustainability

According to Folke et al. (2002, p. 7) the goal of ‘sustainable development’ is to “create and maintain prosperous social, economic, and ecological systems”. Tainter (2006, p. 92) shares a similar view as for him ‘sustainability’ is “the capacity to continue a desired condition or process, social or ecological”. However, as systems are ‘intimately linked’ they can affect the development of one another which is an observable phenomenon across the world where trespassing of the Planetary boundaries (Rockström et al., 2009) is contributing to the uncertainty and unpredictability of future living conditions. Hence, resilience comes as a tool to help sustain development in a “changing world where surprise is likely” (Folke et al., 2002, p. 9) and as the “ability of a system to adjust its configuration and function under disturbance” (Tainter, 2006, p. 92).

Both concepts – resilience and sustainability – are important for the future development of urban areas. As mentioned by Acuti et al. (2020, p. 3), “rational urban development can be achieved only when it is both resilient and sustainable”. Although the concepts are different and should not be used interchangeably, they can be used in conjunction (Delgado-Ramos & Guibrunet, 2017). First, it is important to emphasise the difference between the two. According to Delgado-Ramos & Guibrunet (2017) the biggest difference between the two concepts is the type of outcome of a change. While ‘sustainability’ implies a desirable, positive outcome, ‘resilience’ does not imply whether the adaptation to a disturbance is desirable or undesirable (Delgado-Ramos & Guibrunet, 2017). Even more, the purpose of (engineering) resilience is to ‘bounce back’ as soon as possible after the disruption takes place even though that state might not have been previously optimal (i.e., desirable). Resilience can also be achieved in a particular geographic area at the expense of another or it can be achieved from the consumption of stock resources (i.e., non-renewables) at the expense of future generations (Folke et al., 2002). Especially in times of disruption, as Tainter (2006) puts it, resilience can neglect or abandon sustainability goals and values. Hence, this is a reason why the principles of strong sustainability should guide the development of a resilient transportation system. At the same time "if a city is to be sustainable it also needs to be resilient to disruptions" (Kim & Lim, 2016, p. 6) in order to minimize the negative impacts of disruption on society, economy and environment. This has already been recognised globally as both concepts have made it into the development plans of transport in urban areas (Figueiredo et al., 2018; POLIS & Rupprecht Consult, 2021; United Nations, 2013).

Cities can pursue and have the possibility to achieve both – sustainability and resilience – by focusing on the promotion of bicycling and investing in cycling infrastructure. *How*? Acuti et al., 2020) focuses on two strategies contributing to the resilience capacity of cities. The first is urban connectivity which, in addition to providing physical connectivity through transportation, also has to be sustainable to "provide better integration while respecting the environment" (Acuti et al., 2020, p. 3). Secondly, modularization is defined as the ability of "system components to have enough independence so that the failure or damage to another part of the system will have a low probability of affecting the functionality of other similar or related components of the system" (Acuti et al., 2020, p. 4). Bicycling positively contributes to both strategies contributing to the overall resilience while having the lowest environmental impact on the environment and being accessible to most members of society. Some urban areas and their transport system demonstrated this (the adaptive and transformative capacities of the SES resilience) during the pandemic (see **Chapter 2.4**). In cities that already invested in bicycling pre-pandemic, cycling has seen a substantial increase as people avoided crowded spaces such as public transport. There was also a rise in pop-up cycling lanes answering this demand – an action that has been implemented in an extremely short period of time[4] (Kraus & Koch, 2021). No other transport mode can adapt to the built environment as quickly as cycling did.

As mentioned in **Chapter 2.3** on resilience, collective human actions influence the development of SES. Thus, mobility and transport during the pandemic should be assessed from the perspective of its users – citizens of urban areas. An individual relying on public transport proved

[4] Research found that within a period of four months, on average 11.5 km of provisional pop-up bike lanes were built per city and cycling rates increased between 11 – 48% across 106 European cities included in the study (Kraus & Koch, 2021).

to be “less resilient” to disruptions during the pandemic, as many lines were suspended or capacities reduced to halt the spread of the virus. In other cases, people were simply afraid of catching the virus and hence decided to not move in highly-congested areas. However, people still needed to make trips – either for professional reasons or daily errands. Thus, from the perspective of those individuals, owning a car would imply more flexibility, independence and resilience to such disruptions. However, this does not suggest that people should invest in cars to increase their resilience as that would have undesirable outcomes (as can be currently observed in congested cities due to the growing number of cars on the road). On the other hand, multiple urban areas that already have cycling capacities integrated with their transport mix were able to better serve their citizens. Through cycling, they ensured the sustainability and resilience (i.e., the ability of the system to adapt and transform) of the system.

3.4 Sustainability of transport

Due to the negative impacts of transport on the biosphere (as explained in **Chapter 1.1**) it is necessary to address different aspects of transport and look for “innovations” that could help ease the current pressures on the environment. A strong approach to ‘sustainability’ of transport is needed because some innovations termed ‘sustainable’ are promising high results yet prove to be ‘unsustainable’ in the long term. For example, e- scooters as one of the micro-mobility options are appearing in urban areas promising to ‘decarbonise’ mobility. Yet research shows that trips made by scooters replace the trips that would otherwise be made through active modes such as walking and cycling (Fitt and Curl, 2019, cited in Milakis et al., 2020). Similarly, electrification of vehicles is promising high environmental benefits yet the topic is highly controversial as electrification contributes to cost-shifting (i.e., externalisation of environmental impacts through international trade), problem-shifting (i.e., technological solutions solving one problem and creating a new one such as when production of electric cars drives extraction of lithium, copper, and cobalt resources, which incurs high environmental costs in countries that export them), results in rebound effects (e.g., with fuel-efficient cars people drive more often and for longer distances) and generates additional harmful waste (Parrique et al., 2019). In search of a new sustainable mode of transport, the benefits of simple solutions such as walking and cycling are ofter overseen. Hence, this chapter aims to provide an overview of different definitions of what ‘sustainable transport’ means, and look for a comprehensive set of indicators that measure ‘sustainability’ of transport while incorporating the principles of ‘strong sustainability’.

3.4.1 Sustainability of transport in urban areas

Sustainability has gained a lot of attention and "space" in development plans on national and international levels. However, no common definition of 'sustainable transport' has been adopted globally (Berger et al., 2014; Bongardt, Schmid, et al., 2011; Brlek et al., 2020; Gudmundsson & Höjer, 1996; UN, 2016) which makes evaluating the 'sustainability' of measures in place challenging. Even more, poor understanding of what makes one mode of transport 'sustainable' has resulted in innovations with high promises, such as previously mentioned e-scooters, which continue supporting the development along with the principles of 'weak sustainability'.

When looking for a definition of sustainable transport, that would guide its future development, it is important to reconsider the purpose or meaning of transport. According to Gudmundsson & Höjer (1996) passenger transport provides mobility and accessibility. Mobility is related to the ability of the individual to move in an urban environment and requires physical infrastructure such as roads, cycling lanes, trains etc. Accessibility, on the other hand, is about having access to 'activity facilities' which does not necessarily require the physical movement of people. For this difference, Gudmundsson & Höjer (1996) argue that access, as the ability of citizens to 'get what they want or need' is a more relevant measure than mobility. This perspective has also been adopted by some organisations such as *the Winnipeg Centre for Sustainable Transport*, which defined sustainability as one that "allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations" (OurWinnipeg, 2011, p. 52). This implies that a reduction of the need to travel while having access to key places and goods is necessary if transport in urban areas is to achieve 'sustainability'. However, the need for sustainable solutions in urban transport that would have wider environmental and social benefits remains present. For this reason, principles guiding the development of transport are needed.

Most definitions across the literature incorporate the 'three pillars of sustainability' (i.e., Tripple Bottom Line Approach) (Berger et al., 2014; Bongardt, Schmid, et al., 2011; Glover & Low, 2020, Litman, 2021; Toth-Szabo et al., 2012; UN, 2016). Existing definitions of 'sustainable transport' have been collected along those three dimensions and are presented in **Table 2.** Some authors find that over time the definition has changed to embrace other impacts that transport has on society such as social equity, health and security, quality of life considerations and economic growth (Berger et al., 2014). For example, Bongardt, Schmid, et al. (2011, p. 5) recognises the need for 'participation' where transport is "to be designed in a participatory process, involving all relevant stakeholders in all parts of society".

Publication	Environmental	Social	Economic
UN, 2016, p. 10	"..minimizing carbon and other emissions and environmental impacts.."	"..the provision of services and infrastructure for the mobility of people and goods— advancing economic and social development to benefit today's and future generations—in a manner that is safe, affordable, accessible, efficient, and resilient, …"	
Bongardt, Schmid, et al., 2011, p. 6 Bongardt et al., 2011, p. 3	"..limits emissions of air pollution, GHG emission, and waste and minimzes the impact on the use of land and the generation of noise.."	"..allows the basic access and development needs of people to be met safely and proposes equity within and between successive generations.."	"..is affordable within the limits by internalization of external costs, operates fairly and efficiently, and fosters a balanced regional development."
Litman, 2021, p. 8	"Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise."	"Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.."	"..is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy."
Gössling et al., 2019, p. 52	"Transportatoin that allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.."		"..is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy."
Brlek et al., 2020, p. 74	"..system where different means of transport produce less pollution and consume least energy per kilometer traveled with the complete safety for passenger.." "..decreases emissions of greenhouse gases, air pollution, noise and minimise land consumption by transport infrastructure.."	"..should ensure that people's needs are met with fair and equitable access to education, health services, jobs and the market, on an intra- and intergenerational basis.." "..system that will come with reasonable costs, that will operate efficiently and that will offer all populations a choice between different transport alternatives.."	"..should enable efficient movement of passengers and goods, enable regionally balanced development while controlling financial capacity and future burdens for present and future generations.."
ECMT, 2005 cited in (Toth-Szabo et al., 2012)	"..limits emissions and waste within the planet's ability to absorb them, uses renewable re sources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes while minimising the impact on the use of land and the generation of noise.."	"..allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.."	"..is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development."
Hall and Sussman, 2004, cited in Glover & Low, 2020, p. 16	"Sustainable development supports, reinforces, and facilitates national policies that aim to reduce the throughput of natural and manmade resources to rates within the carrying capacity of the environment."		
OECD, 1996, cited in Glover & Low, 2020, p. 16	"Does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non-renewable resources at below the rates of development of renewable substitutes."		
Dalkmann and Huizenga, 2010, cited in (Bongardt, Schmid, et al., 2011), p. 6	"Low-carbon, sustainable transport reduces short and long term negative impacts on the local and global environments.."	"..secure access for both persons and goods.."	"..has economically viable infrastructure and operation…"

TABLE 2: DIFFERENT DEFINITIONS OF 'SUSTAINABLE TRANSPORT' AMONG THREE PILLARS OF SUSTAINABILITY.

However, as transport is one of the largest drivers of climate change and environmental crisis, Glover & Low (2020) are of opinion that the environmental dimension should be prioritized when assessing sustainability. This has been reflected in the definition by Hall and Sussman (2004, p. 16, cited in Glover & Low, 2020) which acknowledges transport as one of the drivers of anthropogenic climate change and therefore defines it as development that "supports, reinforces, and facilitates national policies aiming to reduce the throughput of natural and manmade resources to rates within the carrying capacity of the environment". In addition, Glover & Low

(2020) note that the social dimensions should be closely linked to the environmental pillar due to the high probability of environmental crises driving social crises across the world.

Principles of strong sustainability have been considered by Gudmundsson & Höjer (1996) who adopted the four operational principles of sustainability put forward by Daly (1991, p. 44 - 45) which are (1) limiting the human scale (i.e., throughput); (2) increasing the efficiency rather than the throughput of technologies; (3) exploiting renewable resources, and their source (i.e., provision of natural goods and services such as oxygen or drinking water) and sinks (i.e., absorption of waste) functions on a profit-maximising sustained yield basis which does not drive into extinction, and lastly (4) that non-renewable resources should be exploited, but at a rate equal to the creation of renewable substitutes.

According to Gudmundsson & Höjer (1996), the current mobility patterns in industrialized countries are clearly not fulfilling the mentioned criteria, especially in regard to the preservation of natural capital. And although principles 1, 3, and 4 are crucial for the sustainability of any social system, Gudmundsson & Höjer (1996) argue that the first principle of 'limiting human scale' is superior to the other three in order to maintain an 'ecologically stable community'. However, Gudmundsson & Höjer (1996, p. 272) also warn of the four principles not being sufficient as not all "nature's systemic values can be related to scales and limits". For example, biodiversity is very important and essential for the preservation of natural capital, however, it is hard to define what level of biodiversity is appropriate (Gudmundsson & Höjer, 1996; Rockström et al., 2009). As Rockström et al. (2009) mention, the current rate of biodiversity loss has already transgressed its limits which is likely to lead to the transgression of other boundaries and irreversible changes in the Earth system. For this reason, some 'redundancy' is needed when determining the "appropriate" level of biodiversity loss. Furthermore, Daly's (1991) proposal of four principles of sustainability neglects the role of qualitative 'development' in improving human wellbeing and increasing quality of life. For this reason, Gudmundsson & Höjer (1996, p. 273) define 'sustainable' as the "criteria for the long-term stability of the social system, relevant for future generations" while development is "perceptible improvement of the quality of human life, of which consumption for the present generation is an important element".

Due to these differences, Gudmundsson & Höjer (1996) developed four further sustainable principles that the development of transport should follow which are summarized below.

1. **PRESERVING NATURAL RESOURCES FOR FUTURE GENERATIONS**: (a) **Use of non-renewable resources**: If transport is to become more sustainable, the production process of transport-

related consumption of non-renewable resources should be considered. For example, vehicles should be designed for recycling to reduce the extraction and use of non-renewable resources. Other inputs (materials and energy) in the production and recycling process should be accounted for. (b) **Use of renewable resources**: Currently, transport heavily relies on non-renewable resources of energy which contributes to its strong unsustainability. If transport is to become more sustainable, it should use renewable resources as the main source of propulsion. (c) **Use of ecosystems as sinks**: The environment currently serves as a 'sink' for negative transport externalities which is can be observed in multiple phenomena such as fast-changing climate, depletion of the ozone layer, acidification and eutrophication, and accumulation of heavy metals in topsoils, among others. That, however, could have long-term negative effects, hence, using transport as a sink should be of great concern and part of the discussion. (d) **Preservation of biodiversity**: Although some actions have been undertaken to preserve the flora and fauna from the negative side effects of transport (e.g., the division of natural habitats has been solved by building bridges for wildlife over highways), Gudmundsson & Höjer (1996) emphasise the overall need to restrict expansion of transport systems or limiting the current system.

2. **PRESERVING THE OPTION VALUE OF HUMAN AND HUMAN-MADE CAPITAL FOR FUTURE GENERATIONS**: The society has some capital (human or human-made) base which contributes to the development and enhancement of other capital assets in society (development). Hence, sustaining this capital for future generations is of crucial importance for the "enhancement of human knowledge and technical skills such as the discovery of new resources and ideas" (Gudmundsson & Höjer, 1996, p. 278). In order for societies to be able to cope with future scarcities, it will be even more important to maintain the physical flexibility provided by transport. However, simply increasing the current capital (e.g., by building more roads and highways) might incur high (social or environmental) costs and thus contribute to a "socially destructive way of safeguarding access for future generations to what they want or need" (Gudmundsson & Höjer, 1996, p. 278). Gudmundsson & Höjer (1996) rather suggest that other alternatives to resource- and energy-intensive transport should be considered (i.e., active modes of transport over motorized transport).

3. **IMPROVING QUALITY OF LIFE FOR INDIVIDUALS**: Gudmundsson & Höjer (1996) mention the need for a set of indicators that comprehensively assess the impacts on quality of life from transport-related decisions as they can have positive effects (mobility, access, cheaper

goods and services, more diversity of supply, visual enjoyment) and negative effect (accidents, air pollution, noise etc.) on the overall well-being. In addition to using the economic evaluation metrics such as CBA, they suggest the application of multiple 'value systems' (e.g., regulatory philosophy, absolute measures based on physical and social health criteria) that should be developed through "open political processes influenced by scientific advice and public opinion, and not only economic calculus" (Gudmundsson & Höjer, 1996, p. 279).

4. **ENSURING A FAIR DISTRIBUTION OF LIFE-QUALITY**: According to indicators and evaluation techniques driving current development (i.e., planning and provision of funds) such as CBA, the financial benefits might offset the environmental costs paid (e.g., car-dominated culture has been extremely beneficial for the economic growth). Although putting more cars on the road, and investing in necessary infrastructure indeed drove the development of economies (i.e., economic growth) it in turn incurred large costs for the environment and already most vulnerable groups of people. Less affluent part of the society was suddenly faced with the loss of space (e.g., natural or built environment primarily to be used by citizens), and insufficient capacities of previous transport modes (e.g., of active modes or public transport) to reach different locations due to 'urban sprawl'. If transport is to become 'sustainable' it should halt the development of unfair distribution of mobility, which has contributed to a larger gap among the rich and poor citizens regionally and globally.

Among, the reviewed literature the most comprehensive definition of sustainable transport that also integrates some of the above-mentioned principles was provided by Hall (2006, cited in Joumard & Gudmundsson, 2010) (see **Table 3**).

Table 49. A comprehensive definition of sustainable transport (Hall, 2006).
A sustainable transport system…

Environment	
Health & environmental damage	- minimises activities that cause serious public health concerns and damage to the environment; [a, b, d]
Standards	- maintains high environmental quality and human health standards throughout urban and rural areas; [a]
Noise	- minimises the production of noise; [b, c, d, e]
Land use	- minimises the use of land; [c, e]
Emissions and waste	- limits emissions and waste to levels within the planet's ability to absorb them, and does not aggravate adverse global phenomena including climate change, stratospheric ozone depletion, and the spread of persistent organic pollutants; [b, c, d, e]
Renewable resources	- ensures that renewable resources are managed and used in ways that do not diminish the capacity of ecological systems to continue providing these resources; [a, b, c, d, e]
Non-renewable resources	- ensures that non-renewable resources are used at or below the rate of development of renewable substitutes; [a, b, c, d, e]
Energy	- is powered by renewable energy sources; and
Recycling	- re-uses and recycles its components. [c]
Equity / society	
Access	- provides access to goods, resources, and services while reducing the need to travel; [a, c, e]
Safety	- operates safely; [a, c, e]
	- ensures the secure movement of people and goods;
Intragenerational equity	- promotes equity between societies and groups within the current generation, [c, e] specifically in relation to concerns for environmental justice; and
Intergenerational equity	- promotes equity between generations. [c, e]
Economy	
Affordability	- is affordable; [a, c, e]
Efficiency	- operates efficiently to support a competitive economy; [a, c, e] and
Social cost	- ensures that users pay the full social and environmental costs for their transport decisions. [a]

[a] DoE (1996); [b] OECD (1997); [c] CSTC (1997); [d] OECD (2000); [e] European Council (2001)

TABLE 3: A COMPREHENSIVE DEFINITION OF SUSTAINABLE TRANSPORT (SOURCE: HALL, 2006, CITED IN JOUMARD & GUD-MUNDS-SON, 2010).

3.4.2 Indicators of sustainability of urban transport

Current issues help determine the goals of sustainable transport which have to be measured, hence the need for indicators. Indicators are "a variable, based on measurements, representing as accurately as possible a phenomenon of interest, and a tool for measuring impact" (Joumard & Gudmundsson, 2010, p. 67). They are important because they help measure progress towards our objectives and goals (Litman, 2021). However, compiling a comprehensive list of indicators that are also "convenient" (i.e., provided in such a way that institutions actually are able to use them) is difficult (Joumard & Gudmundsson, 2010; Litman, 2021). As multiple authors mention, having a comprehensive list of indicators might incur high collection costs, be hard to interpret or even unable to be used due to data unavailability in some regions. On the contrary, a simple list of indicators might not reflect the full picture and hence have negative long-term effects if decisions are made on limited knowledge. There is already a wide range of indicators available for measuring the sustainability of transport. Due to the comprehensiveness of papers providing lists of existing indicators and different approaches, the following section provides a brief overview of those relevant to the research topic of this thesis. The dimensions and indicators that could help make transport sustainable in a post-COVID-19 world to provide access to all citizens while acknowledging the principles of 'strong sustainability' are provided.

Bongardt, Schmid, et al. (2011) provides a list of ten key indicators for the attainment of different goals of sustainable transport that serve as a starting point for further discussion among stakeholders. In addition to the three pillars of sustainability, Bongardt, Schmid, et al. (2011) also provides the fourth one – governance. See **Table 4**:

Dimension/Indicator	Underlying sustainability goal	Indicator type	Current availability of data
Environment			
Land consumption by transport infrastructure (as % of total surface)	Avoid sprawl and destruction of the environment by transport infrastructure	Effect / impact	Low
Transport GHG emissions per capita	Reduce transport contribution to climate change	Effect / impact	Medium
Percentage of population affected by local air pollutants (e.g. PM10 concentration, Non-Methane Hydrocarbons [NMHC] emissions, ...)	Reduce detrimental effects on human health and the environment	Effect / impact	Medium
Equity/Social			
Road fatalities	Reduce the number of people killed or injured in road traffic accidents	Effect / impact	High
Modal share of PT/NMT	Foster transport modes that are both accessible for a large part of the population and environmentally sound	Outcome	Medium
Share of transport cost from total household expenditure	Provide affordable transportation for all members of the society	Outcome	Medium
Economy			
Minimum taxation on fuel	Consider the external costs caused by transportation based on fossil fuels (especially road traffic)	Performance	High
Transport investments by mode	Prefer transport modes that are accessible and environmentally sound	Performance	High
PKM/TKM per unit GDP	Decouple economic growth from transport demand	Effect / impact	Medium
Governance			
Participatory transport planning	Involve the public in the decision process for transport policies and projects	Performance	Low

TABLE 4: INITIAL SUGGESTION FOR TEN KEY INDICATORS FOR MORE SUSTAINABLE TRANSPORT (SOURCE: BUENO ET AL., 2021, P. 12).

Sustainable Urban Mobility Indicators (SUMI) (see **Table 5**) by the EC (European Commission, n.d.) are another set of indicators that help cities measure their progress towards 'sustainable transport'. Those indicators are said to be practical, reliable and comprehensive and have been "tested" in a pilot project with fifty participating cities between 2017-2020. The set of indicators consists of 13 core indicators and 5 non-core indicators.

No.	Indicator	Definition	Core indicator
1	Affordability of public transport for the poorest group	Share of the poorest quartile of the population's household budget required to hold public transport (PT) passes (unlimited monthly travel or equivalent) in the urban area of residence.	Yes
2	Accessibility of public transport for mobility-impaired groups	This indicator determines the accessibility of public transport services to persons with reduced mobility. Such vulnerability groups include those with visual and audial impairments and those with physical restrictions, such as pregnant women, users of wheelchairs and mobility devices, the elderly, parents and caregivers using buggies, and people with temporary injuries.	Yes
3	Air pollutant emissions	Air pollutant emissions of all passenger and freight transport modes (exhaust and non-exhaust for $PM_{2.5}$) in the urban area.	Yes
4	Noise hindrance	Hindrance of population by noise generated through urban transport.	Yes
5	Road deaths	Road deaths by all transport accidents in the urban area on a yearly basis.	Yes
6	Access to mobility services	Share of population with appropriate access to mobility services (public transport).	Yes
7	Greenhouse gas emissions (GHG)	Well-to-wheels GHG emissions by all urban area passenger and freight transport modes.	Yes
8	Congestion and delays	Delays in road traffic and in public transport during peak hours compared to off peak travel (private road traffic) and optimal public transport travel time (public transport).	Yes
9	Energy efficiency	Total energy use by urban transport per passenger km and tonne km (annual average over all modes).	Yes
10	Opportunity for active mobility	Infrastructure for active mobility, namely walking and cycling.	Yes
11	Multimodal integration	An interchange is any place where a traveller can switch from one mode of travel to another, with a minimum/ reasonable amount of walking or waiting. The more modes available at an interchange, the higher the level of multimodal integration.	Yes
12	Satisfaction with public transport	The perceived satisfaction of using public transport.	Yes
13	Traffic safety active modes	Fatalities of active modes users in traffic accidents in the city in relation to their exposure to traffic.	Yes
14	Quality of public spaces	The perceived satisfaction of public spaces.	No
15	Urban functional diversity	Functional diversity refers to a mix of spatial functions in an area, creating proximity of mutual interrelated activities	No
16	Commuting travel time	Duration of commute to and from work or an educational establishment, using any types of modes.	No
17	Mobility space usage	Proportion of land use, taken by all city transport modes, including direct and indirect uses.	No
18	Security	The perceived risk of crime and passenger security in urban transport.	No
	Modal split	For passenger mobility: Modal split according to passenger kilometres ran Modal split according to vehicle kilometres ran Modal split according to the number of trips ran Modal split according to the number of vehicle kilometres per trip ran For freight: Modal split according to goods vehicles kilometres ran Modal split according to freight tonnes kilometres ran	Yes

TABLE 5: A LIST OF SUMI INDICATORS WITH THEIR DESCRIPTION (SOURCE: RUPPRECHT CONSULT, 2020, P. 6).

Based on the literature review, Medina et al. (2020) compiled a list of 42 indicators (see **Figure 7**) for measuring the sustainability of transport along five key dimensions (environment and human health; economic and social, operational, fiscal and governance, and the mobility system effectiveness and land use) (Medina et al., 2020, p. 617). Although the indicators are good in terms of their measurability (i.e., the data for measuring is usually available), the parameters lack comprehensiveness and multidimensionality. There is very little focus put on measuring the environmental impact of sustainable transport in addition to some conflicts among the indicators and the goal of sustainable transport. For example, including 'parking capacity' (i.e., number of parking spaces per citizen) as one of the indicators of "sustainability" goes against the goal of decreasing car traffic in cities, decreasing noise and air pollution, increasing security etc.

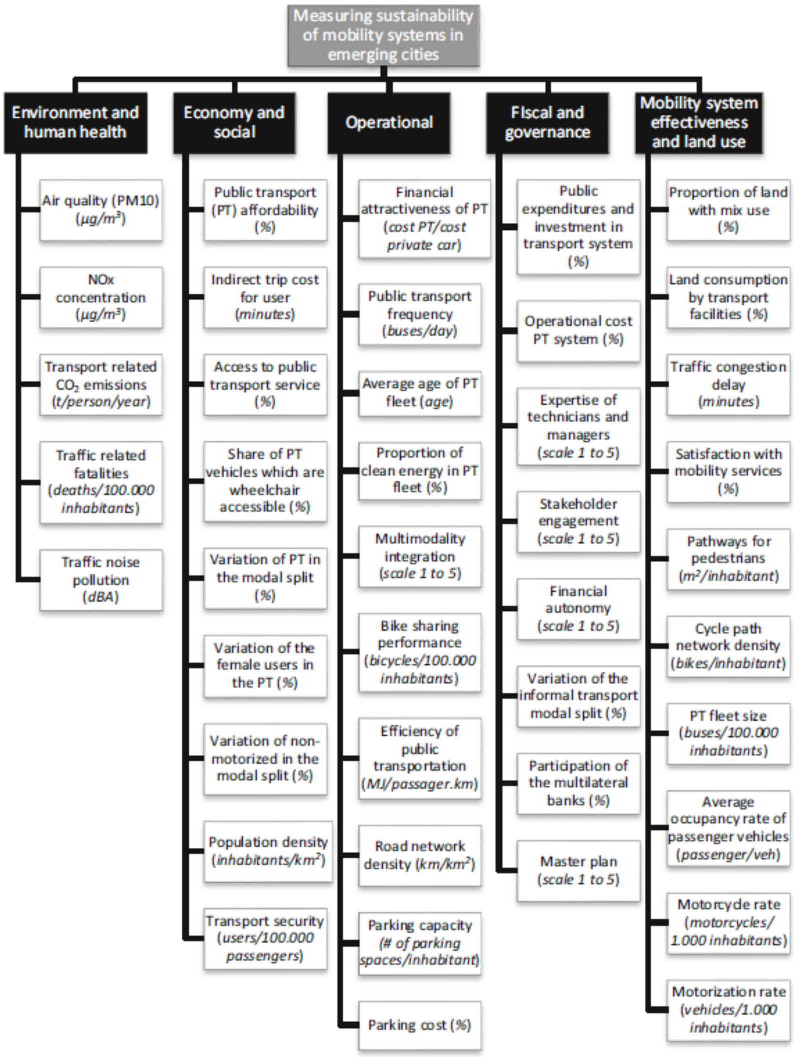


FIGURE 7: FRAMEWORK WITH DIFFERENT DIMENSIONS OF SUSTAINABLE TRANSPORT (IN BLACK) AND INDICATORS (IN WHITE) (SOURCE: MEDINA ET AL., 2020, P. 619).

On the contrary, a book by Joumard & Gudmundsson (2010) provides an interdisciplinary approach to compiling indicators of (environmental) sustainability in transport. Among all reviewed literature on sustainability indicators, this book offers the most comprehensive approach to addressing the complexity of environmental issues. That is approached through a systemic approach called the 'chain of causalities', which describes all (possible) impacts of transport on the environment. For example, 'impact on land' results in land take, habitat fragmentation, soil erosion and visual qualities of landscape (Joumard & Gudmundsson, 2010, p. 73). Within each of the categories, further impacts (i.e., chain of causalities) can be identified. For example 'land take' results in the loss of natural habitats, degradation of ecosystems, modification of outdoor recreational areas and loss of cultural heritage (Joumard & Gudmundsson, 2010, p. 73). Although the book does not provide a final list of all parameters, seven chains of causalities are described. Contrary to other reports, Joumard & Gudmundsson (2010) adopts the elements of 'strong sustainability' (e.g., the incommensurability of values) and recognises the importance of 'multi-criteria decision analysis'. This method "considers multiple indicators in situations where different alternatives have to be compared or new alternatives generated" (Joumard & Gudmundsson, 2010, p. 270). That is achieved through 'join consideration' of indicators through methods such as multi-criteria decision analysis (MCDA) which "allow to a choose better alternative, taking in account evaluation of preference by many non-comparable criteria" (Joumard & Gudmundsson, 2010, p. 224).

The framework for tracking the sustainability of the transport system by Toth-Szabo & Várhelyi (2012) identifies key indicators by incorporating horizontal and vertical diversity of 'sustainability-related areas'. Horizontally they identify six key areas (see **Table 6**) along the three pillars of sustainability (i.e., economic, social and environmental), whereas vertically they split the indicators in the hierarchical order:

1. **Outcome indicators**, which are the overall goals of sustainable transport and can either be *objective* (e.g., the annual number of reported incidents of personal security violations in the transport system) or *subjective* in nature (e.g., percentage of population feeling safe in the transport system);
2. **Output indicators**, which show the effectiveness of input indicators and contribute towards a particular goal (e.g., percentage of motor vehicles above the speed limit); and
3. **Input indicators**, which contribute to the improvement of output and outcome indicators (e.g., percentage of local streets with traffic calming measures).

Table 1. The Adopted framework for monitoring sustainability of the transport system.

		Economic	Social				Environmental	
Out-come	Subjective	Efficiency	Accessibility Business	Accessibility Personal	Safety	Live-ability	Emission	Resource use
	Objective							
Output								
Input								

TABLE 6: THE FRAMEWORK FOR MONITORING SUSTAINABILITY OF THE TRANSPORT SYSTEM (SOURCE: TOTH-SZABO & VÁRHELYI, 2012, P. 2038; TOTH-SZABO ET AL., 2012, P. 25).

The most recent paper by Litman (2021) that compiled a list of performance indicators measuring the sustainability of transport was performed through an extensive review and comparison of different reports and indicator lists. The paper identified how different planning objectives also support the same sustainability goals and compiled a list of indicators showing the progress of those goals and objectives (see **Table 7**). Similarly to Bongardt, Schmid et al. (2011)

a paper by Litman (2021) also added 'governance' as the fourth dimension in addition to social, environmental and economic pillars.

Table ES-3 **Key Sustainable Transport Goals, Objectives and Indicators**

Sustainability Goals	Objectives	Performance Indicators
I. Economic		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	• Per capita GDP • Portion of budgets devoted to transport. • Per capita congestion delay. • Efficient pricing (road, parking, insurance, fuel, etc). • Efficient prioritization of facilities
Economic development	Economic and business development	• Access to education and employment opportunities. • Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	• Per capita transport energy consumption • Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	• Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). • Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.
II. Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	• Transport system diversity. • Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	• Per capita traffic casualty (injury and death) rates. • Traveler assault (crime) rates. • Human exposure to harmful pollutants. • Portion of travel by walking and cycling.
Community development	Helps create inclusive and attractive communities.	• Land use mix. • Walkability and bikability • Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	• Preservation of cultural resources and traditions. • Responsiveness to traditional communities.
III. Environmental		
Climate stability	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of greenhouse gases (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce harmful pollutant exposure	• Per capita emissions (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Minimize noise	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality & hydrologic functions	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
IV. Good Governance and Planning		
Integrated, comprehensive and inclusive planning	Clearly defined planning process. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning.	• Clearly defined goals, objectives and indicators. • Availability of planning information and documents. • Portion of population engaged in planning decisions. • Range of objectives, impacts and options considered. • Efficient and equitable funding allocation

This table summarizes sustainability goals, objectives and performance indicators.

Table ES-2 **Sustainable Transport Goals and Objectives**

Sustainability Goals	Transport Planning Objectives							
	Transport Diversity	System Integration	Affordability	Resource (energy and land) Efficiency	Demand Management (efficient pricing & prioritization)	Land Use Accessibility (smart growth)	Cost Effective Operations	Comprehensive and Inclusive Planning
Economic productivity	✓	✓		✓	✓	✓	✓	
Economic development	✓	✓	✓	✓	✓	✓		✓
Energy efficiency	✓	✓		✓	✓	✓		
Affordability	✓	✓	✓	✓	✓	✓		
Operational efficiency					✓		✓	✓
Equity / Fairness	✓	✓	✓		✓	✓		
Safety, security and health	✓	✓	✓	✓	✓	✓		✓
Community development	✓	✓	✓	✓	✓	✓		✓
Heritage protection	✓			✓	✓	✓		✓
Climate stability	✓	✓	✓	✓	✓	✓		
Air pollution prevention	✓	✓	✓	✓	✓	✓		
Noise prevention	✓			✓				
Water pollution	✓	✓	✓	✓	✓	✓		✓
Openspace preservation	✓	✓	✓		✓	✓		✓
Good planning								✓
Efficient Pricing				✓	✓		✓	

This table indicates which planning objectives support various sustainability goals.

TABLE 7: KEY SUSTAINABLE TRANSPORT GOALS, OBJECTIVES AND INDICATORS (SOURCE: LITMAN, 2021, P. 98).

In comparison with other reports, Litman (2021, p. 27) also recognises the importance of the precautionary principle according to which "a wide range of alternatives (including 'business as usual' scenario) has to be examined, considering inputs from affected stakeholders, and overall being cautious about making decisions resulting in actions that could in any way cause irreversible damage and create a risk to human and environmental health". Furthermore, it applies 'systems thinking' approach "to understand and value the relationships in an ecosystem and use an approach that reflects and sustains ecosystem services; re-establish the integral and essential relationship between natural processes and human activity" (Litman, 2021, p. 27).

Among reviewed reports is also a report that applies the 'avoid-shift-improve' framework (see **Figure 8**) (SLOCAT, 2021). At first sight, it reminds the reader of the three principles of circular economy (Reduce, reuse, recycle). The 'avoid-shift-improve' approach adopts the perspective of strong sustainability with an emphasis on the 'reduction' rather than following the 'demand-supply' approach (i.e., increasing the supply when the demand is higher). As mentioned, solely transport cannot achieve those objectives because it is embedded within a larger complex system (i.e., panarchy) that influences its development. For this reason, the possible approaches and dimensions of 'avoid-shift-improve' have to be implemented at the city level. For example:

- **Avoiding or reducing** the unnecessary travel or transport: 15-minute city, e-communication, from using cars to using public transport, walking and cycling, cargo bikes for last-mile deliveries (SLOCAT, 2021; UN, 2016)
- **Shifting** from motorized travel to more active travel (i.e., less carbon-intensive modes) or even 'off-peak travel' (SLOCAT, 2021; UN, 2016). It is obvious that transport per se cannot achieve that goal without the changes in the built environment (e.g., reducing the distances among key locations).
- **Improving** the "environmental performance of transport modes by making them more energy-efficient or less carbon-intensive" (UN, 2016). Or by improving "vehicle design, energy efficiency, and clean energy sources for different types of freight and passenger vehicles" (Litman, 2021, p. 42). However, the 'rebound effects' should be taken into account. For this reason, it is important for the development of sustainable transport to first address the other two points.

According to the report, the avoid and shift strategies alone could contribute to a 40 – 60% reduction of emissions and at significantly lower costs compared to 'improvement strategies' (SLOCAT, 2021, p. 33).

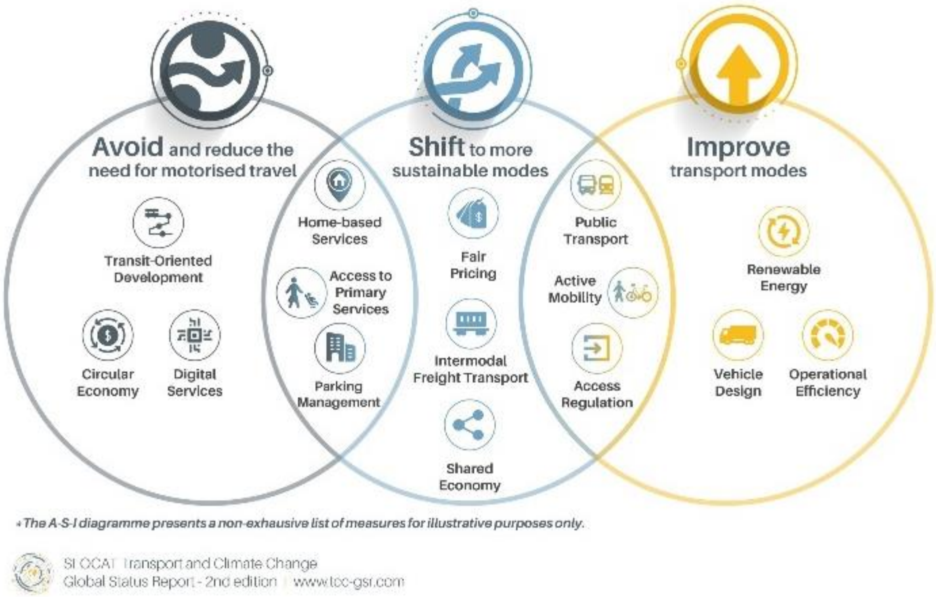


FIGURE 8: THE AVOID-SHIFT-IMPROVE FRAMEWORK (SOURCE: SLOCAT, 2021, P. 33).

3.5 Resilience of transport in urban areas

The resilience of transportation systems in urban areas is still a poorly researched area (Mattsson & Jenelius, 2015). The definitions of the resilience of transportation systems are not clear as different authors come from different backgrounds, have different perspectives and understanding of the topic (Gonçalves & Ribeiro, 2020). Gonçalves & Ribeiro (2020) find that the biggest difference in how the resilience of transport systems is defined across the literature is, in how the system reacts to the disturbance (later referred to as outcomes or actions). Wang (2015), for example, mentions that most literature focuses too extensively on building engineering resilience (i.e., on reliability and recovery of the system) which has the potential to reduce the overall resilience of other systems. There is a lack of literature addressing how different disruptions affect the performance of the system. Fernandes et al. (2017) especially recognise the lack of discussion on the dependence of motorized transport systems on fossil fuels. The goal of the following sections is to provide an overview of different definitions of resilience in the context of transport, and characteristics contributing to a more resilient transportation system.

3.5.1 The resilience of transport

As mentioned, the definitions of the resilience of the urban transportation system are very distinctive therefore it is necessary to look at different perspectives and characteristics. Generally, the literature on the resilience of transport systems adopts either the dynamic or static perspective on resilience. However, the final definition of the resilience of transportation systems combines characteristics and dimensions of SES resilience.

Resilience was first applied to transportation systems by Murray-Tuite (2006, p. 1) who defined it as "a characteristic that indicates system performance under unusual conditions, recovery speed, and the amount of outside assistance required for restoration to its original functional state". Murray-Tuite (2006, p. 1) identified ten dimensions of transportation resilience which are: redundancy, diversity, efficiency, autonomous components, strength, collaboration, adaptability, mobility, safety, and the ability to recover quickly. In this definition of resilience, there is still no sign of the ability of the system to find a new equilibrium (i.e., the ability to transform itself). This was introduced into the literature on transportation resilience through the perspective of dynamic resilience due to the influence of research on ecological and SES resilience. Static and dynamic resilience of transportation systems are defined as follows:

- **Static resilience** refers to the ability or strength of the transportation system to maintain its functions and capacity with the available resources even after the disruption or shock takes place (Gonçalves & Ribeiro, 2020; Mattsson & Jenelius, 2015; Pan et al., 2021; Martins et al., 2019). Paper by Pan et al. (2021, p. 7), which mainly discusses resilience from the perspective of ‘engineering resilience’, therefore defines ‘transport resilience’ as “the ability to resist external disturbances and threats, absorb the loss of internal turbulence, and return to the original state”. This ability of the system to “maintain the system operating after a shock or hazard happens without the immediate infrastructure restoration” (Gonçalves & Ribeiro, 2020, p. 3) is characterised by its robustness. Strategies contributing to the static resilience of transportation systems are “conservation, input substitution, inventories, excess capacity, relocation resource unimportance, import substitution, export substitution, technological change, production recapture, and logistics refinement” (Gonçalves & Ribeiro, 2020, p. 3). In conclusion, the static resilience primarily focuses on the “ability of the system to maintain function and does not consider reconstruction activities and recovery” (Pan et al., 2021, p. 7).

- **Dynamic resilience** refers to the ability of the transportation system to “re-establish the initial level of performance and operation as quickly as possible after the disruption takes place” (Gonçalves & Ribeiro, 2020, p. 3). This refers to the ability of the system to endure the effect of disruption (engineering perspective) but also its capacity and “ability to adapt and reduce the impact” (ecological perspective) to prevent partial or entire failure of the system (Gonçalves & Ribeiro, 2020, p. 3). Some of the strategies for increasing dynamic resilience are “removing operating impediments, management effectiveness, speeding restoration, input substitution, import-substitution, and inventories” (Gonçalves & Ribeiro, 2020, p. 3).

Based on those two perspectives, Gonçalves & Ribeiro (2020, p. 3) propose the following definition for the resilience of transportation system in urban areas: “the ability of a system to resist, reduce and absorb the impacts of a disturbance (shock, interruption, or disaster), maintaining an acceptable level of service (static resilience), and restoring the regular and balanced operation within a reasonable period of time and cost (dynamic resilience).” A paper by Pan et al. (2021, p. 7) combines dynamic and static resilience perspective and provides the following definition: “The abilities of the transportation system to resist and adapt to external disturbance and then quickly return to a normal service level to meet the original travel demand after being disturbed by internal or external factors.” Cheng et al. (2021), defines transport resilience as “the ability of the transport network to withstand the impact of extreme weather, to operate in the face of such events and to recover promptly from its effects” (Cheng et al., 2021, p. 2). POLIS & Rupprecht Consult (2021, p. 10), on the other hand, define resilience of urban mobility as the capacity of the “social-ecological system to cope with disturbances” and as mobility that “promotes safe, equitable and inclusive accessibility by providing sustainable, integrated, flexible and robust mobility options”. This definition adapts the perspective of SES resilience where the system not only deals with disturbances but also “reorganises to maintain the core functions, identity, and structure and enables adaptation, learning and transformation” when the shock is too large to be endured (POLIS & Rupprecht Consult, 2021, p. 10).

3.5.2 Outcomes/actions of a resilient transport system in urban areas

As mentioned, authors of reviewed literature define ‘transport resilience’ from different perspectives for which reason it is difficult to provide a common set of actions “performed” by a resilient system. In **Table 8** the four main actions across the reviewed literature are presented: persistence, absorption, adaptability, and transformability.

Outcomes / actions of resilient system	***Author(s)***						
	Gonçalves & Ribeiro, 2020	Pan et al., 2021	Fernandes et al., 2017	Fernandes et al., 2019	Wang, 2015	Cheng et al., 2021	Leobons et al., 2019
Resistance/maintaintenance /persistence	■	■	■	■		■	■
Recoverability / restore	■	■			■	■	■
Absorb / adaptability	■	■	■	■	■	■	■
Transformability	■		■	■	■		

TABLE 8: DIFFERENT OUTCOMES AND ACTIONS OF A RESILENT TRANSPORT SYSTEM ACCORDING TO REVIEWED LITERATURE.

Persistence (also resistance or maintenance) relates to the ability of a system to maintain the same functionality, mobility patterns and social-economic conditions without affecting the wellbeing and quality of life during times of disruption (Fernandes et al., 2017; Fernandes et al., 2019; Leobons et al., 2019; Martins et al., 2019). Thus the system remains in the same equilibrium and endures the disruption (Gonçalves & Ribeiro, 2020). **Recoverability** (also restoration) is the ability of a system to return to the initial state or to arrive at a different equilibrium (i.e., a completely different system) (Gonçalves & Ribeiro, 2020; Leobons et al., 2019; Wang, 2015). On the contrary Cheng et al. (2021) and Pan et al. (2021) refer to ‘recoverability’ only as the ability to arrive at the previous equilibrium. For example, Pan et al. (2021, p. 7) define it as follows: “related to understanding the ability and speed of systems to recover after a disruptive event”. **Adaptability** (also absorbability or flexibility) relates to the ability to change the mobility patterns without affecting the well-being and quality of life (Fernandes et al., 2017; Martins et al., 2019). In addition, adaptability is “linked with the potential of maintaining the system in the stability domain, but also learning, through the combination of experience, knowledge, and opportunities, to avoid future instability” (Fernandes et al., 2019, p. 4). A system with adaptive capacity would arrive at a different equilibrium compared to the period before disruption (Gonçalves & Ribeiro, 2020). According to Pan et al. (2021, p. 7), adaptability (i.e., flexibility) is “the ability of a system to respond to shocks and adjust to changes through contingency planning after disruptions". Lastly, **transformability** refers to the ability of a system to create new conditions (i.e., to transform itself) to create a new environment that is adaptable and persistent to future disruptions (Fernandes et al., 2017; Fernandes et al., 2019). A system is rebuilt or transformed into a completely different system (i.e., it completely changes the state of equilibrium) (Gonçalves & Ribeiro, 2020; Wang, 2015).

3.5.3 Indicators of resilient urban transport

The outcomes (i.e., actions) of a resilient transportation system (see **Table 8**) depend on its characteristics. Those characteristics can be evaluated in different ways or through indicators thus this section looks at three papers and different approaches to defining them.

Among the reviewed papers, the most integrative research on transportation resilience by Gonçalves & Ribeiro (2020) visualised the relation between the main characteristics and actions (i.e., outcomes) of the resilient transportation system. According to Gonçalves & Ribeiro (2020), the five main characteristics of the resilience of the transportation system are **robustness, preparedness, redundancy, rapidity and adaptation**. More further research, also emphasises the importance of the transportation system being **integrative**, **inclusive**, and **flexible** (POLIS & Rupprecht Consult, 2021). **Robustness** refers to the 'strength or capacity of elements' (Gonçalves & Ribeiro, 2020) within the transportation systems that have to endure a certain level of stress or demand without reducing the function or quality of service (POLIS & Rupprecht Consult, 2021; Pan et al., 2021). **Preparedness**, also referred to as resourcefulness, is about the transportation system "having prepared measures before a disruption happens and increasing resilience by reducing the effect of the potential negative impacts of disruptive events" (Gonçalves & Ribeiro, 2020, p. 5). **Redundancy** refers to the ability of some components of the transport system to meet the demand of failed components without the overall reduction of the systems' performance (i.e., mobility) (Gonçalves & Ribeiro, 2020; Murray-tuite, 2006, POLIS & Rupprecht Consult, 2021). **Rapidity**, also referred to as 'recoverability' (Pan et al., 2021) or the ability to recover quickly is the capacity of the transport system to meet the demands and needs of citizens in time to prevent substantial losses or damage (Gonçalves & Ribeiro, 2020; Murray-tuite, 2006; Pan et al., 2021). **Adaptation** is the capacity of the transportation system to be flexible, respond to new pressures (Gonçalves & Ribeiro, 2020; Pan et al., 2021) and capability to learn from past experience (Murray-tuite, 2006).

According to Gonçalves & Ribeiro (2020), a robust and prepared system can withstand most disturbances (i.e., can maintain the status quo in times of disruption). On the other side, a robust system is prepared and has the ability to react on time, and can recover more easily and quickly after the disturbance takes place (Gonçalves & Ribeiro, 2020). Redundancy of the system in relation to other subsystems implies that it can "absorb most of the disturbances and impacts" (Gonçalves & Ribeiro, 2020, p. 5). Lastly, a system that does not possess the ability to recover or return to the initial operational levels but has the ability to adapt to the new environment, can transform and arrive at a different equilibrium (i.e., qualitatively changes its operation) (Gonçalves & Ribeiro, 2020).

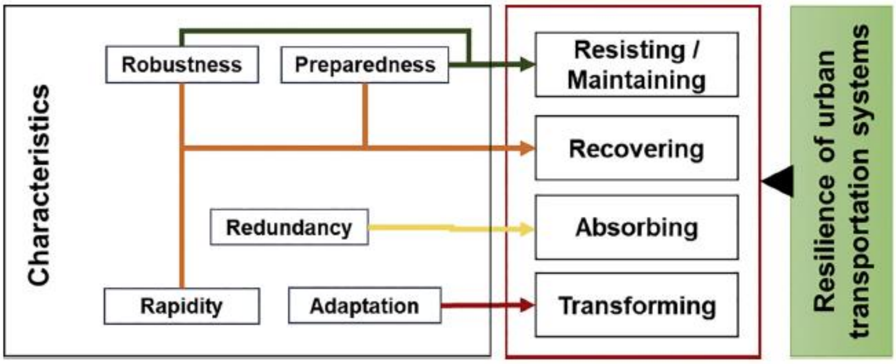


FIGURE 9: THE RELATION BETWEEN THE MAIN CHARACTERISTICS AND MAIN ACTIONS OF THE RESILIENCE OF A TRANSPORTATION SYSTEM (SOURCE: GONÇALVES & RIBEIRO, 2020, P. 6).

The research by Gonçalves & Ribeiro (2020, p. 7) found that the three most frequently used indicators to measure all five outcomes of resilient transport (robustness, preparedness, redundancy, rapidity and adaptation) are the amount of 'multiple routes', 'extra infrastructure' and 'diversity in transportation modes'. Hence, urban areas can primarily increase overall resilience by constructing a well-connected transportation system that offers multiple routes to arrive at the final destination and by integrating multiple modes of transport, also known as a multimodal transportation system, that are different in their functionality (Murray-tuite, 2006; Wang, 2015) (e.g., cycling and underground railway). Designing urban spaces and transportation system for walking and cycling can reduce the dependence on motorized modes (POLIS & Rupprecht Consult, 2021). Even in times of disruption, such as price hikes of petrol, people who are physically fit enough can use a combination of active modes such as walking and cycling (Fernandes et al., 2019; Wang, 2015). **Preparedness or resourcefulness** can be improved by investing in additional capacities to predict future scenarios, encouraging collaboration among different stakeholders (POLIS & Rupprecht Consult, 2021), preparing mitigation measures or estimating the associated costs with potential disruptions of the future (Gonçalves & Ribeiro, 2020).

Similarly to Gonçalves & Ribeiro (2020), Leobons et al. (2019) proposed specific indicators to measure different outcomes or actions of a resilient transport system (see **Table 9**). However, in comparison to Gonçalves & Ribeiro (2020) (see **Table 8**), Leobons et al. (2019) do not consider 'transformation' as one of the outcomes and appropriate indicators that would measure it. According to Leobons et al. (2019, p. 326), the robustness and redundancy are directly related to the "infrastructure and the ability of an entire system to maintain an acceptable level of services". While resourcefulness and rapidity are related to "the gravity of the event and the availability and quality of resources offered" (Leobons et al., 2019, p. 326).

PROPERTY	INDICATORS
Robustness	• Network connectivity/vulnerability • Route capacity • Mass transportation capacity • Demand • Travel time/distance (post-event)
Redundancy	• Alternative routes regarding critical points (e.g., number of independent routes that do not intersect between origin-destination pairs) • Accessibility levels (e.g., by measuring travel cost in terms of distance, time and prices of transport) • Alternative modes (e.g., the number of available transportation modes between zones)
Resourcefulness	• Time required to start to recover from when the disturbance happens • Availability of people and other resources to act
Rapidity	• Time required to restore normal operation or near it

TABLE 9: INDICATORS MEASURING THE DIMESNIONS OF RESILIENCE PROPOSED BY (SOURCE: LEOBONS ET AL., 2019, P. 326).

Interesting is also how Martins et al. (2019) developed indicators for direct comparison of different mobility options. Rather than measuring the 'resilience' of a system as a whole, Martins et al. (2019) look at different trips and how they "react" during times of disruption (i.e., persist, adapt, transform). First are trips characterised by **persistent resilience** which are those that manage to maintain the same capacity to enable mobility patterns without decreasing the quality of well-being of citizens (e.g., trips done by active modes of transport such as cycling and walking) (Martins et al., 2019). The second type of trips is characterised by **adaptable resilience** and is those that have the "potential of adopting alternative mobility patterns without compromising the current quality of life levels" (e.g., motorized modes within the limits of maximum possible distance that one would be willing to walk) (Martins et al., 2019, p. 353). Third, trips characterised by **transformable resilience** are those that have the ability to transform current mobility patterns into adaptable and present ones. Those trips are too long to be made by active modes of transport (e.g., walking, cycling), hence they are at risk of not being made and are therefore made by motorised modes. Lastly, Martins et al. (2019) also add a group of exceptional trips which are active modes of transport used for trips longer than those of the respective

MPD values for walking and cycling. It is important to mention, that the assumption of active modes of transport being used over motorized options would be chosen in times of disruption is made as trips still have to be made.

From the reviewed literature on the resilience of transport in urban areas, the main outcomes of a resilient transport system are its ability to resist/maintain, recover, absorb or transform while the main characteristics of the resilient system are its robustness, preparedness, redundancy, rapidity, and adaptation. As mentioned in **Chapter 3.1,** transport is a complex system embedded within a larger system (urban area) which influences how resilient or vulnerable it is. Looking forward there is a clear need to address whose resilience we are addressing. It is important to know that resilience is discussed from the point of view of members in the urban areas – citizens and therefore, looking at how resilient the transport system has been during the COVID-19 pandemic in meeting their needs (i.e., accessibility) and demands (e.g., infection-safe transport mode).

4 METHODOLOGY

The overarching research question of this master thesis is: "*What is the role of bicycling for the resilience and sustainability of transport in urban areas in the world after COVID-19?"*. This study aims to explore how the pandemic disrupted the status quo of transport in urban areas (see RQ1 in **Table 10**) and what role bicycling had for the resilience of cities in those times (see RQ2 in **Table 10**) to gain a new understanding of its role in the world post-COVID-19. In parallel, the role of bicycling for the sustainability of transport in urban areas will be assessed which is an important aspect, especially during times of disruptions (i.e., crisis) when we opt for survival and tend to abandon the sustainability principles (see RQ3 in **Table 10**). Hence, new evidence on the basis of real-life phenomena on the importance of investing in bicycling in urban areas will be provided. The implications of the research could be useful for further academic research, policy-makers, and industry such as providers of shared-cycling infrastructure or urban areas that wish to improve the sustainability and resilience of their transport.

- *RQ1: How did transport in urban areas react during COVID-19 pandemic (times of disruption)?*
- *RQ2: How can 'bicycling' contribute to the resilience of transport in urban areas?*
- *RQ3: How can 'bicycling' contribute to the sustainability of transport in urban areas?*

TABLE 10: THREE SUB-RESEARCH QUESTIONS.

Creswell (2014) identified three types of research approaches: quantitative, qualitative and mixed-methods. In cases when the research topic is relatively new and when the researcher is not completely aware of which variables to examine, Creswell (2014) recommends the researcher adopts the **qualitative research approach**, which is also selected for this master thesis. Furthermore, Creswell (2014) mentions it is important for the researcher to consider three further components as a particular approach consists of an interaction between different elements: (a) **philosophical worldviews** (e.g., postpositive, social construction, advocacy/participatory and pragmatic), (b) **different research methods** (questions, data collection, data analysis, interpretation, write-up and validation) and (c) **research design** (qualitative, quantitative and mixed methods strategies). The following subchapters define all three components of the research approach for this master thesis whose interconnections are visualized in **Figure 10**.

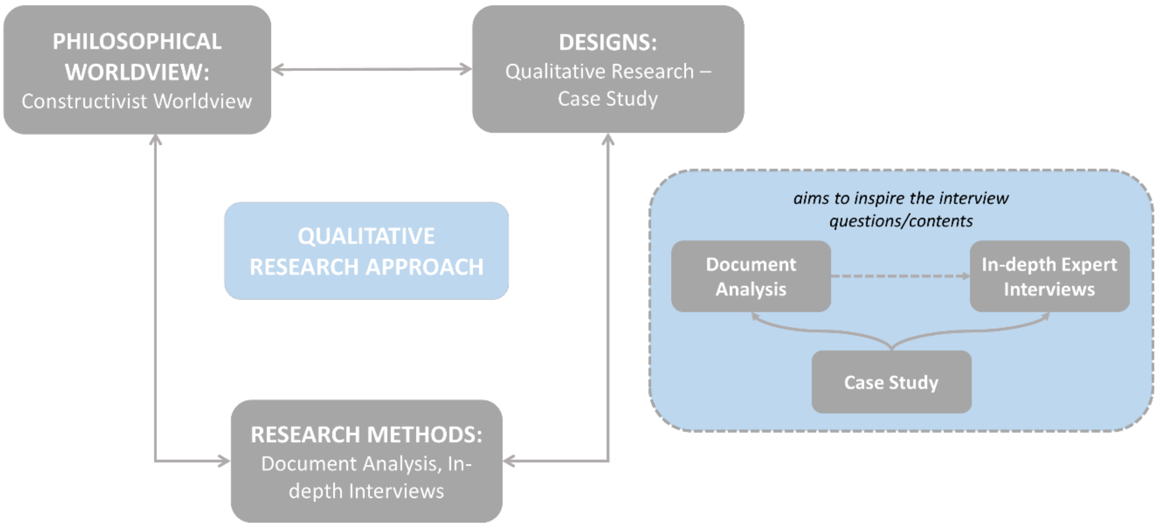


FIGURE 10: A FRAMEWORK FOR RESEARCH—THE INTERCONNECTION OF WORLDVIEWS, DESIGN, AND RESEARCH METHODS (ADAPTED AFTER FIGURE 1.1 BY CRESWELL, 2014, P. 5).

4.1 Philosophical Worldview

Creswell (2014) emphasizes that researchers need to address their philosophical worldview assumptions as they bring them into the study and influence the selection of methods and procedures of research. He divides them into: postpositivism, constructivism, transformative and pragmatism. Qualitative research typically requires a social **constructivist worldview** where the researcher "seeks an understanding of the world in which they live and work, develop the subjective meaning of their experience towards certain objects or things and look for the complexity of views" (Creswell, 2014, p. 8). The researcher, therefore, relies on the views of the participants rather than starting from a list of a few categories and ideas. This is reflected in how the expert interviews are structured and conducted (see **Section 4.3.2**). Although this worldview offers a lot of "flexibility" through the generation of meaning from collected data through inductive approach, Rowley (2002) advises the adoption of **positivist** and **deductive** approaches when conducting a case study. According to Rowley (2002, p. 18), the adoption of positivist and deductive approach to the case study "provides a firmer foundation for understanding and managing issues such as validity and reliability, and for structuring data collection and analysis". This implies that the researcher will have to 'define basic components of the investigation' (e.g., defining research questions and propositions) before the data collection takes place (Rowley, 2002). In other words, the researcher will need to make assumptions about the potential findings of the case study in advance basing it on the reviewed literature and earlier evidence on the topic. Those propositions are derived from the overarching research questions to guide the case study design (see **Table 12**).

4.2 Research Design: Case Study

An action plan or proposal to conduct research and collection of data is termed 'research design' and outlines what data will be collected to answer the research question or test the hypothesis (Rowley, 2002; Bhattacherjee, 2012). Creswell (2014) divides types of research design into three categories: (a) **quantitative** (e.g., experimental and non-experimental designs), (b) **qualitative** (e.g., narrative research, phenomenology, grounded theory, ethnographies, case study) and (c) **mixed methods** (e.g., convergent, explanatory sequential, exploratory sequential, transformative, embedded, or multiphase). Rowley (2002) also mentions that the most frequently used strategy of inquiry for qualitative (flexible) research design are **case studies, ethnographic studies and grounded theory** (Rowley, 2002).

To answer the research question of this thesis, the selected research design is a **comparative case study** where two cities of similar size and background are compared (*the city of Ljubljana* and *the city of Graz*) to highlight a specific phenomena (i.e., the COVID-19 pandemic) and its impacts on further development of urban areas. Over the past few decades, the two selected cities recognized the harmful side effects of motorized transport in the urban environment and the importance of sustainable modes of transport such as cycling. Both cities provide cycling infrastructure to the citizens with one large difference. The city of Ljubljana invested in the shared-cycling scheme BicikeLJ while Graz continued to invest in cycling infrastructure and other activities promoting cycling-oriented culture. Therefore, the goal is to also compare the reaction of bicycling to the pandemic and draw conclusions about the future development of other urban areas.

According to Creswell (2014, p. 14) the advantage of the case study is, that the researcher has the ability to develop an "in-depth analysis of a case, often a programme, event, activity, process, or one or more individuals" that is bounded by time and activity. This is also the case in this master thesis which is comparing the state of the art of urban transport and bicycling before and during the COVID-19 pandemic in the two cities of choice. Another advantage of case studies is the ability to combine qualitative as well as quantitative data from different sources and through different collection methods (e.g., interviews, documentary analysis, observation) (Bhattacherjee, 2006, p. 93; Creswell, 2014; Rowley, 2002). As such, the case study has the ability to provide insights that might not be achievable with other approaches (Rowley, 2002) and derive a more contextualized and authentic interpretation of the observed phenomena (Bhattacherjee, 2006, p. 93).

Furthermore, the **comparative case study** allows for a systematic comparison between the two subjects of research and "exploration of different research issues" (Rowley, 2002) where similarities but also distinctiveness between the two subjects of research can be identified. This is especially useful for this thesis as the goal is to explore the perspectives of different stakeholders involved in the planning of transport in urban areas (e.g., providers of shared cycling infrastructure, NGOs, municipalities, and urban planners). This will help the researcher draw conclusions on how transport, and specifically bicycling, should develop in the world post-COVID-19 pandemic based on its role during the pandemic.

As can be seen from the **Figure 11**, the first step to answering the research question is to conduct a literature review where the definitions of resilience and sustainability of transport in urban areas are provided. The literature review also provides an overview of the most recent literature on the impact that the COVID-19 pandemic had on transport, specifically bicycling, in urban areas and helps determine the structure of the case study. This is followed by **document analysis** through which secondary data and informational material on transport in both cities before and during the COVID-19-pandemic in the context of bicycling is collected (e.g., reports, documents published by operators of SCI and municipalities, statistical data) for the two subjects of research (i.e., two European cities of comparable size). **In-depth expert interviews** are conducted to explore the perception of stakeholders within a selected geographic area on how bicycling could contribute to the resilience and sustainability of transport in urban areas. More information on both research methods are provided in the subsequent sections.

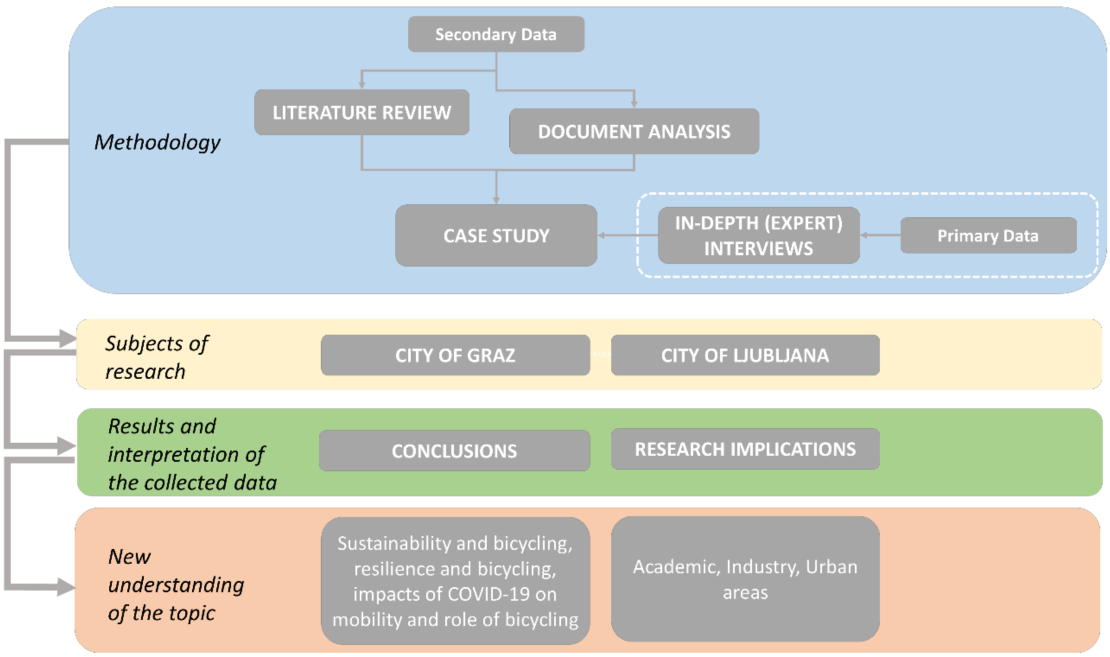


FIGURE 11: CONCEPTUAL FRAMEWORK (AUTHOR'S OWN).

4.3 Research Methods

Strategies of inquiry also termed 'approaches of inquiry' or 'research methodologies' (Creswell, 2014) are grouped according to the type of research approach: **qualitative** (experimental designs, non-experimental designs), **quantitative** (narrative research, phenomenology, ethnographies, grounded theory studies and case study) and **mixed methods** (sequential, concurrent, transformative). They involve different forms of **data collection, recording, analysis, and interpretation** (Creswell, 2014, p. 16) (see **Table 11**). Two types of data collection methods will be used to answer the research question of this master thesis: **expert interviews** and **document analysis**. The following subchapters elaborate on the data collection and recording procedure, what data will be collected and how it will be analyzed and interpreted.

Quantitative Methods	Mixed Methods	Qualitative Methods
• Pre-determined • Instrument based questions • Performance data, attitude data, observational data, and census data • Statistical analysis • Statistical interpretation	• Both pre-determined and emerging methods • Both open- and closed-ended questions • Multiple forms of data drawing on all possibilities • Statistical and text analysis • Across databases interpretation	• Emerging methods • Open-ended questions • Interview data, observational data, document data, and audio-visual data, text and image analysis, • Themes, patterns, interpretations

TABLE 11: QUANTITATIVE, MIXED, AND QUALITATIVE METHODS (SOURCE: CRESWELL, 2014, P. 17).

4.3.1 Document Analysis

According to Bowen (2009, p. 28), document analysis is an appropriate method for qualitative studies where researchers seek "convergence and corroboration through the use of different data sources and methods". This method provides the background and context to the case study and is specifically useful in situations when the observed situation cannot be repeated (Bowen, 2009), as in the case of what effect the pandemic had on the transport in urban areas and what was the role of bicycling during that period. To provide coherent empirical evidence, meaning and understanding of the topic, the researcher has to systematically review and interpret documents (e.g., texts, images) (Bowen, 2009). Although the primary goal of document analysis is to support the insights from the interviews with different types of data, this method also helps determine additional questions (Bowen, 2009) to be asked during in-depth expert interviews. This is also a frequently used method to enhance the validity of a study, and establish triangulation of data when combined with the data from other methods, such as interviews, which in turn minimizes bias and establishes credibility (Bowen, 2009). This data collection method enables the researcher to obtain the data at any time, and saves time and resources as transcription is not necessary. On the contrary, the downside of this data collection method is that the documents might be incomplete, inaccurate or unauthentic, or simply inaccessible (Creswell, 2014).

By conducting a document analysis, the goal is to collect information on the state of transport, specifically bicycling, in urban areas before and during the COVID-19 pandemic. Different types of documents can be found in a variety of places such as "libraries, newspaper archives, historical society offices, and organisational or institutional files" (Bowen, 2009, p. 28). They can either be public (e.g., minutes of meetings, newspapers) or private documents (e.g., journals, diaries, letters) (Creswell, 2014). As the topic of this thesis is relatively recent, most documents are available online. Hence the researcher collected the following types of documents mentioned by Bowen (2009, p. 28): agendas, background papers, books and brochures, journals, event programs, maps and charts, newspaper articles or clippings, press releases, programme proposals, summaries, organization and institutional reports, and survey data. Such documents are available in verified academic sources such as ProQuest, Taylor and Francis Online, Science Direct, and Google Scholar or through accessing different web pages of cycling scheme operators, national or local governments, non-profit organizations, institutes or statistical organizations, among others.

Data collection procedure: The process of document analysis requires the researcher "to find the right documents, read them and think about them" (Thomas, 2011, p. 164). Keeping a journal during the research study, analysis of the publicly available documents (e.g., minutes, records, archival materials, official memos), and examining autographies and biographies is what Creswell (2014) recommends when conducting a document analysis.

Data recording: Creswell (2014, p. 193) recommends that the researcher identifies "what data to record and procedures to recording the data prior to entering the field". For the document analysis, the data collection is guided by propositions derived from the research question (see **Table 12**).

In addition to insights from the documents, the statistical data plays an especially important role to enrich and support the information derived from the documents. For example, the goal is to find statistical data supporting the claims on how more cycling in the city contributes to the reduction of CO_2 emissions or noise pollution. Or the claim that more people started to cycle in the city as a result of the pandemic (e.g., fear of disease transmission on public transport) is supported by the insights derived from the time-series analysis of monthly cycling rates in each city.

(1)	The COVID-19 pandemic has significantly changed the mobility patterns in urban areas.
(2)	Urban areas invest in the promotion and facilitation of ‚bicycling' because it contributes to their resilience.
(3)	Urban areas invest in the promotion and facilitation of ‚bicycling' because it contributes to their sustainability.

TABLE 12: PROPOSITIONS GUIDING THE COLLECTION OF DATA THROUGH DOCUMENT ANALYSIS.

Data analysis: As the goal of conducting a document analysis is to enrich the insights from the expert interviews, the data found through document analysis is recorded in a journal for the researcher to have at their disposal when writing the section on findings and discussion. The data in the journal is divided into three sections guided by each of the propositions (see **Table 12**).

4.3.2 Expert Interviews

Along with the document analysis, the in depth interviews are conducted to gain an understanding of how bicycling contributes to the sustainability and resilience of transport in urban areas and their motivations, beliefs, attitudes and feelings on the topic. Interviews are a recommended technique in situations where the participants or phenomena cannot be directly observed (Creswell, 2014), as in the case of the effects of the COVID-19 pandemic. In addition, the individuals participating in the interviews can provide historical information on the trajectory of the pandemic. Furthermore, the benefit of this data collection type is that the researcher has the ability to "control the line of questioning" (Creswell, 2014, p. 191). Some of the limitations are that the researcher "provides information filtered through the views of the interviewees" which can be biased, does not provide the information in the natural setting but rather in pre-determined environment, the presence of the researcher might bias and direct the responses and lastly, that not all people are equally articulate and perceptive (Creswell, 2014, p. 191). This also includes the language barrier, for which reason the insights from *Interview 7* are not very insightful and therefore excluded from the analysis.

Creswell (2014, p. 191) mentions four options for conducting qualitative interviews: (a) face-to-face, one-on-one, in-person interview, (b) telephone interview where the researcher conducts the interview via a telephone call, (c) focus group where the researcher interviews several participants in a group meeting, and (d) e-mail internet interview. For the purpose of this master thesis the researcher offered to either conduct in-person, face-to-face interviews or internet interviews conducted via the platform Zoom. In agreement with the contacted experts, four interviews were conducted online via Zoom and four in-person, face-to-face in the city of Ljubljana and Graz.

The interviewees were selected through ‘expert sampling’, which is a nonprobability sampling technique, where the researcher decides which population elements are appropriate for the research based on their expertise on the phenomenon being studied (Bhattacherjee, 2012, p. 70). The element of analysis are stakeholders involved in the planning of transport in urban areas which work or live within the ‘extent of the research’ which are two cities (e.g., Ljubljana and Graz), and based on the time frame (e.g., April 2022). Snowball sampling is a useful method when it is not clear who the target population could be or when that particular population is difficult to reach (Bhattacherjee, 2012, p. 70). This method was used for the selection of further interviewees in Graz when one of the interviewed experts further directed the researcher to more stakeholders important for the development of the city of Graz. A brief description of all interviewed experts and the relevance to them and the organizations they represent are provided in **Table 13**.

Data collection procedure: Semi-structured interviews enable the researcher to follow a particular structure during the interview and provide enough flexibility to follow up on any topics if necessary (Thomas, 2011). For this reason, the researcher used the semi-structured format of the interviews where a list of potential interview questions was compiled to guide the interview. Hackett et al. (2016) suggest that the interviewer intervenes as little as possible during the interview and does not impose personal opinions on the interviewee. Creswell (2014, p. 193) recommends that the researcher “conducts a semi-structured interview, audiotapes it and transcribes it for the analysis”, which was also done for the purpose of further analysis.

Data recording: Creswell (2014, p. 193) recommends that the researcher identifies “what data the researcher will record and procedures to recording the data” prior to entering the field and developing an interview guide of planned topics of discussion, and potential questions to be addressed (Adams, 2015). For this purpose, the **interview protocol**, also termed the *interview schedule* (Thomas, 2011) was developed and helped the researcher guide the interview and ask questions. The interview protocol (see **Appendix 1**) consists of three sections and was shared with the selected interviewees in advance for them to familiarize themselves with the topic and questions. According to Bhattacherjee (2012), questions for interviews to be used in a case study can be open-ended, closed-ended or a combination of both. Although the interviews were video and audio-recorded, the researcher also made notes throughout the interview in case the recording would be lost or unusable.

Data analysis: First, the interviews were transcribed and the notes from the interviews were organized. Then the interview insights were organized and prepared for the analysis by collecting the most relevant insights for each topic. This was followed by coding of the data which, according to Rossman & Rallis (2012, in Creswell, 2014, p. 197) is "the process of organizing the data by bracket chunks and writing word representing a category in the margins". During this process, the text data from the interview transcript were segmented into categories.

Creswell (2014) mentions that in the traditional approach in the social sciences the codes are allowed to emerge during the data analysis. For this purpose, a **qualitative codebook** which is "a table containing a list of topics used for coding the data" was prepared (Creswell, 2014, p. 199). For the purpose of answering the two sub-research questions (see **Table 10**), two qualitative codebooks were prepared. The first was used to organize the insights on what the role of bicycling is for the sustainability of transport in urban areas (see **Picture 2**). The different categories in the codebook were gathered based on the insights from the interviews (see **Section 5.3**).

		I1	I2	I3	I4	I5	I5	I6
Environmental	Reduction of CO2 emissions	X	X	X		X	X	
	Reduction of noise pollution	X	X	X		X	X	
	Reduction of land and natural resources	X	X	X	X	X	X	
	Reduction of environmental degradation		X	X	X	X		X
Social	Increase in interaction among citizens	X			X		X	
	Increase in accessibility for mobility of all		X	X	X	X	X	X
	Reduction of health issues		X	X	X	X	X	X
	Increase in life quality and functionality of the urban area			X	X	X	X	
	Flexibility and independence		X		X			X
	Ability to meet different needs		X	X		X		
Economic	Lower investments in infrastructure and maintenance	X	X	X	X	X		X
	Increase in economic activities		X	X		X	X	
	Incerase in touristic attractiveness of the city		X			X		
	Reduction of external costs		X	X	X	X	X	

PICTURE 2: CODING TABLE USED FOR ORGANISATION OF INSIGHTS FROM THE EXPERT INTERVIWES ON THE TOPIC OF SUSTAINABILITY (SOURCE: AUTHOR'S OWN).

Similarly, the codebook was prepared for organizing the insights from the interviews on how bicycling can contribute to the resilience of urban areas (see **Picture 3**). Different perspectives on how bicycling makes urban transport system more sustainable were gathered based on the insights from the interviews and later interpreted by the researcher how those dimensions contribute to different characteristics of resilience (e.g., robustness, adaptability) (See **Section 5.4**).

	I1	I2	I3	I4	I5	I6	I8
Independence	X	X	X	X	X	X	X
Multimodality		X		X	X	X	
Flexibility		X	X	X	X	X	
Inclusivity and accessiblity		X	X		X		
Simplicity (usage, repairs, production)				X	X	X	
Different routes			X		X	X	

PICTURE 3: CODING TABLE USED FOR ORGANISATION OF INSIGHTS FROM THE EXPERT INTERVIEWS ON THE TOPIC OF RESILIENCE (SOURCE: AUTHOR'S OWN).

As mentioned, the insights on how the COVID-19 pandemic affected transport in each city were organized in a database. As Creswell (2014, p. 200) suggests, the researcher can "use the narrative passage to convey the findings of the analysis". For this purpose, the insights from interviewees on how the pandemic impacted the transport and bicycling in each city were provided in a chronological manner (i.e., the trajectory of the pandemic) and combined with the time-series analysis. In the last step of the data analysis, the data was interpreted based on the findings and results (see **Section 5.1.5** and **Section 5.2.5**). The author provided the lessons learned through her own interpretation of the events and data, through a comparison of the two cities and through a comparison of findings with the reviewed literature. Based on the results, further research opportunities have been defined and questions to be asked.

Interview 1 (I1): • **City**: Ljubljana • **Name and position**: Uršula Longar, Head of Department of Transport • **Organisation**: Department for Commercial Activities and Traffic, City of Ljubljana • **Interview Date**: 18. April 2022	Ms Uršula Longar is the *Head of the Department of Transport* which is part of the *Department for Commercial Activities and Traffic at the city of Ljubljana*. As the name implies, the *Department of Transport* is responsible for planning, execution and maintenance of transport and related infrastructure in the city of Ljubljana for passenger transport, stationary traffic, bicycle traffic as well as other areas such as emergency transport, delivery services, parking areas, and taxi services. The city of Ljubljana has played a key role in the transformation of the urban environment in Ljubljana, therefore the insights of Ms Longar on the development of the city and the impacts of the COVID-19 pandemic were of great importance. More about the organisation: https://www.ljubljana.si/sl/mestna-obcina/mestna-uprava-mu-mol/oddelki/oddelek-za-gospodarske-dejavnosti-in-promet/organizacijske-enote-v-sestavi/
Interview 2 (I2): • **City:** Ljubljana • **Name and position:** Lea Rikato Ružič, President • **Organisation:** LKM • **Interview Date:** 26. April 2022	Ms Lea Rikato Ružič is the president of *Ljubljanska kolesarska mreža* (angl., *Ljubljana Cycling Network*) association which has been representing cyclists in Ljubljana since year 2000. Through their work, they strive to improve cycling conditions in Ljubljana, spread awareness on the role of cycling in urban areas and increase the popularity of cycling among the citizens. As an organization run by a wide network of volunteers, they organize a number of events to promote cycling, and regularly communicate with the city of Ljubljana to inform them of any shortcomings of the urban infrastructure (e.g., maintenance of the roads, "traps for the cyclists", lack of bicycle locks) and advocate for safe, comfortable, attractive, direct and connected cycling network through their activism and by suggesting different measures and priority actions. More about the organization: http://lkm.kolesarji.org/
Interview 3 (I3): • **City:** Graz • **Name and position:** Simone Feigl, Member of the Board • **Organisation:** Radlobby ARGUS Steiermark • **Interview Date:** 26. April 2022	Ms Simone Feigl is a secretary and member of the board of *Radlobby ARGUS Steiermark.* The association, which is part of the Austrian cycling lobby, is representing the interests of cyclists and promotes non-motorized traffic, gentle mobility and bicycling. They drive the infrastructure improvements for cycling, increase awareness on the needs of cyclists and promote bicycling. In Graz, they work closely with Mr Helmut Spinka (current cycling officer at the city of Graz) to whom they provide suggestions on how to improve cycling infrastructure (e.g., roads, markings, signage). Their activism, however, goes beyond advising. They are part of the MoVe iT (German for "*Mobilität und Verkehr in Transformation"*) campaign which is committed to a socially just and ecologically sustainable mobility system in Graz.

	Within the Graz area they were responsible and involved in the creation of a cycling forum advising the city officials, establishing a 'cycling officer' role within the transport planning department of the city of Graz, construction of the bicycle station at the main train station in Graz, improvement of multiple individual locations around the city that needed improvements to be safe for cycling, among others. More about the organization: https://www.radlobby.at/argus-steiermark/radverkehrsanliegen-melden-und-die-radverkehrszukunft-besser-machen
Interview 4 (I4): • **City**: Ljubljana • **Name and position:** Klemen Gostič, Project Manager and Coordinator of EU projects on mobility • **Organisation:** RRA LUR • **Interview Date:** 26. April 2022	Mr Klemen Gostič is a project manager at the Regional Development Agency of the Ljubljana Region (RRA LUR) which supports sustainably oriented business, infrastructure and other types of activities. The agency connects different stakeholders and through the implementation of different projects helps bring sustainable practices to the region. The agency has been involved in multiple international projects, among other CIVITAS and Interreg projects. They also work closely with the city of Ljubljana and developed the Sustainable Urban Mobility Plan of the Ljubljana Urban Region (2019). More about the organization: https://rralur.si/
Interview 5 (I5): • **City**: Graz • **Name and position:** Karl-Heinz Posch, member • **Organisation:** Move-It • **Interview Date:** 4. May 2022	Mr Karl-Heinz Posch is a member of the MoVe iT (ger., *Mobilität und Verkehr in Transformation*) campaign - a movement that was founded during the preceding conservative government in Graz to lobby for sustainable transport. It consists of multiple associations, companies and citizens who work towards a socially just and ecologically sustainable mobility system in the city of Graz. They organize public events and campaigns, develop concrete political demands, hold dialogues with politicians and other interest groups, advise and campaign for different purposes and contribute to the monitoring of the implementation of measures. The team consists of several working groups that are responsible for different areas. In 2020, a team of experts from science and civil society published the 'MoVe iT Mobility Plan Graz 2030' with twelve demands for sustainable mobility in the Graz area. More about the organization: https://move-it-graz.at/
Interview 6 (I6): • **City**: Graz • **Name and position:** Stefan Bendiks, Director • **Organisation:** Artgineering • **Interview Date:** 4. May 2022	Mr Stefan Bendiks is an architect, urban planner and the director of *Artgineering* – a company based in Brussels, where he devises and implements design strategies for complex urban conditions with a focus on mobility and especially the role of cycling for a more livable urban environment. In the context of the city of Graz, he is the master planner of the Rad-Offensive 2030 – a master plan for the implementation of cycling infrastructure which is going to be implemented in the next 10 years. Prior to that, he has also advised the city of Groningen on drafting their new cycling strategy. Mr Bendiks has also published a handbook *Cycle Infrastructure* (2013) and is a member of the Dutch Cycling Embassy. More about the organization: https://www.artgineering.eu/about/
Interview 7 (I7): • **City**: Graz • **Name and position:** Mr. Helmut Spinka, Bicycle Traffic Coordinator • **Organisation:** City of Graz • **Interview Date:** 4. May 2022	Mr Helmut Spinka is the bicycle traffic coordinator at the Traffic Planning Department of the city of Graz. As the department, they prepare plans for strategic, cross-modal concepts, prepare the plans for the pedestrian and cycling traffic, individual motorized vehicles, public transport and stationary traffic. They are also responsible for raising awareness and managing mobility to foster a positive change in the perspective and behaviors of citizens towards more sustainable urban mobility. More about the organization: https://www.graz.at/cms/ziel/7743948/DE/
Interview 8 (I8): • **City**: Ljubljana • **Name and position:** Boštjan Berčan, CFO • **Organisation:** Europlakat d.o.o. (BicikeLJ) • **Interview Date:** 5. Mai 2022	Mr Boštjan Berčan is the chief operating officer at company *Europlakat d.o.o.* The company finances and operates BicikeLJ – a self-service bicycle rental system in Ljubljana for citizens and temporary visitors of Ljubljana. In 2011, the company entered a public-private partnership with the city of Ljubljana to provide one of the most affordable bicycle rental services in the world and to complement the public transport mix in the city with a faster alternative to walking. Since its inauguration, many people signed up to use it and as of today, the company operates a scheme of bicycles comprising of 83 stations and 820 bicycles. More about the organization: https://www.bicikelj.si/sl/home

TABLE 13: AN OVERVIEW OF INTERVIEWED EXPERTS WITH INTERVIEW CODES.

4.4 Strategies for validating findings

To ensure the quality of the research design and establish the trustworthiness of a case study the researcher is advised to carefully address the validity, generalizability and reliability of the research (Bhattacherjee, 2006, p. 35; Creswell, 2014). Rowley (2002, p. 23) recommends to ensuring validity, generalizability, and reliability of data through three principles: triangulation, case study database and chain of evidence. Although some of the aspects of validity and reliability have already been discussed throughout the previous chapter, the following section provides an overview of all of them.

- **Construct validity** is about ensuring that measuring the data will actually measure the expected findings (Bhattacherjee, 2006). Thus, it is important to link the initial research question and propositions (i.e., expected results of the study) questions and measures through which data will be collected. Construct validity can be enhanced during the data collection phase by using multiple methods of data collection (e.g., for example through triangulation where evidence from different sources confirms the same result), establishing a chain of evidence (i.e., ensuring the traceability of resources, making the evidence accessible through a database) or even by requesting a review and feedback from the potential readers (i.e., key informants or someone who will benefit from the results) (Rowley, 2002).
- **Internal validity or causality** is examining whether the "observed change in a dependent variable is indeed caused by a corresponding change in hypothesized independent variable" (Bhattacherjee, 2006, p. 35). It is applicable to explanatory and causal studies and can be enhanced during the data analysis phase by looking for different patterns, building explanations or doing time series analysis (Rowley, 2002).
- **External validity or generalizability** is related to the ability of the case study findings to be generalised (Bhattacherjee, 2006; Creswell, 2014; Rowley, 2002). As Rowley (2002) mentions, generalisation can be performed only if the research has been informed by the theory and can contribute to the results of the study to an already established theory. The generalizability of case studies is about analytical (rather than statistical) generalisation where "previously developed theory is used as a template with which to compare the empirical results of the case study" (Rowley, 2002, p. 20). It can be enhanced by using a case study protocol that guides the data collection (Rowley, 2002).
- **Reliability** is about the consistency of a measure or, put differently, whether the same results of the study would be obtained if it was repeated (Crewsell, 2009; Rowley, 2002). To ensure the reliability of the case study Rowley (2002) suggests developing a 'case study database' where all the procedures and documents are thoroughly collected.

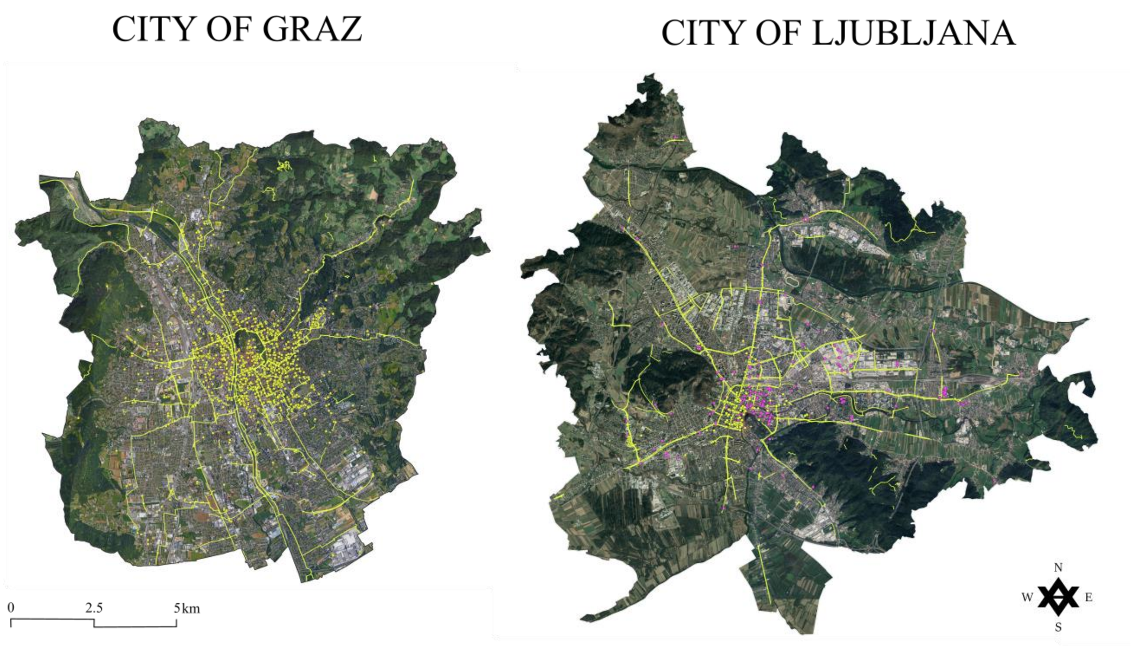
5 CASE STUDY OUTLINE

The case study follows a structured format. First, a description of both cities is provided to equip the reader with background information on the development and state of the art of both cities. The first section provides some general information on both cities today (see also **Table 14** where data for both cities is compared) which is followed by an overview of the historical development of the city. This section is especially important for the reader to understand the motivations and drivers of (sustainable) development in both cities and how they influenced the integration of bicycling. This section is followed by two segments providing information on 'mobility and transport' and 'cycling conditions' in each city today. The last section describes the impact of the COVID-19 pandemic on bicycling in each city where the results from the time-series analysis, document analysis and interview insights have been used to explain the observed phenomena. This is followed by a section on the role of bicycling for the sustainability of urban areas, where the results from the interview analysis are presented. To validate the claims made by the interviewed experts, secondary data for selected dimensions of sustainability are provided. Lastly, the section on the role of bicycling for the resilience of urban areas provides insights from the interviews. In addition to a general comparison of the main statistical information for both cities (see **Table 14**), the statistical data on bicycling in both urban areas was also derived from the publicly available geospatial data or based on the datasets directly shared by the organizations (see **Table 15**). The data on cycling infrastructure has also been depicted on the map of both cities (see **Picture 5**).

	Parameters	Ljubljana	Graz
City	Inhabitants	294.054	333.049
	Surface (km²)	163	128
	Green space (% of surface)	75%	68%
	River length (km)	n/a	15.87
	Population density (inhabitants/km²)	1,069	2,771
Economy	Number of companies	44,341	10,000
	Economically active population	220,851	184,849
	Self-employed	13,495	n/a
	Employment rate (%)	65.1%	n/a
Education	Number of universities	1	4
	Number of private higher education institutions	18	2
	Number of academies	3	n.d.
	Number of students	41,247	62,000
	Number of students from other regions	28,000	n.d.
Trans-port	Pedestrian area size (m²)	100,000	70,000
	Number of city public transport buses	213	170

	Bus lines	33	37
	Bus lines (km)	400.18	250
	Trams (lines in operation)	n/a	6
	Trams (nr. of vehicles operating)	n/a	85
	Length of tram network (km)	n/a	60.15
	Number of journeys made using city public transport	36,988,034	n/a
	Number of registered motor vehicles	186,421	182,901
	Number of registered private vehicles	150,439	142,066
	Number of taxi licenses issued	836	n/a
	P+R stations	9	10
	Nr. of cars (per 1.000 inhabitants)	571	485,6
	Nr. Of people commuting for work to the city	140,000	85,581
Cycling	Length of cycling paths (km)	300	150
	Length of 30km/h roads	n/a	800
	Bicycle stands (for locking)	10.000	6.000
	Recreational parks (for bikes and other smaller mobility tools)	8	n/a
	Cycling share in the city (%)	16.5	20.3

TABLE 14: COMPARISON OF BOTH CITIES.



PICTURE 4: COMPARISON OF CYCLING INFRASTRUCTURE IN CITY OF GRAZ AND LJUBLJANA (SOURCE: AUTHOR'S OWN).

	Parameters	Ljubljana	Graz
CYCLNIG	**Length of cycling paths** (km)[5]	201[6]	257[7]
	Number of locations with parking for bicycles	216[8]	1,269[9]
	Number of locations with bicycle stands[10]	140	n/a
	Number of BicikeLJ docks[11]	82	n/a
	Length of cycling network in 2030[12]	n/a	265

TABLE 15: DATA ON CYCLING INFRASTRUCTURE IN BOTH CITIES BASED ON DIFFERENT SOURCES OF GEOSPATIAL DATA.

As mentioned, maps of both cities cities depicting the cycling infrastructure was created (see **Picture 5**) based on the publicly available geospatial data and some datasets provided by Europlakat, Land Steiermark and JP LPT. The yellow lines depict the cycling lanes and yellow or pink dots represent the bicycle stands where people get to lock their bicycles. The map which is depicting the cycling network to be implemented in the city of Graz by 2030 has been depicted in **Picture 6**. The locations of all BicikeLJ docks in Ljubljana were depicted in **Picture 8**. Based on the available geospatial data, the statistics on cycling were collected and are available in **Table 15**. JP LPT (2022) provided the dataset of all bicycle stands which is slightly different compared to the data from Geofabrik (2022d) for which reason both data sets were used and the locations of bicycle locks depicted on the map. Lastly, it is important to mention that the length of cycling paths in Ljubljana and Graz includes all cycling lanes even when two lines (representing two directions) are depicted on the same street. This is also the reason, why the total length of cycling lanes to be implemented in the city of Graz by 2030 does not significantly differ from the current state of the art (see **Table 15).** The dataset provided by Land Steiermark (2022c) covers the main cycling paths with a single line marking both directions on one road. The larger versions of both maps with legend is also available in **Appendix 2** and **Appendix 3**.

[5] This number includes the cycling lane in both directions (i.e., when there is a one-directional cycling lane located on each side of the road).
[6] Geofabrik, 2022b.
[7] Three datasets on the cycling routes in Graz were combined as each of them depicted only a partial cycling networks in Graz (Geofabrik, 2022a; Land Steiermark, 2022b; Land Steiermark, 2022d).
[8] Geofabrik, 2022d.
[9] Geofabrik, 2022c.
[10] This number represents the total number of locations with bicycle stands. The total number of bicycle stands in those locations is 2,428 (JP LPT, 2022).
[11] Europlakat, 2022.
[12] This number represents lines that depict the planned cycling network by 2030. However, there is only one line (not two lines representing two directions) which is the reason why the length of the current cycling network is only slightly below the planned cycling network by 2030 (Land Steiermark, 2022c).

5.1 The city of Graz

5.1.1 About

Graz is the capital of the region Styria and the second-largest city in Austria with 333,049 habitants as of January 2022 (City of Graz, 2021) and a population density of 2,771 people living per km^2 (WIBIS, 2017). The city is divided into 17 districts, and stretches over an area of 127.58 km^2 out of which 68% is green space (City of Graz, 2021; KDZ, n.d.). Graz is a very densely populated area with 2,771 people living per km^2 compared to the national average of 274 inhabitants per km^2 (WIBIS, 2017). River Mura flows through the city over a distance of 15.87 km (City of Graz, 2018a).

After the breakup of Yugoslavia in the early 1990s, new people started to move to the city. Just between 2002-2006 there were 18,400 new citizens registered (Arandelovic, 2015). Today, Graz is a very cultural city as there are people of approximately 160 different nationalities living there (City of Graz, 2018a). It is also a student city where 40,000 young people go to school, with four universities and two technical colleges with more than 62,000 students in addition to 14 research and competence centres (City of Graz, 2013). The city is described as “the center of culture, science, and technology, a city of soft mobility and short distances” (City of Graz, 2018a, p. 12). In 1999 the inner part of the city and the Eggenberg Castle was added to the UNESCO cultural heritage protection list (City of Graz, 2018a). In 2003, Graz was named the ‘European Capital of Culture’ and became the ‘City of design’ in 2011 (City of Graz, 2018a). This substantially increased the international recognition of the city, contributed to the increase in tourism and generated economic benefits for the local economy (Arandelovic, 2015). The city was also awarded the title of ‘fair trade municipality’, ‘eco city’, and Austria’s first ‘Capital of Delight’ (City of Graz, 2018a). In Graz, there are approximately 10,000 registered companies and a working population of 168,738 out of which 99,268 individuals work in the city of Graz, 34,735 individuals work outside the city and 85,581 individuals commute to the urban area for work daily (Land Steiermark, 2020). Graz is also the fourth most popular city in Austria for tourists. In 2018, there were 1,134,215 overnight stays recorded out of which 55.7% were by international tourists (Österreichischer Städtebund, 2020).

5.1.2 Development of the city of Graz

Before 1980, the city of Graz focused mobility policies and development primarily on private motorised vehicles (Bulkeley et al., 2010; Kotler, 2019). To make space for cars and motorised traffic, the “existing tram lines were shut down, many open spaces, green courtyards, parks and trees were turned into parking lots" (City of Graz, 2018b, p. 6). When it became clear that this has multiple negative effects on the quality of life (e.g., air pollution, quality of life, smog alarm warning about the air pollution, noise and substantial space consumption, poor mobility), the city administration refocused to environmentally friendly development and sustainable mobility (Kotler, 2019). One of the most impactful events was the 'smog winter of 1988/1989' when the smog levels reached extremely high levels and the air quality was very poor (Bulkeley et al., 2010). Since then the environmental policies in the transport policy field started to develop. In the 1990s the city started to invest in 'soft (gentle) mobility**'** (Bulkeley et al., 2010; City of Graz, 2018b; Kotler, 2019), started to prioritise walking, cycling and the development of public transportation. Graz was the first European city that implemented the measures restricting the speed of motorised transport within a large city area to 30km/h. The process was announced in 1992 and resulted in a significantly lower number of accidents, more security and improved quality of life (Bulkeley et al., 2010; City of Graz, 2018b). Meanwhile, the attention toward sustainable development practices was also shifting on the global level. 'Agenda 21' (1992) is a comprehensive plan of action that was to be adopted on all levels and in all areas where human activities negatively affect the environment and was adopted by 178 governments after the UN Conference for Environment and Development held in 1992 in Rio de Janeiro. Among those was also the city of Graz which developed the first Austrian '**Local Agenda 21'** (Magistrat Graz, 1996b) and the local environmental programme '**Ökostadt 2000'** (Magistrat Graz, 1996a) which was accepted by the local politicians in 1995. The programme provided the "analysis of the current situation, guidelines relating to environmental policy and principles for a sustainable urban development" and consisted of nine action plans to provide a list of measures that would help achieve the set targets (Magistrat Graz, 1996a, p. 2). For those efforts, the city has received multiple awards such as the 'Most Pedestrian-Friendly city of Austria' (1992), won the campaign 'Road Traffic Sage for Children' by the Austrian Road Safety Board (1993), the 'climate protection award' (1993) by Greenpeace, won the award by the Austrian Transport Clubs for the campaign 'Children on the Road' (1994) and became the first European city to receive the 'European Sustainability City Award' (1996) (Bulkeley et al., 2010; Magistrat Graz, 1996a). Just like in the case of Ljubljana, those awards also helped the city gain considerable international attention and attracted foreign visitors and investors (Bulkeley et al., 2010).

Austria entered the EU in 1995 which influenced the further development of the country. In 1999, the city hosted the 'Velo-City Conference' in cooperation with the city of Maribor which had a "sustainable effect on the city" (City of Graz, 2018b, p. 15). Several bicycle paths and connections on the outskirts were completed in preparation for the event and some were completed post-event (City of Graz, 2018b). Since 2002, the city has been working with CIVITAS and participated in multiple projects: TRENDSETTER project (2002-2006), CATALIST (2007-2011), hosting of the CIVITAS forum (2003), being part of the CIVITAS Political Advisory Committee (2007-2012) and being a member of the CIVITAS Management Board since (2013-2017) (Kotler, 2019, p. 8). One of the most important projects was TRENDSETTER where the city of Graz implemented 17 measures such as a bus fleet running on biodiesel (Graz was one of the first Austrian cities to have implemented that), establishing a night bus line, a mobility centre 'Mobil Zentral' to help citizens use the public transport system, digital bicycle map (Kotler, 2019, p. 8). Within the CATALIST (2007-2011) project the city supported the transfer and implementation of best practices in other urban areas. As part of the other projects supported by CIVITAS the city has "redesigned public space to prioritize people over cars, reduced the speed limits across the city, implement an environmentally-friendly parking management system, extended public transportation services, developed zero-emission urban freight logistics solutions, inaugurated the TIM intermodal service hubs" (Kotler, 2019, p. 9), among others. As a follow-up to the 'CIVITAS Trendsetteer' project, the city of Graz participated in the project 'SUGRE – Sustainable Green Fleets' aimed at making the public transport more environmentally friendly (e.g., through low or zero-emissions vehicles, increasing gentle and environmentally friendly mobility) (City of Graz, 2018b). Another project 'Partner Initiatives for the Development of Mobility Management' (PIMMS) (2005 - 2007) was implemented through awareness-raising activities, mobility education, and the promotion of gentle mobility (City of Graz, 2018b). The project also proved that investing in sustainable mobility can be profitable as "every euro spent on measures towards gentle mobility yielded a profit of €10 by reducing the burden of traffic on the environment" (City of Graz, 2018b, p. 25). The city also participated in project 'ASTUTE' (2006-2009) which aspired to increase the share of cycling and walking in the traffic mix by 10% and reduce the CO_2 emissions by 10% and indeed resulted in more walking and cycling as well as reduction of emissions (City of Graz, 2018b). During that period, they received the 'Traffic Safety Award' (2005) by the Austrian Safety Board, received the 'Osmose Award' (2006) for their biodiesel bus fleet, received the 'CIVITAS city of the year award' (2008) and the 'Sustainable Energy Europe Award' (2008). However, as mentioned by Bulkeley et al. (2010, p. 97) at the beginning of the new century the "dynamics of urban environmental change significantly cooled down for a decade" resulting in the implementation of fewer initiatives, reduced investments and poor public attention. Despite all the achievements, the city continued to record "poor air quality and high levels of particulate matter" which negatively impacted the image of the urban area being a "green city" (Bulkeley et al., 2010, p. 97). At the start of the new century, the development of the city of Graz was also redirected to turn it into a cultural hub. This is noticeable in the multiple implemented initiatives and awards the city has received such as becoming the UNESCO World Heritage (1999), becoming the 'European Cultural Capital' (2003), and receiving the 'City of Design' award (2011).

According to a study by Bulkeley et al. (2010, p. 98) which compared the development of the city of Graz with the city of Freiburg (Germany), the development in Graz before the 2000s was mainly "driven by experts and administration" while the development in Freiburg was driven by an "active network of civil society initiatives". Sometime later that also changed in Graz when the civil society started to organise and demand more environmentally friendly policies, especially in the field of mobility and transport. For example, already since 2007, the cyclists in Graz have been meeting monthly for the 'Critical Mass' where they ride together through the city. The movement is aimed at encouraging policy makers and planners to recognise cyclists as "an important element in the mobility and allocate full transport policy recognition to it" (Nachhaltig in Graz, 2022). Another example is the initiative 'Ghost bikes' organised by ARGUS Styria cycling lobby, *Fahrradküche* and citizens of Graz in memorial of the cyclists killed in 2014. The movement was further intensified in 2015, with the death of two cyclists involved in the accident when car doors were carelessly opened (Radlobby, 2018). This resulted in the 'Distance makes safe' campaign by ARGUS Steiermark which demanded that drivers maintain a distance of 1.5m when overtaking the cyclists and cyclists maintain 1.2m distance from cars (Radlobby, 2018). The citizens' demands further intensified after 2018, when the 'Fridays for Future' international movement started requesting bolder actions to address climate change. Another example of the engaged citizenry is also the work of Mag. Dr Christian Kozina Radegunder who criticised the current transport policy for being passive and who published '18 innovations for the transport system in Graz' (Kozina, 2018) with the support of ARGUS Styria cycling lobby and the Styria passenger association. In the document, he proposed 18 innovations for the transport system (e.g., new pedestrian zones, shortcuts, connecting the network of cycle paths, new parking spaces etc.) and was supported by at least 1,400 citizens who signed the online petition (Graz Verkehr, n.d.).

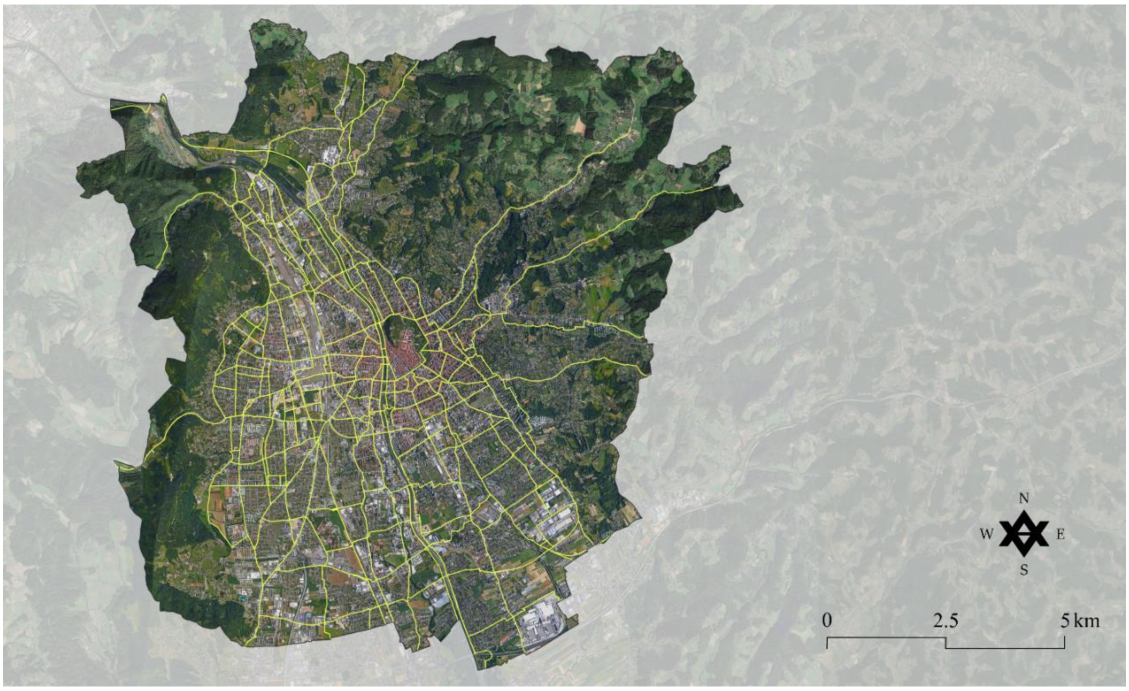
In 2010, the city of Graz published a new 'Transport Policy 2020' (City of Graz, 2015) followed by the 'Graz Mobility Concept' (2012) (City of Graz, 2015) along with 'Objectives of the mobility strategy 2020' (2012) (City of Graz, 2015) and 'Traffic Planning Guidance' (2012). The new transport policy continued to build on the 'gentle mobility' concept, aimed to shift the ratio between motorised individual traffic to sustainable modes of transport from 45:55 (2008) to

37:63 (2020), prioritize the environmentally friendly modes of transport and increase the mobility through the strengthening of the public transport, walking and cycling network. Specifically, the goal was to reduce motorized traffic to 37%, public transport to 24%, cycling to 20% and walking to 19% by 2021 (City of Graz, 2015). In addition, the plan by the city of Graz (2015) also recognised the importance of interregional collaboration as a large share of traffic comes from other parts of Styria and the role of spatial planning, economic policy instruments and other control measures that would help halt the 'urban sprawl' (i.e., decentralized settlement development) and encourage 'conurbation' (i.e., when multiple populated areas are merged together). For example, improving the local mobility of citizens by providing close access to the facilities (i.e., within walking distance of 300 metres) used on a daily basis (e.g., grocery stores, kindergartens, public transport options). The 'Graz Mobility Concept' (City of Graz, 2015) also provided a vision of mobility for 2050 with the set goal of reducing motorised private transport from 45% to 17% of all journeys and increasing the share of people living in the walkable urban area from 63% to 90%. The document also outlined seven strategic measures to be implemented to achieve the set goals, among which is also the 'Rad-Offensive' (i.e., cycling offensive).

The motivation of the local government reflected in the 'Traffic Policy 2020' (City of Graz, 2015) is also noticeable in other projects developed at the time. In 2013, the city has published the 'Smart City Graz – the Vision for 2050' strategy which outlined actions to be taken for the city to become a 'zero emissions city' with reduced consumption of resources, energy and emissions emitted (City of Graz, n.d.-c). Additional motivation was also the growing population trend and scarcity of available building land. The vision specifically mentioned that the goal of mobility by 2050 is to ensure that different activities by citizens (e.g., local supply of goods, services, education, leisure) are carried out with the lowest possible consumption of resources and provide the chance to promote social contacts (City of Graz, n.d.-c). That was to be achieved through the creation of an urban structure with short, walking, cycling and public transport-friendly routes where the space previously allocated to motorized transport is reallocated to citizens (City of Graz, n.d.-c). Over the years, the city undertook multiple strategies to create a dynamic city with compact buildings and urban mix-use, attractive public spaces, prioritizing sustainable mobility (attractive green footpaths, cycle paths, improving public transport connections) to reduce the share of private motorized transport (City of Graz, n.d.-c). In 2012 and 2014, the city of Graz also organised a competition 'corporate mobility management' in which companies competed against each other and helped the city of Graz create a more sustainable transport system through increased use of environmentally friendly transport modes. The activities involved improving the company transport route (i.e., making them more economical as well as ecological), introducing employees to new approaches and solutions for cheaper and healthier mobility, and contributing to a more sustainable transport system in Graz through the use of sustainable modes of transport. The city had a good experience with the project and went on to publish 'Company Mobility Management Programme 2019-2021' (City of Graz, 2019) with which they aimed to individually consult 15 companies, and prepare tailored-made solutions for their work routes and optimise their vehicle fleets. The main goal was to motivate the companies and their employees to use public transport, car sharing, cycling and walking to get to the workplace (City of Graz, 2019).

Move-It is another campaign organised by multiple associations, which is very active in the field of public transport in Graz. In 2019, they published a document with 12 demands for further development of the city which was signed by more than 12,000 citizens. The 12 demands were used to develop a mobility plan for Graz presented in May 2020. In March 2021, they published another document outlining proposals for a fast, effective and financeable public transport network to be implemented in the next 10 years. The modal split targets were set at 30% pedestrian traffic, 35% cycling, 25% public transport and 10% motorized private transport (Kozina et al., 2021). They also call for improvement of interregional traffic and namely to increase cycling from 0% to 10%, to increase public transport use from 15% to 40% and to decrease the use of cars from 85% to 50%. They specifically emphasise that the traffic problem cannot be solved without advancing the infrastructure alone when the distances between places continue to increase. They rather call for the planning of a built environment that mixes together with a wide range of facilities and one that reduces the need to travel by 50% which is likely to also contribute to an increase in walking and cycling (Kozina et al., 2021).

The most recent project is the master plan 'Radoffensive 2030' which was published in August 2021 by the *Artgineering* office. The document presents a 10-year implementation plan that will require more than €100 million in investments allocated to the construction of 100km of new, safe cycling lanes, cycling infrastructure and promotion of active mobility (see **Picture 5**). The goal of 'Radoffensive' until 2030 is to increase the share of cycling to 30%, walking to 23%, public transport to 25% and motorised transport to 22% (VCO, 2021). The overall goal is to make the city of Graz more cycling-friendly and consequently increase the quality of life, create more outdoor recreational areas, reduce noise pollution and improve the quality of air.

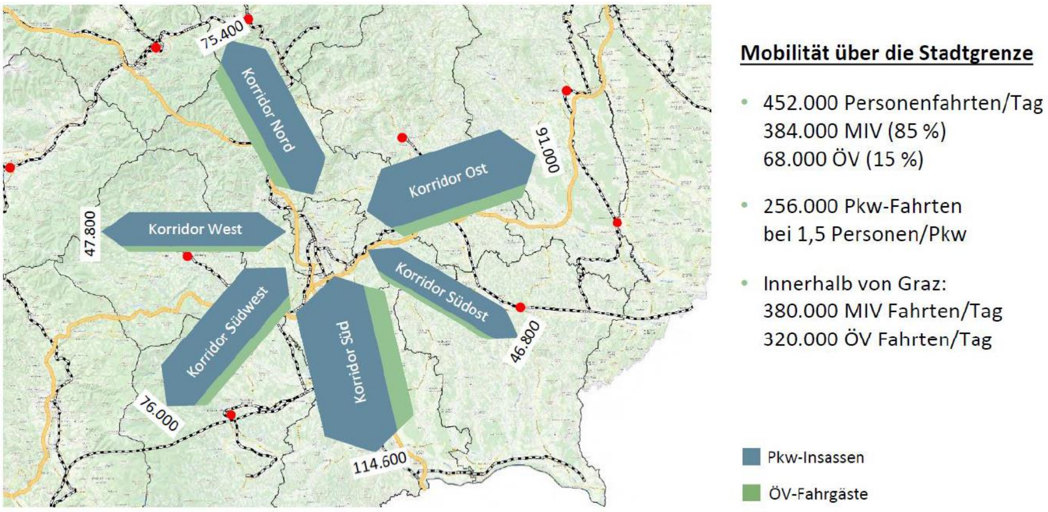


PICTURE 5: THE PLANNED CYCLING NETWORK IN THE CITY OF GRAZ BY YEAR 2030. (SOURCE: AUTHOR'S OWN. DATA SOURCE: LAND STEIERMARK, 2022).

5.1.3 Mobility and transport in Graz

Today, Graz is described as the ‘city of short distances’ where most errands, especially in the city centre, can be done on foot. Apart from that, the city promotes ‘soft mobility’ and offers multiple transportation options that make life without cars easy. The multimodal transport system in Graz encompasses a bus fleet and tram network, a free old town tram in the city centre, on-demand transport service, regional train, car-sharing *Tim* and cycling. Holding Graz operates a fleet of more than 160 buses, and 28 bus lines out of which 8 operate throughout the night in addition to the 6 tram connections (Holding Graz, 2022; Stadt Graz, 2018). In Graz’s old town there is a ‘free travel zone’ where citizens and visitors can use the “Old Town Tram” (German *Altstadt-Bim*) free of charge (Holding Graz, 2022). In addition to operating the public transport, *Holding Graz* also operates an innovative mobility model *tim* which stands for “*täglich. intelligent. mobil.”* and was inaugurated in 2016 (Stadt Graz, 2018). At various locations around Graz, *tim* combines different mobility options such as e-car sharing, rental cars, e-Taxis, cargo bikes, bicycle parking spaces and charging stations for private electric vehicles (Holding Graz, 2022). The locations were strategically selected to complement the existing public transport network and cycling. At those intersections, there are also ten P&R stations (Stadt Graz, 2018).

Due to the urban sprawl, today more people commute to the city by car (see **Picture 7**). As mentioned, the city of Graz was one of the first cities in Europe that introduced 'speed reductions' and limited the motorised traffic to 30km/h which today accounts for 80% of the road network (Stadt Graz, 2018; City of Graz, 2018b). The calmed traffic enables more safety for the residents, cyclists and pedestrians (ibid.). There were reported to be 182,901 registered motor vehicles and 142,006 registered private vehicles as of 2021 (Statistik Austria, 2021). According to Land Steiermark (2021), there are 485.6 cars registered per 1,000 inhabitants which is lower compared to the national average of 570 cars per 1,000 inhabitants (Statista, 2022).



PICTURE 6: MOBILITY BETWEEN THE CITY OF GRAZ AND SURROUNDING REGIONS (SOURCE: KOZINA ET AL., 2021).

The city of Graz is conducting periodic surveys among citizens to learn about their travel habits. According to the most recent survey (Feigl & Urban, 2021) in which 3,311 people over the age of six participated, 20.3% of journeys were made by bicycle, 21.0% on foot while 18.2% were made by public transport and 40.5% were made by cars either as passenger or driver. The share of trips by bicycle increased by one percentage point from 19.3 % in 2018 to 20.3% in 2021 and the share of trips by foot increased by 1.7 percentage points from 19.3% in 2018 to 21.0% in 2021 (Feigl & Urban, 2021). The effect of the COVID-19 pandemic, which started in 2020, is the most noticeable in the lower share of trips made by public transport which decreased by 1.6 percentage points from 19.8% in 2018 to 18.2% in 2021 (Feigl & Urban, 2021). Despite this, the proportion of trips by motorised vehicles was the lowest in the last 40 years (Feigl & Urban, 2021) (See **Figure 12**).

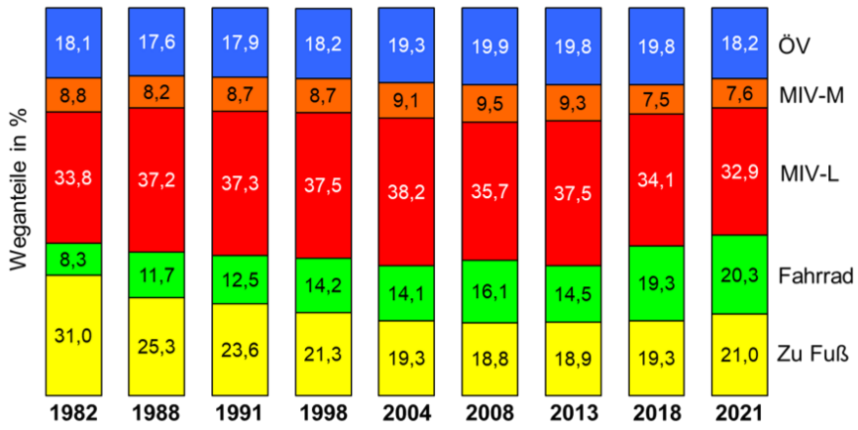


FIGURE 12: MODAL SPLIT IN GRAZ OVER TIME (SOURCE: FEIGL & URBAN, 2021).

5.1.4 Cycling in Graz

Graz is a cyclist's friendly city. According to the city of Graz (2018c), cycling is the most popular mode of transport among students (i.e., the age group from 15 to 25 years old) who do 31% of all trips by bicycle. There is appx. 150km of cycling lanes, 13 main cycling routes going through the city (Stadt Graz, 2018) and appx. 800km 'bike-friendly' streets with a 30km/h speed limitation stretching across the city (Stadt Graz, n.d.). According to MoVe iT Graz (n.d.), there were approximately 6,000 public bicycle parking spaces available in Graz in 2010 and 143 newly built parking spaces in 2018. In addition, cyclists can safely store their bikes at the main train station for a monthly parking fee of €7.00 or a yearly parking fee of €70.0 (City of Graz, n.d.-b). There are also more than 20 bicycle service boxes (i.e., boxes containing tools for quick bicycle repair, air compressors, and other tools) distributed around the city whose purchase is subsidised by the city of Graz (Nachhaltig in Graz, 2020). In addition, there are also more than 14 repair shops offering bicycle repair services around the city (Graz Tourism, n.d.).

Despite efforts to implement a shared cycling scheme in the city, no project until today succeeded (Factum, 2021). For example, in 2017 the free-floating bike scheme *OBike* tried to provide its service in Graz, however, the project was rejected due to fear of free-floating bicycles becoming another barrier in a city with already limited urban space (Radlobby, 2020). According to one of the more recent articles, the implementation of a bike rental system again became part of the discussion with the 'Radoffensive' (Winter-Pölsler, 2021a). It is important to mention, that Graz was also the first city to speak against and reject the implementation of e-scooter sharing due to their short shelf life, additional production of electronic waste and being a direct competitor to cycling and walking (which goes against the perception of car drivers switching to more environmentally friendly e-scooters) (Kleinezeitung, 2019; Müller, 2019).

On the other hand, the city of Graz supports the cargo bike offer in the city. Since 2021, LaRa Graz cargo bike offers 15 cargo bikes which can be rented free of charge when booked 24 hours in advance (https://www.radverteiler.at/lara-graz). The project is operated by *Holding Graz* and cofinanced by the *Climate protection fund* by the city of Graz. Furthermore, outside visitors also have the possibility to rent a bike from one of the rental offices at the main train station or in the city (e.g., Bicycle.at, rentabike-graz, Gigasport, RadAktiv) (Graz Tourism, n.d.).

Since 26th April 2022, the Austrian citizens can also get a repair bonus for their e-bikes which accounts for 50% of the repair costs or €200 per repair and is part of the campaign by the Ministry of Climate Protection of Austria aimed at encouraging citizens to repair their electrical and electronic devices (https://www.reparaturbonus.at/). The city of Graz also provides subsidies for the purchases of cargo bikes, bicycle parking facilities and bicycle service boxes (Stadt Graz, 2018). In February 2022, the city of Graz also started providing subsidies to companies, institutions or house communities for the construction of bicycle parking facilities to encourage and increase the use of bicycles (City of Graz, n.d.-a).

According to the mobility survey from 2018 (City of Graz, 2018c), almost every second Grazer owns a bicycle. In 2008 the share of trips done by bicycle was 16.1%, in the year 2013 decreased to 14.5% but increased again in 2018 to 19.3% and further increased to 20.3% in 2021 (Feigl & Urban, 2021). According to the recent data from bicycle counters, there are also more people starting to cycle in the colder winter months. According to the analysis by the *Austrian Traffic Club*, there were 16.2% more cyclists counted in the winter of 2021/2022 compared to the preceding winter (Winter-Pölsler, 2022). In Graz, there is also a very connected cycling community increasing the popularity of cycling. People gather and learn how to repair their bikes in the 'bike kitchens' (German for Fahrradküche) (http://fahrradkueche.com/). Throughout the year, there are also multiple cycling events organised in the city such as *Grazer CityRadeln* to cycle 18-20km circle through the city, *Tour de Graz* which is part of the European 'car-free-day' movement, *Schlossbergman* where people cycle to the clock tower in Graz, and a monthly *Critical mass* where people cycle through the city together (iFahrrad, 2022).

5.1.5 COVID-19 Impacts on cycling

In the city of Graz, the data on cycling rates is collected by the Department for Transport Planning of the city of Graz administration. The monthly reports on cycling rates are publicly available and published on the city of Graz website: https://www.graz.at/cms/beitrag/10116349/12063979/Rad_Zaehlstellen.html. Mr Spinka who holds the role of bicycle traffic officer at the Department for Transport Planning, provided the historical data on daily cycling rates for five different locations around the city for the period 2017-2022. Daily cycling rates for each station were added together to get monthly cycling rates for each year and are available in **Table 16**.

	2017	2018	2019	2020	2021	2022
January	261,220	362,940	339,944	433,184	252,873	345,975
February	330,885	220,105	347,085	403,472	339,903	359,632
March	642,384	355,612	575,805	362,529	485,208	546,947
April	530,780	653,185	544,154	355,256	479,502	
May	772,692	680,588	583,802	546,147	546,200	
June	665,128	592,664	706,964	606,496	725,948	
July	563,741	620,428	597,785	646,339	666,762	
August	515,450	576,727	533,732	544,228	557,520	
September	437,436	544,418	592,495	603,664	628,602	
October	644,459	605,172	699,017	n/a due to server failure	597,112	
November	447,583	380,490	474,108	402,996	468,697	
December	286,546	303,700	361,067	251,640	294,471	

TABLE 16: MONTHLY CYCLING RATES IN THE CITY OF GRAZ (SOURCE: CITY OF GRAZ, 2022).

This data has been used to compare the pre-pandemic cycling rates (i.e., average monthly cycling rates from 2017 to 2019) depicted with a grey dotted line (see **Figure 13**) with cycling rates during the COVID-19 pandemic in 2020, 2021 and 2022. It is important to mention, that within the period of five years some data on cycling in Graz was lost due to server failures. The largest loss occurred in October 2020 when all data was lost (see **Figure 13**). Below **Figure 13**, a timeline of the COVID-19 measures in Austria that had the biggest impact on the daily lives of people and mobility patterns in Graz has been provided. The data was accessed from the blog by the University of Vienna where the chronology of the pandemic has been recorded (https://viecer.univie.ac.at/corona-blog/themenuebersicht/).

On March 11th 2020 the World Health Organization classified the Corona crisis as a pandemic and on March 16th 2020 a strict lockdown was announced in Austria. All interviewed experts mentioned that public life completely stopped at that point, and the city and streets were completely empty (I3, I5, I6). As can be seen from **Figure 13**, also the cycling in Graz at that point significantly decreased. The rates decreased by 10.1% from 403,472 cyclists in February 2020 to 362,529 cyclists in March 2020. Comparing March 2020 with the pre-pandemic period 2017-2019 when on average 524,600 cyclists were recorded, the monthly cycling rates were 30.9% lower (see **Table 17**). The rates continued to decrease during April 2020 and were 38.3% lower compared to the average cycling rates in March 2017-2019 (see **Table 17**). After the initial shock, the traffic eventually started to recover but was still much lower compared to the pre-pandemic levels due to remote work and home office (I3). Although public transport companies continued to operate and offered their services, the interviewed experts mentioned that many people changed their travel mode from public transport to private cars due to the fear of disease transmission (I3, I5, I6). After the first lockdown, many people started to cycle especially in their free time but also to commute to work (I5, I6). In May 2020, when cycling rates started to incre-ase again, 546,147 cyclists were recorded which was 19.6% lower compared to the pre-pande-mic period 2017-2019 when on average 679,027 cyclists were recorded. In the summer months (June, July, August, and September) the cycling rates continued to increase and were higher by 8.8% in July, and 0.4% in August compared to the pre-pandemic period 2017-2019. Although the second wave began on the 14./15. September 2020, the cycling rates in September 2020 were still 15.0% higher compared to the pre-pandemic period 2017-2019. As some data for the months of July-September 2020 has been lost due to server failure the real cycling rates in those months were even slightly higher. Due to the server failure also all data for the month of October 2020 was lost. The cycling rates in November were only 7.2% lower compared to the pre-pan-demic period 2017-2019 despite the continuing pandemic and lockdown measures (e.g., closure of educational facilities, all-day curfew). In December 2020, the cycling rates continued to dec-rease and were by 20.6% below the pre-pandemic period 2017-2019.

In January 2021, there were 252,873 cyclists recorded which was 21.3% lower (see **Table 17**) compared to the average of 321,368 cyclists in the months of January for the period of 2017-2019. During this period another lockdown was announced in Austria. In March, April and May the cycling rates continued below the pre-pandemic levels. The cycling rates significantly incre-ased in June and remained above the pre-pandemic levels until October 2021. Compared to the pre-pandemic period 2017-2019 the cycling rates were higher by 10.8% in June 2021, by 12.3% in July 2021, by 2.9% in August 2021 and by 19.8% in September 2021. In October 2021, the rates decreased by 8.1% but increased again in November and were higher by 8.0% compared to the pre-pandemic period 2017-2019. In December 2021, the cycling rates were lower by 7.1% compared to the months of December during 2017-2019.

Compared to the cycling rates in January, February and March for the period 2017-2019 the cycling rates were higher by 7.7% in January 2022, by 20.1% in February 2022, and by 4.3% in March 2022 (see **Table 17**). As mentioned by (I3, I6), this could be due to the increasing po-pularity of cycling that was already observed before the pandemic but also due to the change in thinking when people discovered cycling durnig the pandemic (I6).

	2020	2021	2022
January	34.8%	-21.3%	7.7%
February	34.8%	13.5%	20.1%
March	-30.9%	-7.5%	4.3%
April	-38.3%	-16.8%	
May	-19.6%	-19.6%	
June	-7.4%	10.8%	
July	8.8%	12.3%	
August	0.4%	2.9%	
September	15.0%	19.8%	
October	-100.0%	-8.1%	
November	-7.2%	8.0%	
December	-20.6%	-7.1%	

TABLE 17: COMPARISON OF MONTHLY CYCLING RATES (%) IN 2020, 2021, AND 2022 WITH THE PRE-PANDEMIC PERIOD 2017-2019.

The pandemic could have also served as an "accelerator" for more cycling. Many people started to cycle for recreation and health reasons, which (I3) sees as a positive thing as such occasional habits also get transferred into the daily routines of people. Many new cyclists also joined the trend which was mentioned by (I3, I5, I6). All three see this as a very positive trend for the further development and transformation of the city as the cycling rates have not substantially changed in the past years. They mentioned that this is due to the lack of new, safe and comfortable cycling infrastructure. Although the city of Graz already provides very good cycling conditions, in order to attract new cyclists and reach the cycling share of 30% by 2030 it is of crucial importance to continue improving and expanding the current cycling infrastructure. New cyclists do not have the same level of experience as old cyclists and are not as comfortable driving next to cars. Although suggestions have been forwarded to the city administration, no temporary measures in the field of mobility have been implemented in Graz. This is different compared to other European metropolises such as Berlin, Paris or Vienna where the local governments implemented pop-up cycling lanes or completely closed streets for motorised traffic to promote and encourage more cycling in the city. According to (I3, I6), the local government in Graz did not join the trend due to administrative and legislative barriers which they see as a "missed opportunity" to promote sustainable mobility. Lastly, all three experts were of opinion that the pandemic will not have a long-lasting effect on the perception of future development of transport, and specifically cycling, on the local government. They are all of the opinion, that the recent elections (fall 2021) which resulted in a change of government from conservative to a liberal are going to drive further development of the city and drive investments in bicycling in Graz.

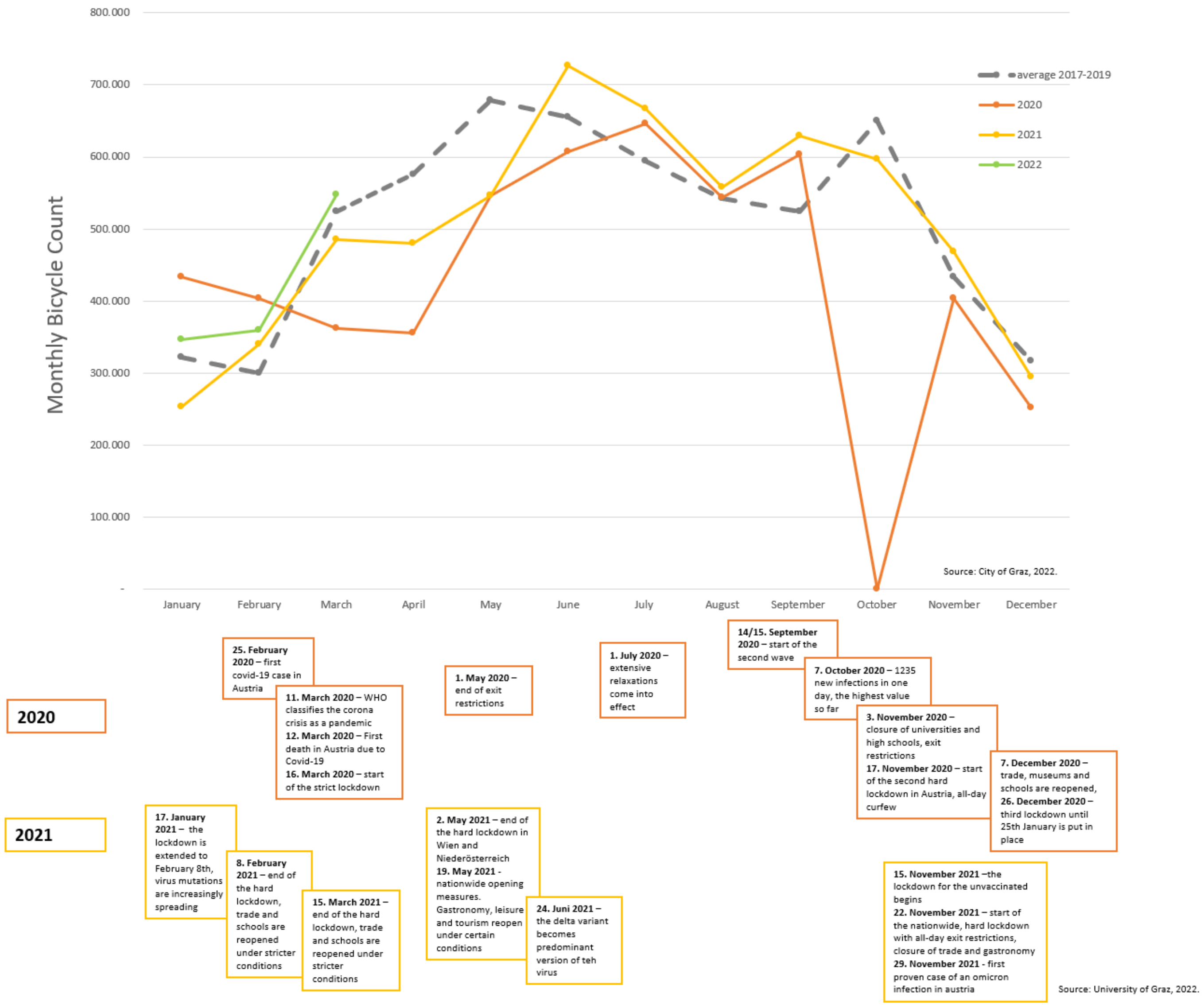


FIGURE 13: MONTHLY CYCLING RATES IN GRAZ BEFORE AND DURING THE COVID-19 PANDEMIC WITH A TIMELINE OF PANDEMIC MEASURES (SOURCE: AUTHOR'S OWN).

5.2 The city of Ljubljana

5.2.1 About

Ljubljana is the capital city of Slovenia with 294,054 habitants as of 2020 (SURS, 2020). The city stretches over an area of 275km^2 (SURS, 2020) and is divided into 17 internal territorial units (European Union, 2015). More than 46% of the urban area is covered by native forests and almost 75% are green areas (European Union, 2015). Ljubljana is also one of the most densely populated areas in Slovenia, with 1.069 inhabitants living per km^2 compared to the national average of 104 inhabitants per km^2 (SURS, 2020). Once the banks of the river Ljubljanica flowing through the city were renovated and multiple bridges constructed, the area became an attractive area for social gathering, pedestrians and cyclists (European Union, 2015).

Due to the city's central position and as the capital city of Slovenia, Ljubljana holds an important economic, cultural, historical, political and educational role. Most economic and educational activities in Slovenia are concentrated in the city of Ljubljana. The city became an important educational area and student-friendly city as the largest university in Slovenia – the University of Ljubljana - with 23 faculties in addition to 18 other private higher education institutions, 3 academies and 401 research organisations are located in Ljubljana (MOL, n.d.-c). There are approximately 41,250 young people studying in the city out of which a large share comes from other regions in Slovenia (MOL, n.d.-c). According to Gojčič (2019), 28,000 students from other regions migrate to the capital to pursue higher education. The city of Ljubljana is also an important economic hub with 44,341 registered companies, 220,851 economically active population and 13,495 individuals reported to be self-employed. This implies that Ljubljana offers jobs to more than a quarter of all economically active individuals in Slovenia[13] (SURS, 2020). Due to this centralisation of jobs and activities, there are more than 120,000 people commuting to the urban area for work daily (Gojčič, 2019, p. 6). The city of Ljubljana also lies at the intersection of the 5th and 10th TEN corridors and in the proximity of only the national airport which additionally increases its geostrategic importance (RRA LUR, 2010). However, the daily commuting of a large share of the working population in Ljubljana puts additional pressure on the transport network and contributes to congestion (Gojčič, 2019, p. 6).

[13] In Slovenia, there were 794,623 individuals economically active as of 2020 compared to 220,851 in Ljubljana, or 27.8 % of the active population in Slovenia (SURS, 2020).

5.2.2 Development of the city of Ljubljana

In 1991, Slovenia split from the former Yugoslavia and joined the European Union in 2004. Since then, the city focused on the development practices contributing to Ljubljana becoming a more liveable urban area, following the global urban sustainable development trends and integrating the recommendations made by the EU that helped transform the city of Ljubljana 'from a socialist into a sustainable city' (Svirčić Gotovac & Kerbler, 2019). In 2002, the city introduced the *Sustainable Development of the city of Ljubljana Strategy* (EC, 2016). Since 2006, more than 1,600 projects were implemented and contributed to a higher quality of life in the city (European Union, 2015). The city administration introduced the *Ljubljana 2025 vision* which was adopted in 2007 and marked the start of the new area (Svirčić Gotovac & Kerbler, 2019; Kotler, 2019). The plan followed three development principles (a) becoming an ideal city for living, working, and recreation, (b) becoming a sustainable city where the natural and urban environment is preserved and (c) becoming a competitive city in the EU (Svirčić Gotovac & Kerbler, 2019; Koželj, 2009). The principles have been integrated into twenty-two projects where one of the goals was also to make the cycling network three times larger and to close the city centre for motorized transport (Koželj, 2009). In 2007, the ecological zone was established when the city centre of Ljubljana was closed to all motorized traffic and 100,000m^2 where usually 60,000 vehicles drove on a daily basis (Kotler, 2019) was allocated to pedestrians and cyclists (European Union, 2015).

The city of Ljubljana has been a CIVITAS member since 2003 and joined the CIVITAS ELAN project in 2008. Through CIVITAS ELAN project, 17 measures focusing on the transport in the city were implemented(Kotler, 2019). The aim was to reduce the motorized transport in the city, increase the share of active modes of transport and the use of public transport (Kotler, 2019). In parallel to the CIVITAS ELAN project, the project document *Public transport in the Ljubljana Urban Region* (2010) has been published and provided the foundation for the development of sustainable mobility by 2027 (RRA LUR, 2010). The most important projects to attract more public transport use, cycling and walking were to close the city centre to traffic, introduce the Urbana city card, provide high-quality public transport routes, build new P&R schemes, launch new bus connections with neighbouring municipalities, introduce a comprehensive cycling strategy and city bike scheme, among others (RRA LUR, 2010, p. 5-6). Some of the other measures implemented as part of the CIVITAS ELAN project were the replacement of the old fleet of buses with 25 lower emission buses, the introduction of the Urbana e-ticketing system, presenting the cycling strategy in 2010 and the introduction of a BicikeLJ cycling scheme in 2011 (Kotler, 2019).

In 2012, the city of Ljubljana adopted a Traffic Policy consistent with the SUMP guidelines. One of the main objectives was to shift the modal share of 67% private cars, 33% public transport, 20% walking and cycling to reach the modal split of one-third of walking and cycling, one-third of public transport use and one-third of mortised vehicles (see **Figure 14**) (Alexe, 2017).

In 2015, RRA LUR also published the *Regional Development Programme 2014-2020* which was a fundamental programme for the development at the regional level (RRA LUR, 2015). Within the programme, sustainable mobility focused on the promotion of public transport use and non-motorised modes of transport (RRA LUR, 2015). *Environmental Action Programme 2014-2020* was published in 2014 and outlined the strategic goals to protect the environment in addition to presenting the long-term vision for the city where one of the goals was to pursue sustainable mobility principles and accessibility over the flowthrough of the cars (MOL, 2014). In 2015, the Slovenska street was redesigned in such a way that only traffic for the city buses, pedestrians and cyclists is allowed there (European Union, 2015). This change contributed to the reduction of black carbon concentrations by 58% (European Union, 2015).

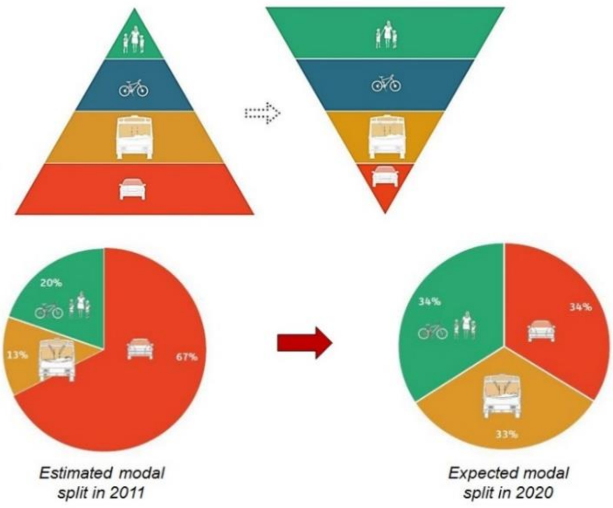


FIGURE 14: THE AMBITIOUS GOAL TO SHIFT THE MODAL SPLIT OF DIFFERENT TRANSPORTATION MODES BY 2020 (SOURCE: ALEXE, 2017).

In 2017, the city of Ljubljana published a *Comprehensive Transport Strategy for the city of Ljubljana* to verify and upgrade the objectives of transport policy, and set new goals and targets until the year 2027 (Milovanovič, 2017). According to the strategy, the goal of 33% of trips made by car and 33% of trips made by active modes of transport has been achieved, while the use of public transport use lags behind the set goals (Milovanovič, 2017). Therefore, the newly set target aims to maintain the 1/3 share of motorised vehicles, and 2/3 of sustainable modes of transport (see **Figure 16**) (Milovanovič, 2017). Specifically, the city aims to increase the share of trips done by bicycle or public transport (Milovanovič, 2017, p. 19).

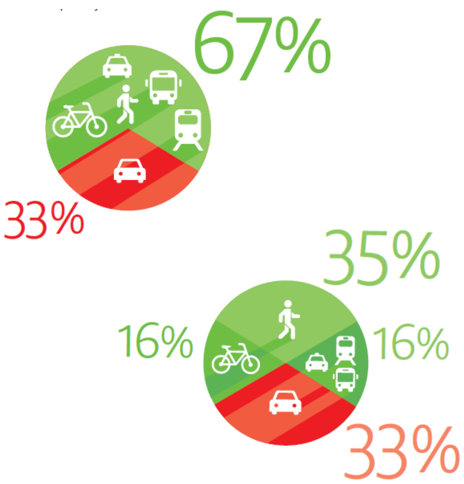


FIGURE 15: THE GOAL OF THE COMPREHENSIVE TRANSPORT STRATEGY IS TO ENSURE 66% OF TRIPS ARE MADE BY SUSTAINABLE MODES OF TRANSPORT UNTIL 2027 (SOURCE: MILOVANOVIČ, 2017, P. 18).

In 2018, a *Sustainable Urban Mobility Plan for the Ljubljana Urban Region* was prepared by RRA LUR (2019) in collaboration with 26 municipalities and stakeholders through which the efforts of the city to improve its sustainability are to be improved and extended to the entire region. The strategy focuses on strategic goals along the five pillars of sustainable mobility: walking and cycling, public transport, freight transport and logistics, and sustainable mobility planning. Three main strategic objectives have been identified in relation to bicycling: (a) improving the cycling infrastructure and increasing the interconnectedness between places, (b) increasing the share of journeys made by bicycle, and (c) providing the universal accessibility for all groups of people (e.g., elderly, sensory impaired, children, people with wheelchairs) (Gojčič, 2019, p. 37). The role of e-bikes has been recognised to improve interregional mobility as electric bicycles allow the users to travel further and are appropriate for the elderly (Gojčič, 2019).

As mentioned by Svirčić Gotovac & Kerbler (2019, p. 13), planning for the long term and prioritizing sustainable development practices over attractive short-term political and economic decisions helped transform the city from 'socialist to sustainable'. Improving the quality of life for the citizens of Ljubljana has been one of the main motivations for the development. In turn, such development created new opportunities for the development of the cultural and economic role of the city centre and along the river (e.g., the opening of multiple cafés, restaurants, and hotels) (Svirčić Gotovac & Kerbler, 2019). It also increased the worldwide visibility of the city and made it attractive for foreign investors and visitors. Over the years, the city of Ljubljana has won multiple awards. It has received two European Mobility Week Awards (2003 and 2013), received a Max Fabiani national award (2012) for its Urban Master Plan and special achievements in spatial planning (EC, 2016), made it to the Sustainable Destinations Global Top 100 list (2014), received the Bronze Access City Award (2015) in recognition of the efforts made to the accessibility of public areas, public transport, provision of information and availability of services for the people with disabilities (European Union, 2015), received a Tourism for Tommorrow Award (2015) by the World Travel and Tourism Council in recognition of the most sustainable tourism destinations (European Union, 2015), became the EU green capital (2016)[14], received the European Capital of Smart Tourism Award (2019), WTM Responsible Tourism Award, Global Top 100 Sustainable Destinations, European Capital of Smart Tourism Award.

The pursuit (i.e., driver of the development) of such prestigious awards that appraised the sustainable development efforts of the city administration in turn substantially increased its worldwide recognition. One of the most recent drivers of development has been the announcement of the city of Ljubljana being the host city of the *VELO-CITY 2022 Conference* taking place in June 2022. The conference is a yearly flagship event organised by the European Cyclists' Federation in collaboration with the cities hosting the conference. Every year, the conference is organised in a different city that contributes to the promotion of cycling and attracts a large group of people working in the field of policy, promotion and provision of cycling, active mobility, and sustainable urban development (Velo-City, 2022). As mentioned by most of the interviewees (I1, I2, I4, I8) rather than the impacts of the COVID-19 pandemic it was hosting the VELO Conference that drove the development of the sustainable and cycling-related development policies leading up to the conference. Recently, Ljubljana has also been selected as one of the '100 climate-neutral and smart cities by 2030', which is likely to drive further development and promotion of sustainable modes of transport.

5.2.3 Mobility and transport in Ljubljana

The multimodal transport system in Ljubljana comprises of a bus fleet managed by a public company *Ljubljanski Potniški Promet* (LPP), shared cycling infrastructure BicikeLJ operated by *Europlakat d.o.o.*, on-demand transport service *Kavalir*, regional train, and electric train URBAN for sightseeing. In Ljubljana, LPP operates 28 bus city lines that add up to more than 391km in length, and 217 buses out of which almost one-third is fuelled by methane (LPP, 2022b). The bus network covers appx. 97% of the urban area (i.e., households in Ljubljana are less than 500 m away from the first bus stop) (LPP, 2022b). In 2018, almost 37 million journeys were made by public transport (MOL, n.d.-c). LPP also provides complimentary inclusive service *Kavalir* which

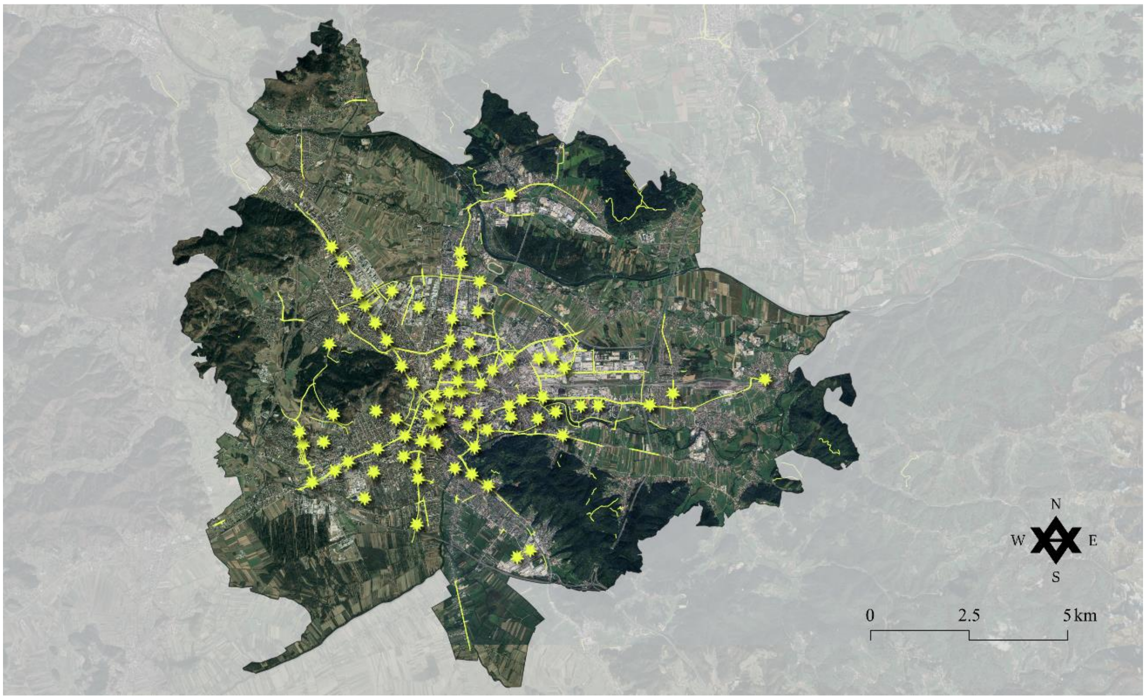
[14] In 2016, Ljubljana became the 8th Green Capital of Europe due to the sustainable changes in the urban environment of the past years and for "achieving high environmental standards, setting ambitious goals for further sustainable development and serving as a good role model to other cities" (European Union, 2015, p. 13).

provides a cost-free ride for up to five passengers to those who have difficulties walking and accessing the final destination in the pedestrian zone of Ljubljana (LPP, 2022a). In addition, it also operates the urban electric train URBAN taking visitors of Ljubljana around the circular route with ten stops of the city's biggest attractions and nine P+R parking spaces (LPP, 2022a). The citizens of Ljubljana get to pay for those services by using a smart city card *Urbana* which also allows for simple transfer from one bus to another for the same fee within the 90-minute period. The card is also used for other services such as the rental of bicycles provided by BicikeLJ, Ljubljana city library services, paying the parking fees and the P+R services, and a cable car ride to the Ljubljana Castle (LPP, 2022a), among others. As mentioned, through years the city centre was closed for motorised traffic and space for pedestrians and cyclists increased. For this reason, getting around in the city centre is fastest by bicycle. In the region, there were reported to be 836 taxi licenses issued, 186,421 registered motor vehicles and 150,439 registered private vehicles as of 2018 (MOL, n.d.-c). Despite the efforts of the city to increase the use of public transport and encourage active modes of transport, there are 517 cars registered per 1,000 inhabitants which is relatively high when comparing it to the national average of 555 cars per 1,000 inhabitants (SURS, 2020).

5.2.4 Cycling in Ljubljana

Past changes to the built environment mentioned in **Chapter 5.2.2** also contributed to better cycling conditions in the city. In Ljubljana there are appx. 300km of managed cycling routes, out of which more than 200km are connected and 70 one-way streets where cyclists are allowed to move in both directions (MOL, 2020). Cyclists are also allowed to drive in pedestrian zones; however, their speed is restricted as they should not pose a threat to pedestrians (MOL, 2020). There are more than 10,000 bicycle stands (i.e., stands where cyclists can safely lock their bicycles) (MOL, 2020). Based on different sources, the city of Ljubljana has estimated that the share of cycling in Ljubljana has been between 16% – 17% in 2019 (MOL, 2020). According to the Copenhagenize index, which ranked Ljubljana 14th on the list of Top 20 cycling-friendly cities, this share has been 13% in 2019 (Copenhagenizeindex, 2019).

The shared-cycling infrastructure in Ljubljana was established in cooperation between the public company *Europlakat d.o.o.* and the local government of the city of Ljubljana. In return for the financing and operating of BicikeLJ scheme, the city of Ljubljana allowed *Europlakat d.o.o.* to set up display cases, billboards and other types of advertising infrastructure around the city (MOL, n.d.-d). In return, a service almost free of charge for the user (yearly subscription fee costs €3,00 and the bicycle can be used for free for the first 60 minutes) has been provided in the city since 2011 (MOL, n.d.-d). Today *Europlakat d.o.o.* operates a scheme which comprises 83 stations and 820 bicycles (see **Picture 8**) (MOL, n.d.-d). Since its inauguration, a total of 196,399 individuals registered to use the system out of which 40,088 were active users in 2019 and 6.95 million bicycle rentals have been made by December 2019 (MOL, 2020).



PICTURE 7: A MAP OF ALL BICIKE(LJ) STATIONS AND CYCLING LANES (SOURCE: AUTHOR'S OWN. DATA SOURCE: EUROPLAKAT, 2022).

In addition to BicikeLJ, foreign visitors can also rent a "Ljubljana bicycle" from the Tourist Information Centre in the centre of Ljubljana and explore the city through one of the four themed cycling trails (MOL, 2020). In 2019, there were 2,108 borrows for 2 hours, 729 borrows for 4 hours and 223 borrows for the entire day in addition to 633 individuals taking part in the guided cycling tour (MOL, 2020).

As a result of the CIVITAS ELAN initiative, the association LKM created an interactive map of cycling-related infrastructure in Ljubljana which contains data on the cycling network around the city, roads where cycling is not allowed, thematic cycling routes in addition to bicycle stands, bicycle services, and bicycle rental shops, among others. On the map, citizens were also able to mark "traps for the cyclists" (i.e., sections of the city where current infrastructure poses a threat to the cyclist) which informs the authorities in the city that the area needs to be fixed (MOL, n.d.-b). To additionally promote cycling, the city has turned several degraded areas into recreational parks for cyclists but also other recreational tools (e.g., scooters, rollerblades, skateboards) (MOL, 2020). Today, there are eight such recreational parks in Ljubljana (MOL, 2020).

5.2.5 COVID-19 Impacts on cycling

In the city of Ljubljana two private companies collect the data on cycling:

- company *Europlakat d.o.o.* provides BicikeLJ services and collects the monthly usage rates of the bicycles of their shared-cycling scheme (i.e., the number of times the bicycles have been borrowed from the system in a month);
- the public company *Javno podjetje Ljubljanska parkirišča in tržnice, d.o.o.* (hereinafter: JP LPT d.o.o.) is owned by the city of Ljubljana and collects data on cycling rates from more than five counters positioned in different places around Ljubjana.

The company *Europakat d.o.o.* provided the data on the number of times bicycles have been borrowed from the BicikeLJ scheme in a month for the period 2017-2020 (see **Table 18**).

	2017	2018	2019	2020	2021	2022
januar	23,672	50,871	51,955	68,439	23,696	62,970
februar	31,998	31,192	59,447	77,031	37,052	76,811
marec	75,723	52,542	98,740	44,252	69,415	128,810
april	78,519	100,872	100,809	24,866	56,253	
maj	103,898	125,486	90,870	55,353	86,795	
junij	106,731	123,219	125,323	88,711	124,174	
julij	89,348	104,822	105,259	95,743	108,036	
avgust	89,326	108,264	110,675	85,349	113,056	
september	68,470	111,546	110,700	98,238	124,246	
oktober	99,605	130,597	137,799	72,211	139,050	
november	59,635	90,076	82,567	40,498	99,403	
december	37,006	64,657	65,594	26,426	65,893	

TABLE 18: MONTHLY BICYCLE USAGE RATES OF THE BICIKELJ SCHEME (SOURCE: EUROPLAKAT, 2017-2022).

The most important COVID-19 measures affecting life in Slovenia and the city of Ljubljana have been retrieved from an online platform *COVID-19 Sledilnik* (https://covid-19.sledilnik.org/sl/stats) where the data and information from official Slovenian institutions (e.g., National Institute of Public Health, Ministries of the Republic of Slovenia) related to the COVID-19 pandemic are collected (see **Figure 16**).

As can be seen from **Figure 16**, the usage rates of the BicikeLJ system significantly decreased in March 2020 at the start of the COVID-19 pandemic. On March 16th the government of Slovenia temporarily banned all public passenger transport and was one of the rare countries that decided to do so (Brezina et al., 2021). The rates decreased by 42.6% from 77,031 bicycle borrows in February 2020 to 44,252 bicycle borrows in March 2020 and by 67.7% or to 24,866 bicycle borrows in April 2020.

However, comparing March 2020 with the pre-pandemic period 2017-2019 when the bicycles have been borrowed on average 75,668 times, the usage rates were 41.5% lower (see **Table 19**). The usage rates further decreased in April 2020 when they were in total 73.4% lower compared to April 2017-2019 when the bicycles have been borrowed 93,400 times. This was a clear consequence of the strict governmental measures to halt the spread of the virus and the overall fear of catching the virus. At the end of April 2020, when the government released the lockdown measures allowing for the movement among different municipalities, the usage rates of BicikeLJ started to slowly recover. In the summer months (June, July, and August) the usage rates were still below the pre-pandemic rates by 25.1% in June 2020, by 4.1% in July 2020, and by 16.9% in August 2020 compared to the same months in 2017-2019. This could be attributed to the ongoing pandemic, increased number of people working from home and the summer holiday period. According to (I8) from *Europlakat d.o.o.* the usage rates usually significantly increase in October when students start a new student year. This has, however, not been the case for October 2020 as universities continued with distance learning. In the fall of 2020, the second wave of the COVID-19 infections started and multiple governmental measures have been reintroduced. The bicycle usage rates further decreased and were lower by 41.1% in October 2020, by 47.7% in November 2020 and by 52.6% in December 2020.

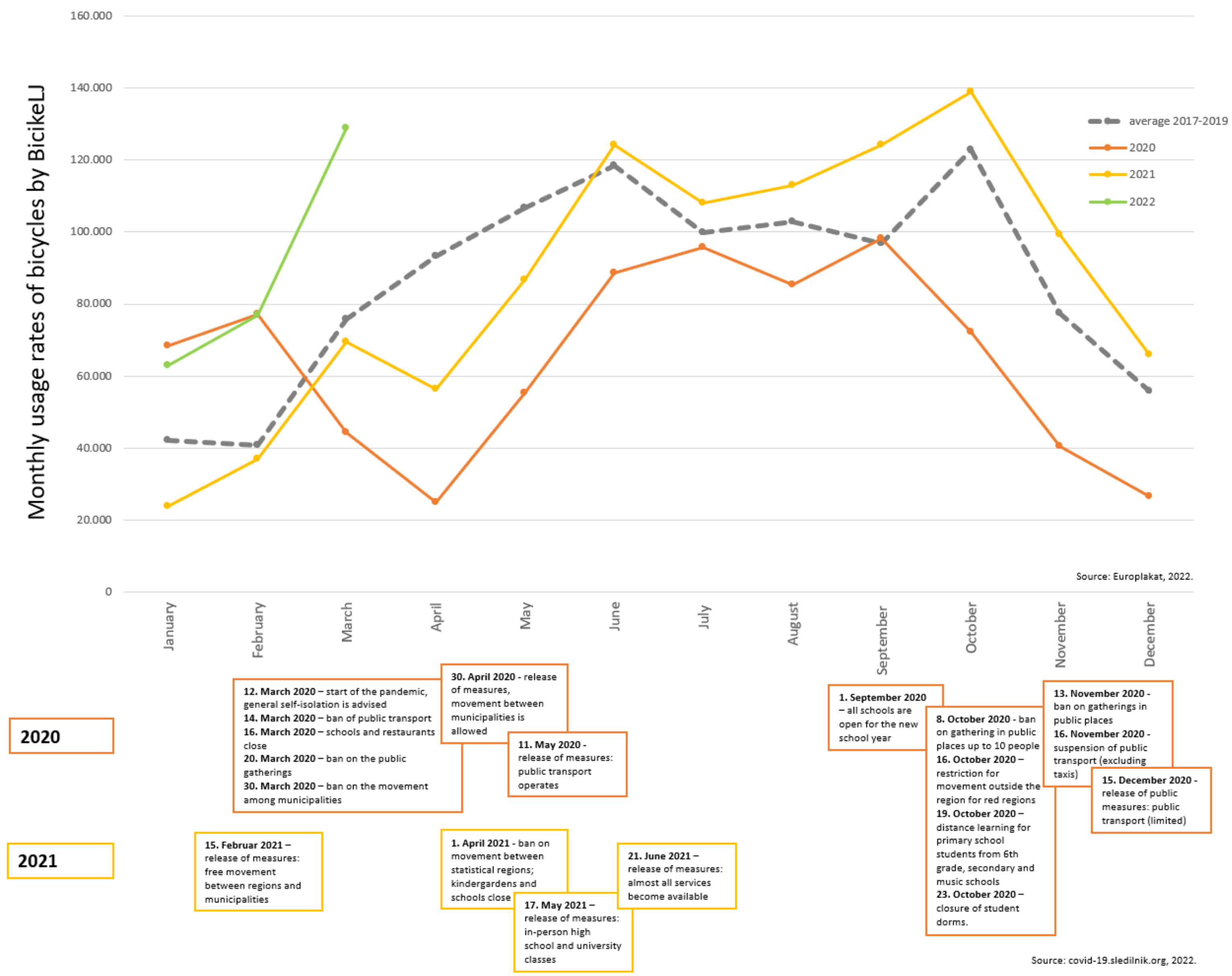


FIGURE 16: MONTHLY USAGE RATES OF THE BICYCLES BY BICIKELJ BEFORE AND DURING THE PANDEMIC WITH A TIMELINE OF PANDEMIC MEASURES (SOURCE: AUTHOR'S OWN).

In January 2021, the bicycles have been borrowed 23,696 times which was 43.8% lower compared to the average of 42,166 borrows in January 2017-2019. However, from February onwards the usage rates started to increase again. In February 2021, the bicycles have been borrowed 37,052 times while they have been borrowed on average 40,879 times during the month of February from 2017-2019, and 69,415 times in March 2021 compared to the average of 75,668 in the month of March from 2017-2019, which is only 9.4% (February 2021) and 8.3% (March 2021) below the pre-pandemic levels. In April 2021, the rates significantly decreased due to the start of the third COVID-19 wave and another set of strict lockdown measures prohibiting any movement outside of the region of permanent residence. In April 2021, the bicycles have been borrowed 56,253 times which is 39.8% lower compared to the average of 93,400 average in 2017-2019. However, the usage rates during the third wave in April 2021 were noticeably lower compared to the 73.4% drop in bicycle usage rates in April 2020. On May 17, 2021, the government allowed the students to switch to in-person classes which could have contributed to the increase in the bicycle usage rates in the month of May and especially in June 2021. Compared to the pre-pandemic period 2017-2019 the usage rates have been higher by 4.9% in June 2021, by 8.2% in July 2021, by 10.0% in August 2021 and by 28.4% in September 2021. In October 2021, the usage rates reached a new record of 139,050 borrows compared to the average of 122,667 in October 2017-2019 and were higher by 13.4%. This was also the highest number of monthly borrows since 2017 (see **Table 18**). In November 2021, the usage rates started to decrease again but remained above the pre-pandemic levels by 28.4 % in November 2021 compared to November 2017-2019, and by 18.2 % in December 2021 compared to December 2017-2019.

The most positive results are to be observed at the beginning of the year 2022. In January 2020 (i.e., before the start of the pandemic) the bicycles have been borrowed 68,439 times compared to the average of 42,166 in the months of January 2017-2019. In January 2022, the bicycles have been borrowed 62,970 times which is still 8.0% behind the usage rates in January 2020. However, in February 2022 the usage rates already matched the increasing trend that has been observed right before the start of the pandemic and finally overcame the pre-pandemic usage rates in February by 87.9% and in March 2022 by 70.2%.

Mr Berčan from *Europlakat d.o.o.* (I8) mentioned that in the years during the pandemic two additional BicikeLJ stations have been added to the scheme in addition to upgrading the technology underlying the system. Furthermore, other factors could have also contributed to the higher borrows of bicycles (e.g., weather). However, as has been mentioned (I2, I4) as well as experts from Graz (I3, I5, I6), the pandemic also served as an "accelerator" for new habits. As multiple interviewees mentioned, people in both cities started to cycle during the pandemic as a way to exercise which could have contributed to the change of habits post-pandemic.

	2020	2021	2022
januar	62.3%	-43.8%	49.3%
februar	88.4%	-9.4%	87.9%
marec	-41.5%	-8.3%	70.2%
april	-73.4%	-39.8%	
maj	-48.1%	-18.7%	
junij	-25.1%	4.9%	
julij	-4.1%	8.2%	
avgust	-16.9%	10.0%	
september	1.4%	28.2%	
oktober	-41.1%	13.4%	
november	-47.7%	28.4%	
december	-52.6%	18.2%	

TABLE 19: COMPARISON OF MONTHLY USAGE RATES (%) OF BICICYLES BY BICIKELJ IN 2020, 2021, AND 2022 WITH THE PRE-PANDEMIC PERIOD 2017-2019.

In Ljubljana, the data on cycling rates is collected by *JP LPT d.o.o.* and is not publicly available. The company *JP LPT d.o.o.* provided the data in text format (.txt) which was collected daily for more than five bicycle counters located in different locations in Ljubljana. Although more counting stations have been recording the cycling rates in Ljubljana since 2020, the analysis only focused on the cycling rates collected by the five stations collecting data since 2017. Daily cycling rates for all stations have been added together to get monthly cycling rates for each year and are available in **Table 20**.

	2017	2018	2019	2020	2021	2022
January	68,267	113,692	103,578	125,548	77,390	49,586
February	87,544	58,405	108,389	148,424	109,980	51,748
March	199,694	96,736	184,837	118,325	182,116	81,763
April	180,119	190,426	179,105	133,605	143,996	
May	251,784	227,074	170,902	215,133	201,956	
June	271,510	237,222	267,367	254,214	293,841	
July	233,775	220,479	241,930	242,392	258,882	
August	241,622	185,116	220,760	224,383	253,950	
September	170,145	233,552	197,832	285,473	287,197	
October	229,458	229,707	232,825	198,235	195,268	
November	134,679	154,774	142,810	142,391	156,298	
December	79,792	120,009	130,471	81,102	67,051	

TABLE 20: MONTHLY CYCLING RATES IN THE CITY OF LJUBLJANA (SOURCE: JP LPT, 2017–2022).

This data has been used to compare the pre-pandemic cycling rates (i.e., average monthly cycling rates from 2017-2019) depicted with a grey dotted line (see **Figure 17**) with cycling rates during the COVID-19 pandemic in 2020, 2021 and 2022. The timeline of COVID-19 related measures is available in **Figure 18.**

First, the data from JP LPT d.o.o. was compared with the results obtained through the analysis of BicikeLJ usage rates. The results are depicted in four graphs for each period (see **Figure 17**) and picture a very similar trend over time.

As can be seen from **Figure 17**, the cycling rates in Ljubljana also significantly decreased when the COVID-19 pandemic started. The rates decreased by 20.3% from 148,424 cyclists in February 2020 to 118,325 cyclists in March 2020. However, the cycling rates started to increase again in April 2020 when 133,605 cyclists were recorded which is 10.0% lower than cycling rates in February 2020. This is interesting because the usage rates of BicikeLJ continued to decrease also during the month of April 2020 (see **Figure 17, (B)**). Comparing the two it can be argued that people were probably still reluctant to go out and use BicikeLJ bicycles due to the fear of disease transmission while many people used their personal bikes either to get around or for recreation. In May 2020, there were 215,133 cyclists recorded which lagged behind the pre-pandemic rates by 6.8% in the month of May 2017-2019 when 216,587 cyclists have been recorded. In the months of July, August and September the cycling rates were even higher compared to pre-pandemic rates by 4.5% in July 2020, by 4.0% in August 2020 and by 42.4% in September 2020 (see **Table 21**). From October 2020 onwards the cycling rates continued to decrease and stayed slightly below the pre-pandemic levels. One of the pandemic measures implemented in October 2020 was also the closure of all student dorms forcing the students to leave Ljubljana and migrate back home to their permanent residencies (ŠDL, 2020). Due to this and an online teaching mode at the universities, the spike in cycling rates typically recorded in the month of October has not been recorded in 2020. In fall of 2020, the second COVID-19 wave started and cycling rates continued to decrease until the end of the year.

In January 2021, there were 77,390 cyclists recorded which was 18.7% lower compared to the average of 95,179 cyclists in the months of January in 2017-2019. However, the cycling rates increased above the pre-pandemic levels in February 2021 by 29.7% and by 13.5% in March 2021 compared to the same months in 2017-2019. Similarly to the usage rates of BicikeLJ bicycles, the cycling rates also decreased again in April 2021, due to the start of the third COVID-19 wave and another set of lockdown measures. There were 143,996 cyclists recorded in April 2021 which is 22.6% lower than the average of 183,217 cyclists recorded in the month of April 2017-2019. As mentioned, in the month of May 2021 the government started to release COVID-19 restrictions which also resulted in an increase in cycling rates.

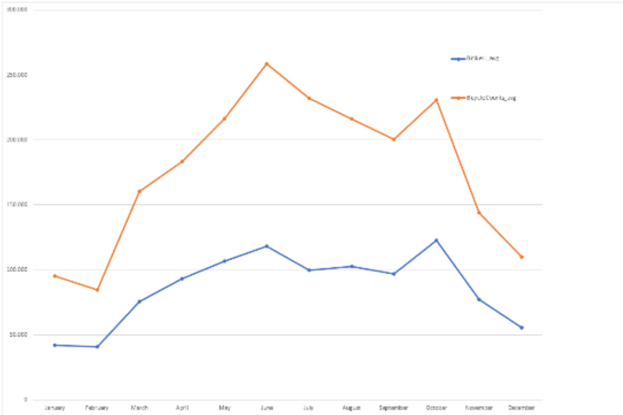


FIGURE 17 (A): AVERAGE CYCLING RATES FROM 2017-2019

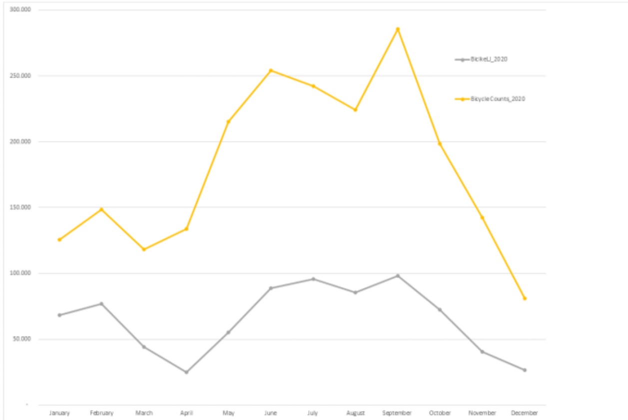


FIGURE 17 (B): CYCLING RATES 2020

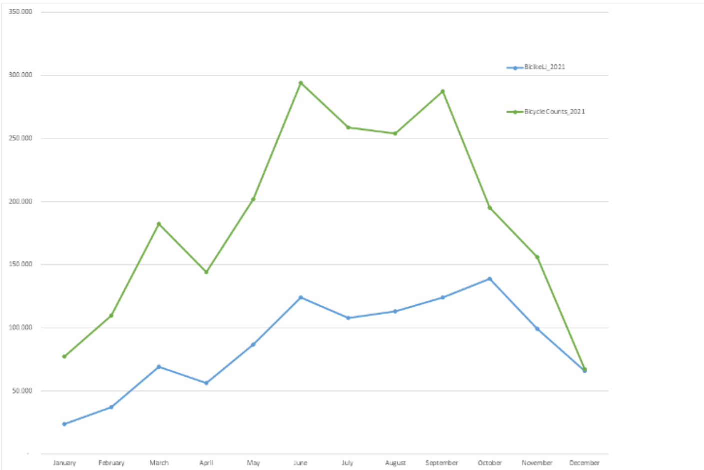


FIGURE 17 (C): CYCLING RATES 2021

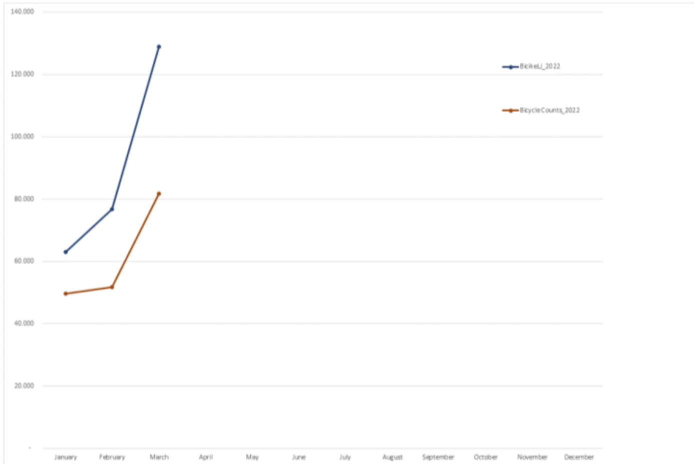


FIGURE 17 (D): CYCLING RATES 2022

FIGURE 17: COMPARISON OF DATA ON CYCLING RATES PROVIDED BY EUROPLAKAT AND JP LPT (2017–2022).

In the month of June 2021, the number of cyclists was 13.6% higher compared to the pre-pandemic period 2017-2019, with 293,481 cyclists in June 2021 compared to 258,061 average cyclists in June 2017-2019 (see **Table 21**). During the summer months (July, August 2021) the cycling rates slightly decreased but remained above the pre-pandemic levels by 11.6% in July 2021 and 17.7% in August 2021, and spiked in September 2021 when the cycling rates were higher by 43.2% compared to August 2017-2019. From October 2021 onwards, the cycling rates continued to decrease until the end of the year 2021.

Based on the number of cyclists recorded by the counters in the first three months of 2022 (January, February, and March) the cycling rates have been increasing (see **Figure 18**). However, comparing the cycling rates in 2022 with the pre-pandemic and even pandemic months, the rates are lower by 47.9% in January 2022, by 39.0% in February 2022 and by 49.0% in March 2020 (see **Table 21**). Especially when considering the increased usage rates of BicikeLJ during the same period in 2022. Although the employee of JP LPT d.o.o. was not able to explain why this could be the case, the reason could be construction works and partial or full closure of the streets with the cycling counters during this period.

	2020	**2021**	**2022**
January	31.9%	-18.7%	-47.9%
February	75.1%	29.7%	-39.0%
March	-26.2%	13.5%	-49.0%
April	-27.1%	-21.4%	
May	-0.7%	-6.8%	
June	-1.7%	13.6%	
July	4.5%	11.6%	
August	4.0%	17.7%	
September	42.4%	43.2%	

TABLE 21: COMPARISON OF MONTHLY CYCLING RATES (%) IN 2020, 2021, AND 2022 WITH THE PRE-PANDEMIC PERIOD 2017-2019.

As mentioned in the previous sections, the cycling rates started to recover after the initial shock. According to (I1, I2, I4), there was an increase in cycling specifically for recreational purposes. The estimate of (I4) is that before the pandemic the share of cycling was 13% which is currently at about 15%. (I8) is of opinion that the pandemic probably affected the perspective of people when they were unable to use any other mode of transport which resulted in an overall increase in BicikeLJ usage rates in 2022. He, however, also mentioned that this is not necessarily a consequence of the pandemic as the usage rates of BicikeLJ were already increasing before the start of the pandemic. (I1, I4) also mentioned that the delivery services on bicycles (e.g., Glovo) increased during the pandemic. This, however, also caused some conflicts between cyclists delivering food and other members of transport as the former did not respect the traffic signage. (I4) also mentioned, that some private companies decided to build additional bicycle stands for their employees to be able to cycle to work. As the national government announced a ban on all public transport services (also taxi services), the bicycle was the only mode of transport available at the time. Because the shared cycling scheme BicikeLJ continued to offer its services, those who otherwise do not own any other vehicles were also able to get around. (I8) specifically mentioned an example of a healthcare worker reaching out to the BicikeLJ call center to ask about the fastest way to register for the scheme as she was unable to get to her work in one of Ljubljana's hospitals.

Just like the city of Graz, the city of Ljubljana also did not follow the trend of temporary cycling infrastructure. Although the requests from the cyclists and civil organisations for such measures did reach the city administration, they decided not to implement them as those measures were very unlikely to stick after the pandemic, due to complex legislation and overall lack of resources. In addition (I1) mentioned, that the cyclists in Ljubljana are already allowed to cycle in most areas of the city and were also able to drive on the empty streets for motorised transport (I1). In the opinion of (I2, I4), this was a missed opportunity to promote cycling and sustainable mobility.

Lastly, all four (I1, I2, I4, I8) experts from Ljubljana were of opinion that the pandemic did not have any effect on the perception of future development and local government. On the contrary to Graz where the development is currently driven by the change of government, they all mentioned that the biggest driver of development is currently preparing for the Velo-City Conference which will be hosted by Ljubljana in June 2022. All measures implemented leading up to the conference, were therefore a consequence of previously agreed plans and not the pandemic.

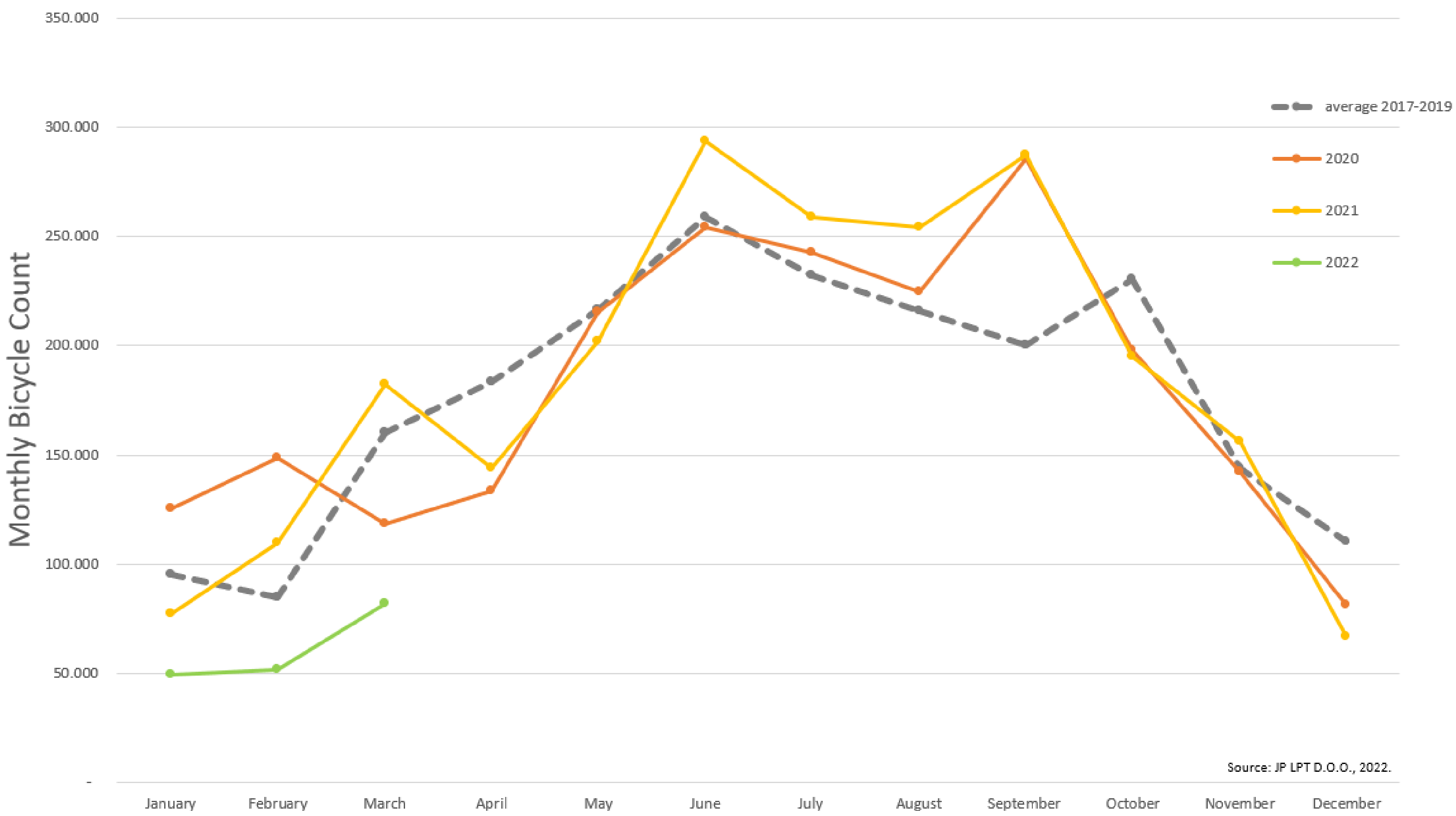


FIGURE 18: MONTHLY CYCLING RATES IN LJUBLJANA BEFORE AND DURING THE COVID-19 PANDEMIC (SOURCE: AUTHOR'S OWN).

5.3 The role of cycling for the sustainability of urban areas

The following section provides the insights from the interviews where the interviewed experts were asked about the role of bicycling for the sustainability of transport in urban areas. The overview of theIR answers is provided in **Table 22**. The three further subchapters provide more details from the interviews. A few selected dimensions were also further researched and secondary data for the two cities provided.

		I1	I2	I3	I4	I5	I6	I8
Environmental	Reduction of CO_2 emissions	X	X	X		X	X	
	Reduction of noise pollution	X	X	X		X	X	
	Reduction of land and natural resources consumpition	X	X	X	X	X	X	
	Reduction of environmental degradation		X	X	X	X		X
Social	Increase in interaction among citizens	X			X		X	
	Increase in accessibility for mobility of all		X	X	X	X	X	X
	Reduction of health issues		X	X	X	X	X	X
	Increase in life quality and functionality of the urban area			X	X	X	X	
	Flexibility and independence		X		X			X
	Ability to meet different needs		X	X		X		
Economic	Lower investments in infrastructure and maintenance	X	X	X	X	X		X
	Increase in economic activities		X	X		X	X	
	Incerase in touristic attractiveness of the city		X			X		
	Reduction of external costs		X	X	X	X	X	

TABLE 22: ASSOCIATIONS OF EXPERTS ON THE ROLE OF BICYCLING FOR THE SUSTAINABILITY OF URBAN AREAS (SOURCE: AUTHOR'S OWN).

5.3.1 Environmental Pillar

During the interviews with different experts, the main suggestions on how bicycling can contribute to the sustainability of urban areas were reduction of CO_2 emissions, reduction of noise pollution, an overall reduction of environmental degradation and lastly the land and resources consumption.

Reduction of noise levels and CO_2 emissions

Cycling has the lowest environmental impact possible and does not emit CO_2 emissions as well as uses the resources in the most efficient way for the given type of trip (I2, I4).

Less consumption of urban space and natural resources

When streets became more congested with traffic and more space was reallocated to road expansion, children stopped playing on the streets and people gathering outdoors which decreased the overall attractiveness and liveability of urban areas (I4). As mentioned by the experts, bicycling can have a positive effect on land consumption in urban areas as its infrastructure requires less built environment and space (I1, I4, I5, I6). Overall, bicycling is also less material and energy-intensive (I1, I4, I5, I6) which has a positive effect on the environment but also on the society and economy (i.e., through lower dependence on fuel imports and sensibility to price hikes). Bicycling helps save space that can be allocated to more green areas, parks, trees and people (I2, I3). As further emphasised by (I3) and (I4) this increases the overall quality of life in cities which become more attractive for people to live and work there. (I6) also emphasised that "in cities, the impact of space usage is very undervalued because we usually just talk about CO_2 emissions. But the use of public space is very important factor to which bicycling positively contributes. For example, electric cars help with the overall reduction of emissions but still consume a large share of urban space. Hence, the problem of urban space consumption remains."

The reduction of noise pollution in Ljubljana

The noise pollution has substantially decreased in Ljubljana in areas where the motorized traffic has been reduced and alternative modes of transport such as cycling, walking and public transport introduced. Research from 2001 on noise pollution in Ljubljana, has uncovered that the centre used to be one of the areas that were the most heavily impacted by the noise pollution due to high levels of motorized traffic (e.g., on Slovenska street) and more frequent social gatherings (Notar et al., 2005). Throughout the year 2001, the noise levels recorded in the city centre were between 65-75 dBA (Notar et al., 2005, p. 35). Also in the years 2002 and 2003, the weekly values of noise pollution were above 65 dBA (Notar et al., 2005, p. 35-37). The noise pollution has been reassessed in the years 2007 and 2014 (see **Figure 19**). The results from **Figure 19** show, that the share of the population exposed to higher levels of noise pollution (above 55 dBA) has significantly decreased. After the city centre has been closed for motorized traffic, the noise levels decreased by 6Dba (MOL, n.d.-a). Based on the data from the European Union (2016; MOL, n.d.-a; Strojin Božič et al., 2014) the share of the population exposed to noise levels exceeding the value of 65 Dba was lower in Ljubljana (14%) compared to the other European contourites (20%). And also the number of people who were exposed to overnight noise levels above 55 Dba was lower in Ljubljana (14%) compared to the rest of Europe (30%) (Strojin Božič et al., 2014, p. 94; European Union, 2016).

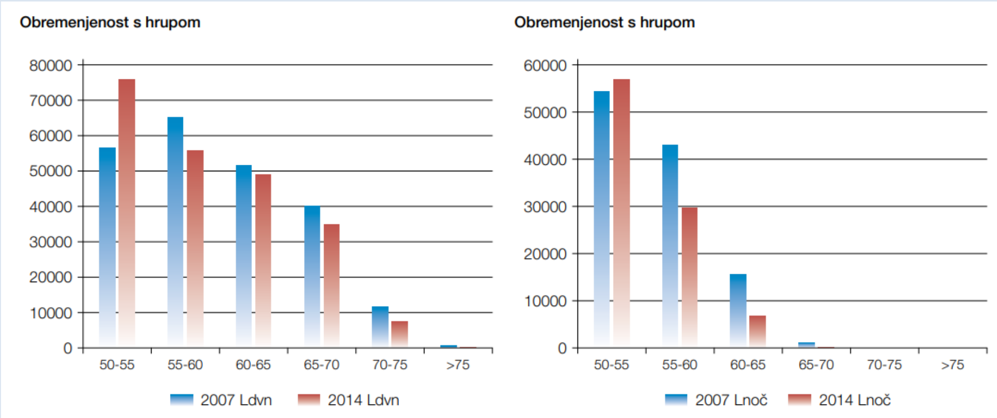


FIGURE 19: COMPARISON OF NOISE POLLUTION LEVELS FOR YEARS 2007 (BLUE) AND 2014 (RED) DURING THE DAY (LEFT FIGURE) AND DURING THE NIGHT (RIGHT FIGURE) (SOURCE: ČERMELJ ET AL., 2018, P. 111).

The reduction of air pollution in Ljubljana

More cycling and less motorised transport contribute to fewer emitted emissions and cleaner air. According to Strojin Božič et al. (2014), the quality of air has been traced for the past 45 years. The trends show a decreasing levels of nitrogen oxide (NO_X) and fine particles (PM10), that the sulphur dioxide air pollution has been eliminated and that ozone and benzene pollution remain within permitted limits (Čermelj et al., 2018, p. 26). After the city centre has been closed to the motorised traffic, the city administration continued to completely renovate one of the main streets bypassing the city centre – 'Slovenska street'. The 400-metre-long avenue was lined with 63 ash trees and turned into an area where pedestrians, cyclists and city buses "live together". Since then, the concentrations of black carbon have decreased by 58% (European Union, 2015). The overall trend in the reduction of emissions in Ljubljana can also be observed in **Figure 20** which reports the number of emissions (kg) per inhabitant between 1995-2015. It is of course important to mention that this was achieved in a combination with other measures implemented in the city of Ljubljana such as stricter requirements on the combustion of motorised vehicles meeting higher environmental standards or due to the change in the structure of fuel use (i.e., replacement of fuels used for heating with natural gas) (Čermelj et al., 2018).

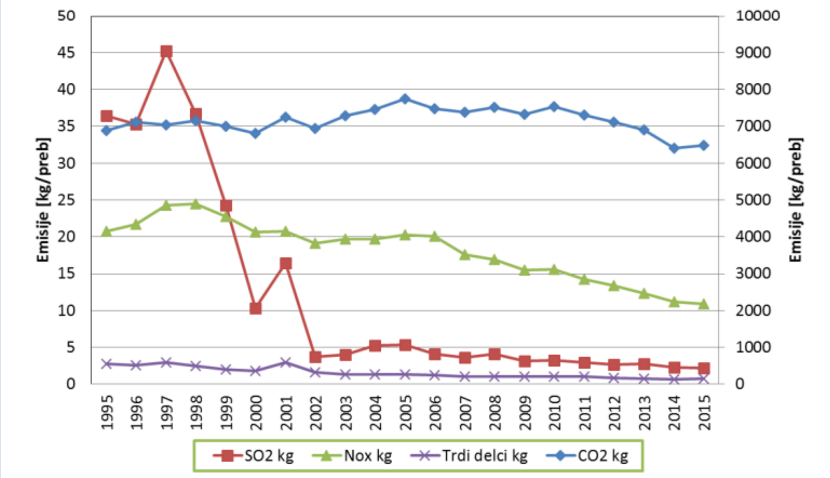


FIGURE 20: EMISSIONS PER EACH CITIZEN (KG/INHABITANT) IN LJUBLJANA FOR THE PERIOD BETWEEN 1995-2015 (SOURCE: MOL, N.D.-E, P. 53).

5.3.2 Social Pillar

The interviewed experts mentioned six different aspects of more bicycling for the social aspect of sustainability of urban areas: increase in interaction among citizens, increase in accessibility for the mobility of all, reduction of different health issues, increase in the overall life quality and functionality of the urban areas, flexibility and independence of citizens and the ability to meet different needs.

Increase in interaction among citizens

Some stakeholders mentioned that more cycling in cities also increases the interaction among citizens (I1, I4, I6). That is because when people cycle, they need to pay attention to their environment and directly interact with it. On the contrary, people driving in cars become very isolated and distant from their environment. As mentioned by (I6), the more car traffic there is within a city, the fewer interactions people have with each other. More bicycling, therefore, makes urban areas more liveable and socially connected (I4).

Increase in accessibility and affordability for mobility for all

Cycling is one of the most accessible and affordable modes of transport (I2, I3, I5). It is cheaper than public transport (I4) and minimises other expenses connected to mobility such as insurance, gas, car maintenance, and parking tickets (I6, I3). It is a very "socially equitable" mode of transport as almost anyone can afford or have access to bicycles (I5). This will become an even more important aspect that urban areas will have to consider in the future, due to upcoming disruptions contributing to an increase in fuel prices and energy poverty (I4). Thus, when the cycling conditions are provided, also the mobility of citizens in urban areas increases. In the case of the city of Ljubljana, that was even further enhanced by the implementation of the shared-cycling scheme BicikeLJ which is one of the cheapest self-service bicycle rental systems in the world (yearly subscription fee is only €3.00) (I8).

Reduction of health issues

Cycling has also a positive effect on health (I6, I3, I4) as it keeps people fit (I5, I8), reduces the chance of cardiovascular disease, prevents excessive weight (I2), heart strokes and diabetes (I6). People who cycle also tend to feel better and happier which in turn positively influences their job performance (I4). Another advantage of cycling for the employers is the fact that people who cycle tend to get sick less frequently which implies that employers save up on the number of sick leaves paid as well as maintain their operations at the same level (I6).

Increase in life quality and functionality of cities

Another social aspect to which bicycling positively contributes is increasing the life quality (I3) and functionality in the cities. Bicycling makes urban areas more functional as people get to choose among multiple modes of transport (I2, I4). As mentioned, bicycling does not consume lots of space so more activities can be moved outdoors. This was mentioned by (I5) who emphasised that the well-being and life quality in cities increase when people actually get to enjoy the built environment such as street cafés, lively evening culture, children playing on the streets, and when people get to interact with one another. But this can only happen in a 15-min liveable city with many pedestrian areas that are accessible on foot or by bicycle which does not require significant infrastructure or space (I5).

(I5) mentioned, although cars are in some way good for a society as they increase mobility (i.e., ability to go more or less everywhere and transport anything), he specifically emphasised that "what on an individual level looks good, is on a collective disastrous". When car-oriented cultures are prioritized, the cities develop in a completely different direction compared to 15-min cities where cycling and walking are prioritized. "Car-oriented cities, suburbs, shopping centres, large roads and streets for parking, large public and private costs, millions of car deaths and injuries, noise and pollution" all, in turn, make car-oriented development worse for the society (I5). This was also emphasised by (I4) who mentioned that cities are the most liveable and enjoyable when people spend their time outdoors, gather in street cafés or bars in the evening and when children get to play on the streets.

A few experts also referred to urban areas as complex systems (I4, I5, I6) where sustainable transport goes beyond the integration of sustainable modes of transport (i.e., simply building cycling lanes). (I4) emphasised that urban areas (e.g., traffic, distribution of space and services) should develop in a decentralised manner as cycling mostly gains its value on short distances. This was also emphasised by (I5) who mentioned that "cycling makes cities extremely functional, as they enable great public spaces and a 15-min city with lots of local shops". However, (I4) also mentioned that more recently the development in Ljubljana, despite its efforts to make mobility more sustainable, has been moving in the opposite direction. Many activities are being moved to the outskirts of the city to centralised areas with shopping centres and business zones (e.g., BTC City, Rudnik, Stanežeče) which are more difficult to be reached by bicycle. Lastly, (I6) spoke about the importance of designing the infrastructure while having final users (i.e., citizens) in mind. Cyclists are immediately interacting with their environment (i.e., they use their senses such as seeing and smelling). Therefore, it is not sufficient to simply provide infrastructure but to integrate nature into the built environment to make the city beautiful and desirable (not only for cyclists but also for other members of the urban system).

Ability to be flexible and fast

As mentioned by (I4), every hour lost in traffic has a negative impact somewhere else on the personal or societal level. Therefore, cities that prioritize cycling over motorized transport positively contribute to the flexibility of people as they get to reach any destination by bicycle (I2, I4). In cities that enable cycling conditions, bicycling is also the fastest mode of transport, especially during rush hours (I4, I8).

Inclusivity

Many stakeholders also emphasised the inclusivity aspect of bicycling. Due to the availability of different types of bicycles (e.g., cargo bikes, e-bikes), cycling became more accessible for people with different needs (e.g., parents, elderly, and people who are not as physically fit) (I2, I3, I5). Some disabilities can also be overcome by bicycle. (I3) mentioned an example of a lady who was not mobile as she could not walk but retained her independence (i.e., mobility) through cycling. Many people also tend to switch from cars to bicycles when they get older (I3).

The social cost of high motorisation in Graz

Although the social cost (e.g., deaths, personal injuries) of motorisation in urban areas was not among the most frequently mentioned aspects by the interviewees, it is an important consequence. In cities with higher levels of motorised transport, the number of accidents that involve people increases. In addition to having a large negative social cost, they also have economic (e.g., insurance costs, recovery and rehabilitation costs) and environmental impacts (e.g., pollution, damage to public utilities). In the city of Graz, the number of road traffic accidents has significantly decreased over time (see **Figure 21** and **Figure 22**). Of course, this is not purely the result of higher cycling rates. For example, the overall motorized traffic in the city has decreased and the city introduced the 30km/h speed restriction in 1992 which applies to 80% of all roads in Graz today. According to the city of Graz (2018b), just with the introduction of the 30km/h restriction, the number of accidents fell by 24% (City of Graz, 2018b) which in turn increased the cycling and walking rates. Furthermore, the vehicles and technologies are more advanced and overall awareness of participants has increased as a consequence of multiple awareness-raising campaigns and social movements. Still, this proves that urban development prioritizing active modes of transport such as cycling and walking positively affects the social pillar of sustainability.

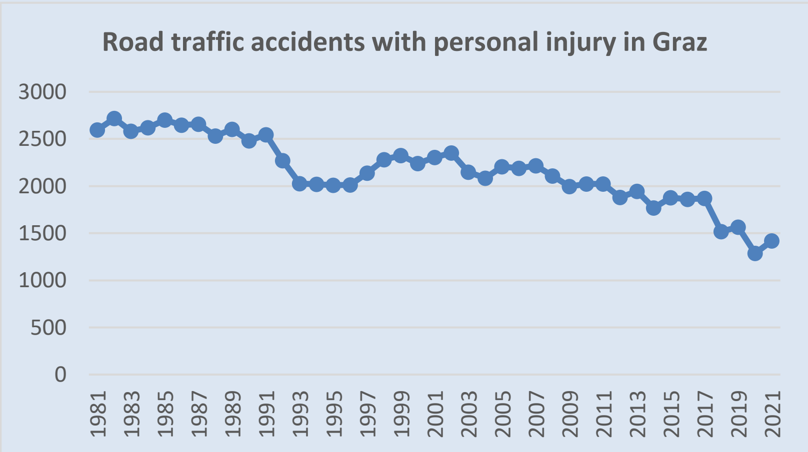


FIGURE 21: NUMBER OF ROAD TRAFFIC ACCIDENTS WITH PERSONAL INJURY IN GRAZ OVER TIME (SOURCE: LAND STEIERMARK, 2021B).

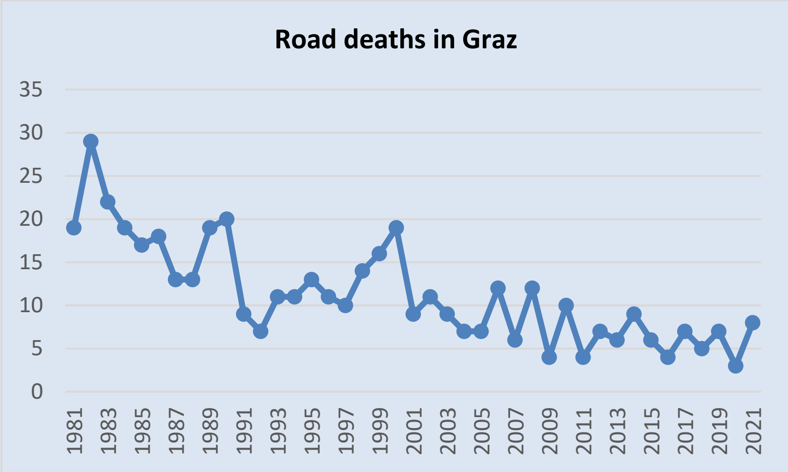


FIGURE 22: NUMBER OF ROAD TRAFFIC DEATHS OVER TIME IN GRAZ (SOURCE: LAND STEIERMARK, 2021B).

5.3.3 Economic Pillar

When associating bicycling with the effects on the economic pillar, the experts mentioned that bicycling requires lower investments in infrastructure and its maintenance, contributes to the development of local activities and touristic attractiveness of the destination and reduces the external economic costs of traffic.

Fewer investments in infrastructure and its maintenance

Compared to other modes of transport (e.g., cars or public transport), the infrastructure such as roads, pathways, parking and operations is less complex, requires less space and fewer resources (I1, I2, I5) in addition to lower maintenance costs (I3, I5). (I8) also mentioned that shared-cycling schemes are a very economical solution for mobility in cities as bicycling itself is not associated with high investment costs in the infrastructure. (I4) also referred to 'bike-economics' and mentioned that investing in cycling infrastructure has higher returns in the long term compared to investing in infrastructure for other modes of transport. However, (I4) did also mention that convincing the decision-makers to invest in cycling instead of car infrastructure is currently very challenging as the cycling infrastructure is still relatively expensive compared to the construction of roads (i.e., €300 for 1 metre of cycling lane compared to €500 for 1 meter of the road[15]). Hence, there is a need for more research on the long-term economic benefits of cycling.

Increase in economic activities

More cycling also creates new jobs in the service sector, manufacturing and wholesale (I2, I3, I6). This was also observed during the pandemic when the bicycle sales increased significantly (I2, I5) and the number of bicycle service shops increased (I3). This is also good for the economy in the long term as those businesses can be sustained and their services in demand also post-COVID-19 pandemic (I3).

Touristic attractiveness of the city

Better cycling conditions in the city also attract foreign visitors who like to spend time outdoors and explore the city by bicycle. More cycling, therefore, increases the touristic attractiveness of the city (I2). This was also emphasised by (I5) who mentioned that more visitors come to Graz to explore the city and surrounding region by bicycle which they either bring along or rent at the hotel.

Reduction of external costs of transport

Negative external costs of the transport system usually have an impact on all three pillars of sustainability but also incur additional economic expenditures that are paid for by the society. More cycling in cities, therefore, also reduces the extremal costs of transport (I2, I3, I4, I5, I6) such as **loss of time and resources** due to traffic jams (I2), **pollution of the environment** (I2, I6) and consequently the costs for treating the water or cleaning the environment; **human costs** in form of accidents, injuries, deaths, respiratory illnesses due to air pollution or the effect of noise pollution on the health of people and therefore additional pressure on the health system; and expensive costs of suburbanisation (I5).

[15] These are the estimates.

The financial benefit of the cycling boom in Austria and Slovenia

Organisations *Verband der Sportartikelerzeuger und Sportausrüster Österreichs* (VSSÖ) and *ARGE Fahrrad* have been tracing the bicycle market in Austria and have been surveying the market volume since 2009. In 2020, the bicycle sales reached the highest value since 2009 with 496,000 new bicycles being sold worth almost €878 million (VSSÖ, 2020). There was also a noticeable increase in demand for bicycle services and spare parts, as many people wanted to restore and repair their old bicycles. According to VSSÖ, approximately 1,000 people work in production and 7,000 - 8,000 people work in sales in the cycling industry in Austria (VSSÖ, 2020). In 2021, the bicycle sales have further increased to almost €1,03 billion (out of which 73% were e-bikes) and as such tripled since 2015 (VSSÖ, 2021). In 2021, the sales volume of cargo bicycles has increased by 135.5% compared to 2020 (VSSÖ, 2021). As concluded by the spokesman of ARGE Fahrrad, Hans-Jürgen Schoder: "The bicycle is not only an important economic factor for Austria but also a central component of the future of mobility." (VSSÖ, 2020).

According to one of the largest wholesalers in Slovenia, in recent years the size of the bicycle market is expected to be comparable to the car market (in terms of units sold) and reach annual unit sales of 60,000 – 70,000 (AMZS, 2021). The e-bike imports have increased from 5,600 in 2019 to 7,000 in 2020 and the sales of regular bicycles have reached 80,000 – 90,000 units (BIKEeurope, 2021). The demand for bicycles has increased by 20 – 30% and the prices have increased by 10% in 2021 due to the pandemic (Rabuza, 202). According to one of the merchants, bicycle sales have increased even by 40 – 50% (AMZS, 2021).

5.4 The role of cycling for the resilience of urban areas

This chapter starts by providing insights on how a resilient transport system should react in times of disruption (i.e., persist, recover, adapt, transform). This is followed by a section on what makes a transport system resilient where the interview insights have first been structured (see **Table 23**) and then interpreted.

Resilience is a term that describes one of the following outcomes of a resilient transportation system: to persist or maintain its function, to recover or restore from the disruption, to absorb or adapt to the disruption or transform during the times of disruption. The experts were asked about their perception on what makes a transport system resilient, how important they consider each of the outcomes of a resilient transport system and how bicycling can contribute to more resilience.

Most stakeholders recognised 'adaptability' as the most important characteristic of a resilient transport system (I1, I2, I4, I5, I6) where the bicycle is the most adaptable mode of transport. (I2) mentioned that each of the outcomes of a resilient system is important on its own but emphasised that the ability to adapt is very important as the transport system should be dynamic rather than static. In the opinion of (I4), the most important outcome of a resilient transport system is the ability to adapt to the disruption. While other cities such as Milano or Paris were able to react quickly to the pandemic and transform streets into cycling lanes, in Ljubljana the system was unable to react in such a way. One of the few measures implemented in Ljubljana was to offer free parking spaces in the city centre which is counterproductive to the efforts the city has been making toward the promotion of sustainable mobility. (I5) mentioned that in the short term it is important that a resilient transport system has the ability to persist or continue as it is. However, this is only possible if the disruption is not too large. If the disruption is very large, then the system needs to have the ability to adapt or even transform in a massive way. (I6) also mentioned that times of crisis require a very quick reaction and that a resilient transport system needs to have the ability to adapt. On this note, he emphasised that cycling displays this as the transport mode itself does not require any massive transformations of infrastructure and environment to change. (I8) mentioned that a resilient system needs to primarily maintain its function in times of disruption. During the pandemic, BicikeLJ was the only public mobility system that maintained its function while it also had the ability to recover fast after the disruption (i.e., in terms of usage rates) which the public transport system did not (i.e., they are still facing low usage rates). However, (I8) is of opinion that the adaptability or transformability capacity does not apply to a system such as BicikeLJ.

Based on the review of literature, a resilient transport system is characterised by **redundancy, adaptability, robustness, preparedness** and **rapidity**. These characteristics can be measured by looking at different performance variables which were mentioned in **Chapter 3.5** *Resilience of transport in urban areas.* One performance variable applies to different characteristics. For example, the multimodality of a transport system contributes to its redundancy, adaptability, robustness, preparedness and rapidity. During the interviews, experts were asked about their opinion on how bicycling contributes to the resilience of a transport system in urban areas.

The list of their answers was compiled (see **Table 23**) and the discussion on how those performance variables contribute to the overall resilience of a transport system provided.

When referring to disruptions, it is important to repeat that there are different types of disruptions. An overview has been provided in the introduction of this master thesis (see **Table 1 in Chapter 1.2**). It is also important to mention, that focus of the following section is not to discuss whether people would choose to cycle in bad weather conditions or on larger distances, which, of course, are some of the limitations of cycling, but rather to acknowledge the role of cycling in times of disruption when some trips need to be done in spite of everything else.

When asked about the role of cycling for the resilience of the transport system the most frequently mentioned aspect was its reliability and **independence** (I1, I2, I3, I4, I8) compared to other modes of transport. Bicycling is completely independent of any energy sources, does not require parking space or sophisticated infrastructure (I1, I2, I3, I5) or requires very little energy as in the case of e-bikes (I5). Cycling is also not affected by disruptions of logistical chains, energy supply, infrastructure performance or natural or human-caused disasters (I5).

	I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I8**
Independence	X	X	X	X	X	X	X
Multimodality		X		X	X	X	
Flexibility		X	X	X	X	X	
Inclusivity and accessiblity		X	X		X		
Simplicity (usage, repairs, production)				X	X	X	
Different routes			X		X	X	

TABLE 23: THE PERFORMANCE VARIABLES CONSTITUTING A RESILIENT TRANSPORT SYSTEM (SOURCE: AUTHOR'S OWN).

This implies, that more bicycling in urban areas can contribute to the overall redundancy of the transport system, as cycling can take over the function (i.e., providing access) of other transport modes in times of disruptions. The independence of cycling also enables the transport system to adapt to different pressures. This has been observed during the pandemic when people stopped using public transport due to the fear of disease transmission and switched to walking or cycling. The independency of cycling also contributes to the robustness of the overall transport system which is defined as the "strength or capacity of the elements" (Gonçalves &

Ribeiro, 2020) that a transport system endures. Independence from anything else also contributes to the overall preparedness of the transport system (i.e., the ability to reduce the effect of disruption) and rapidity (i.e., the ability to quickly recover from disruption to meet to needs and demands of citizens).

Bicycling also contributes to the **multimodality** (i.e., ability to arrive at the final destination with various modes) of a transport system which positively contributes to the redundancy, adaptability, robustness, preparedness, and rapidity of the overall transport system (I2, I4, I6). This was mentioned by (I2) who emphasised that having different mobility options makes a system more resilient as it does not purely depend on one element. This was also mentioned by (I6) who said that "not a single mode of transport can fulfil all the needs. It is always a combination of them." He went on to make a remark, that if everyone would switch from cars to public transport and bicycles that would probably result in a collapse of the system (I6). Some trips are to be made by cars, so it is more important to teach people "what mode of transport to use for what trip" (I6). The transport system is resilient when "people use the right means of transport for the right purpose" (I6).

Bicycling is also the most **flexible** mode of transport and can therefore adapt to almost anything (I1). Even in times of disruptions such as fallen trees on the road or traffic accidents, the barriers can easily be overcome by carrying the bicycle over the barrier or simply choosing a different path (I3). This ability to react quickly (i.e., adaptability) is also typical for cycling, as making the cycling lane is much quicker and cheaper (i.e., takes less time and budget) and enables one to react more quickly (I6). With a bicycle, you can adapt in the easiest way (I8). Bicycling adapts and renews more than any other mode of public transport such as cars and buses unless limited by roads (I8). This contributes to the overall resilience of the transport system as it enhances its preparedness (i.e., having prepared additional measures or in this case mobility options before a disruption happens) and rapidity (i.e., the ability to quickly recover from disruption to meet needs and demands of citizens). As mentioned by (I1), the robustness of cycling has also been displayed during the pandemic when the daily routines of people who cycle daily did not change significantly compared to those relying on public transport. This was also emphasised by (I8), who mentioned that cycling adapted to the pandemic circumstances the best (i.e., people were only able to move around by bicycles as all other modes of transport were banned) and also renewed (quickly recovered) after the initial shock compared to other modes of transport (e.g., usage rates of public transport), hence displaying the rapidity (i.e., recoverability) characteristic of a resilient transport system.

A resilient transport system is **inclusive** in nature as it meets different needs (I2). (I2) mentioned that not everyone can afford to drive a car but almost everyone can drive a bicycle (e.g., young, elderly, poor). Cycling is accessible and inclusive to anyone (I2), at any time (I5) and does not require any extensive training (I3). It serves the greatest number of people in a reliable way (I5). New bicycle designs (cargo bikes, e-bikes, trikes) also allow for greater distances as well as usage by less mobile persons (old, with reduced mobility, children) as well as a large part of city logistics (cargo-bikes) (I5). Therefore, it is important that a resilient system through the diversity of mobility options meets different demands (I2). However, as mentioned by (I3) cycling can also exclude some groups of people such as the elderly or parents if they do not have access to e-bikes or cargo bikes that would meet their needs (I3).

It is also very **accessible** in terms of repairs or production as both can be done locally (I5). This positively contributes to the redundancy of the system, as almost anyone can switch to cycling when other components of a transport system fail. Being so accessible, it also enables a larger group of people to adapt to the disruption. As has been observed during the pandemic, people who had access to bicycles during the pandemic were also able to endure (i.e., robustness) the stress imposed by the pandemic and were better prepared compared to those who did not cycle. This has especially been the case in Ljubljana, where people had the possibility to use the shared cycling infrastructure BicikeLJ. Even those who did not own bicycles were prepared and able to quickly adapt (i.e., rapidity) to the new situation.

Lastly, (I2) emphasised that cycling can substantially contribute to the overall resilience of a transport system when connected with public transport, as it enables people to travel larger distances and because cycling supports the vulnerabilities of public transport. Within a resilient transport system transitioning from one mode of transport to another is very easy and flexible (I6), which cycling further enhances. This was also mentioned by (I5), who said that only “good cycling infrastructure (driving, parking, charging, maintenance, repairs) and very high cycling usage (e.g. for everyday trips, by children, students, prestigious professions, and logistics)” can help cities, such as Graz and Ljubljana, become more resilient and meet the target of 40-60% of trips done by bicycle.

5.5 Limitations of bicycling

Of course, bicycling also has its own limitations which were addressed by the stakeholders. Firstly, the bicycle has a limited range and is not very suitable for hilly districts (I2, I5). However, both (I2, I5) agree that this problem can be overcome as people gain access to e-bikes or when cycling is combined with other public transport modes such as trains or trams (I2, I5).

The second weakness of cycling is the weather (I3, I5). When it rains, snows or is very hot, cycling is not as attractive. However, as mentioned by (I5) "Experience shows, that in cities with a very high share of cycling, such as in Denmark and Holland, more than 80% of the cyclist also cycle in winter. In very hot climates, people pause or search for shelter during the daytime and are more active in the morning and evening". The same also applies to times of disruptions under the assumption that some trips simply have to be done (e.g., access to medical services, work, grocery shopping).

More cycling in cities does not necessarily imply positive change as that development can result in conflicts arising between cyclists, pedestrians and cars. (I1) mentioned that raising awareness of responsible cycling is necessary as cyclists also need to be aware and conscientious of other road users (e.g., pedestrians). (I8) also mentioned the problem of 'arrogant cyclists' who might become very reckless when driving and do not respect the traffic signage.

Cycling also has its limitations when it comes to transporting people or cargo (I2, I5). However, as mentioned by (I6), rather than enforcing cycling onto everyone at all times it is rather more important for the people to learn when and for what to use a certain mode of transport.

Lastly, although cycling is considered a very inclusive and accessible mode of transport, it can also exclude some groups of people (I5, I6). Some cannot cycle due to their age, physical restrictions and other health conditions. However, as mentioned by (I6), using those groups as the reason why cycling should not be prioritised in cities sounds more like an excuse than a reason as those individuals are also probably unable to travel by motorised vehicles themselves. Those groups of people need inclusive solutions (I6) such as rikshaw service or bicycle taxi services that were mentioned by (I5), public transport vehicles adapted to people with disabilities (e.g., signage on the floor, the lower floor of buses or trams, audio messages on public transport), or transport on demand such as *Kavalir* service (https://www.lpp.si/en/informations-passensgers/electric-train-urban-and-electric-vehicle-kavalir) on-demand provided in the city centre of Ljubljana.

6 CONCLUSIONS

6.1.1 Summary

The main findings have been structured in three sections to address each of the three sub-questions of the main research question (see **Table 10**).

RQ1: How did transport in urban areas react during COVID-19 pandemic (times of disruption)?

At the beginning of the pandemic, the public life and therefore also cycling rates in Graz drastically decreased. After the initial shock, the rates slowly started to recover but were still below the pre-pandemic levels due to home office and remote work. Due to the fear of disease transmission, many people switched from public transport to private cars. Some even started to commute by bicycling, however, at that point the increase in cycling has mainly been observed as a new way of exercising. Cycling rates first started to recover and overtake the pre-pandemic levels in June 2021 and remained above them until today. Although the increasing trend in cycling has been observed in Graz over the past years, the interviewed experts mentioned that the pandemic could have served as an “accelerator” for more cycling. As mentioned, many people started to cycle in their free time (physical activity, health reasons) – a hobby that easily gets transferred into a daily habit of people. The pandemic also encouraged many new people to join the increasing cycling trend. This is positive, as the city of Graz previously had trouble attracting new cyclists and increasing the higher cycling rate in the modal split. The reason behind that was lack of new, safe and comfortable infrastructure that would motivate and encourage unexperienced cyclists to travel to work. Therefore, it is important, that further developments and improvements of cycling infrastructure take place after the pandemic to achieve a 30% cycling rate in the modal split by 2030.

Similarly to Graz, the cycling rates also significantly decreased at the start of the pandemic in the city of Ljubljana. On the contrary to Graz, where the government promised to compensate public transport companies for their revenue loss in ticket sales, the national government in Slovenia banned all public transport (including taxi services) which significantly reduced the mobility of citizens.

After the initial drop in monthly usage rates of BicikeLJ cycling scheme, the usage rates started to increase in May 2020 but remained below the pre-pandemic levels. In addition to more home office and remote working, a large share of individuals (i.e., students) using BicikeLJ was not using it. Young people from other regions in Slovenia who study in Ljubljana, had to return to their permanent residencies when the dormitories closed due to the COVID-19 pandemic. Despite overall decrease in commuting, the BicikeLJ usage rates matched a similar pattern compared to the pre-pandemic period but remained below the pre-pandemic levels during 2020. In 2021, the usage rates of BicikeLJ started to overtake the pre-pandemic rates un the summer months. However, the most positive results have been observed from January to March 2022, when the usage rates were substantially higher compared to the pre-pandemic period. Similarly to the city of Graz, that could have been a result of increased cycling trend before the pandemic but also due to “new habits” people adopted during the pandemic. Very interesting to observe is also the comparison of data from BicikeLJ and cycling counters. After the initial drop in public life from February to March 2020, the cycling rates already started to increase from March to April 2020 while the BicikeLJ usage rates continued to decrease and stared to recover in May 2020. People might have been reluctant to use a public bicycle sharing system due to the possibility of disease transmission.

R***Q2: How can 'bicycling' contribute to the resilience of transport in urban areas?***

In the years leading up to the pandemic, both cities encouraged the use of public transport and active modes to promote sustainable mobility and reduce the negative environmental and social impact of motorized transport. Yet what happened during the pandemic was counterproductive to those efforts. People in both cities were reluctant to use public transport due to the fear of disease transmission and started to switch to commuting by car. Worse yet as the national government of Slovenia introduced a ban on all public transport, people who previously relied on public transport services were suddenly cut off. From the perspective of an individual, car ownership was perceived as positive during that period as that would enable them to be completely independent from the regulations and therefore more resilient to disruptions such as the COVID-19 pandemic. For this reason, it is important to address different ways on how the resilience of transport system in urban areas can be improved.

More bicycling in urban areas contributes to the overall ‘adaptability’ of the transport system. When the disruption is too large to adapt to it, the system also has to have the ability to transform itself. Although ‘transformation’ (e.g., pop-up cycling lanes) has not been observed in the city of Graz and Ljubljana - mainly due to the reluctance of local government (see Section 5.1.5 and Section 5.2.5), the system was able to adapt to the disruption due to previously implemented measures. For example, in the city of Graz the traffic speed is limited to 30km/h on 80% of all roads which reduces the dangers and risk of road accidents. Or the fact that even people who did not previously cycle and needed to move from point A to B within the city of Ljubljana were able to use bicycles from the shared-cycling scheme BicikeLJ and therefore adapt to the new "reality".

Bicycling increases the overall resilience of a transport system as it makes it more redundant, adaptable, robust, prepared and rapid. First, bicycling is completely independent of any energy resources (or very little electricity in the case of electric bicycles), disruptions in supply chains, human-caused disruptions and does not require sophisticated infrastructure. Second, it positively contributes to multimodality of transport system in the city as the transport system relies on multiple elements that have the ability to absorb the capacity of the failed element to some extent. Overall transport provides accessibility to different locations where bicycling can contribute to the overall flexibility of the system. For example, cyclists can quickly overcome traffic jams or accidents, road barriers or take a different route on the spot while other modes of transport do not offer the same level of flexibility (e.g., getting stuck on the underground and not being able to quickly switch to another mode of transport). Furthermore, bicycling contributes to the overall inclusivity and accessibility of transport system in urban areas. It is accessible to almost everyone, at any time and does not require extensive training. This has also been observed during the pandemic in the city of Ljubljana, when new cyclists were able to quickly register for BicikeLJ and start using their bicycles right away. As the repairs or production of bicycles can be done locally this also increases its overall accessibility. This has been observed in the city of Graz, where people started to bring out their old bicycles and turn to repair shops (i.e., bike shops) for a quick fix. The benefits of bicycling are, of course, the largest when connecting it with public transport. That enables people to travel for larger distances while at the same time meeting the shortcomings of public transport such as the 'last- or first mile problem' (i.e., low willingness to use public transport when the first station is within a larger distance than 500 metres). Overall, there are more benefits of bicycling for the resilience of transport in urban areas than its limitations (see **Chapter 5.5**) and therefore a good investment.

RQ3: How can 'bicycling' contribute to the sustainability of transport in urban areas

Lastly, more bicycling in urban areas also significantly improves the sustainability of transport in urban areas. It is probably of no surprise that more bicycling at the cost of fewer motorized transport has multiple positive effects on the three pillars of sustainability. In **Chapter 5.3** the insights from the expert interviews were compiled in three sections along the three dimensions of sustainability – environment, society and economy. Their answers were also complemented with secondary data on selected parameters to show how more sustainable mobility affected the three pillars of sustainability in both cities over time. The most frequently mentioned environmental benefits of more bicycling in urban areas are reduction of CO_2 and noise emissions, reduction of land consumption, and reduction of environmental degradation. Lower land consumption is very important as certain mobility solutions (e.g., electric cars, electric scooters) promise environmental benefits (e.g., reduction of emissions and noise) yet consume urban space (e.g., parking lots, pavements or cycling lanes where e-scooters are parked) that could otherwise be used by citizens or allocated to the environment (green areas, parks, trees).

The most suggestions on how more bicycling improves sustainability of urban areas were provided within the social dimension of sustainability. Bicycling increases interaction among citizens as people interact with each other when cycling or walking, while driving in cars contributes to very isolated and individualistic behaviour. It increases accessibility to mobility of almost everyone as it is one of the most affordable modes of transport (i.e., even cheaper than public transport) and further minimizes other expenses (e.g., insurance, gas, maintenance, parking tickets). In the future, the affordability of mobility will become an even more important aspect due to disruptions contributing to the increase of fuel prices pushing the most vulnerable members of society into mobility and energy poverty. Not only do urban areas need to plan for such disruptions by accommodating the infrastructure for such needs (rather than continue to invest into car-oriented infrastructure only those financially better off will be able to use), but also consider implementing affordable public self-service bicycle schemes such as BicikeLJ. With only €3.00 yearly subscription fee anyone can start using it at any time. Unsurprisingly, the physical activity of cycling also reduces the health issues of people (e.g., cardiovascular diseases, obesity, heart stroke, diabetes) and naturally keeps people physically fit. Furthermore, more cycling generates positive benefits for the employers, as people who cycle tend to feel better, happier which improves their job performance. In addition, people who cycle also get to get sick less frequently resulting in fewer absence days at work. When urban areas are organised around the needs of people (i.e., cyclists and pedestrians) they become more functional, the overall life quality and attractiveness of the city increases. The transformation of the city of Ljubljana is a very good example of a city that went from congested and heavily polluted city centre, to attractive zone with lively street culture that is accessible only to pedestrians and cyclists. However, as mentioned by the experts, bicycling cannot be completely successful in transformation of urban areas on its own. It is important to plan with purpose as cycling gains its highest value over short distances. This implies that urban areas need to promote decentralisation (e.g., 15-min city where most errands can be done on foot or by bicycle) rather than centralizing services in industrial areas on the outskirts of the city. Lastly, as cyclists directly interact with their environment, the developments go well with further aims to make urban areas more liveable. For example, it is not sufficient to build a plain cycling lane. Cycling has to be integrated with the environment (e.g., paths lined by trees, wildflower meadows) to protect the cyclists from the heat or separate them from the motorized transport which instantly also increases the attractiveness of the city. People who get to cycle in urban areas are completely flexible and independent of traffic jams or other traffic conditions. Due to the availability of multiple bicycle types, cycling has also become more accessible for people with different physical needs (e.g., elderly, parents, people with disabilities).

Lastly, bicycling also positively affects the economic dimension as it itself requires fewer investments in infrastructure and maintenance (in terms of financial investments as well as resource consumption), contributes to increase in economic activities (e.g., repair services, manufacturing, wholesale), increases the touristic attractiveness of the city, and reduces the external costs paid by the society (e.g., loss of time, pollution of environment, human cost).

6.1.2 Limitations of the research

The selected research method for this master thesis of course also comes with certain limitations. First, the case studies have been bounded to a geographic scope of two cities within the EU. The two subjects of research (i.e., the city of Ljubljana and Graz) were selected due to the familiarity of the researcher with the development of both cities, knowledge of the language, geographical proximity to the researcher, and availability of data. It is, however, important to mention that cities in the EU are subject to a very supportive environment that incentivizes (e.g., by providing funding and expertise) and challenges (e.g., through restrictive legislation) them to pursue strategies contributing to the overall resilience and sustainability of urban areas. Urban areas in other parts of the world might not have access to as many resources thus the good practices might not be simply transferrable to other regions. Secondly, it is important to acknowledge the size of both cities. Larger urban areas might be approaching mobility and development of transport differently. For example, while many European metropolises (e.g., Paris, Berlin, Vienna) implemented pop-up cycling lanes during the COVID-19 pandemic, the city of Ljubljana and Graz did not do so. This could be due to the smaller size of the city compared to other larger European capitals.

Another limitation of the case study is also the influence of the researcher’s bias on the research outcome (e.g., interpretation of interviews). For this reason, secondary data confirming the interpreted claims has also been provided to support the interpreted insights. For example, secondary data demonstrating the overall reduction over time in noise pollution or CO_2 emissions in the city of Ljubljana. Another limitation of the research is related to the selection of interviewees. As they are all involved in city planning, they might be biased when providing insights. For this reason, a group of experts with a diverse background, involved in different areas contributing to the development of the city has been selected and their perspectives included in the research (e.g., associations, traffic department at the municipality).

Another disadvantage comes from using secondary data (i.e., data on cycling rates) as the researcher does not have any control over how the data has been collected or on factors influencing data collection. This has also been the case for the city of Graz where the data for certain periods was lost due to the server failure. Or in the case of the city of Ljubljana where the cycling rates for 2022 do not correspond the current cycling trends (which could be attributed to external influences such as closures of roads due to construction works where the cycling counters are located). Lastly, as mentioned by Creswell (2014) the information and data provided in documents used in the document analysis might also be incomplete, inaccurate or unauthentic.

6.1.3 Future research

The limitations of the study also imply the need for further research. First, more research on the role of bicycling for the resilience and sustainability of larger urban areas is needed. As mentioned in the chapter on limitations, the reaction of both studied cities to the COVID-19 pandemic was very similar but different when compared to the reaction of larger cities such as Berlin, Paris or Vienna. The purpose of this thesis was to explore how bicycling contributes to the resilience of the urban transport system from the point of view of different stakeholders. However, more research and development of indicators measuring and putting the role of bicycling for the resilience of urban transport into numbers is needed. Lastly, it would have been interesting to simultaneously also conduct research on the role of bicycling for the resilience of the transport system in urban areas from the perspective of citizens.

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APPENDICES

Appendix 1: Interview Guideline

Name of the company:
Interviewee name:
Interviewee position:
Date:

Presentation:

My name is Ana Marija Udovič and I am an *MSc Sustainable Development, Management and Policy student* at Modul University Vienna. The purpose of my study is to better understand the role of *bicycling* for the resilience and sustainability of urban areas by studying the impacts of the COVID-19 pandemic and drawing conclusions on how transport in urban areas should develop after the pandemic. This interview will help me answer the research question "*What is the role of bicycling for the resilience and sustainability of transport in urban areas in the world after the COVID-19 pandemic?"* of my master thesis. Below you can find a list of questions related to the research question. The interview should not take longer than 50 minutes.

Interview consent agreement:

By participating in the interview, you consent to the collection and use of provided information to Ana Marija Udovič (i.e., researcher). The answers provided during the interview as well as other audio-visual materials will be stored in the researcher's database and only be used for the purpose of this Master Thesis during the research period (April – June 2022). After, the researcher will delete all the audio-visual materials. Upon request, the answers can be anonymised and the privacy of the respondents ensured. The lawfulness of the processing of personal data, based on consent, is determined pursuant to Article 6 of the EU's General Data Protection Regulation (GDPR).

Part I: The effects of the COVID-19 pandemic on transport in urban areas

The following section is related to the effects of the COVID-19 pandemic on the transport in the city of Ljubljana/Graz. Please provide some insights from your perspective on the following topics.

1. According to your observations, how did the transport in Ljubljana/Graz respond to the pandemic?
2. How have the mobility patterns of citizens changed due to the pandemic?
3. What was the role of *bicycling* during the COVID-19 pandemic?
4. How has the pandemic influenced the perception on the future development of transport in the city? Would you say anything has changed to prepare for future disruptions?
5. Are there any new plans in the planning of transport within the city expected to be implemented in the near future as a result of the "lessons learned" during the pandemic? Who are the actors that initiate new plans and how are you (i.e., your organisation) involved in the process? If yes, could you please provide more insights?

Part II: Resilience of urban transport and bicycling

The term 'resilience' is used to describe a transportation system that can do one of the following: persist/maintain its function, recover/restore from the disruption, absorb/adapt to the disruption or transform during the times of disruption. Please provide your opinion on what makes the urban transportation system in Ljubljana/Graz resilient and how bicycling can contribute to that.

1. How would you describe the resilience of an urban transport system? What makes a transport system in cities more resilient?
2. Thinking of different modes of transport (e.g., private vehicles, public transport, active modes), how would you describe a 'resilient' mode of transport? Why would you describe it as such?
3. Some of the outcomes or actions (i.e., what happens during the times of disruption) of a resilient transport system are persistence, recoverability, absorbability and transformability. Based on your professional experience and industry observations of different trends, how important do you consider each of them for the transport?

4. In your opinion, how can *bicycling* contribute to the resilience of transport in cities in the future? (e.g., pandemics, fuel supply shortages resulting in higher prices, political conflicts)
5. How would you describe *bicycling* in terms of resilience (e.g., robust, flexible, adaptable)? What are some of its strengths but also limitations (i.e., weaknesses)?
6. How can *bicycling* contribute to the resilience of transport in urban areas in the future?
7. In your opinion, how resilient was the transport in Ljubljana/Graz during the COVID-19 pandemic?

Part III: Sustainability of urban transport and bicycling

Transport is responsible for multiple negative externalities to the environment, society and also the economy. Thus, there is a growing demand and pressure for transport to become more sustainable. Sustainability is typically discussed in terms of three pillars – environment, society and economy. Thus, please think of how transport negatively affects each one of them and how changing the current status of transport would help reduce those negative impacts. Please provide your view on what makes transport in the city of Ljubljana/Graz more sustainable and the role of bicycling.

1. How would you describe a 'sustainable transport system'? Why would you describe it as such? What makes a transport system in cities more sustainable? / How would you describe the current status of transport in the city of Ljubljana/Graz in terms of its 'sustainability'?
2. Thinking of different modes of transport (e.g., private vehicles, public transport, active modes), how would you describe a 'sustainable' mode of transport?
3. In your opinion, how can *bicycling* contribute to the sustainability of transport in cities in the future?
4. How would you describe *bicycling* in terms of its 'sustainability' (i.e., along the three pillars of sustainability)? What are some of its strengths but also limitations (i.e., weaknesses)?
5. How can *bicycling* contribute to the sustainability of transport in urban areas in the future?

Would you like to add or comment on anything else that you consider important for the topic of my master thesis?

Appendix 2: Map of the City of Graz

Appendix 3: Map of the City of Ljubljana