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The future of cycling in Kigali: Climate change and socio-economic factors

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Radical Urban Lab

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INTRODUCTION

In recent years, transport has become one of the largest sources of air pollution (Walker et al., 2022), accounting for 21% of global carbon emissions (Brand et al., 2022). Cycling is increasingly being presented as an alternative to motorised vehicles to reduce emissions and achieve more sustainable mobility. In addition, cycling can help tackle congestion, energy shortages, air pollution and physical inactivity (Liu et al., 2017; Walker et al., 2022; Edberg, 2023; Galich et al., 2021; Wadud, 2014). This has led to a growing interest among governments, municipalities, urban planners and the transport sector, who are now beginning to explore the implementation of cycling and its use as a mode of transport that can help mitigate climate change (Ahmed et al., 2010; Winters et al., 2013; Walker et al., 2022).

As well as the environmental benefits of cycling, it also has multiple benefits for society. Firstly, it ensures that the population is more active and achieves recommended levels of physical activity, which directly reduces health problems by increasing cardiovascular fitness and limiting risk factors (Flynn et al., 2012; Hardinghaus & Weschke, 2022; Li et al., 2023). Cycling has also been shown to improve mental health and well-being (Hudde, 2023). Secondly, cycling is cheaper than commuting by private car. Making cities more bike-friendly therefore increases individual mobility, which indirectly promotes a more equitable environment by making cities accessible to everyone and extending social life within the city (ibid.). Finally, cycling makes cities more attractive and liveable, for example by reducing congestion or the amount of space dedicated to cars, such as roads or parking spaces (ibid.).

However, as an open-air mode of transport, cycling is very vulnerable to the weather and the outside environment. Consequently, understanding how cyclists respond and adapt to weather will be essential for future city planners to design appropriate infrastructure, especially in light of climate change predictions. The latest IPCC report predicts that climate change will cause an increase in the frequency and intensity of extreme weather events, as well as an increase in temperature, with a more than 50% chance of exceeding the 1.5°C limit of the Paris Agreement by 2040 (IPCC, 2023). Understanding how weather dictates cycling patterns and how those might evolve with regional climate change is essential to build the cities of tomorrow. This research focuses on Kigali, the capital of Rwanda and one of Africa's pioneering cities in terms of cycling innovation (Odero et al., 2020). By focusing on this city, this research aims to add to the literature on cycling in the African region, which is currently lacking. As the continent is currently experiencing rapid urban growth, a focus on Africa is necessary to ensure sustainable development (Agyemang et al., 2022). The original aim of this research was to measure and quantify the impact of climate change on cycling patterns and the cycleability - the ease and suitability of cycling - of Kigali in the future. However, this dissertation found that weather is only one small factor in a complex web of socio-economic factors. This research looks at how weather has affected cycling patterns, but will further explore how socio-economic status has dictated cycling in Kigali and what this means for the future of cycling in Kigali.

The first section of this research presents a literature review of research on weather and cycling and introduces the city of Kigali. This will allow this research to be contextualised within the academic field and provide background information on the case of Kigali. The second section will describe the methodology used for the research and its limitations. The dissertation then discusses the key findings and explores what they imply for the future of cycling in Kigali, concluding that weather patterns are currently secondary to the future of cycling in Kigali and that more work needs to focus on the socio-economic factor to ensure the development of cycling in Kigali.

1. LITERATURE REVIEW

Over the years, there has been an increasing number of studies linking cycling and weather patterns (Liu et al., 2017). This section aims to explore previous research linking cycling and weather patterns, to show how the weather affects the cycling habits of a population, and how this is part of a larger complex social system with interdependent factors. Finally, it presents Rwanda and Kigali as a case study for this research.

1.1 Weather as a modeler of cycling habits

Current scholars agree that the daily weather has a significant impact on the decision to cycle (Hudde, 2023; Flynn et al., 2012; Ermagun et al., 2018; Böcker et al., 2019; Liu et al, 2017). It has been found that around 80% of the variation in cycling patterns can be explained by changes in weather conditions (Liu et al, 2017). Most studies have focused on specific weather factors such as precipitation, temperature, wind, humidity and snow conditions (Flynn et al., 2012; Hudde, 2023; Ermagun et al., 2018; Böcker et al., 2019; Ahmed et al, 2010; Galich et

al, 2021). Overall, the presence or absence of certain weather conditions has been found to determine whether individuals feel comfortable cycling (Ahmed et al, 2010). Precipitation, temperature and the absence of daylight have been found to play a more significant role in shaping habits than humidity, fog, sunshine and cloud cover (Liu et al., 2017; Flynn et al., 2012; Hudde, 2023; Ermagun et al., 2018; Böcker et al., 2013, a).

Precipitation reduces the distance that cyclists are willing to travel (Böcker et al., 2013, a). It also reduces the probability of one deciding to cycle (Hudde, 2023), as individuals tend to switch to sheltered motorised transport (Böcker et al., 2013, a; Liu et al., 2017). In particular, snow has been observed to have an even more significant effect (Flynn et al., 2012). This trend has been observed to be non-linear, with the slightest sight of rain leading to a sharp decline in cyclists, followed by a much more steady decline (Liu et al., 2017).

Regarding temperature, warmer weather has been correlated with an increase in cycling. However, it has been observed that this trend follows a parabolic curve, with the number of cyclists decreasing when a certain threshold temperature is reached (Hudde, 2023; Böcker et al., 2013, a; Liu et al., 2017; Böcker et al., 2013, b). In previous studies conducted in cities in Canada, Australia, the US and the Netherlands, this threshold temperature varied between 24°C and 33°C depending on the geographical location, with colder regions having a lower threshold compared to warmer regions (Böcker et al., 2019). Moreover, the perception of temperature varies with the seasons. For example, in temperate regions, 10°C in summer is perceived as a 'cold' summer day, which may lead to a decrease in cycling, whereas the same temperature in winter is perceived as 'hot' winter weather, which may lead to an increase in cycling on that day (Liu et al., 2017).

Seasonal variations in daylight were also found to be an important factor in shaping cycling. Seasons coincided with shorter and longer days in temperate regions. Research has found a clear correlation between sunlight and the number of cyclists, with most cyclists cycling during the day and only a small proportion cycling before sunrise or after sunset (Hudde, 2023). Therefore, the number of cyclists is lower in winter, when the days are shorter, compared to summer, when the days are longer (Böcker et al., 2019). For example, a study by Müller et al. found that walking and cycling to school doubled in summer compared to winter, at the expense of public transport (Müller et al., 2008).

It is important to note that these variables are not independent, but rather interrelated (Böcker et al., 2013, a) (Liu et al., 2017). For example, the co-occurrence of light rain and wind lead to a greater decrease in cyclists than either light rain or wind experienced separately (Böcker et al., 2013, a; Liu et al., 2017).

1.1.1 Weather indirect effects on cycling

Several other factors have been observed to influence individual perceptions of weather and indirectly affect cycling habits, forming a complex web of factors (Liu et al, 2017).

Firstly, research in psychology has found that an individual's decision to cycle in adverse weather depends on how much they value their time. Adverse conditions affect the duration of the trip due to reduced visibility and speed. Therefore, individuals may not be able to cycle under adverse weather conditions if they have limited time (ibid.). Furthermore, weather can affect an individual's mood and wellbeing, which indirectly affects whether they feel comfortable cycling (ibid.).

Secondly, weather has been found to have a more significant effect on one's decision to cycle if they are flexible (ibid.). Flexibility here refers to the ability to change mode of transport, route or destination, or to reschedule or cancel a trip. Therefore, it has been observed that individuals who cycle for leisure or sport are more affected than those who cycle to work (Ermagun et al., 2018; Böcker et al., 2019; Mathisen et al., 2015). When cycling for leisure or sport, people have the option to postpone or cancel, whereas those who cycle to commute on a daily basis have commitments and therefore less flexibility. This explains why weather has been observed to have a greater effect at weekends compared to weekdays (Liu et al., 2017), as individuals are more likely to cycle for leisure or sport at weekends and less likely to commute to work.

A lagged model has also been observed, where weather conditions observed on previous days appear to influence decision-making (Böcker et al., 2019). For example, a study conducted by Mathisen et al. found that perceptions of the weather over the previous six days influenced cycling use (Mathisen et al, 2015).

Finally, it is important to note that in addition to weather patterns, a range of other factors influence the ability to cycle, including access to quality infrastructure, access to good cycling equipment (Flynn et al., 2012), local safety measures, how energy-demanding the trip is, and the aesthetics of the trip (Böcker et al., 2013, a). The list of direct and indirect factors are presented in Figure 1 to offer a more succinct visualisation. This section

enables to see which factors have been observed to be the most important and to see whether Kigali will present the same trends. Furthermore the studies will be used as guidance to design the survey.

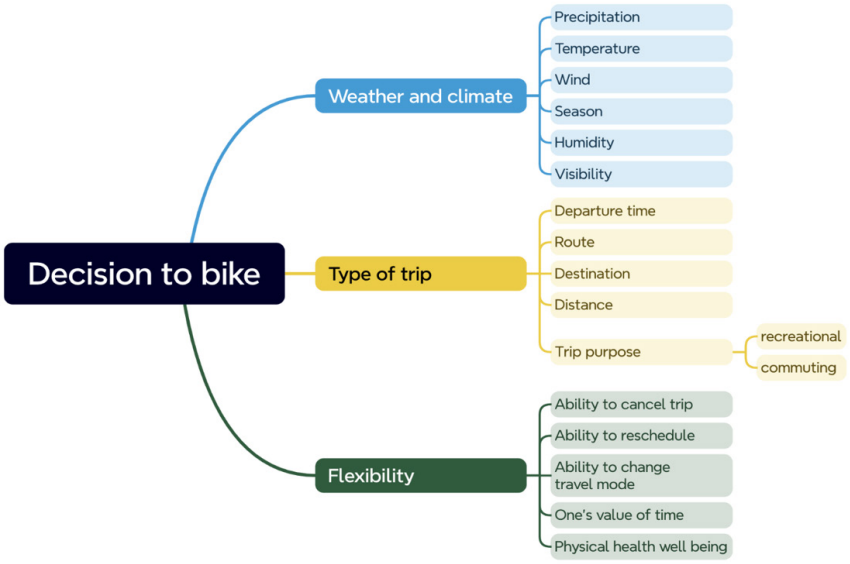


Figure 1: Different factors affecting one's decision to cycle. This diagram shows the various factors discussed throughout the literature review. Created by author.

1.1.2 Is the issue the weather or the mindset?

As the number of studies in this area of research has increased, academics have seen divergent cycling habits in areas with similar weather patterns, leading them to question whether the adverse weather conditions were a barrier or rather an individual's subjective response to them (Flynn et al., 2012; Hudde, 2023). This is illustrated by Hudde's article. In it, the author compares cycling patterns in German and Dutch cities. The research findings show that even though the cities have similar weather patterns, cyclists in Germany cycle twice as less during the winter season, compared to Dutch cyclists. He suggests that this is due to different mobility cultures and that by implementing new infrastructure, policies and changing mentalities, year-round cycling could become the norm in Germany, increasing winter cycling by a factor of three (Hudde, 2023). Weather is subjective, and perceptions of 'normal, cold, warm' weather vary by region and culture (Liu et al., 2017), and challenging these standards will be key to increasing cycling. The weather is not something that society can change to suit itself, society needs to adapt. This is important to note as this dissertation aims to look at a different world region with a different culture. Therefore, it is necessary to keep in mind that Rwandan's understanding of weather differ from a European perspective.

1.1.3 Remaining uncertainties and limits

There remains uncertainties and research gap in this field of study. More research is needed to better understand individual decision process. Future research is needed to understand how factors are interrelated. Studies so far have treated factors as independent, overlooking the relationships between factors (Böcker et al, 2013, a). Additionally, most research relies on physical data, but, one's decision to cycle is made based on subjective and future expectations. Better understanding this subjectivity is essential to better understand user and provide initiatives and infrastructures which best-fit them. In addition, scientists have begun to correlate weather and cycling patterns to see how climate change may alter cycling habits (Galich et al., 2021; Böcker et al., 2013, b; Wadud, 2014; Aaheim, 2009; Mathisen et al., 2015). Collectively, this research predicts an increase in cycling in western cities due to rising temperatures, which will extend summer travel patterns and reduce the impact of winter. For example, a study by Galich et al. predicts that the city of Berlin will experience an increase in traffic flow of 1-4% per year, with the largest changes expected in the winter season, with an increase of 11-14% (Galich et al., 2021). However, this research topic is very new and lacks in-depth research, and more research is needed to gain a complete and global understanding of the impacts of climate change on cycling (Mathisen et al., 2015) These projections are also subject to many assumptions and often assume that social, economic and environmental dynamics will remain the same, which is often not realistic. In the future, society is likely to experience political change, demographic growth, technological progress and changes in energy and transport costs (Böcker et al., 2013, b; Mathisen et al., 2015).

The articles by Böcker et al. and Liu et al. provided a detailed insight into this area, but these were mainly focused

on western cities. In Böcker et al. literature review on the impact of weather on daily travel activities, more than 90% of the 54 studies were conducted in Europe or North America, with the remainder covering Australia and Asia (Böcker et al., 2013, a). In Liu et al's literature review on travel behaviour and weather variability, half of the papers took place in Europe and the rest in North America or Australia (Liu et al., 2017). There is a need to look at a wider range of geographical areas, particularly areas closer to the equator that experience hotter climates, such as the global south, which is largely unexplored (Böcker, 2019; Böcker et al., 2013, a) (Liu et al., 2017). Most studies look at the western world, which experiences temperate or continental weather (Böcker et al, 2013, a; Liu et al, 2017), completely overlooking other biomes with different weather and climates. To begin to address this research gap, this study uses Kigali as a case study.

1.2 Kigali: A Case Study

Africa as a whole is projected to be a centre of demographic growth. The global urban population is expected to grow by 2.5 billion by 2050, of which 1 billion will be in Africa (Agyemang et al., 2022). Accommodating this booming population will be essential, however this should be done sustainably in order to limit further environmental impacts. Africa is already experiencing a shift towards car-centric cities (Agyei-Boakye, 2022). This has led to an increase in air pollution, which is rapidly becoming one of the largest causes of death in Africa, accounting for approximately 1.1 million deaths in 2019 according to the United Nations Environment Programme (Walker et al., 2022). Working to implement green urbanisation will be essential to mitigate emissions, reduce social inequality and achieve sustainable growth. Gaining more knowledge about how cycling is perceived and how climate change might affect this mode of transport will be essential for urban planners in Africa to design adequate and appropriate infrastructure that is durable and promotes active mobility.

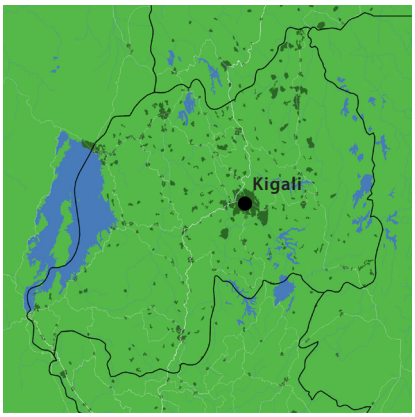


Figure 2: Map of Rwanda. This map shows the location of Rwanda and Kigali in Africa and its distance from the equator.

Rwanda is a small landlocked country in central Africa, bordered by Uganda, Tanzania, Burundi and the Democratic Republic of Congo (Dove & Sato, 2021) (see Figure 2). It is one of the fastest growing economies in Africa (REMA, 2002) (Baffoe et al., 2020) and its government has worked extensively to improve social and environmental well-being (Baffoe et al., 2020) (Dove & Sato, 2021). Since 2011, the government has been implementing a Green Growth and Climate Resilience Strategy, which aims to reduce greenhouse gas emissions and adapt to climate change (UNEP, n.d.). One of the goals of this strategy is to expand non-motorised transport and promote active mobility such as cycling and walking. However, the transport sector has grown to emit around half of the country's greenhouse gases (USAID, 2022; Walker et al., 2022) and the number of registered vehicles has almost doubled since 2010 (USAID, 2022). This has led to an increase in air pollution, which now exceeds World Health Organization air quality guidelines (ibid.). In 2013, a total of 2,277 deaths in Rwanda were attributed to air pollution (Twahirwa, 2021). In addition, congestion in Kigali has increased, with roads almost at full capacity during peak hours, and the urban landscape has warmed significantly (Jean de Dieu, 2020). More work is needed to ensure that Rwanda meets its environmental targets. Promoting a shift from motorised transport to active mobility is one of the most cost-effective ways for Rwanda to reduce its transport sector emissions (USAID, 2022) and achieve a net-zero economy by 2050 (Twahirwa, 2021).

Rwanda has a tropical climate and a hilly topography (Dove & Sato, 2021), and is known as 'the land of a thousand hills'. The average rainfall is between 1,100 and 1,300 mm per year and the average temperature is between 18 and 20°C (ibid.). The area is characterised by 4 seasons: a long rainy season from March to May, a long dry season from June to August, a short rainy season from September to November and a short dry season from December to February. Figure 3 shows how temperature and rainfall varies between seasons (ibid.).

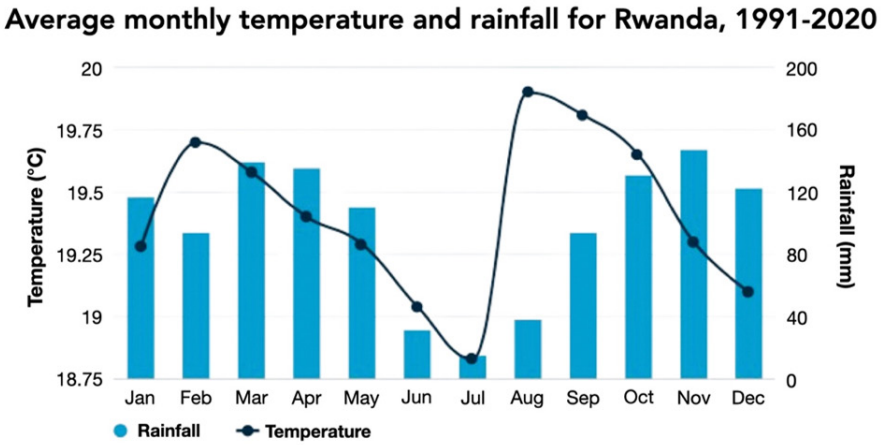


Figure 3: Average monthly temperature and rainfall for Rwanda. This data averages measures taken from 1991 to 2020, showing a clear alternating pattern between rainy seasons and dry seasons. From Dove & Sato, 2021.

Rwanda has been predicted to be highly vulnerable to climate change (Dove & Sato, 2021). An increase in the frequency of extreme rainfall events, floods, and an increase in the duration and frequency of droughts (REMA, 2022), as well as an increase in seasonal variability are projected (Dove & Sato, 2021). Using the medium projection pathway, temperatures in Kigali are projected to increase by an average of 2.5°C by 2100 (REMA, 2022; Dove & Sato, 2021; Cole et al., 2011). On the other hand, precipitation projections are uncertain, with some models predicting a slight increase (REMA, 2022; Dove & Sato, 2021), while others predict a slight decrease (Bizimana et al., 2023; Cole et al., 2011). This can be explained by the fact that although the rainy seasons are predicted to be more intense, they are also predicted to be shorter (UNEP, n.d.). Furthermore, dry seasons are predicted to be longer and drier, balancing out the annual average (Cole et al., 2011). It is important to treat these projections with caution. Due to limited historical data on rainfall and temperature, predicting Rwanda's future climate is fraught with uncertainty and conjecture (Dove & Sato, 2021; Cole et al., 2011).

Kigali is increasingly being portrayed as a model city for Africa (Baffoe et al., 2020), and it "aspires to be a centre of urban excellence in Africa" (Nkurunziza et al., 2021, P221). Active mobility is very important in Kigali, with 52% of trips made by non-motorised transport (Odero et al., 2020), but as noted above, cars are gaining interest. The population of Kigali was 1.2 million in 2018 (Marie et al., 2023), representing half of Rwanda's urban population. This urban population is expected to grow to 5 million by 2045 (Nkurunziza et al., 2021). If this growth is not accompanied by the implementation of adequate and sustainable infrastructure, Kigali risks becoming a dense, congested environment, further increasing health risks from air pollution and threatening the

well-being of the city.

Photo 1: A bicycle used to transport goods. Taken by author

The following paragraphs aim to explore the role of cycling in Kigali and provide context. The findings of the United States Agency for International Development, Rwanda Bicycle Market System Profile 2022 will be used extensively. This report surveyed over 400 respondents across Rwanda, mostly men aged 18-24, who cycle as part of their economic activities or to run errands. It aimed to identify constraints and potential solutions for the bicycle market system in Rwanda (USAID, 2022). Cycling is widely used as an economic activity in Rwanda to transport goods and people, particularly in the agricultural sector. It is an important source of income for the working class and enables people to overcome mobility barriers (ibid.). Rwanda also has bicycle taxi services, known as 'abanyonzi', which transport people and goods around the city. However, these have been banned from operating in the centre of Kigali since 2012 due to increasing congestion, and can now be found on the outskirts of the city or in other cities in Rwanda (ibid.). Cycling is the most affordable mode of transport after walking. It was found that people who cycled to work spent on average 50% less than someone who used motorised transport (ibid.).The USAID survey found that 43% of participants owned a bicycle. Overall, Rwandans use bicycles to travel to work or markets, and as a complementary mode to other motorised transport (ibid.). This is particularly the case in rural areas, while its implementation in Kigali faces several barriers (NISR, 2023).

Firstly, there is a lack of continuity between bicycle lanes in Kigali. Currently, the city has 215 km of cycle lanes scattered throughout the city (Twahirwa, 2021), with a few high quality lanes in the centre. However, there is no connection between the city centre and the suburbs, creating a discontinuity (Nkurunziza et al., 2021; Twahirwa, 2021). Conversely, the motorcycle and pedestrian infrastructure is good and is widely used as a means of mobility in Kigali, reducing the competitiveness of bicycles (USAID, 2022).

Secondly, Rwanda's hilly topography makes cycling difficult and less accessible to people with reduced mobility (ibid.). On average, it is expected that road gradients for cyclists should not exceed 5%, but implementing this in Kigali is challenging due to the difficult terrain (USAID, 2022; Nkurunziza et al., 2021).

Thirdly, due to the increase in traffic and private vehicles, road space for cycling has reduced, making cycling an unsecure mode of transport (Agyei-Boakye, 2022).

Finally, good quality cycling equipment is not affordable. People with limited means can often only buy single-geared bicycles. Additionally, it is expensive to maintain due to the cost of spare parts. Making cycling more accessible and affordable is essential to increasing daily use (USAID, 2022).

This research aims to further explore the future of cycling in Kigali and the different barriers that Kigali faces in implementing cycling as a daily mode of transport. Initially, the research focused on the role of weather as an important factor, but throughout the study a more complex system emerged in which weather appeared to be a secondary factor at present and socio-economic factors are playing an important role. The following section describes the methodology used and its limitations.

2. METHODOLOGY

This research used a mixed methodology of quantitative and qualitative data. This allowed for insights at two scales: the individual level and the governance level, which complement each other to provide a more detailed data set. Furthermore, this approach provides a dual structure by mixing top-down and bottom-up methods (Freudendal-Pedersen & Kesselring, 2016).

First, a survey was conducted to collect quantitative data. It was distributed to cyclists in Kigali through Facebook cycling groups, WhatsApp cycling groups, cycling associations and universities in Kigali, using a snowball sampling method. The advertising poster that was shared on social media is found in appendix 1. The aim of the survey was to reach a large sample of cyclists and explore their relationship with the weather and cycling in Kigali. Secondly, 5 interviews were conducted with stakeholders who work on or have close links with cycling and shaping cycling activities in Kigali. These were contacted by email after researching them through the organisation's website. In addition, some of the participants also put me in contact with other actors, thus widening the scope of the research. I spent 2 weeks in Kigali to conduct my research. This allowed for a more hands-on approach by meeting my interviewees in person, observing cycling in the field, and discussing my project with people living in Kigali.

The design of the survey was inspired by the research detailed in the literature review (Selzer, 2021; Böcker et al., 2019; Flynn et al., 2012). In addition, the survey conducted by USAID was used as a guide for questions and already implemented habits. It was designed on Qualtrics and made available in English and French. Furthermore, all answers were made anonymous. It allowed for a better understanding of individual rationalities (Freudendal-Pedersen & Kesselring, 2016), which play a key role in shaping daily cycling habits and observing trends and shared opinions. Due to the limited time frame, it focused on subjective understanding of weather, to show the complexity and interrelationship between transport and society (ibid.) and to understand why cyclists behave in a certain way (Ermagun et al., 2018). The survey was divided into 4 parts, as shown in Table 1.

Photo 2: A parked bicycle in Kigali. Taken by author.

In part 4 of the survey, participants were presented with different weather scenarios and travel needs and asked what they would do. This section was designed using weather data from Kigali and input from the USAID survey. The aim of this section was to confront participants with real-life situations to see how they would react. The survey was also designed as a personality quiz to motivate people to complete the survey. At the end of the survey, each person was assigned a type of cyclist based on their answers: A bold cyclist, an adventurous cyclist, a contemplative cyclist or a sporty cyclist. In total, the survey received 82 responses.

On the other hand, the interviews provided insights from stakeholders who play a role in shaping cycling in Rwanda, for example through funding, facilitating the flow of information about cycling or organising cycling events. The interviews were semi-structured,

which allowed the main points to be discussed, but also allowed the flow of discussion to be followed. A total of 5 interviews were conducted, all of which agreed to be fully identifiable. Table 2 names the different interviewees and their contribution to cycling.

Division of survey questions in 4 parts	
Parts	Aims
Part 1: General Information	Gain information on who completed the survey and to observe correlation between social background and cycling habits
Part 2: Participants relation to cycling	View cycling patterns and habits amongst the sample
Part 3: Cyclist experience of cycling in Kigali	Gain opinions, feedback and observations on the overall perception of cycling in Kigali
Part 4: Weather and cycling	Find how comfortable participants feel cycling in different weather

Table 1: Division of Survey in 4 parts. This table show how the survey was divided in 4 different parts and how the questions covered all 4 subjects.

Interviewee roles and interest in cycling		
Interviewees	Roles	Interests
Florent Massat	Cooperation and cultural action Attaché at the French Embassy in Rwanda	The France embassy has been supporting professional cycling in Rwanda and has worked to provide funding, equipment, coaching and training for Rwanda cyclists
Jean Pierre Byiringiro	A former sport cyclist and admin of a Facebook cycling page 'Rwanda Cycling Network'	The aim of the page Is to inform his followers of professional cycling events in Rwanda
Regis Gahuranyi	Executive director of the Rwandan Cycling Federation (FERWACY)	The federation support cycling in Rwanda by acting as a facilitator of professional cycling events and is responsible for licensing and regulation of clubs, ensuring their progress.
David Mihigo	Postgraduate at the University of Kigali	His research focused on active mobility in Kigali.
Steven Laget	Founder of the association 'Rouler pour le Rwanda'	The association aims to make professional cycling more accessible by giving the opportunity for Rwandan cyclists to participate in European competitions and training mechanicians to fix high quality bicycle.

Table 2:Interviewee's role and interest in cycling. This table show the interviewees name, roles and details why they are actors of cycling in Kigali.

The results were analysed using Qualtrics. Two statistical analysis methods were used: data correlation and cluster analysis. Data correlation consists on relating two variables to observe if they are related and have a statistical relationship. A cluster analysis enables to organise variables together depending on how closely associated they are. Enabling to group respondents. These methods enabled to observe trends and patterns. Data that had the most statistically significant relationship are discussed part 3. Raw data can be found in appendix 3. The visuals of the discussions where designed on Keynote and made to best represent the data following a colour code of the Rwandan flag.

2.1 Limits of the methodology

The survey was mainly shared through cycling groups on social media, and was completed by people who primarily cycle for leisure rather than commuting, with 59% of participants cycling for leisure only and 33% cycling for commuting only. Similarly, most of my interviews were with people involved in professional cycling, reducing my input on commuter cycling. This will influence the findings as the experiences will reflect leisure cyclists rather than commuters, limiting feedback. However, this may also lead to more critical reflections, as leisure cyclists are the ones who choose not to cycle to commute, and therefore provide insight into the limitations that block them from commuting via cycling and identify the main barriers that need improvement (Edberg, 2023).

In addition, due to the length of the survey, many participants did not complete it until the end. The average time taken to complete the survey was 24 minutes . Therefore, only 60% of respondents completed more than 75% of the survey. As a result, questions reflecting cyclists' relationship with the weather and their experience of cycling in Kigali were not answered. A more concise survey might have ensured a higher completion rate. However, when designing the survey, I wanted it to be as complete as possible, knowing that it would represent half of my data. Due to the unbalanced completion of the survey, only the responses of respondents who completed more than 40% are used in the analysis to ensure that the general information represents the findings of the entire survey, thus limiting the total number of responses to 65.

Furthermore, the results of the survey are not representative of the population of Kigali. The respondents to the survey were predominantly young, middle-class, higher educated males, and 31% of the respondents were foreigners. A national census conducted in 2022 found that only 12% of the population of Kigali had a university degree and that foreigners made up only 1.18% of the total population (NISR, 2023). This differs from the sample of survey respondents. This can be explained by the fact that the use of a snowball sampling method has limited the diversity of the research, reflecting only the experiences of respondents with similar social backgrounds, mainly middle class. In addition, my positionality played an important role in shaping this research. Firstly, the network I used in Kigali was mainly middle and upper class European. This can be explained by my cultural background. Furthermore, being bilingual in French and English, I was unable to communicate with locals who only spoke Kinyarwanda, which limited my ability to interact and reach out to them. This limited my ability to represent the experiences of the local working class. Finally, coming from a European background, I am used to European norms of cycling and mobility culture, such as safety norms and social expectations. Although I tried to be as neutral as possible when asking questions, my background will have influenced my research. For example, I do not feel comfortable cycling in Kigali due to the hilliness of the roads, but I admire cyclists who do. However, they do not necessarily have a choice and such environmental features are the norm for them. When analysing my data, I will have been more attracted to findings that deviate from my cultural understanding, inflating the importance of certain findings and reflecting a European critique of Kigali. The research used to compare and analyse my findings is also largely from European universities, reinforcing a European lens and analysis.

[1] One participant took 30 h to complete the survey, however this data point has been classified as an outlier and not representative of the overall data and therefore was not used to calculate the mean

3. FINDINGS AND DISCUSSION

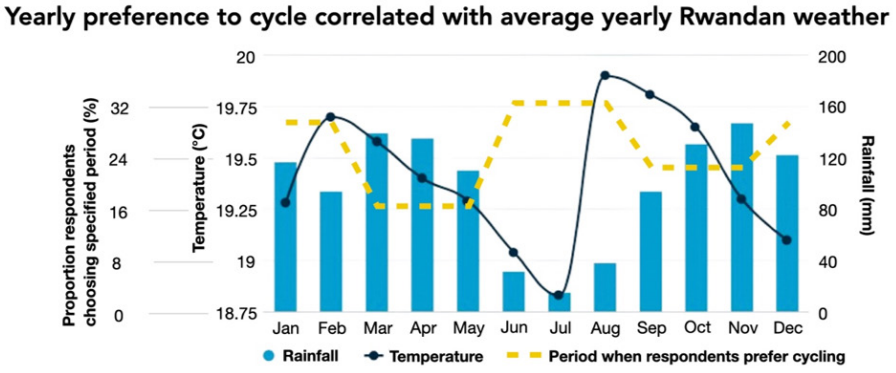
The first part of this section will look at how weather affects cycling habits and the different weather factors that have been found to play an important role. These findings will then be put into the context of climate change. The second part of this section will look at the socio-economic factor.

3.1 Weather impact on Cycling in Kigali

The survey asked respondents to rate 8 different factors [2] to show which were more important in their decision to cycle. On average, weather was ranked as the most important factor, followed by time of day and destination [3]. This shows that weather conditions play an important role in people's decision to cycle. In addition, respondents were later asked to rank the most important weather factors they considered before cycling. Precipitation was ranked first, followed by the weather in the previous days and the outside temperature [4]. The high ranking of precipitation and outside weather confirms the findings of Böcker et al., Hudde and Liu et al. (Böcker et al, 2013; Hudde, 2023; Liu et al, 2017). These findings show similar results from European cities, where temperature and precipitation play an important role in shaping cycling habits. Furthermore, the importance of precipitation is strongly reflected later in the study. For example, rain is often cited as one of the most important reasons for not cycling in the different scenarios. This is also observed when looking at seasonal variations, as discussed in the following part.

3.1.1 Seasons

Overall, participants prefer to cycle in dry conditions and mild temperatures, as shown in Figure 4. Cyclists cycle more between dry seasons, with a decrease in both rainy seasons. These findings show that seasons influence the decision to cycle, as stated in the literature review (Böcker et al., 2013, b). With a different calendar compared to western cities, the binary is not between winter and summer, but between rainy and dry seasons. Cyclists often plan their year according to the seasons, cycling more during the dry seasons and limiting their movement during the rainy seasons. This was mentioned in the interview with Regis Gahuranyi, who explained how people who work in the agricultural sector plan their year so that they work on their crops during the rainy season, when the soil is fertile and well irrigated, and use the dry season to transport their goods and sell them.



Preference to cycle during the year	
December-February	29%
March-May	16%
June-August	32%
September-November	22%

Figure 4: Yearly preference to cycle correlated with average yearly Rwandan weather. This figure shows the period where participant preferred to cycle (Data from research's survey) depicted on average monthly temperature and rainfall for Rwanda 1991-202 (work from Dove & Santo, 2021)

[2] The factors included: The time of the day, the route, the destination, the distance, the purpose of the trip, one's plan for the rest of the day, the outside weather and the hilliness of the route

[3] When analysing those results it was found that several respondents may not have ranked all factors, therefore in order to analyse the results it was decided to omit all response that had not interacted with the last factor (the hilliness of the route), excluding 9 answers out of 65

[4] When analysing those results it was found that several respondents may not have ranked all factors, therefore in order to analyse the results it was decided to omit all response that had not interacted with the last factor (the weather in the previous days) excluding for 3 responses out of 65

3.1.2 Precipitation

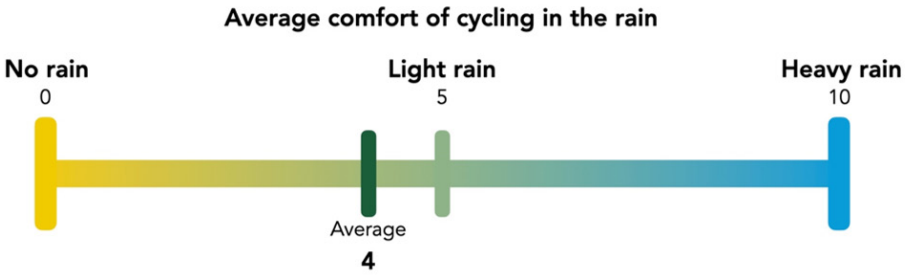


Figure 5: Average comfort of cycling in the rain. This figure depicts on average how comfortable felt cycling in the rain on a scale of 0-10. Data from research's survey

On average, as depicted in figure 5 cyclists did not feel comfortable cycling in rain in Kigali. Rain in Rwanda is characterised by 'showers'. These are brutal and sudden downpours that often last for a short period of time. In the survey, participants said that they found it difficult and uncomfortable to cycle during these showers. This can be explained by the fact that, as an open-air vehicle, the bicycle is particularly vulnerable and lacks protection. Visibility is reduced, the roads are slippery and the high gradient of the roads increases the risk of falling. In addition, the 'showers' are often accompanied by strong winds, adding to the stress. As a result, bicycles cannot be used during these events and people who rely on them end up waiting for the rain to stop, which can take 1-3 hours. This was highlighted by Florent Massat.

> "[Bicycles] stop because there is no shelter from the rain, it becomes quite dangerous to move around as the roads are quite steep, both uphill and downhill" (Interview with Florent Massat)

It was also found that the effect of rain varies according to how often one cycles (see figure 6). The more often people cycle, the more comfortable they are with cycling in heavier rain. This can be explained by the fact that people who cycle more often are commuters and do not necessarily have the flexibility to switch to another mode of transport due to limited flexibility. Therefore, these participants have become more resilient to rain and heavier precipitation because they do not have a choice and therefore have to be more adaptable than people with more flexibility. Form these findings one could suppose that the more individuals get used to cycling in Kigali, the higher their level of comfort is to cycle in the rain. However, a change in cycling frequency will not be enough increase the number of cyclist during rain events, the development of protective infrastructure will be necessary.

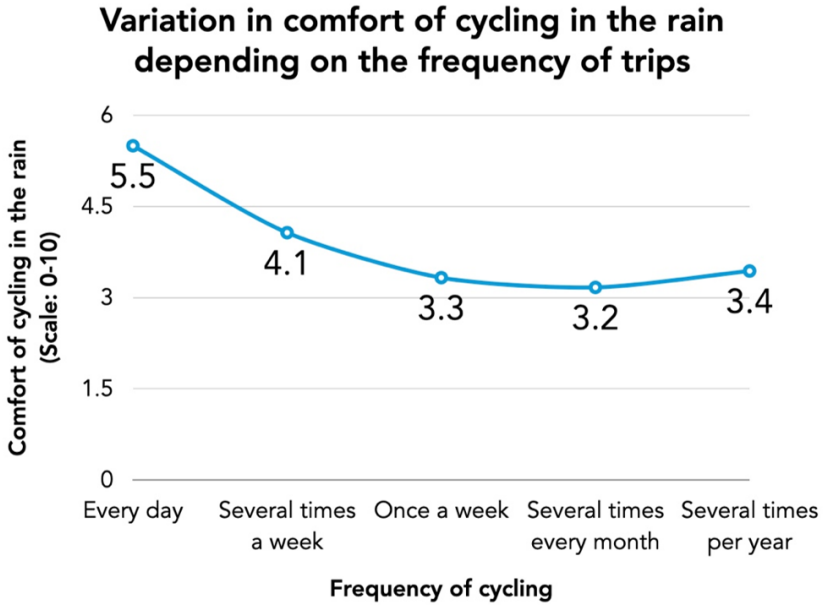


Figure 6: Variation in comfort of cycling in the rain depending on the frequency of trips. this graph shows how participants resilience to rain varied depending on how often they cycle. Data from research's survey.

3.1.3 Temperature

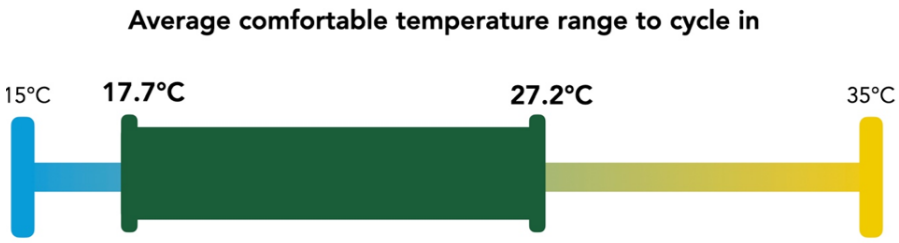


Figure 7: Average comfortable temperature range to cycle in. This diagram shows the average maximum and minimum temperature respondent felt comfortable cycling in. Data from research's survey.

On average, participants were found to be comfortable cycling in a temperature range of 17.7-27.2°C (as depicted figure 7). However, this varied according to the nationality of the participants. On average, foreigners feel comfortable cycling in a temperature range of 13-31°C. Rwandans, on the other hand, have a much more modest range of 20-25°C. This follows Hudde's argument that mobility culture plays an important role in shaping mobility (Hudde, 2023). Different cultural backgrounds lead to different comfort zones. Foreigners, 70% of whom come from European countries, are more used to a temperate climate and therefore colder weather, with temperatures that vary considerably depending on the season. Therefore, someone who is used to this type of weather is more willing to cycle in a wider range of temperatures. On the other hand, Rwanda's mobility culture is accustomed to hotter weather with a limited range of variability between seasons, and therefore individuals may be less comfortable with large changes in temperature. This finding further demonstrates that perceptions of weather are subjective and vary according to culture and experience (Liu et al., 2017). It also shows the parabolic curve which is consistent with the literature review (Böcker et al., 2013, a).

3.1.4 Climate change and cycling in Kigali

When asked, most respondents and interviewees said they had experienced a shift in the seasons, with rain experienced during the dry season and no rain during the rainy season, making the seasons less predictable. In addition, some participants reported that they had experienced more frequent flash floods. Some participants explained how this had affected their cycling habits, as they cycled less often due to the change in weather. This follows the findings discussed in the literature review on climate change predictions (REMA, 2022; Dove & Sato, 2021; Cole et al., 2011).

Considering the results of the impact of weather patterns on cycling habits alongside climate change predictions, some interpretations can be made. With a changing climate, the number of cyclists may increase during more frequent dry periods. Due to ambiguity in rainfall predictions, suppositions are uncertain, whilst a decrease in precipitation could lead to an increase in cycling, conversely an increase in precipitation could lead to a decrease in cycling. More in-depth research is needed to make specific predictions about climate change. These findings are a starting point, further research is needed to test and verify these assumptions and provide scientific leverage.

Whilst weather holds an important role in shaping cycling habits, it is found to be currently a secondary factor. Social and economic factors were found to play a more significant role, particularly social class differences and will have important impact on the future of cycling in Kigali. The following part of this section explores this socio-economic factor, how it relates to the weather and its significance for the future of cycling in Kigali.

3.2 Social class as a modelling factor

At the start of the survey, respondents were asked to define their social class, with a choice between upper, middle and working class, in order to observe how wealth affects cycling habits. Using a cluster analysis, it was found that respondents fell into two groups. On the one hand, there were those who described themselves as working or middle class. Those were mostly Rwandans, they were more likely not to own a car or a bicycle and, therefore, were more likely to rent bicyles. They cycled on average once a week to run errands, covering a distance of 3-5 km. On the other hand, participants who defined themselves as upper class were mostly foreigners. On average, they owned at least one car, cycled for leisure several times a week, and cycled more than 20 km per trip. The difference in car ownership (shown in Figure 8) is important as it reflects a difference in flexibility between the two groups, where higher classes are more likely to have access to a car making them more flexible when choosing a mode of transport.

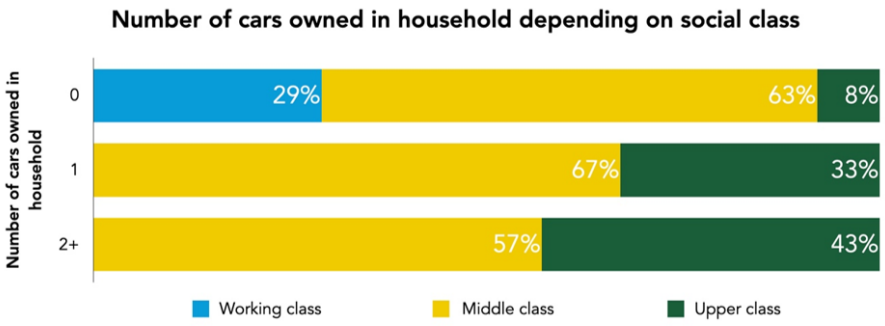


Figure 8: Number of cars owned in household depending on social class. This graph shows that the number of cars owned by participants varied depending on their social class. Data from research's data.

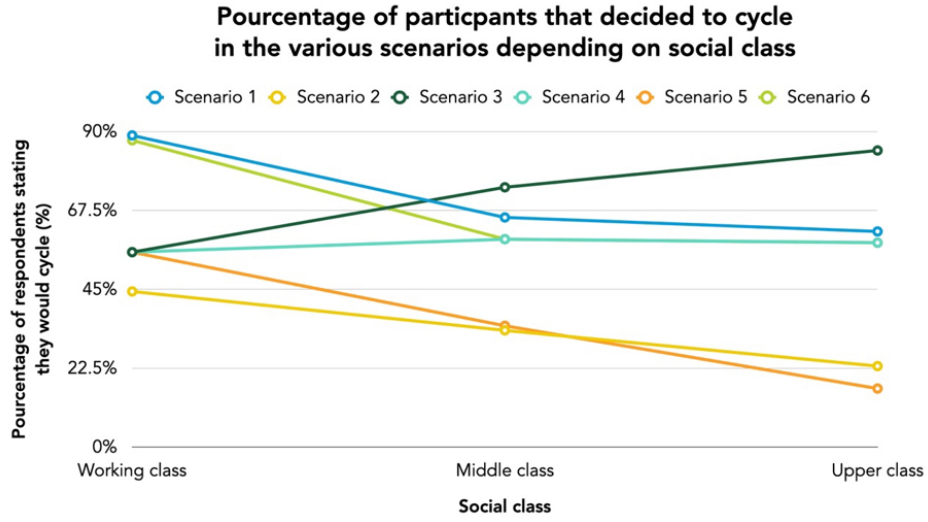


Figure 9: Percentage of participants that decided to cycle in the various scenarios depending on social class. This graph shows how upper and middle class are often less likely to cycle compared to working class. Data from research's survey.

This was also observed in the different scenarios, with the upper and middle classes tending to switch to driving in rainy weather conditions. Conversely, the working class were 19.41% more inclined to cycle for commuting (scenarios 1, 2, 5, 5, 6; more detailed figures on the various scenarios can be found in appendix 3) (see Figure 9). When the working class decided to change their mode of transport, they often chose public transport as an alternative. These results show that the working class has less flexibility in their mode of transport. Due to a lack of alternatives, they are often limited to cycling in bad weather or, if they can afford it, public transport, which may limit their independence due to fixed timetables. It can be argued that this lack of flexibility has made the working class more resilient in the face of rain. As shown in Figure 10, the working class are more comfortable with cycling in the rain than the upper and middle classes. One of the reasons for this may be that, due to a lack of flexibility, the working class need to be more adaptable to a wider range of weather conditions and cannot be as picky as the upper and middle classes who have more alternatives. This follows Liu et al's finding that flexibility plays an important role in cyclists' decision making (Liu et al., 2017).

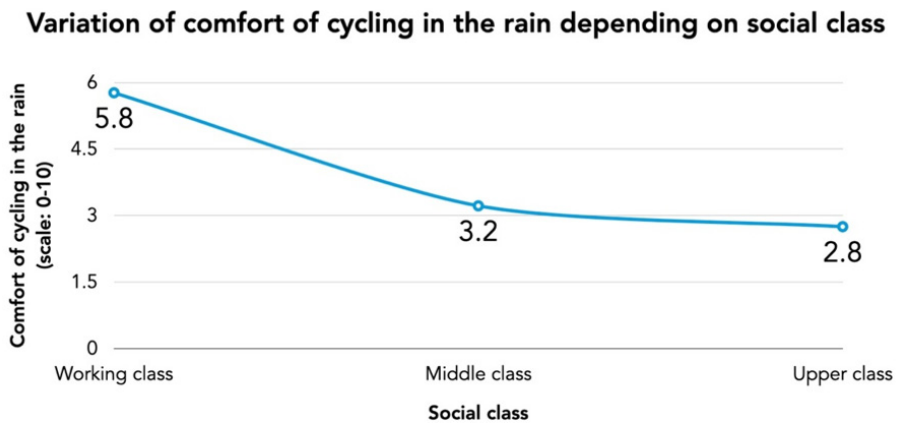


Figure 10: Variation of comfort of cycling in the rain depending on social class. This graph shows how working class are more resilient in the face of rain compared to middle and upper classes. Data from research's survey.

3.2.1 Access to cycling equipment

In addition, wealthier classes have access to more equipment than working classes. This is important because good equipment enables cyclists to cycle in more adverse weather conditions. As some participants in the scenarios stated, light or heavy rain is not necessarily an obstacle if one is well equipped. For example, some respondents stated that disc brakes rather than rim brakes made it safer to cycle in the rain. However, equipment and bicycles with disc brakes are more expensive and therefore less accessible to the working class. Therefore, although the working class may feel more comfortable cycling in the rain, they may be more at risk due to inadequate equipment. For example, only 44% of working class participants had a helmet, compared to an average of 77% for the upper and middle classes. In a sense, limited wealth prevents users from protecting themselves against the risks of cycling. As well as having less access to cycling equipment and accessories, the working class are also less likely to own a bicycle. 66% of the working class said they did not own a bicycle and 30% said they owned 1 bicycle. In contrast, 56% of the middle class owned 1-3 bicycles and 54% of the upper class owned more than 4 bicycles. This is in line with USAID findings that the cost of bicycles, bicycle parts and their maintenance is expensive, reducing their affordability and accessibility to the working class population (USAID, 2022). An interesting finding from the survey is that even though the majority of working class do not own a bicycle they still largely cycle to commute. This can be explained as 67% of the working class rented bikes, mainly from public shared bicycles. This enables them to cycle around even though they do not have the money to own a bicycle. However, as a whole, users who did not own a bicycle cycled less frequently and covered shorter distances than those who owned at least 1 bicycle. Therefore, it could be concluded that by just making bicycles more accessible this will lead to an increase in cycling and ensure Kigali reaches its sustainable mobility goals. However, the issue is more complex and social acceptance is currently acting as an important barrier.

3.2.2 Cycling as the "poor-man's-mean of transport"

The results of the survey showed that the more bicycles respondents owned, the less they cycled: 25% of users with one bicycle cycled daily, compared to 8% of users with two or more bicycles. As people experience upward social mobility, they change their mode of transport and cycling becomes a leisure or sport activity rather than a means of commuting. At present, the high price of sport bicycles means that leisure cycling is reserved to wealthier populations, while daily cycling is mainly used by the working class. It was found that 65% of the upper and middle classes used a bicycle for leisure, compared to 44% of the lower classes. On the other hand, 56% of the working class cycled to work/university compared to 33% of the upper/middle class. There is a clear distinction between cycling for leisure and cycling to commute. This can be explained by the current economic hierarchy that exists between modes of transport (Twahirwa, 2021). As Florent Massat put it, there is a hierarchy of transport modes:

> "If individuals have the economic capacity, they will own a car and drive, if not, they will move by motorcycle or motorbike taxis, if not, they will use a bicycle and as a last resort, they will walk." (Interview with Florent Massat)

As individuals achieve financial stability, they invest in moving up this hierarchy, switching from active mobility to private motorised transport.

> "Bicycles are seen as poor-man's-mean of transport. If you are really poor you might not be able to afford a bike, if you are more affluent, you might not want to ride a bike and look like a poor person" (An anonymous survey participant)

The car is currently a symbol of socio-economic status (Twahirwa, 2021; Agyei-Boakye, 2022). Owning a car and driving around Kigali represents a certain level of wealth. As people gain financial status, they are likely to invest in a car, not only to be more flexible and independent, but also as conspicuous consumption. A wealthy person who can afford a car would be less likely to cycle, as they would be socially perceived as a poor individual. There are important social pressures that motivate people to switch from active mobility to private motorised vehicles in order to fit in and dispose of their wealth (Agyei-Boakye, 2022). Not only is commuting by bicycle associated with poor people, but drivers in Kigali feel contempt for cyclists in Kigali, creating a tense relationship between cyclists and drivers. Jean Pierre Byiringiro described the situation:

> "(In rural areas, the drivers) they say hi, or they just move aways so that you can pass. But in Kigali the drivers are crazy, what they have in mind, is that they want to get wherever they are going fast, so they're only focusing on themselves instead of focusing on others." (Interview with Jean Pierre Byiringiro)

This is one of the reasons why leisure and sport cyclists feel safer cycling outside of Kigali. Currently, Kigali is not

an attractive place to cycle due to high congestion, limited space and driver behaviour (Sovacool et al., 2022). Furthermore, cycling for leisure is much more accepted than as a mode of transport, and this lack of acceptance is a barrier to the adoption of cycling for commuting in Kigali (Twahirwa, 2021).

Photo 3: Individual cycling. Photo taken by author.

This poses a threat to the future of cycling in Kigali, because as people move up the social ladder, they will increasingly own private motorised vehicles, putting further strain on the road network, leading to more congestion and an increase in transport emissions and air pollution. Edberg explains that historically, the car was seen as a status symbol and cycling was a leisure activity reserved for the wealthy. Over time, however, it became a dominant mode of transport for the working class and was later marginalised, before regaining interest and use in recent years (Edberg, 2023). If this linear development of cycling were to take place in Kigali, the next logical step would seem to be the marginalisation of cycling. Breaking this path-dependency (Freudendal-Pedersen & Kesselring, 2016) will be essential to achieving Kigali's master plan. If nothing is done, Kigali is likely to reproduce the mistakes made in western cities and become a car-dependent city, and will face the 'wicked problem' that western cities currently face in trying to transform their car-dependent cities into active mobility cities (ibid.). However, the effort to ensure that people do not change their mode of transport is complicated. Over the years, the transport sector has enabled poverty reduction and economic growth in Kigali, and these trends are expected to increase (Nkurunziza et al., 2021). Restricting access to cars and motorised transport could be a counterproductive strategy for socio-economic development. Kigali must find a way to balance economic and social growth with maintaining active mobility as one of the main modes of transport in Kigali to ensure sustainable development. This is a challenge that Kigali has to take up by challenging the linear growth of cycling and reinventing itself. If it succeeds, it will become a model city for all developing cities, thriving economically, socially and environmentally.

Achieving this will not be easy and will require constant policy change, as well as a change in spatial and social context to ensure its longevity (Selzer, 2021).

3.3 Key recommendations

The city of Kigali has already started to implement some projects, such as the car-free day, which takes place every two weeks on Sunday, when certain streets in the centre of Kigali are closed to motorised vehicles from 7am to 10am to allow the population to walk, cycle or run in a safe environment (Nkurunziza et al., 2021). In addition, the government has provided bicycles to government and institutional staff (USAID, 2022), and the Rwandan government has waived a 25% tax on sport bikes to further promote their use and ownership (USAID, 2022; Odero et al., 2020). Finally, as part of the Kigali Master Plan, they aim to further expand bicycle lanes (Surbana Jurong Consultants, 2020). However, more work is needed to challenge the current social status of the car and to ensure that cycling remains attractive and accessible to all. The following part of this section proposes a set of recommendations to address this challenge, aimed at improving cycling infrastructure to ensure accessibility and attractiveness.

3.3.1 Improving infrastructures

Participants did not necessarily feel safe cycling in Kigali, and felt at risk when sharing lanes with motorised vehicles such as motorbikes and cars. Due to the increase in motorised vehicles, participants felt that the roads were very congested, reducing their space on the road, comfort and sense of safety. It is currently estimated that 28% of road traffic injuries in Rwanda occur to cyclists (Walker et al, 2022). It was also found that participants who cycled on cycle lanes felt safer than those who cycled on roads or shared paths with pedestrians, with an average feeling of safety of 7 compared to 3 respectively . In addition, participants who cycled on good quality roads felt safer. Implementing and improving the current cycling infrastructure and cycle lanes will ensure that users feel safer and will increase the cycleability and attractiveness of Kigali.

The extension of protected cycle lanes, such as those in the centre of Kigali, as shown on KN 3 Avenue in photo 4, will be essential for the future of cycling in Kigali. As depicted in figure 11, these are designed to have a central zone for motorised vehicles and a vegetated buffer zone to protect cyclists and pedestrians. This buffer zone will, in the long term, provide shade that could help protect cyclists and pedestrians from increasing heat and make them more resilient to climate change. In addition, the pedestrian path is elevated above the cycle path to provide a clear demarcation and reduce the risk of collisions. This was shown by David Mihigo. Improving this infrastructure and ensuring it is well connected could make cyclists feel safer and make cycling more attractive. Not only would this encourage and

Photo 4: Individual riding bicycle on protected bicycle lane on KN 3 Avenue. Photo taken by author.

Figure 11. ***Cross section of protected bicycle lanes.*** Diagram created by author.

Figure 11: Cross section of protected bicycle lanes. Diagram created by author..

[5] Respondents were given a range from 0-10 to rank how safe they felt when cycling. 0 being feeling very unsafe and 10 being feeling very safe. Respondents drag the cursor to best reflect their feeling.

facilitate cycling as a mode of transport, but good infrastructure could also make users more resilient to adverse weather conditions. The survey found that respondents who cycled on roads they considered to be of very good quality said they felt comfortable cycling in temperatures ranging from 16.7 to 30.4°C, compared to an average of 18.8 to 26.5°C for roads of other qualities. These results seem to indicate that ensuring good quality roads will ensure that cyclists feel comfortable cycling in hotter conditions. This will be particularly important in the coming decades. As mentioned above, climate change projections predict an increase of 2.5°C in Kigali by 2100 (REMA, 2022; Dove & Sato, 2021; Cole et al., 2011). To ensure the viability of cycling in Kigali in the future, it will be essential to ensure that cyclists are comfortable cycling in hotter temperatures. Furthermore, the implementation of these cycleways will need to be designed to be resilient to climate change. For example, by using surfaces that can withstand an increase in temperature, permeable surfaces, or by installing drainage systems to reduce the risk of run-off, which poses a risk to cyclists (USAID, 2022). As mentioned by Florent Massat, benchmarking solutions adopted elsewhere could show what solutions are available and which would best suit the city of Kigali.

In addition, the development of cycle lanes needs to go hand in hand with the implementation of cycle parking facilities.

This was raised in some of the scenarios where participants did not choose to cycle because they did not have a designated place to park their bike and were concerned that their bike would be damaged or stolen.

> "I would not want to deal with […] the prospect of bike theft. Locking a bike up outside a shop doesn't feel safe in Rwanda." (An anonymous survey participant)

Ensuring that bikes can be stored safely throughout the city would further improve the usability and attractiveness of cycling. Improving cycle lanes without improving cycle parking will be counterproductive.

Cycle lanes also need to be equipped with street lighting. Currently, respondents who cycle after 6pm feel less safe cycling, with a safety score of 1.4 compared to an average of 4.1 for the rest . Enabling cyclists to feel more comfortable at night could help make cycling more attractive. Night falls early in Kigali, around 6pm, so making cycling more accessible at night could ensure that people can cycle after work.

Finally, it is important to note that protected cycle lanes may only be feasible on main roads and may be more difficult to implement on smaller roads due to limited space. Therefore, on smaller roads, a designated space could be marked on the road. However, it will be necessary to change the current relationship between cyclists and drivers and create a relationship of respect to ensure the safety of cyclists. Several participants expressed that drivers may be unfamiliar with sharing the road with cyclists; to address this, participants suggested to:

> "Improve driver behaviour or enhance understanding on what to do when bikers are around" as well as implement "more severe rules and fines for drivers misbehaving with cyclists"(From two anonymous survey participants)

Educating drivers will be important to build trust and ensure that cyclists feel safe sharing the road with other users, further promoting cycling in Kigali.

Another type of cycling infrastructure that will benefit Kigali is public shared bicycles. Kigali currently has a public shared bike service called Guraride, which has been implemented in the centre of Kigali since 2021 (Oduku, 2021). It allows users to rent bikes from 18 different stations (Photo 8 shows a station) via an app. The system also offers electric bikes, which are very valuable for Kigali as they allow the topographical terrain to be less of a barrier to cycling. This bike service has made cycling more accessible to users who cannot afford a bike. As noted above, 67% of the working class rented bicycles and 25% of respondents who rented bicycles used public bicycle services. Expanding this service would further support the expansion of cycling in the city and make cycling more accessible to all. However, the initiative is facing difficulties. Currently, only 9 stations are operational, bikes remain unused and the app is dysfunctional (ibid.). By improving this initiative and ensuring good maintenance, it will be possible to make cycling more accessible, increase cycling and reduce private motorised transport, directly reducing transport emissions, air pollution and congestion (Jean de Dieu, 2020).

[6] Respondents were given a range from 0-10 to rank how safe they felt when cycling. 0 being feeling very unsafe and 10 being feeling very safe. Respondents drag the cursor to best reflect their feeling.

The above recommendation would increase the accessibility of cycling and improve the cycleability of Kigali. However, the implementation of this infrastructure will be counterproductive if the social hierarchy of transport is not addressed. The social symbol of the car is currently ingrained in society and challenging this will require radical change. Cycling needs to be popularised. Currently, professional cycling is popular, with several annual competitions such as the Tour du Rwanda, and Rwanda will host the World Cycling Championship in 2025 (Odero et al., 2020). As noted above, the Rwandan government has made important efforts to promote recreational cycling, such as waiving taxes on sport bikes or introducing a car-free day, but more needs to be done to promote cycling as a means of commuting.

Photo 5: Guraride bicycle station. Photo taken by author.

CONCLUSION

Overall, this research explored the future of cycling in Kigali, focusing on 2 main factors: weather and socio-economic class. It aimed to address the current research gap and bring the case study of Kigali to extend the geographical coverage of this area of research. In the first part, a literature review presented the research that had already been done and introduced the case of Kigali. This contextualised the research and provided a knowledge base. The second part presented the methodology used for the research and the limitations of the methodology. The final part presented the findings of the research and concluded that social and infrastructural changes are needed to ensure a future for cycling in Kigali.

Two main findings emerged from the research. Firstly, rainfall and temperature play an important role in determining cycling habits. Due to climate change predictions those factors are likely to shape future cycling habits. It will be necessary to implement infrastructure that is resilient to climate change and that ensure that individuals feel comfortable cycling. This can be achieved by planting vegetation around cycle lanes to provide shade and reduce rainfall. This will improve cycleability and make cycling more attractive. However, weather is currently a secondary factor. The research found that the socio-economic factor has a greater impact.

At present, cycling as a means of commuting is strongly associated with the working class. As the population experiences upward social mobility, they invest in private motorised vehicles to gain more flexibility, and demonstrate their wealth, moving up the social ladder. This threatens sustainable transport in Kigali, currently, economic development is causing a growth the number of cars at the expense of active mobility, increasing congestion and emissions, causing health problems and further exacerbating climate change. This research highlights the importance for Kigali to challenge the linear development of cycling to avoid cycling becoming a marginalised mode of transport. This will not be easy to achieve, but doing so will ensure sustainable development and make it a model for all developing cities. To achieve this, Kigali will need to expand cycling infrastructure and make it more attractive and safe. Simultaneously, it will need to ensure a change in Kigali's mobility culture to challenge the dichotomy between social class and mode of transport. Cycling to commute

in Kigali should no longer be seen as a sign of poverty, but rather as a sign of environmental and social awareness that contributes to the prosperity of the population.

As mentioned in the methodology section, this study has several limitations. The survey sample is not representative of the population of Kigali, the survey completion was limited and there is a lack of response from users who actively cycle to commute. In addition, due to limited capacity, the results collected are highly subjective and the research was not able to verify that participants were acting in accordance with their statements. The limited time also limited the scope of the research. As part of the methodology, the research aimed to conduct a travel diary but this had to be abandoned. Similarly, the Mayor of Kigali was contacted and was interested in being interviewed, but this was not possible due to scheduling conflicts.

This research opens up space for new studies. Firstly, more in-depth scientific research is needed to gain a better understanding of climate change projections in Rwanda. In addition, research that includes rural Rwanda would provide a more representative sample of cyclists in Kigali and allow results to be extended to the wider population. Finally, the electric bicycle was mentioned by several interviewees and survey respondents throughout this research. Further research could explore how e-bikes could be integrated in Kigali, whether this would help to make the population more inclined to commute by bike, how to make their implementation more accessible to all, and whether they could help to curb the expansion of motorised vehicles. Finally, there is a need to further extend the geographical reach of cycling and weather research domain, as this will help to better understand cycling behaviour and further promote active mobility, leading to more sustainable cities.

In conclusion, cycling in Kigali is currently threatened by a shift towards a car-centric society, and ensuring that cycling remains attractive and widely used is a challenge that Kigali needs to take up in order to achieve its sustainability goals and challenge the historical linearity of cycling development. Achieving this would be promising for all developing cities and would make Kigali a model of active mobility and sustainable development.

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