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GFDT Global Facility to Decarbonize Transport

The Case for Cycling Infrastructure Investments

CyclingMax: A Cost & Benefit Scoping Tool for Decision-makers

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Acknowledgments

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1

Introduction

Explore how CyclingMax, the World Bank’s Cost-Benefit Tool for cycling facilities, can help planners and policymakers make informed decisions on building sustainable urban transport infrastructure. Explore use cases and benefits, identify inputs required, and get clear, quantifiable evidence of investment value.

As cities around the world continue to expand rapidly, urban planners and policymakers are confronting the realities of urban mobility in densely populated areas. With rising incomes and urbanization rates, there is a noticeable increase in vehicle ownership, demanding more road space and significant funding for road and vehicle infrastructure maintenance. This trend, driven by an implicit subsidy of private motorized transport, discourages low-carbon and cost-effective travel modes like walking, cycling, and public transport. Such developments run counter to the urgent need for reducing emissions and fostering equitable and livable urban environments.

Cities that promote active mobility enjoy lower emissions, better air quality, and healthier residents. Projections indicate that urban travel by walking, cycling, and public transport will drop 40 percent by 2050, causing greenhouse gas (GHG) emissions to surge 33 percent above current levels. On the other hand, according to the same study, a car-centric transport system costs 50 percent more in transport spending by governments and individuals compared to a system based on walking, cycling, and public transport. Governments could save up to 20 percent on transport budgets, although this percentage may vary by country. This estimate does not account for additional savings from reduced healthcare expenses and increased economic productivity, which could lead to even greater savings. Research shows that walking 30 minutes or cycling 20 minutes daily reduces mortality risk by at least 10 percent (WHO 2022).

Low and Middle Income Country (LMIC) cities have a distinct opportunity to capitalize on their still low motorization rates and the high proportion of trips made by walking and cycling, also referred to as active mobility or non-motorized transport (NMT). Many cities in the Global South joined global networks, actively pursuing cycling as a key strategy to improve air pollution and reduce emissions from the transport sector; improve physical health; and boost the use of sustainable transport across the network. Despite this progress, most LMIC cities continue to experience declining rates of walking, cycling, and public transport use while motorization increases. To reverse this trend and maximize their existing advantages, cities must enhance the safety and quality of active mobility infrastructure. By doing so, they can ensure that residents choose walking and cycling out of preference rather than necessity (Pojani and Stead 2015).

Research from UC-Davis and the Institute for Transportation and Development Policy (ITDP) highlights the massive gap in cycling infrastructure – cities currently build only one-tenth of what they need to meet global climate targets. With 68 percent of the world's population projected to live in cities by 2050, it is critical to invest in infrastructure that supports sustainable transport modes. Strategic investments in cycling infrastructure offer a proven solution that transforms urban mobility while delivering substantial socioeconomic returns.

1.1. Tackling barriers to financing active mobility infrastructure

In response to this looming urban transport crisis, active mobility has gained prominence in both international and local policy agendas. Policymakers now recognize walking and cycling as essential components of safe, healthy, and green transport. This recognition extends to major global frameworks like the Sustainable Development Goals, Global Climate Agenda, and Global Health Agenda.

The report "The Path Less Travelled: Scaling Up Active Mobility to Capture Economic and Climate Benefits" (World Bank, 2023) identifies opportunities to replicate large-scale cycle infrastructure investments, including in cities like Tianjin, China where investments in walking and cycling led to increased metro ridership (and revenues). It also points to the need for a standardized methodology for evaluating the costs and benefits of active mobility projects. The absence of reliable data and tools to assess the real benefits of cycling infrastructure has made it challenging to assess the return on investment. This lack of clarity limits the ability of decision-makers and investors to make well-informed impactful choices. Developing a data-driven tool would help build stakeholder capacity to invest and reduce the risk of scaling up active mobility initiatives.

There is a growing body of evidence supporting the case for the economic and climate benefits of investing in cycling infrastructure. In 2021, the World Bank, along with the Government of the Netherlands and the World Resources Institute (WRI), published "Investing for Momentum in Active Mobility", which compiled general evidence of the costs and benefits of investing in walking and cycling, as well as opportunities for funding and financing such investments. Similarly, in 2022, ITDP published "Making the Economic Case for Walking and Cycling" and "Protected Bicycle Lanes Protect the Climate".

Building on these foundational studies and recognizing the need for instruments that aid practical implementation, the new groundbreaking Cost-Benefit Analysis Tool for Cycling Facilities, also known as CyclingMax, was created in partnership with ITDP and Progress Analytics LLC. This innovative tool is designed to provide decision-makers with actionable insights using just a few simple inputs. It takes the guesswork out of estimating benefits and empowers smarter investments in cycling projects that will deliver long-term benefits for community health, sustainability, and quality of life.

1.2. Empowering policymakers to make informed decisions

The objective of this project is to present a practical interactive tool to estimate the economic returns of cycling investments, particularly in developing regions where transport data is scarce. The CyclingMax tool combines user-friendly design with comprehensive analysis capabilities. Through its web-based interface, users can either work with built-in default values or input their own data to generate customized assessments. The tool calculates two key indicators which provide decision-makers with clear, quantifiable, and comparable estimates of investment value:

- Net Present Value (NPV)
- Economic Internal Rate of Return (EIRR)

A comprehensive, standardized methodology offers the basis for more comparable and reliable estimations across projects of different sizes and in different locations. The tool is particularly useful for early-stage planning and low-data environments. The tool considers a wide spectrum of potential benefits, including:

- Mobility impacts as measured by travel times
- Road safety improvements
- Public health gains
- Environmental benefits

These benefits are converted into monetized annual cash flows for clear comparison. On the cost side, the tool accounts for both initial construction expenses and ongoing maintenance requirements of cycling facilities.

1.3. Creating a pathway to optimize cycling infrastructure investments

The CyclingMax tool allows policymakers and investors to quickly evaluate potential cycling investments in early stages of project planning, from basic infrastructure improvements to protected bike lane networks. It also provides insights to critical questions, such as:

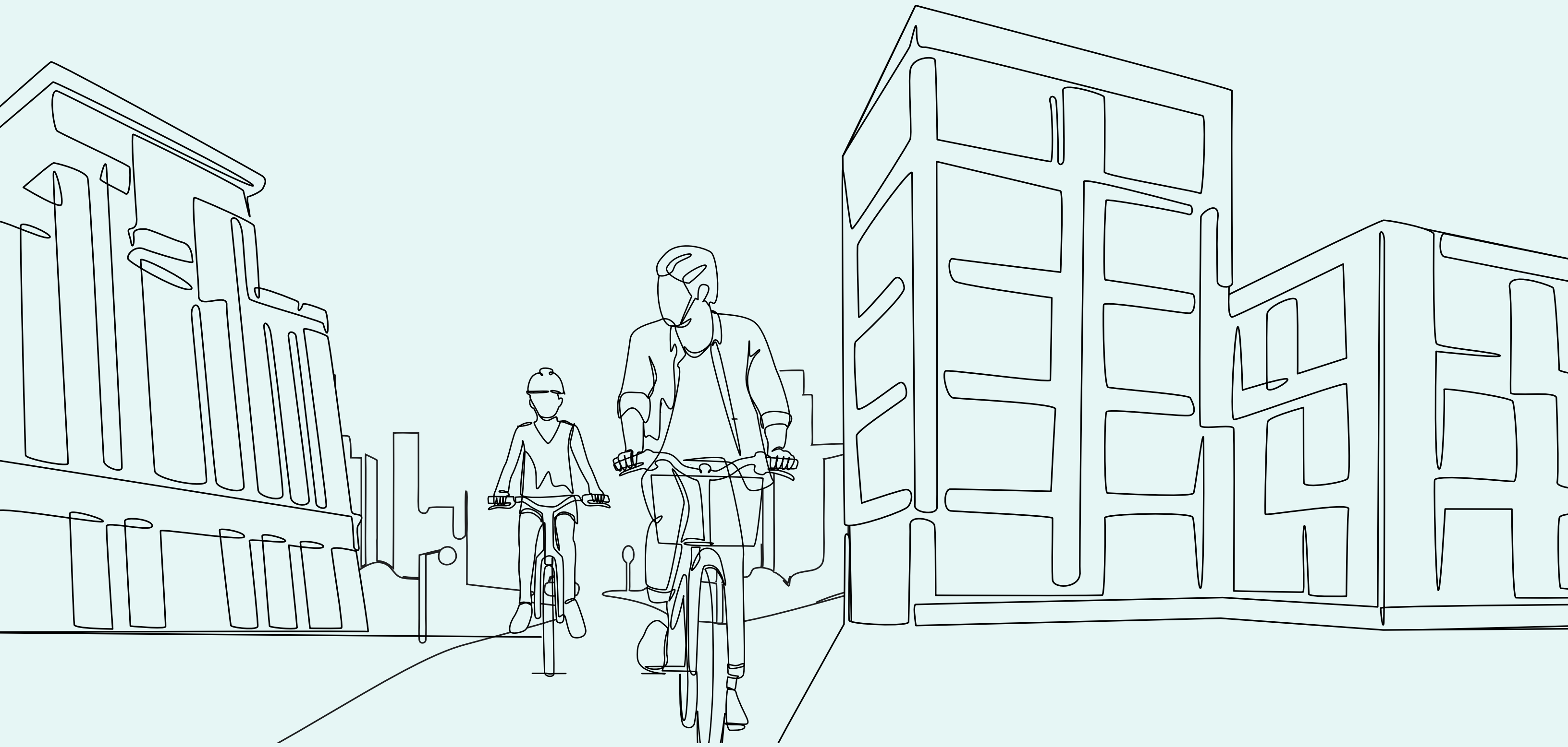
- What are the critical factors that can influence the socioeconomic returns of cycling infrastructure investments?
- How can a standardized cost-benefit methodology support decisions to scale up active mobility investments?

Overall, this approach ensures that decision-makers can quickly assess socioeconomic returns while considering the full range of benefits that cycling infrastructure brings to urban communities.

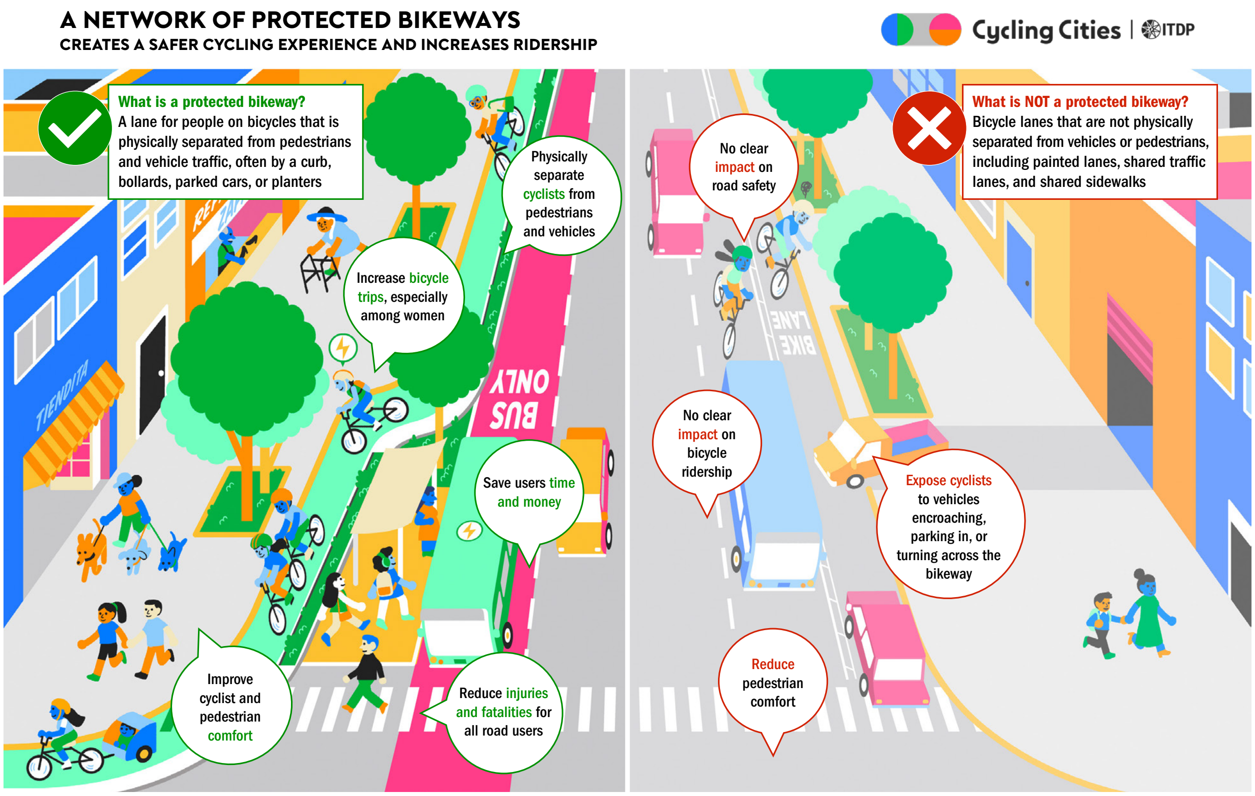
2

The Case for Cycling Infrastructure

Examine the multiple benefits of urban cycling infrastructure worldwide, backed by evidence from existing research on its impacts. This section establishes the positive impact of cycling networks on safety, sustainable personal mobility, health, and the environment to transform cities and enhance urban mobility.



Protected/segregated[1] cycling lanes provide a safe and efficient environment for cycling traffic. This is proven by multiple studies which show that such facilities encourage more people to cycle. Increased cycling use can lead to less reliance on motorized vehicles, which in turn reduces traffic congestion and the associated environmental impacts. Additionally, cycling facilities can improve public health by promoting physical activity, reducing transportation costs for individuals, and creating a more livable urban environment through reductions in noise and improvements in air quality.



Protected bikeways are one of the best ways to get more people on bicycles for more trips

*Cycling lanes (bike lanes) described in the right-hand side are so called "dedicated" cycling lanes – separated only by lane markings on the roadway.
Source: ITDP website https://itdp.org/multimedia/protected-bikeways-infographic-itdp/

Protected/segregated cycle lanes also contribute to safer roads for all users, because they can reduce the likelihood of crashes involving cyclists and motor vehicles. Recognizing the benefits of protected/segregated cycle lanes, considerable research has been conducted to quantify the benefits from various aspects using a variety of models. This chapter provides a review of the major categories of benefits: safety, emissions, health, and travel time.

[1] Off-road dedicated facility: completely separated from motorized traffic

2.1. Safety benefits of well-planned cycling facilities

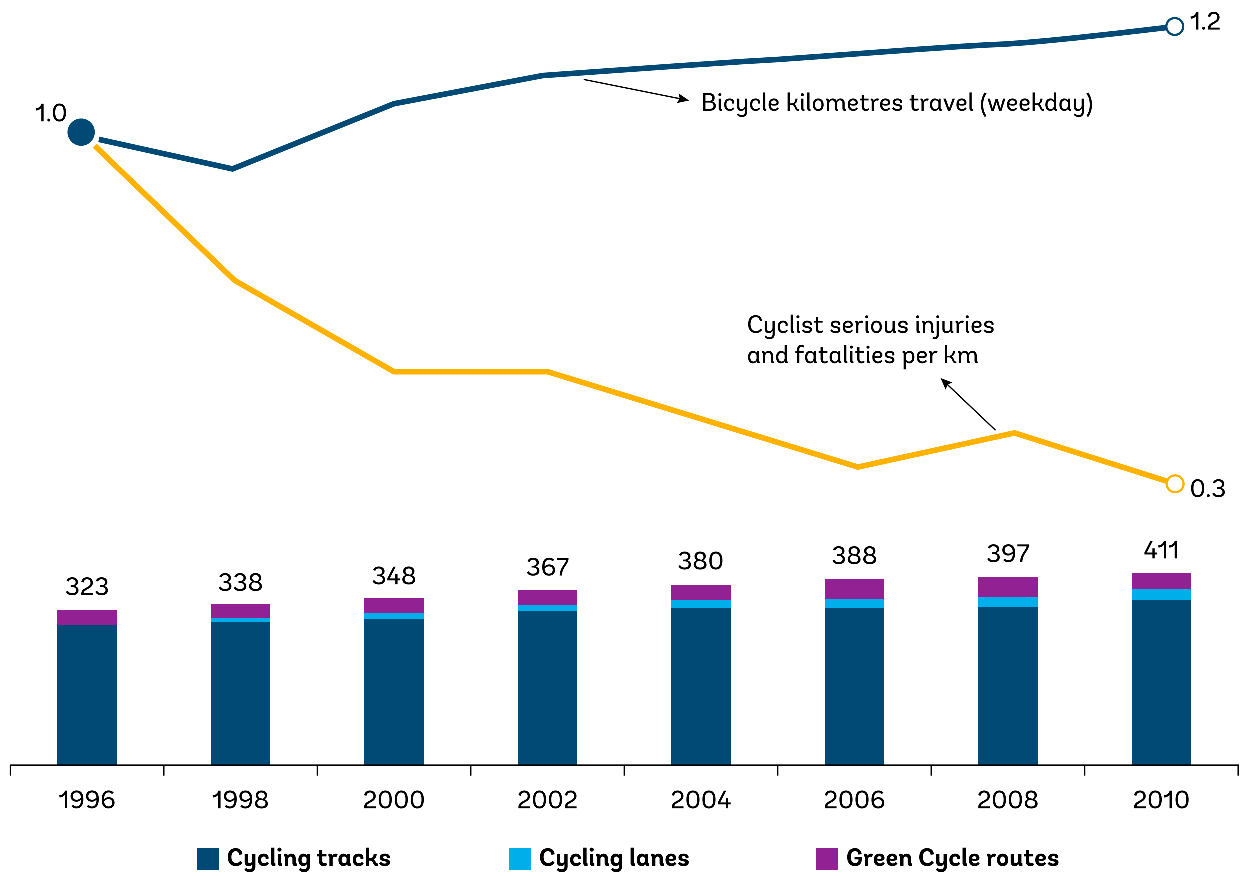
Well-designed cycling facilities can substantially improve safety. Data from the city of Copenhagen has demonstrated that the construction of cycle lanes (which physically separate cyclists from higher speed vehicles) is associated with reduced rates of fatalities and injuries (Figure 2.1). Cycling facilities can improve safety in two major ways:

1. By inducing a shift from driving to cycling, thereby reducing motorized vehicle crashes
2. By improving the safety of existing cyclists (for example, those who were previously riding with motor vehicles on existing roads without cycling facilities)

Protected/segregated cycling lanes can improve safety by providing safeguarded spaces for cyclists, reducing the likelihood of crashes with motor vehicles, and encouraging safer and more predictable interactions between cyclists and drivers. By separating cyclists from motorized vehicles, cycling lanes can also reduce the exposure of cyclists to road hazards and improve overall traffic safety for all road users.

The Australian Transport Assessment and Planning Guidelines uses the difference between the baseline crash rate (the crash rate without the cycling project) and the crash rate after the installation of the cycling facility to estimate the reduction in crashes. A more commonly used approach is the Crash Modification Factor (CMF), which is the ratio of the crash rate with the safety improvement to the crash rate without the safety improvement. In the case of a cycling facility, the CMF represents the crash rate ratio of the newly constructed cycling facility to the existing traffic lane. A CMF smaller than 1 indicates a lower crash rate after the installation of the cycling facility.

Figure 2.1. Cycling travel, per-kilometer cyclist casualties, and kilometers of cycling infrastructure in Copenhagen



Source: *OECD/International Transport Forum (2013), Cycling, Health and Safety, OECD Publishing/ITF.*

Properly designed cycling lanes have been found to reduce fatalities by 25 to 40 percent.[Ref-i] Here, properly designed cycling lanes mean those that are safe and efficient for cyclists in terms of better design and management of intersections, roadsides, midblock, special treatment for vulnerable road users, as well as speed management and traffic calming devices. Data from Bogota shows that despite an increase in bicycle use from 0.2 percent (2000) to 7 percent (2019), the city saw 34 percent fewer cycle-related deaths and 8 percent fewer injuries.

New cyclists induced to use the new facility — referred to as induced cycling — could contribute to increasing the crash rate, particularly in *unprotected* lanes. For example, high traffic volume could increase interactions and conflicts among cyclists, leading to more collisions.

In the absence of in depth studies in LMICs, the following CMFs (Table 2.1) are suggested based on studies from the United States and Australia, which are also adapted in the World Bank's Transport Good Practice requirement assessment model.[2]

[2] In October 2019, the World Bank launched a Good Practice Note (GPN) to address road safety. This GPN provides guidance to World Bank staff on how to support efforts to improve road safety on projects supported by Investment Project Financing (IPF) and thereby meet the requirements of the ESF road safety standards (ESS4). To support the use of the GPN, the World Bank Transport GP has developed a 'Road Safety Screening and Appraisal Tool (RSSAT), which is a tool to identify road safety performance and screen for opportunities for improvement in road and roadside infrastructure. https://thedocs.worldbank.org/en/doc/648681570135612401-0290022019/Good-Practice-Note-Road-Safety

Table 2.1. Suggested CMFs for Cycling Lanes

Type of cycling facility	CMF (base = none)
Segregated cycling path with barrier (or separated from other traffic)	0.41
Non-protected dedicated cycling lane on the roadway (marking only)	0.82
None	1.00

Source: World Bank.

For induced cycling traffic, the crash reduction is calculated based on the mode shift from motorized vehicles to bicycles. The safety benefit is calculated based on the reduction in crashes due to both existing and induced cyclists, including road crashes involved in other road users such as motorized vehicles and pedestrians. Thus, the individual crash risk should be decreased.

Overall, the safety benefit of cycling facilities is well-documented. However, existing CMFs are primarily based on high-income countries. While these factors provide a good starting point, future research on CMFs and other coefficients for LMICs can improve the estimation accuracy. The current CyclingMax tool incorporates the safety benefits of both induced and existing cycling traffic.

2.2. Positive environmental impacts of increased cycling infrastructure

The reduced reliance on motorized vehicles resulting from cycling facilities directly reduces the emissions of GHGs and air pollution. The Health Economic Assessment Tool (HEAT) for walking and cycling developed by the World Health Organization (WHO)[Ref-ii] calculates the differences in carbon emissions between cycling and other modes of transport across three categories:

1. **Operational emissions**, which are determined by analyzing changes in travel demand, energy efficiency, and carbon intensity of the energy consumed.
2. **Energy supply emissions**, which cover upstream emissions from the extraction, production, generation, and distribution of energy supplies, including emissions from fossil fuels and electric sources.
3. **Vehicle lifecycle emissions**, which come from the manufacturing processes of vehicles and are based on aggregate carbon values for each vehicle type, considering factors like typical lifetime mileages, body mass weights, material composition, and material-specific emission and energy use.

The monetary impact is calculated based on the Social Cost of Carbon (SCC), which represents the estimated present discounted value of present and future economic damage from emitting one ton of CO_2 into the atmosphere today.

ITDP has created a model to estimate the climate impacts of installing protected cycling lanes.[Ref-iii] This model calculates potential reductions in CO_2 emissions based on the local population size adjacent to protected cycling lanes and incorporates a user-specified percentage for mode shift to bicycles from other forms of transportation. The environmental benefits are quantified as a reduction in tons of CO_2 per annum, considering that bicycle travel does not emit CO_2 compared to other transportation modes, such as private vehicles, which do. Furthermore, the ITDP tool incorporates essential data such as regional emission factors and the person-kilometers traveled within specific areas.

The calculations of environmental benefits in the Australian Transport Assessment and Planning Tool[Ref-iv] and the California Active Transportation Benefit-Cost Tool reflect the reductions in emissions and energy consumption from the reduced vehicle-distances traveled by motorized vehicles. Cycling facilities can induce demand for cycling and incentivize existing motorized vehicle users to shift to cycling.

The above review showcases the complexity and significance of the emissions-reduction benefits of active mobility infrastructure. Sophisticated models such as HEAT consider the lifecycle and energy supply emissions of vehicles, requiring extensive information as input. The targeted users of the current tool typically do not have such extensive information. In addition, tools such as HEAT, which are intended for city- or country-level benefit evaluation, do not align with the scope of the current tool (project-level evaluation). As such, the CyclingMax tool adopts a relatively straightforward approach based on reduced vehicle distance coupled with emission factors.

2.3. Improved health and mortality rates for cyclists

Active mobility such as cycling involves physical activity that can significantly improve the health of the cyclist. Regular cycling enhances cardiovascular fitness, strengthens muscles, improves joint mobility, and decreases stress levels. By incorporating cycling into daily routines, individuals can achieve substantial health improvements that contribute to longer life expectancy and overall well-being. A systematic review indicates that active commuting by walking or cycling decreased all-cause mortality by 9 percent and cardiovascular mortality by 15 percent.[Ref-v] Well-designed cycling lane infrastructure would thus induce additional cycling traffic to reduce mortality. Multiple studies have considered the health benefits of cycling lanes.

The HEAT model developed by the WHO comprehensively evaluates the effects of cycling facilities on mortality from three aspects. The physical activity benefit describes the positive impact of choosing active transportation modes such as cycling. It is calculated by considering the local mortality rate and the duration of cycling activity. The benefit is reflected in the reduction in all-cause mortality. The HEAT model uses a coefficient of 0.9, indicating a 10 percent lower mortality rate for cyclists compared with non-cyclists.

According to a report published by the World Bank and ITDP, health savings are the largest monetized benefit of cycling infrastructure in Buenos Aires, Argentina and the second largest in Lima, Peru, highlighting the importance of the health benefits of cycling facilities.[Ref-vi] Similarly, the benefit assessment in the Australian Transport Assessment and Planning Guidelines considers the increased physical activity from cycling, which leads to improved health outcomes and reduced healthcare costs.[Ref-vii] The Australian model uses public health data and existing studies to quantify physical activity levels and determine health benefits. The California Active Transportation Benefit-Cost Tool[Ref-viii] calculates the reduction in mortality risk based on the reduction in mortality rate resulting from additional cycling-related exercise and the original all-cause mortality rate in the area.

While cycling in general is associated with positive effects, the WHO HEAT tool also includes two negative impacts. Air pollution risk is a negative effect stemming from cyclists' exposure to local PM2.5 concentrations. Opting for cycling as a mode of transportation can increase pollution-related mortality risk among cyclists. The extent of this increased risk is determined by factors including the local PM2.5 levels, cycling duration, the ventilation rate of the cyclist, and various adjustment parameters. The second negative effect is associated with crashes and is addressed under the safety benefit category.

As most existing studies only consider the benefit of cycling facilities in terms of reduced mortality, the current CyclingMax tool focuses on this aspect. One of the key parameters for accurately estimating the health benefit is the annual reduction in mortality. For example, the CyclingMax tool uses a 4.5 percent annual reduction in mortality for cycling facilities in the United States as suggested by the CALTRAN model.[Ref-ix] This rate is expected to vary by country and region. Accordingly, the CyclingMax webtool provides reference rates for other countries and regions that can be selected by the user. These mortality reduction rates were derived from existing studies, as shown in Table A3 in Appendix.

2.4. Reduced travel time

Because protected cycle lanes shift trips away from private vehicles, travel time reduction can occur. Various studies have captured the time-saving benefits of cycling facilities. For example, case studies indicated that active mobility investments saved travelers 15 minutes per metro trip and 2 to 4 minutes per bus trip in Tianjin, China and amounted to travel-time savings equivalent to USD2.6 billion in Lima, Peru.[Ref-vi] The calculation of time-saving benefits appears to be simple. For example, the Australian Transport Assessment and Planning Guidelines calculate the time saved by cyclists after the implementation of a cycling project by measuring the difference in travel time before and after the project is built.[Ref-iv] This time saving is then valued using the *Value of Time*, which assigns a monetary value to time based on average wages and other societal measures:

Time Saving Benefit = Number of Trips × Time Saved per Trip × Value of Time.

The main challenge in this calculation lies in the accurate estimation of the number of trips and time saved per trip (the current tool estimates the demand as the total cycling time). The time saved per trip depends heavily on the local transit system and motor vehicle infrastructure. Such information typically requires a detailed examination of multiple factors, including the waiting time for transit, connection time, location of parking facilities, and walking distance to and from the parking facilities to final destinations. For this reason, the travel benefit in terms of time saving is included as an advanced benefit calculation in the CyclingMax tool due to the difficulty in identifying default parameter values. Advanced users who have the expertise and resources to accurately estimate the related parameters can opt to include this benefit.

2.5. Broader impacts in other categories

Several other benefit categories in literature were reviewed by the study team. These were not included in the CyclingMax tool for the following reasons:

1) **Journey quality improvement:** A relatively subjective measure that requires a preference matrix from the users to define the preferred index of different cycling facilities (cycling lane, cycling way, cycling path, etc.). The California tool includes the calculation of this benefit. However, this calculation is only applicable in situations where multiple types of cycling facilities will be built, and each type of facility has an existing and quantified preference level in the local community. Thus, it does not apply to the situations where the CyclingMax tool will be used.

2) **Air pollution benefits:** Generally calculated in two categories: lifecycle emissions for vehicles and the emission cost for all pollutants (CO, NOx, PM2.5, and SOx) in the area. The life-cycle emission calculation involves operational emissions of all modes of travel, energy supply emissions (from the extraction, production, generation, and distribution of energy supplies), and vehicle lifecycle emissions (the emissions for manufacturing and disposing the vehicles). The WHO HEAT model includes this calculation based on an embedded database of lifecycle emissions for different modes (cars, trains, buses, etc.). The CALTRAN tool calculates the benefit of emission cost savings for all pollutants because they have the cost data of all the pollutants. The CyclingMax tool does not include these two calculation categories because both involve extensive input parameters. The parameters from other locations are typically not transferrable – they are location specific and vary significantly from area to area.

3) **The absenteeism benefit:** This can be calculated as the decrease in the number of sick days resulting from the mode shift to cycling and the subsequent increase in exercise. This benefit is calculated by the California tool as a function of the following parameters: average absenteeism of employees, percentage covered by short-term sick leave, percentage of sick days reduced when active at least 30 minutes per day, value of reduced absenteeism per day, and cycling days per year. Due to the many uncertainties in these parameters, this benefit was excluded from the CyclingMax tool.

4) **Intersection safety improvement:** This can be calculated based on the effects of adding cyclist-friendly features at intersections, as done in the California tool. This calculation applies mainly to cycling facility improvement projects where intersection improvement counter measures are specified (traffic signal for cyclists, stop bar for cyclists, or markers on the ground for cyclists, etc.) and the corresponding effects are well quantified. Due to the fact that such sophisticated data are highly unlikely available in developing countries, this benefit is not included in the CyclingMax tool.

5) **Impact on local economic development and retail activity:** A review of studies on the impacts of local economy indicates that creating or improving active travel facilities generally has positive or non-significant economic impacts on retail and food service businesses located nearby. There could be negative economic effects on businesses that are auto-centric. The quantification of impact of local economic requires detailed site-specific data and need to be considered for future extension of the tool.

6) **Decongestion:** The calculation method for this factor is straightforward, but requires considerable efforts to validate the input parameters, which include the benefit of decongestion ($/km). This parameter is provided by the users in the Australian tool. It is difficult to validate

without a comprehensive traffic study that confirms the existing number of motor vehicle trips, a car ownership survey, and a detailed traffic fundamental diagram (with locally calibrated parameters including density, velocity, and traffic flow).

Other benefits may be added to the tool in the future if more studies are performed to validate the parameters needed to accurately calculate the benefits. For example:

- Cycling lanes induce *more public transit trips, which stimulate local business,* and more cycling trips will help cycling-related business.
- *The operational costs (VOC) for cyclists* are significantly lower compared to those for car drivers. Therefore, switching from cars to bicycles can lead to substantial *savings in terms of depreciation, insurance, parking costs, fuel, and other expenses*.
- *Increased accessibility* to cycling lanes.

These benefits require additional information to supply the necessary input parameters and are not included in the CyclingMax tool currently.

2.6. Key takeaways

The chapter showcases the complexity of cost-benefit analysis for cycling facilities, which can be summarized as follows:

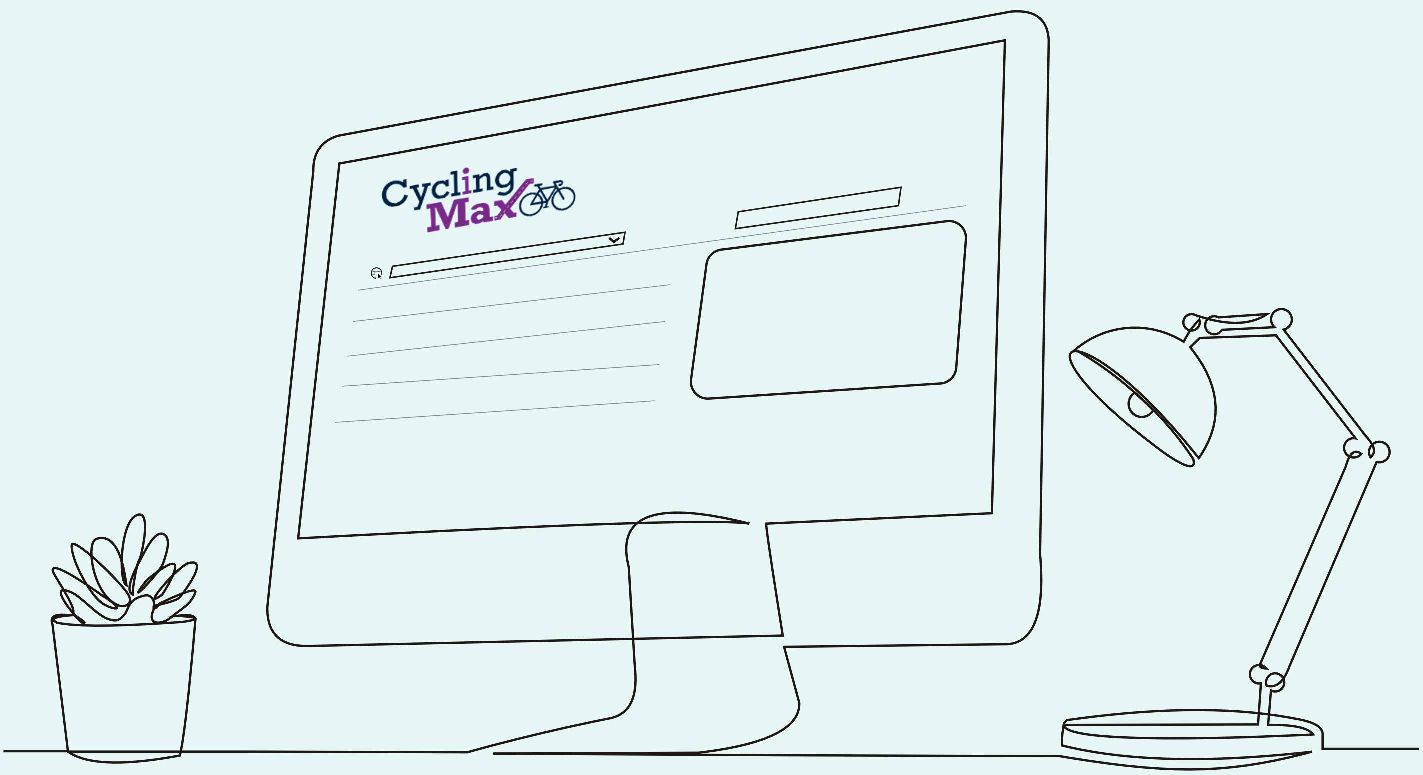
- *Benefits for society can be difficult to recognize or monetize*: The societal benefits of cycling projects, such as improved health outcomes, reduced environmental impacts, and enhanced quality of life, can be challenging to quantify and assign a monetary value. These benefits often accrue over time and may not be immediately apparent, making it difficult to capture their full impact in traditional cost-benefit analyses.
- *Applications at the project level are limited*: Cost-benefit analyses are often conducted at the city or country level. There is limited literature on comprehensive cost-benefit analyses at the project level. As a result, reference parameters and the associated methods are scarce.
- *The costs and benefits can vary substantially based on the location of the project*: The financial costs and benefits associated with a project may differ greatly depending on its geographical location. Factors such as local economic conditions, population density, existing infrastructure, and environmental conditions can all influence the outcomes of a cost-benefit analysis, leading to significant variability in results.
- *Studies using the typical cost-benefit framework with standard metrics are limited*:
Few cost-benefit analyses of cycling facilities have been conducted using standardized frameworks and metrics such as the Economic Internal Rate of Return (EIRR) and Net Present Value (NPV). The lack of consistent methodologies and metrics makes it challenging to compare and evaluate the outcomes of different projects accurately.
- *A user-friendly tool to facilitate benefit estimation is currently lacking*: There is a notable absence of accessible and easy-to-use tools designed to assist in estimating the benefits of projects. This makes it difficult for practitioners and decision-makers to conduct comprehensive benefit analyses, potentially leading to underestimation or misrepresentation of a project's true value.

The CyclingMax tool is intended to address or mitigate some of these limitations by providing a user-friendly, flexible, and expandable webtool that is based on solid methodology.

3

Getting Started with the CyclingMax Tool

Understand how the CyclingMax tool works to optimally evaluate cycling infrastructure investments. This section gives insight into the components, data requirements, calculation processes, and analytical approaches to understand how the tool generates its cost-benefit assessments.



The CyclingMax tool is meant to evaluate new cycling infrastructure projects that create a network of dedicated cycling lanes. While the tool can assess upgrades to existing cycling facilities, users should carefully adjust input parameters, as the values for new construction differ significantly from those for improvement projects.

3.1. Benefits measured by the CyclingMax tool

The CyclingMax tool provides an accounting of the benefits and costs of proposed cycling facilities, giving decision-makers an aggregated view of the positive effects of cycling infrastructure. Here, the focus is on those that can be reasonably estimated based on available research and data and that demonstrate opportunities for future benefits. The CyclingMax includes four benefit categories:

- **Safety.** CyclingMax calculates safety benefits for both traffic shifted from cars and existing cycling traffic, accounting for improved safety resulting from cycling lanes that provide exclusive access to cyclists with road safety features. The benefit from crashes avoided by car riders switching to cycling is estimated from the average cost of car crashes. Existing cyclists who travel in existing facilities (for example, the roadway with no cycle lane or unprotected cycle lane before the cycling facility is installed) in mixed traffic with cars will also benefit. This benefit is assessed using Crash Modification Factors and the average cost of bicycle crashes.
- **Emissions.** The emissions benefit is calculated from the reduction in CO_2 from the mode shift from cars to cycling. The CyclingMax extracts emission costs ($/g) from a lookup table based on World Bank data that extends to 2050.
- **Health.** The health benefit is calculated as the reduction in mortality due to increased exercise. Physical activity associated with cycling will lead to improved health and reduced mortality. The cost savings are estimated based on the value of a statistical life (VSL), which is defined as how much individuals are willing to pay for a very small reduction in the probability of death.
- **Travel time savings.** When calculating savings in travel time, the tool considers both time savings for traffic shifted from walking and additional time costs for traffic shifted from cars and public transit. Given that this tool was designed for use in developing countries, travelers will likely be switching from walking to cycling, resulting in travel time saving benefits. There are ongoing discussions on benefits of travel time savings due to mode shift from car to cycling. While mode shift from car to cycling typically leads to longer travel times, recent meta-analysis on value of travel time savings (VTTS) in developing countries suggest that VTTS for cycling and walking might be smaller. This means that the perceived "negative benefit" of increased travel time could be offset by a much greater willingness to spend time cycling, potentially making it a significant benefit overall. Thus, to avoid overestimation of the benefits of travel time savings, the current tool focuses on the benefits of mode shift from walking to cycling.

3.2. Input and default parameters used by the tool

The benefits and costs of a cycling facility depend strongly on the location. For example, the cost of crashes and the value of statistical life can vary dramatically from country to country. In addition to a comprehensive consideration of benefits from cycling facility construction, the CyclingMax tool incorporates flexible and customizable settings for key parameters. Users can input specific parameter values based on the infrastructure under consideration and the local area.

The user can also opt to use the tool's default parameter values. For example, for time-varying parameters that depend on per capita Gross Domestic Product (GDP) — such as VSL — the tool extracts the most recent value from the World Bank using an API to ensure the calculation is up to date. For location-specific parameters, the tool provides reference default values from published studies. Users can customize any coefficients based on their own research. CyclingMax also allows administrators to add, modify, and delete reference values, allowing for future expansion of the tool.

As the analysis is primarily for new construction, the parameters should be carefully calibrated when used for facility improvements. For example, the percentage of induced cycling traffic and construction cost could differ substantially between new construction and facility improvements.

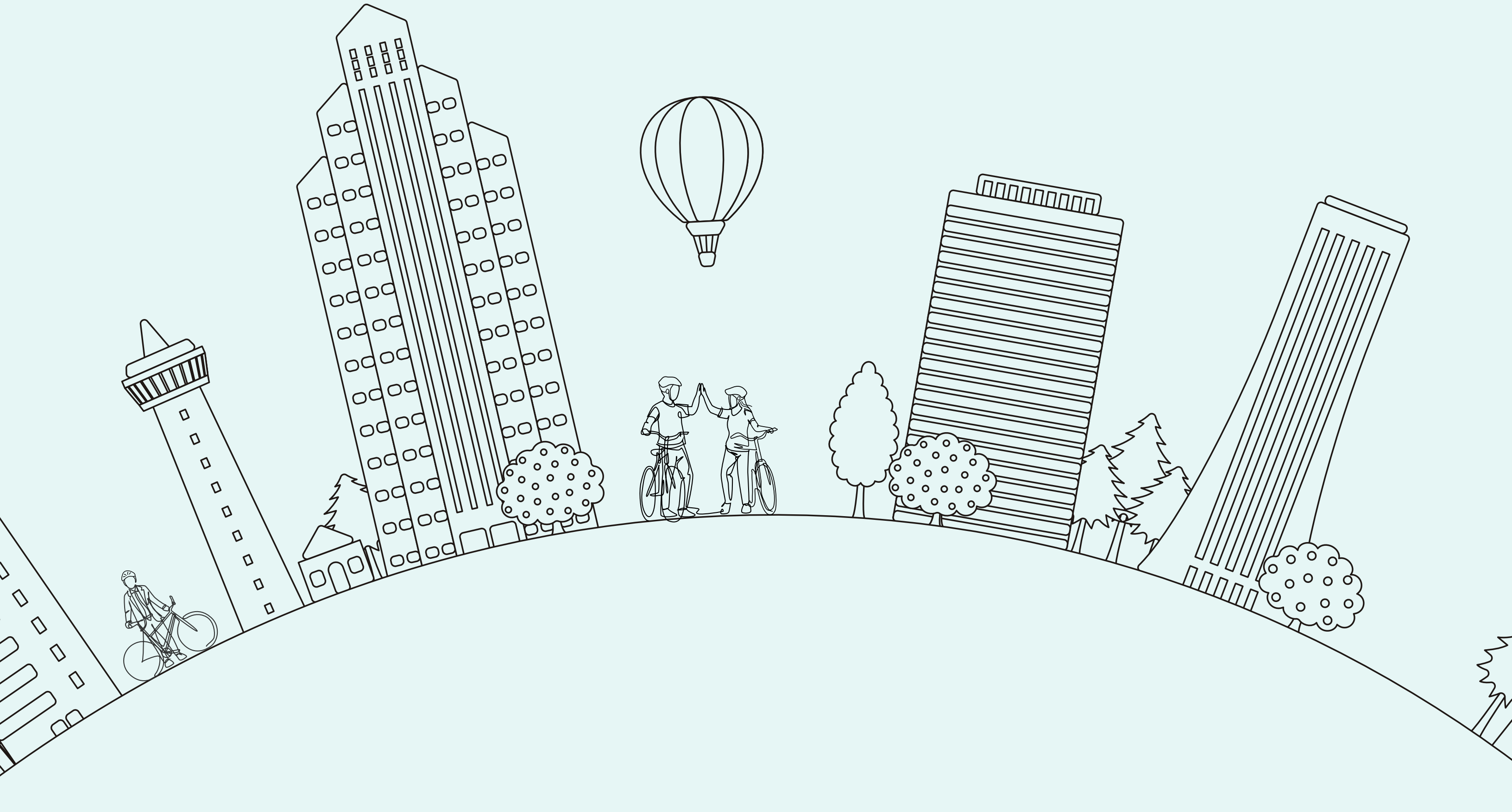
3.3. Key outputs

Importantly, the CyclingMax tool outputs monetized metrics — this includes the total costs of construction and maintenance as well as annual benefits in the four benefit categories over the project evaluation period (multiple decades in the future or the number of years selected by the users). The tool also calculates the Net Present Value (NPV) and the Economic Internal Rate of Return (EIRR), two key metrics for cost-benefit analysis. These tangible and actionable outputs allow users to immediately grasp the cost-benefit of a project and make informed decisions about the economic viability of the investment.

4

Case Studies

This chapter helps determine the effectiveness of the Cycling Max tool by applying it to real-world instances. Insights from eight low- and middle-income cities provides data that can positively impact investment and policy.



In this section, the CyclingMax tool is applied to eight planned or in progress cycle lane or facility projects in low- and middle-income cities. The value and projected returns on investment of cycling infrastructure varies significantly due to project quality and design, existing modal splits, implementation and maintenance costs, and more. Some projects have been completed, others have estimation costs. However, the eight case studies included in this report provide EIRRs well above the minimum required for viability. The EIRRs are greater than the discount rate used in the case studies, which range from 6.0-12.0 percent. In addition, the projects show positive net present values (NPVs) as seen in this summary table.

	Investment ($US)	EIRR	NPV ($US)
Abidjan, Cote d'Ivoire	$6 million	123.5%	$52 million
Dodoma, Tanzania	$27 million	41.6%	$60 million
Kampala, Uganda	$131 million	55.8%	$1.08 billion
Addis Ababa, Ethiopia	$118 million	75.7%	$689 million
Lima, Peru	$17.4 million	85.7%	$144 million
Sao Paulo, Brazil	$18.7 million	88.6%	$156 million
Itajai, Brazil	$37 million	44.3%	$148 million
Recife, Brazil	$55.5 million	91.5%	$594 million

In addition to EIRR and NPV outputs, results for each of the four key benefit areas are provided for every case:

- SAFETY | Impact of the cycle lane or facility on fatal and serious crashes per year
- HEALTH | Impact of the cycle lane or facility on mortality (due to physical activity) per year
- EMISSIONS | Impact of the cycle lane or facility on carbon dioxide emissions per year
- TRAVEL TIME | Impact of the cycle lane or facility on travel time per year

	Cycle Lane KMs	Safety Crashes prevented/ year	Health Mortality prevented/ year	Emissions CO_2 reduced/ year	Travel time Million hours saved/year
Abidjan, Cote d'Ivoire	15	5	12	280 tons	0.7
Dodoma, Tanzania	105	16	7	425 tons	4.8
Kampala, Uganda	493	96	309	5,732 tons	24.4
Addis Ababa, Ethiopia	677	257	405	7,541 tons	15.6
Lima, Peru	50	9	9	1,078 tons	0.3
Sao Paulo, Brazil	14	8	3	654 tons	0.08
Itajai, Brazil	95	7	8	1,632 tons	0.2
Recife, Brazil	156	22	24	5,147 tons	1.2

As discussed in Chapter 2.5, due to data limitations, the CyclingMax tool does not quantify all potential benefits from cycle infrastructure networks. This means that the results are likely an underestimation of benefits. Conversely, observed benefits may be less than projected if designs are altered and the cycle infrastructure is not fully protected when implemented.

4.1. Abidjan, Cote d'Ivoire

Mass transit and active mobility facilities to create reliable public transport networks

City Stats

6.3 million population

2119 sq km area

13.6 million daily trips

Abidjan, the rapidly growing economic hub of Côte d'Ivoire, is home to more than half of the country's population. Despite significant public investments in road infrastructure in recent years, the city struggles with unreliable urban transport, high transport costs and increasing congestion, which undermine its competitiveness.

15 km
Total length

164,703
Population in coverage area

$6 MN
Estimated construction cost of cycle lanes

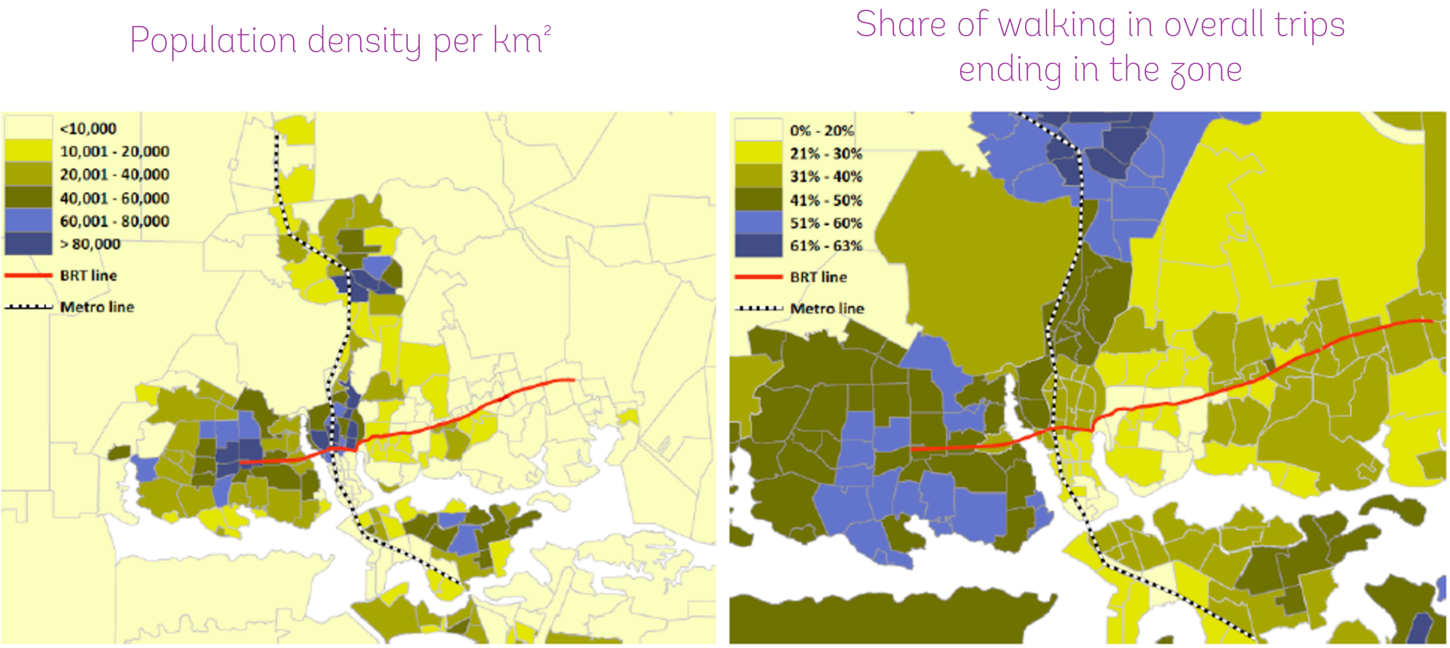
Challenges

- While public transport accounts for 80 percent of all motorized trips in the city, the demand is largely met by informal services that are often inefficient and costly for users. From 1998 to 2013, the share of formal public transport decreased by more than 50 percent. Conversely, the informal sector, comprising Gbaka, metered taxis, woro-woro and inter-communal taxis, increased its share from 68 percent of public transport trips in 1998 to over 85 percent in 2013. Consequently, a significant portion of Abidjan's population continues to rely on walking for their daily mobility needs. Approximately 40 percent of the 13.6 million daily trips in the city are made on foot. This figure rises to 60 percent in economically vulnerable areas, due to the poor quality and unaffordability of the public transport system.

Project Overview

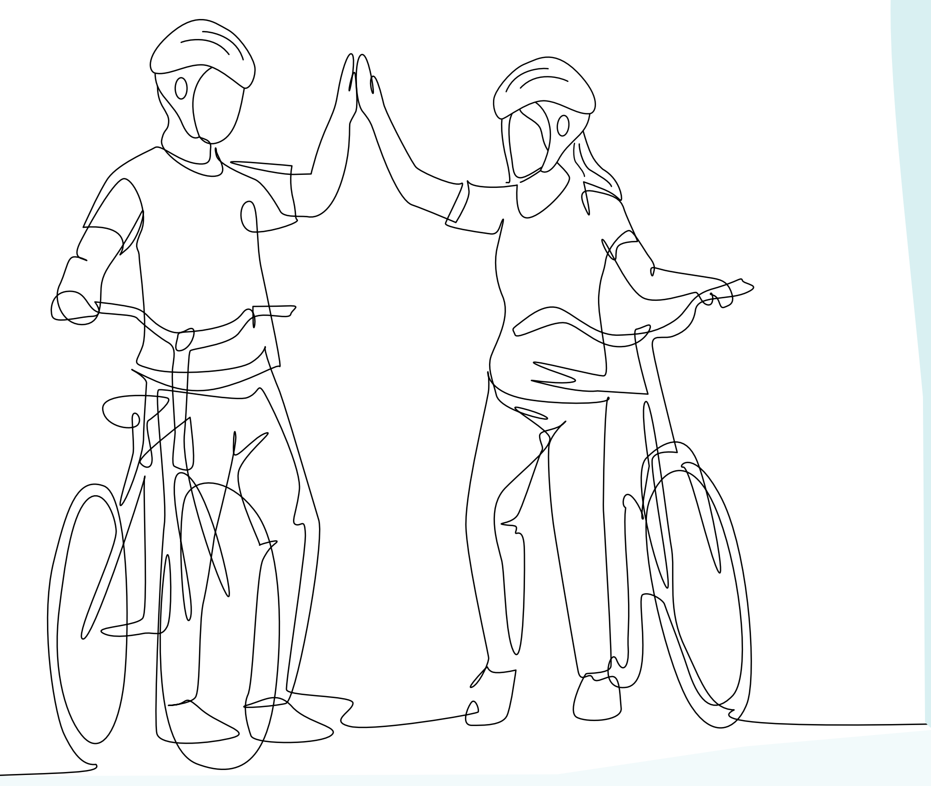
To support its growing population and economy, Abidjan's urban mobility requires substantial improvements, particularly in mass transit and active mobility. Those interventions will improve equitable access to jobs and other services for vulnerable populations, including women and people living in poverty, while also addressing issues such as congestions, road safety, air pollution and greenhouse gas emissions.

Map 4.1. Population density, reliance on walking, and planned mass transit lines



Source: SDUGA, PACOGA.

As a part of a broader initiative to improve urban mobility conditions of Abidjan, an approximately 20km of East-West BRT corridor will be built between the economically vulnerable areas of Yopougon and Bingerville. Cycle lanes will also be implemented to enhance first and last mile accessibility of the BRT service, aiming to encourage safe multimodal trips. The infrastructure design will aim to prioritize cyclists and pedestrians, by re-purposing road spaces from vehicle traffic lanes to protected cycle lanes and sidewalks.



Results

The CyclingMax tool results for the multimodal corridors and walking and cycling network planned for Abidjan include:

EIRR
123.5%

NPV
US$ 52 MN

SAFETY
Number of prevented fatal and serious crashes per year
4.7

HEALTH
Number of reduced mortalities through increased physical activities per year
11.5

EMISSIONS
CO_2 emissions per year
280 tons avoided

TRAVEL TIME
Travel time saved per year
739,849 hours

4.2. Dodoma, Tanzania

Multimodal corridors and climate-resilient active mobility networks for reliable transport

City Stats

765,179 residents in 2022

City's built-up area expanding by more than 440 percent

From 11 km² in 2000 to 60 km² in 2024

Facing a 6.4 percent annual population growth, Dodoma's transport system is in urgent need of upgrades. More than 80 percent of the city's roads are still unpaved, making it difficult for many residents to travel reliably. The city needs resilient road infrastructure to reduce vulnerability to climate impacts. To plan for the future, the city embarked on an integrated transport project to prioritize safe, sustainable mobility through low-emission options and active transport.

Challenges

- Climate resilience
- Emissions and pollutions
- Road safety
- Inefficiency in public transport
- Inclusion of vulnerable people

Component 1: Multimodal Corridors

45.1 km
Total length

127,690
Population in coverage area

$131.3 MN
Total cost of the component

$7 MN
Estimated construction cost of cycle lanes

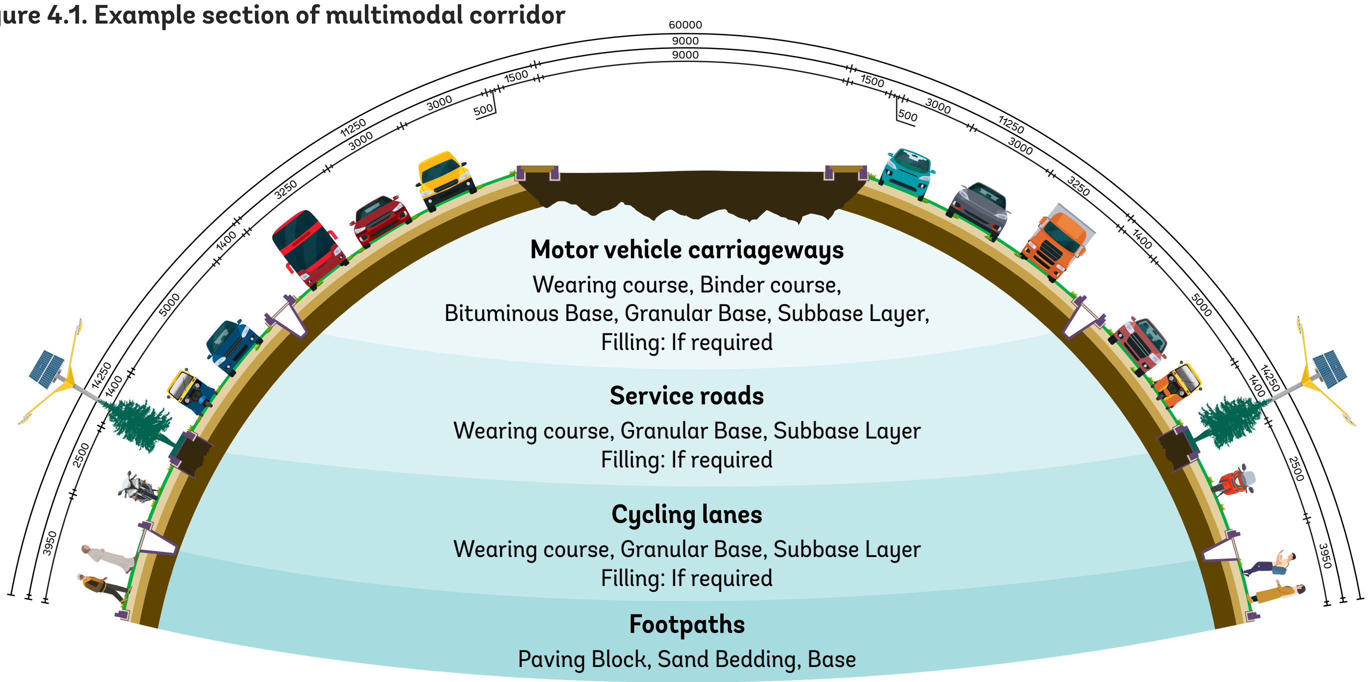
Project Overview

The Dodoma Integrated and Sustainable Transport Project aims to tackle these challenges by implementing complete streets, including cycle lanes, which contribute to sustainable, inclusive, and efficient urban mobility.

This project covers two components: to create multimodal corridors and a climate-resilient walking and cycling network.

The project will upgrade four arterial roads that connect Dodoma's city center to other parts of the country. These roads, which currently have two lanes, will be expanded to include separate spaces for different users: cars, buses, pedestrians, and cyclists. Eight percent of the new road space will be used for cycle lanes. The roads will meet international safety standards (three-star iRAP rating). On each side of these roads, there will be 5 meters of space for walking and cycling, placed at the outer edges. This layout keeps pedestrians and cyclists safe from traffic and prevents future building into the road space. The roads will be accessible to everyone, with features like sloped curbs and textured pavements to help people with disabilities navigate safely.

Figure 4.1. Example section of multimodal corridor



Source: Ministry of Works, Tanzania National Road Agency.

Component 2: Climate-resilient walking and cycling network

Total length: **~60 km**

Population in coverage area: **81,018**

Total cost of the sub-component: **$15.2 million**

Estimated construction cost of cycle lanes: **$20 million**

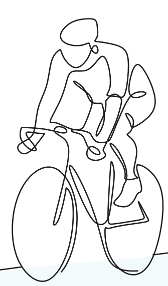
New walking and cycling paths will be built along existing roads and through parks and green areas. These paths will fill in missing links in the current network, making it easier for people to walk or cycle safely. This is especially important in busy areas where walking facilities do not currently exist. The project will add:

- Walkways
- Lighting
- Drainage systems
- New road surfaces where needed
- Cycle lanes where space permits
- Safety improvements in crash-prone areas

When building paths through green spaces, the project will include:

- Walking and cycling paths
- Lighting
- Safe drainage channels
- Landscaping
- Small streets (no wider than 3 meters)
- Dedicated crossing paths
- Features to slow down traffic at intersections

All paths will be designed for ease of use, with sloped curbs and textured pavements to help people with differing abilities to enjoy the infrastructure.



Results

The CyclingMax tool results for the multimodal corridors and walking and cycling network planned for Dodoma include:

EIRR
41.6%

NPV
US$ 60 MN

SAFETY
Number of prevented fatal and serious crashes per year
16

HEALTH
Number of reduced mortalities through increased physical activities per year
7

EMISSIONS
CO_2 emissions per year
426 tons avoided

TRAVEL TIME
Travel time saved per year
4,813,121 hours

4.3. Kampala, Uganda

City Stats

Cycling in the Greater Kampala Metropolitan Area (GKMA) accounts for only 2 percent of trips. Walking is the primary mode of transport, making up 46 percent of trips. In a survey conducted in 2021, residents noted that affordable bicycles, protected cycle tracks, and safe cycle parking would improve the cycling environment in Kampala.

The Kampala Cycle Network Plan (2023-2032) outlines a comprehensive strategy to develop cycling infrastructure in the GKMA, which includes the capital city of Kampala and five surrounding municipalities, addressing the growing population's mobility needs amid increasing congestion and pollution. It emphasizes the importance of a well-connected cycle network for promoting sustainable transport, improving public health, and reducing emissions. The plan identifies cycling as a key strategy to reduce travel costs. It also recognizes the need for complementary measures such as a bikeshare system, secure bicycle parking, and car-free zones to support accessible, safe cycling for more residents. Various cyclist groups and their specific needs are also noted in the plan with calls for equitable access to cycling facilities and highlighting the economic, environmental, and safety benefits of cycling.

493 km

Total length

3.37 MN

Population in coverage area

$131 MN

Estimated construction cost of cycle lanes

Challenges

- GKMA faces several challenges in implementing its cycle network plan successfully:
- Road safety is a key challenge, especially in the Kampala city center where vehicle crashes are concentrated. Motorcycle taxis, known as boda bodas, are widely used, with 200,000 operating across the metropolitan area. Boda bodas contribute to a high rate of crashes, often speeding and violating traffic laws. Posted speed limits exceed 40 kph on many downtown streets, contributing to crashes that result in death and serious injury.
- Another challenge is gender inclusion. Though about 50 percent of women in Kampala use public transport to commute to work, it can be a significant cost, and the quality of vehicles and roads is poor. Women currently account for only 0.04 percent of cyclists.
- The region's topography may present additional challenges for cyclists, with 35 percent of streets in Kampala having gradients above 3 percent (a generally accepted threshold for longer cycling trips).

Project Overview

The Kampala Cycle Network Plan proposes a network of 493 km of protected cycle lanes divided across three phases. Kampala currently has 2 km of cycle lanes.

Phase 1

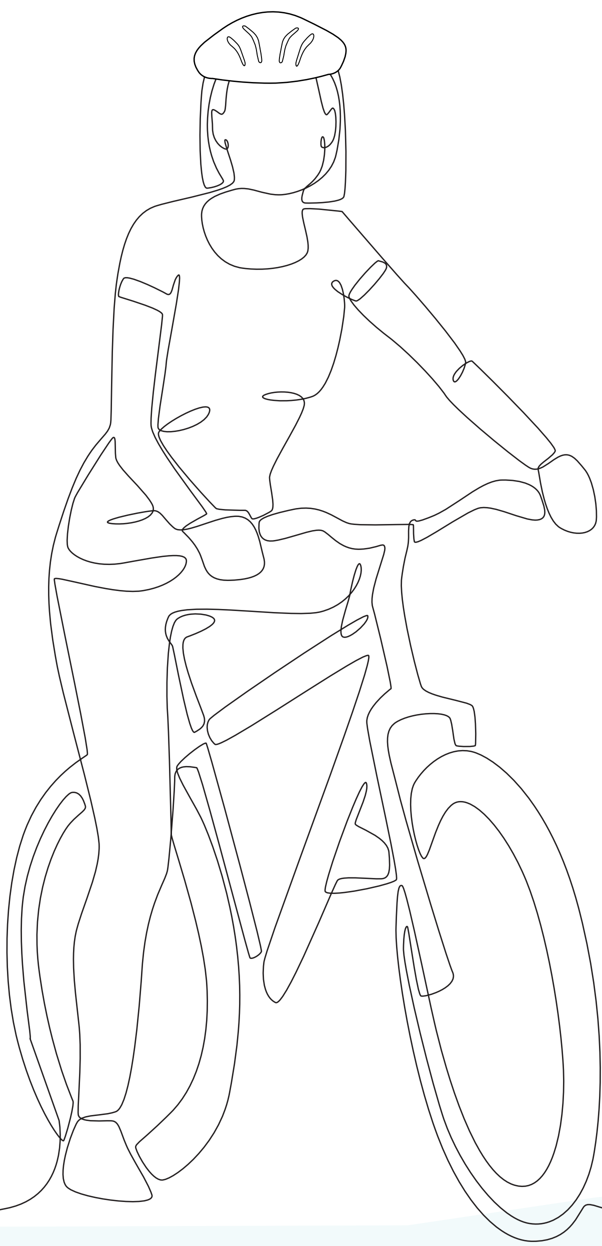
Includes 84 km and will focus on adding lanes along routes with high cyclist counts and to serve as feeders to BRT corridors.

Phase 2

Will total 166 km, making connections between Phase 1 routes and prioritizing lanes along high crash-risk corridors identified in the Kampala Road Safety Report. Lanes will also be planned to align with the Kampala City Roads and Bridges Upgrade Project.

Phase 3

Cycle lanes will aim to connect the network to commercial areas and other major corridors, totaling 241 km.



Results

The CyclingMax tool was applied to the full Kampala Cycle Network Plan, which includes 493 km of protected cycle lanes.

EIRR
55.79%

NPV
US$ 1,082 MN

SAFETY
Number of prevented fatal and serious crashes per year
96.5

HEALTH
Number of reduced mortalities through increased physical activities per year
309.4

EMISSIONS
CO_2 emissions per year
5,732.9 tons avoided

TRAVEL TIME
Travel time saved per year
24,396,127.62 hours

4.4. Addis Ababa, Ethiopia

Comprehensive cycling infrastructure to enhance urban mobility

City Stats

527 sq km area

5.4 million population

25 percent of Ethiopia's urban population

677 km

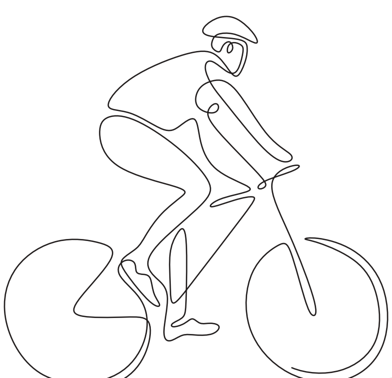
Total length

2.7 MN

Population in coverage area

$118 MN

Estimated construction cost of cycle lanes



Addis Ababa is home to 5.4 million people, or 25 percent of Ethiopia's urban population, and is among the fastest-growing urban areas in the world. About 54 percent of residents walk and 31 percent use public transport for their daily trips. Access to equitable, affordable mobility became an issue due to insufficient public transport service, poor traffic management, and street designs that prioritize motorized vehicles over pedestrians.

Challenges

- In Addis Ababa, bicycle ownership is very low, with about 8 percent of residents reporting owning a bicycle (compared to 25 percent who own a car). About half of the population do not know how to cycle, and only about 3 percent of households use a bicycle for transport on a weekly basis. Surveys show that cycling accounts for between 3-6 percent of trips, primarily among low-income men.

- Encouraging use of cycle lanes, supporting bicycle ownership and providing the right infrastructure is necessary to catalyze a swift uptake of cycling.

- Road safety poses a major challenge, with high-risk crashes concentrated on major roads with high levels of pedestrian and cyclist activity. High vehicle speeds, especially along the urban expressway where there are few designated pedestrian crossings, make walking and cycling particularly dangerous.

Project Overview

The Addis Ababa Cycle Network Plan (2023-2032) aims to create a comprehensive network, totaling 677 kilometers of cycle lanes to enhance urban mobility. The plan emphasizes safety and accessibility for diverse user groups, especially women and children. The implementation is structured in three phases:

Total length: **677 km**

Population in coverage area: **2.7 million**

Estimated construction cost of cycle lanes: **$118 million**

Phase 1

Includes 144 km of lanes focused in high-demand areas to connect cyclists to public transport. In addition to upgrading some existing cycle lanes and adding key corridors connecting the city center with outer areas, it includes the launch of a bikeshare system to increase access to bicycles. Phase 1 implementation began in 2024 with nearly 50km of cycle tracks completed.

Phase 2

Includes 189 km of lanes, expanding and improving existing routes based on user feedback, and enhancing safety by installing segregated lanes.

Phase 3

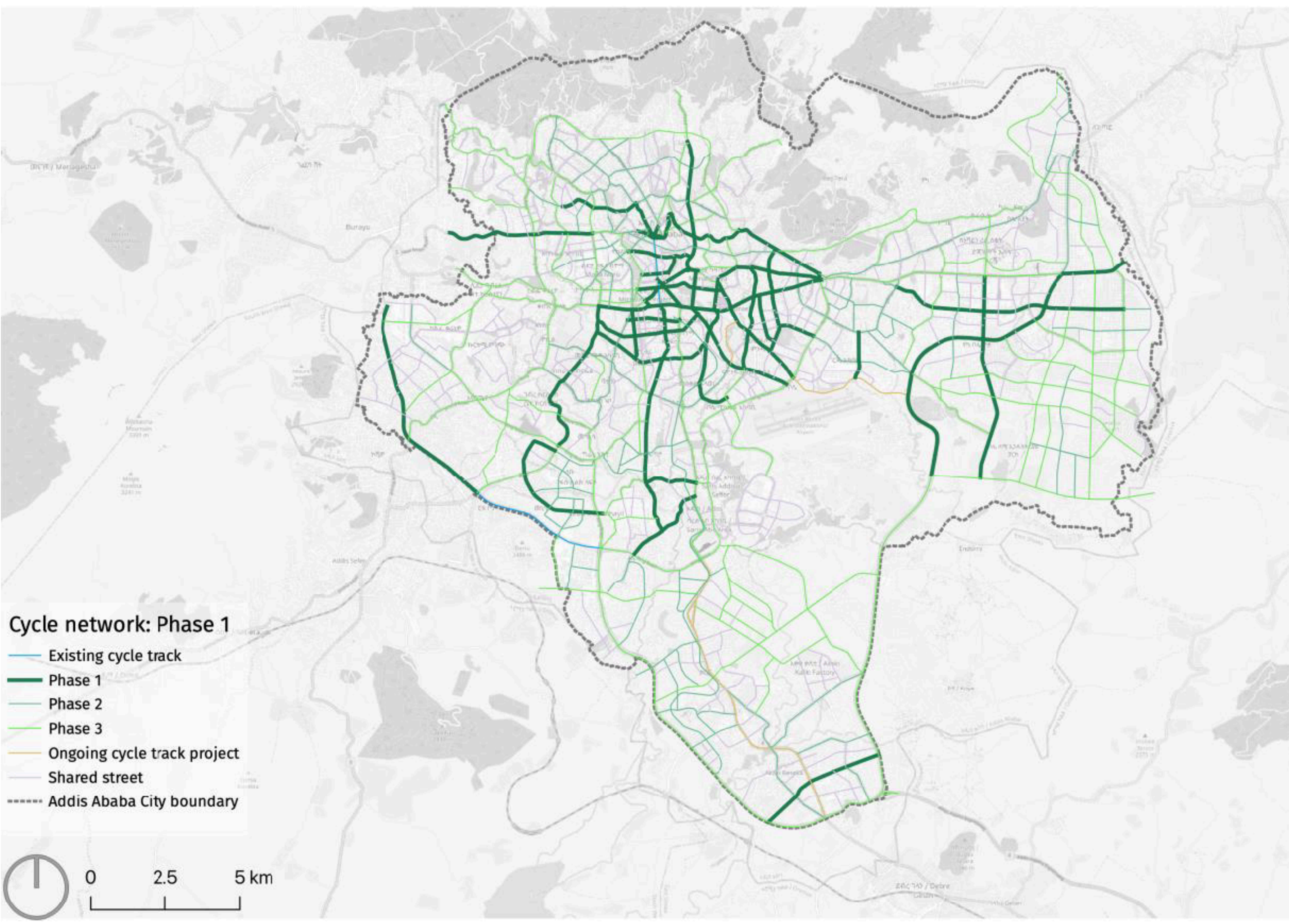
Completes the network with an additional 345 km, integrating cycling with broader urban planning initiatives.

Cycle lanes will also be incorporated along mass rapid transit lines. The Addis Ababa City Master Plan proposed 15 BRT corridors to be implemented over ten years. Any BRT corridor with a width of more than 35 m shall include cycle lanes. To facilitate convenient connections between stations and origins of trips, feeder streets intersecting these mass transport corridors will be equipped with cycle lanes or safe shared spaces. Moreover, all riverside projects are expected to incorporate cycle lanes to encourage cycling in these areas.

Throughout the three phases, cycle lanes in existing streets will be built with physical separation from mixed traffic. New streets will be built with elevated cycle lanes at the same level as the footpath.

Phase 1. Short Term (years 1-2)

Map 4.2. Cycle lane network: Phase 1



Total length:
144 km

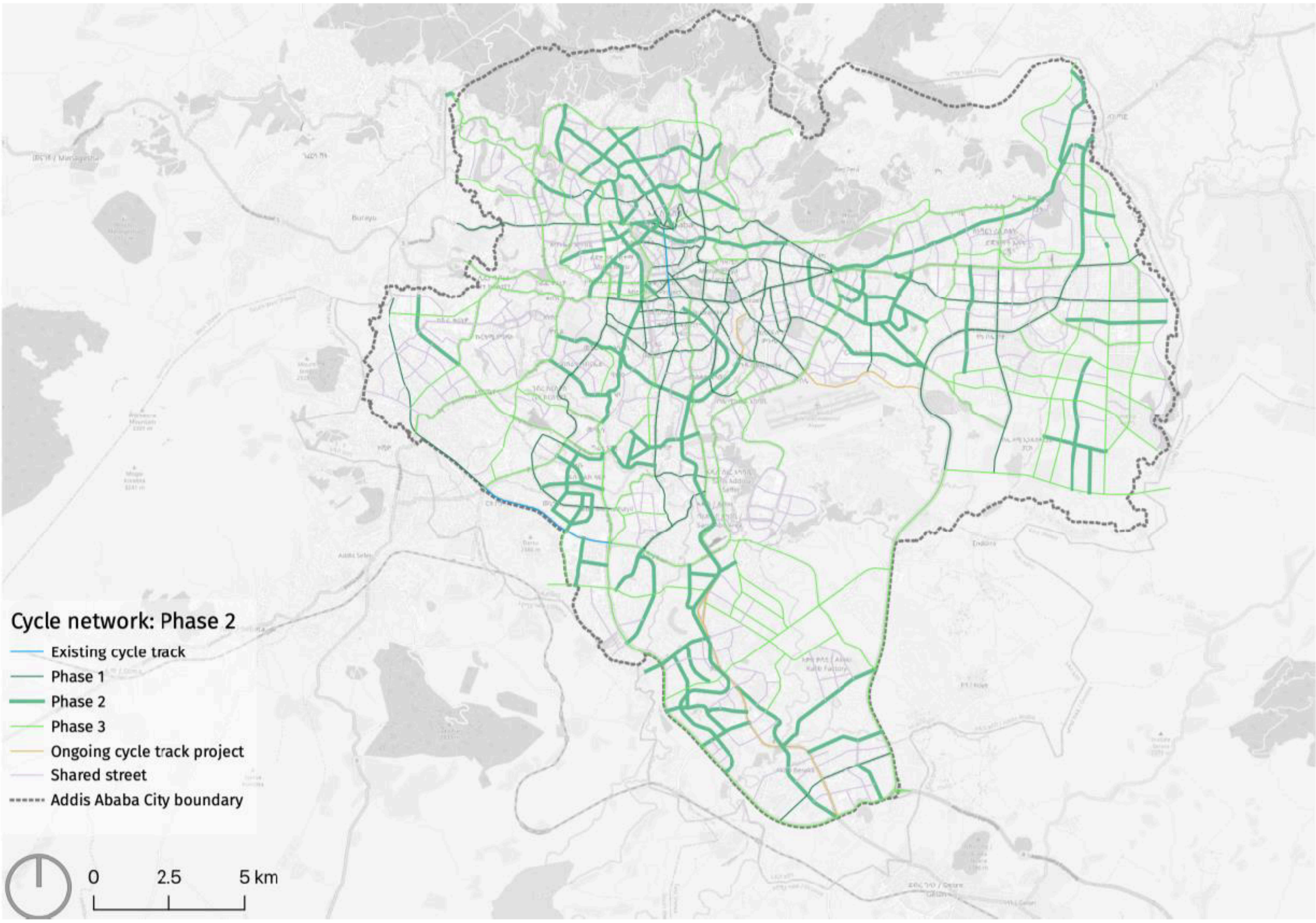
Population in coverage area
937,332

Estimated construction cost of cycle lanes
$26.1 million

The short-term cycle network plan includes ongoing bicycle projects, the first and second phase bikeshare coverage area, trunk corridors connecting the city center with peripheral areas, and upgrades to earlier cycle lane projects.

Phase 2. Medium Term (years 3-5)

Map 4.3. Cycle lane network: Phase 2

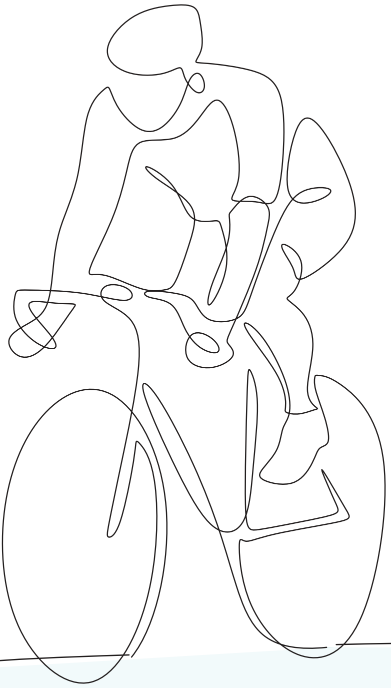


Total length: **187.8 km**

Population in coverage area **866,740**

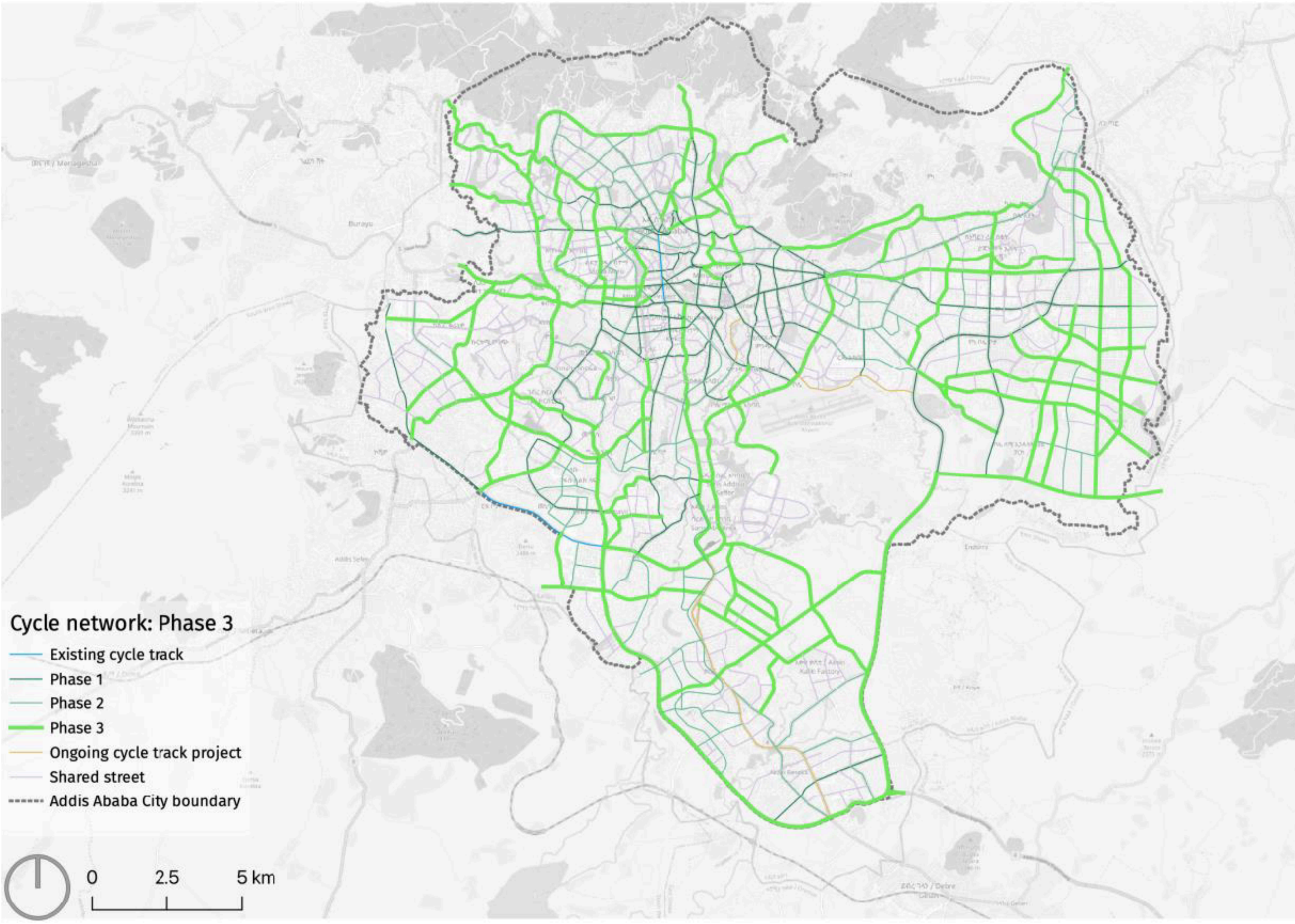
Estimated construction cost of cycle lanes **$34.1 million**

This phase will see 30 percent of the cycle network implemented, targeting corridors within the second phase coverage area of the bikeshare system, corridors that are part of the riverside development projects, new connections between the city center and peripheral areas, and networks within condominium areas.



Phase 3. Long Term (years 6-10)

Map 4.4. Cycle lane network: Phase 3



Total length:
345.2 km

Population in coverage area
794,596

Estimated construction cost of cycle lanes
$118.4 million

In the long term, protected cycling lanes shall be provided on all major streets with a width of 30 m or more. The local streets shall be designed as shared streets to accommodate cycling, walking, and slow-speed vehicle movement. Cycle lanes shall be incorporated along the mass rapid transit lines.

The Addis Ababa City Master Plan proposed 15 BRT corridors to be implemented over ten years. Any BRT corridor with a width of more than 35 m shall include cycle lanes. To facilitate convenient connections between stations and origins of trips, feeder streets intersecting these mass transport corridors will be equipped with cycle lanes or safe shared spaces. Moreover, all riverside projects are expected to incorporate cycle lanes to encourage cycling in these areas.

Results

The CyclingMax tool results for the multimodal corridors and walking and cycling network planned for Addis Ababa include:

EIRR
75.7%

NPV
US$ 678.7 MN

SAFETY
Number of prevented fatal and serious crashes per year
257.25

HEALTH
Number of reduced mortalities through increased physical activities per year
404.55

EMISSIONS
CO_2 emissions per year
7,541 tons avoided

TRAVEL TIME
Travel time saved per year
15,640,499 hours

4.5. Lima, Peru

Upgraded cycling infrastructure network to increase access to jobs and services

City Stats

10.9 million population

2,672 sq km area

332 km of disparate cycling lanes

Multimodal Corridors

50 km
Total length

303,000
Population in coverage area

$38.7 MN
Total cost of the component

$17.4 MN
Estimated construction cost of cycle lanes

Lima's public transport has not kept pace with its expanding population. This hinders access to jobs and services, especially for those with lower incomes. Most residents rely on public transport — the largely inefficient bus transit system — with its significant gaps in service. The city also struggles with:

- Heavy traffic
- Air pollution
- Rising greenhouse gas emissions
- Road safety concerns

The increasing motorization rates have led to a spike in car accidents, negatively impacting human capital and productivity.

Challenges

Cycling in Lima has grown slowly—from 0.3 percent of all trips in 2012 to 0.6 percent in 2023. While the city has 332 kilometers of cycle lanes, they face multiple issues:

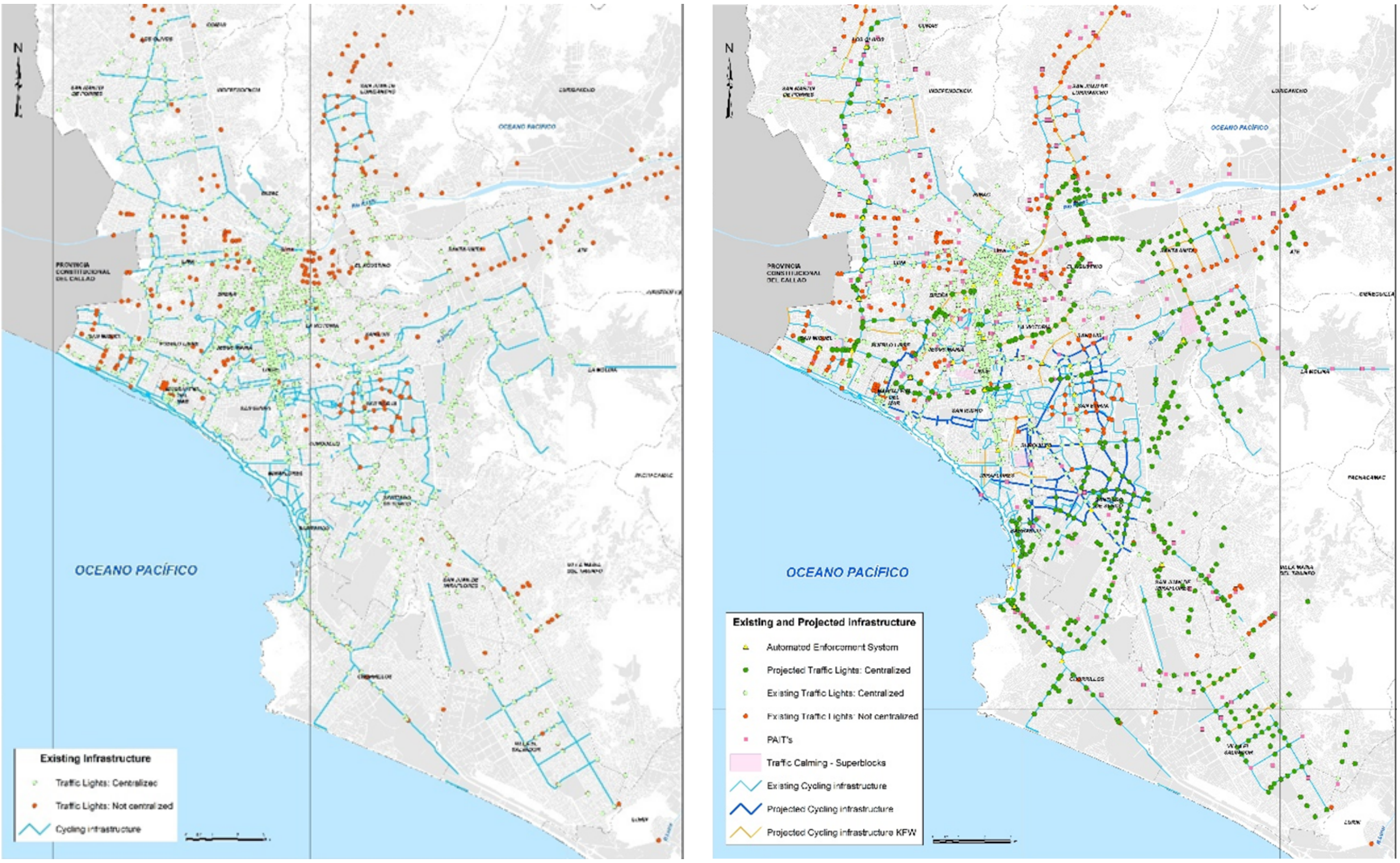
- The lanes don't connect well to each other
- Many areas have no cycle lanes at all
- The lanes aren't built well
- Intersections are dangerous for cyclists and pedestrians
- Only three bus rapid transit stations have bike parking
- Women especially feel unsafe cycling

These problems show in the statistics: pedestrians and cyclists make up 55 percent of all road deaths, mostly at intersections.

Project Overview

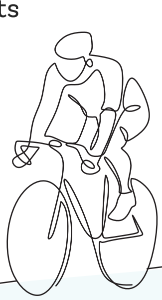
A World Bank study in 2020 found that Lima needs 1,383 kilometers of protected cycle lanes—much more than it has now. The city's current bike lane plan dates back to 2005. While newer studies suggest adding 470 kilometers of lanes by 2040, Lima still doesn't have an up-to-date, official plan that explains how to build and connect all these cycle lanes.

Map 4.5. Before and after project interventions



A connected network of high-quality segregated cycle lanes is being implemented across 15 districts in central Lima as part of comprehensive "complete streets" interventions. The network aims to improve travel conditions for pedestrians and cyclists and integrate non-motorized transport (NMT) with public transport, thereby promoting a modal shift from motorized modes. The 50 km of priority connections have been identified using criteria such as the connectivity of the Lima Center network, with the goal of closing the gaps between existing primary bike lanes.

Climate resilience is incorporated into the design of cycle lanes with the use of durable materials and the implementation of nature-based solutions. The project also includes the preparation of engineering designs for an additional 150 km of cycle lanes, enhancements to safety and functionality at intersections and the implementation of a public bike share service, which aims to be particularly accessible for women.



Results

The CyclingMax tool results for the multimodal corridors and walking and cycling network planned for Lima include:

EIRR
85.7%

NPV
US$ 144 MN

SAFETY
Number of prevented fatal and serious crashes per year
9

HEALTH
Number of reduced mortalities through increased physical activities per year
9

EMISSIONS
CO_2 emissions per year
1,078.16 tons avoided

TRAVEL TIME
Travel time saved per year
302,982 hours

4.6. São Paulo, Brazil

BRT lines and segregated cycle lanes to tackle traffic congestion and social issues

City Stats

12 million population

5th largest metropolitan area in the world

1.3 million residents below poverty line

1,493 sq km area

14 km
Total length

92,114
Population in coverage area

$103.25 MN
Total cost of the component

$18.7 MN
Estimated construction cost of cycle lanes

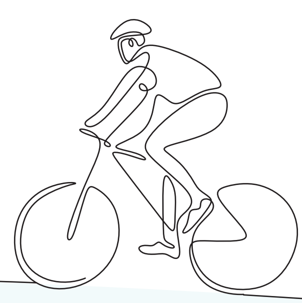
The São Paulo Metropolitan Region (SPMR) is Brazil's most significant economic area, contributing over 20 percent of the nation's GDP. However, rapid urbanization has led to uncontrolled urban sprawl, exacerbating social issues. Within the SPMR, São Paulo City experiences significant social inequality, with 1.3 million of its 12 million residents living below the international poverty line.

Challenges

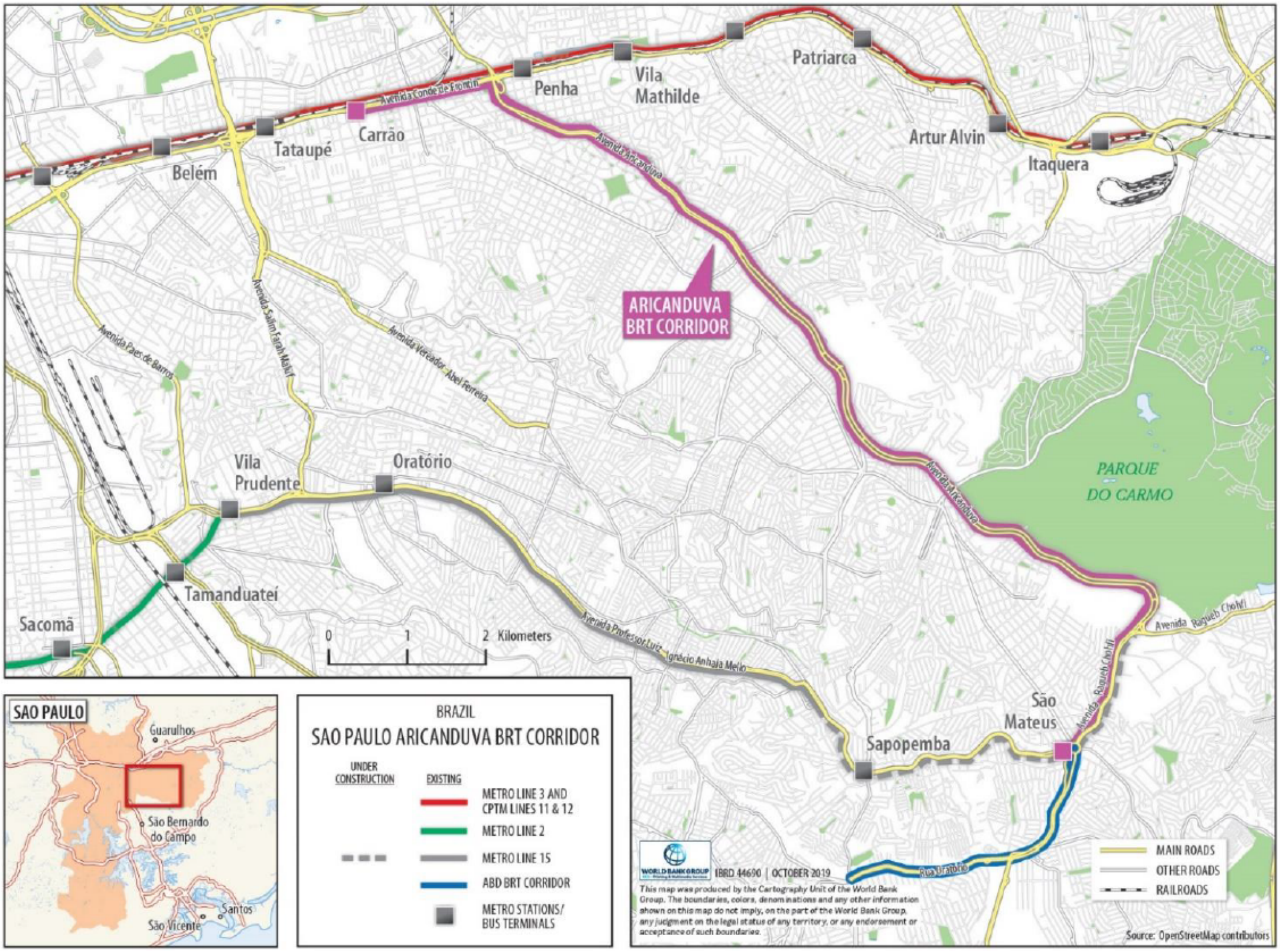
The city's rapid motorization has made it the fifth most congested city globally. Traffic congestion is estimated to cost the city about 8 percent of the metropolitan area's GDP in 2013, or more than percent of Brazil's GDP. This is due to productivity losses, GHG emissions and air pollution, which is responsible for approximately 5,000 premature deaths annually. Despite SPMR's investments in public transport over the past decade, including metro, suburban railways, and buses, the existing bus networks remain disconnected from other modes and are inefficiently operated. Additionally, road safety is a significant concern, with 850 deaths, or 6.56 deaths per 100,000 people, attributed to road accidents annually. The inclusion of women and vulnerable populations in public transport also needs substantial improvement.

Project Overview

To address these issues comprehensively, new BRT corridors with segregated cycle lanes running parallelly have been proposed by the Municipality of São Paulo (MSP). They will enhance access to jobs and services, particularly for one of the city's lowest-income and most socially vulnerable communities. This is meant to impact 52 percent of the population, including 29,000 households in urban slums, who face high social vulnerability and low accessibility. Since bicycles are an affordable and sustainable mode of transport frequently used by women, those segregated lanes will improve safety, inclusion and sustainability.



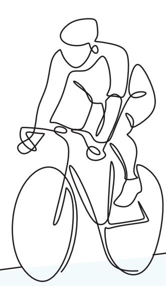
Map 4.6. Cycling lane along Aricanduva bus rapid transit corridor, São Paulo



Source: World Bank.

The segregated bicycle lanes will be constructed throughout the length of the São Paulo Aricanduva Bus Rapid Transit Corridor. To encourage the use of non-motorized transport, São Paulo City has already developed 506 km of the bicycle lanes. According to the Municipal Bicycle Plan (2019), the bicycle lane network will be expanded from 506 km to 1,800 km by 2028.

The bicycle lane along the Aricanduva Corridor has been prioritized in this plan, because of citizen feedback in public consultations as well as being a key piece to ensure a well-connected bicycle network. The planned segregated cycle lanes could mitigate road safety risks for bicyclists and other modes by reducing conflict among different modes. Some BRT stations will have bicycle parking facilities — subject to availability of space — to further promote active mobility.



Results

The CyclingMax tool results for the multimodal corridors and walking and cycling network planned for São Paulo include:

EIRR
88.6%

NPV
US$ 156 MN

SAFETY
Number of prevented fatal and serious crashes per year
7.8

HEALTH
Number of reduced mortalities through increased physical activities per year
3.1

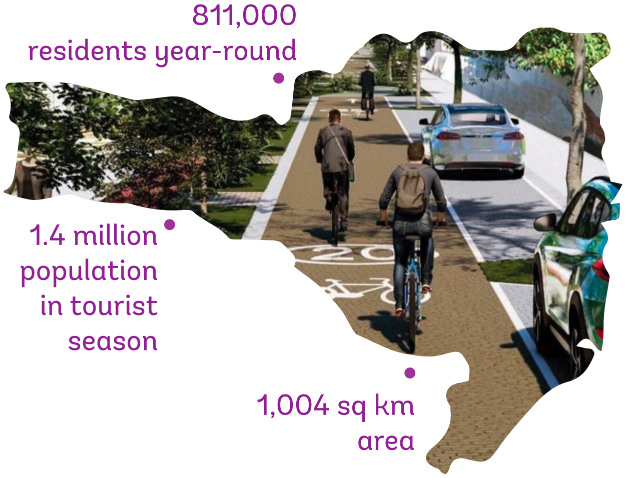
EMISSIONS
CO_2 emissions per year
653.91 tons avoided

TRAVEL TIME
Travel time saved per year
83,732 hours

4.7. Foz do Rio Itajaí Region, Brazil

Integrated, sustainable active mobility for a rapidly growing, tourist-friendly city

City Stats



811,000 residents year-round

1.4 million population in tourist season

1,004 sq km area

Component 1: Dedicated bike paths connecting the different municipalities along the BRT corridors

70 km
Total length

100,000
Population in coverage area

$3 MN
Total cost of the component

$7.6 MN
Estimated construction cost of cycle lanes

The Foz do Rio Itajaí Region has 811,000 year-round residents spread across 1,004 square kilometers. Its population has been growing quickly—3.6 percent each year from 2018 to 2023. By 2030, about 1.1 million people are expected to live here year-round. During the busy tourist season, the population doubles to more than 1.4 million people. While the region is generally wealthier than other parts of the country, there is still a high level of inequality. People with lower incomes often struggle to reach jobs, markets and basic services.

Challenges

The region's 11 municipalities are not well connected by public transport. This has led to several problems:

- High motorization, with increasing dependency on private vehicles
- Rising pollution and greenhouse gas levels
- Poor road safety practices and infrastructure
- Lack of inclusiveness towards women and people with lower incomes

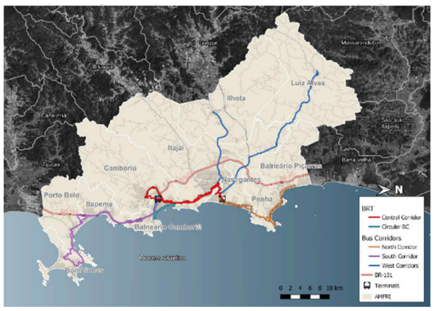
Project Overview

The region wants to make it easier and safer for people to walk and cycle to access public transport as well as economic and social opportunities. Building safe paths and lanes for walking and cycling is especially important to help people from lower-income neighborhoods reach the new bus system that's being planned. This will help make transportation more equitable for everyone.

Two BRT corridors and four e-bus corridors have been planned. They are dedicated to connect jobs, tourist centers, public services and an international airport across the 11 municipalities in the region. Along the new BRT corridors, 70 km of dedicated bike paths will be implemented or improved, along with sidewalks and pedestrian facilities.

This intervention particularly aims to turn trips by private vehicle into multimodal trips, with active mobility and new BRTs/e-buses for commuting, which are more sustainable and efficient. As active mobility serves as the first and last mile, complementing BRTs and e-buses, it will make trips by this public transport system more attractive for users.

Map 4.7. AMFRI Regional mobility plan's vision for a BRT network in the Foz do Rio Itajaí Region



Source: CIM-AMFRI—Corridors as defined by the Mobility Plan (2016).

Component 2: Active mobility corridors connecting economically vulnerable neighborhoods

Total length: **~25 km**

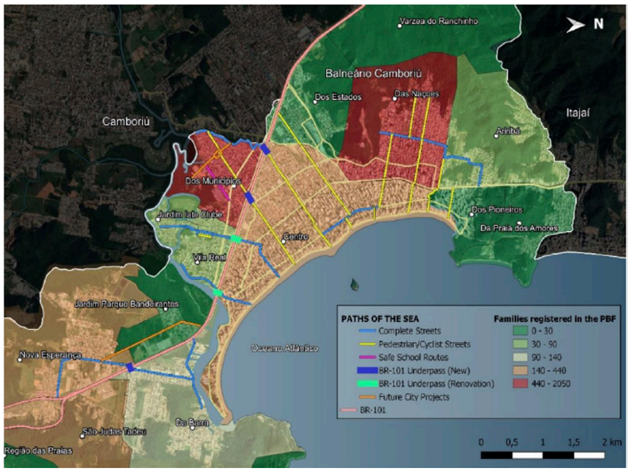
Population in coverage area: **130,000**

Total cost of the sub-component: **$29.5 million**

Estimated construction cost of cycle lanes: **$29.5 million**

The new street design will also help reduce the impact of severe weather.

Map 4.8. Active mobility links to be improved to connect the beach area with the city's low-income areas



Source: World Bank.

Note: The Caminhos do Mar proposal is envisioned in the master plan—with the registered families of the PAB.

Photo 4.1. Basic design before and after Caminhos do Mar interventions

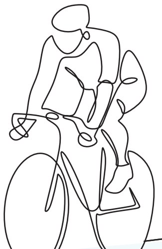
Source: CIM-AMFRI/World Bank.

The project will transform streets between the economically vulnerable neighborhood of Balneário Camboriú's and the waterfront job area. Instead of focusing mainly on cars, these new "complete streets" will make it safer for people to walk and cycle. Some streets will give priority to pedestrians and cyclists, with strict limits on car traffic and speed. The design includes:

- Separate lanes for cyclists
- Better drainage to handle heavy rain
- More trees and plants along the streets
- Features that make the roads safer

These changes will make it easier for everyone to reach jobs near the waterfront, especially:

- People from lower-income areas
- Women traveling alone
- Children
- Other vulnerable groups



Results

The CyclingMax tool results for the multimodal corridors and walking and cycling network planned for Foz do Rio Itajaí Region include:

EIRR
44.3%

NPV
US$ 148 MN

SAFETY
Number of prevented fatal and serious crashes per year
6.8

HEALTH
Number of reduced mortalities through increased physical activities per year
7.7

EMISSIONS
CO_2 emissions per year
1,633 tons avoided

TRAVEL TIME
Travel time saved per year
209,071 hours

4.8. Recife, Brazil

Cycling masterplan to encourage active mobility and curb individual motorized traffic

City Stats

• 218 sq km

1.6 million population •

8th largest metropolitan area in Brazil •

Multimodal Corridors

156 km
Total length

725,154
Population in coverage area

$55.5 MN
Estimated construction cost of cycle lanes

The Metropolitan Region of Recife, with a population of 3.7 million as of 2022, is the 8th largest metropolitan area in Brazil. The region is made up of 14 municipalities, with Recife being the largest – and the fourth largest city in Brazil. Similar to many other Brazilian regions, its economic, urban, and demographic growth has led to a significant rise in individual motorized traffic. The personal vehicle fleet grew by 115 percent in the metropolitan region and by 85 percent in Recife between 2000 and 2013.

Consequently, the region developed its cycling master plan to address mobility challenges including severe congestion, air pollution, and carbon emissions. The plan recognizes the potential for cycling to benefit individual users, local communities, and the city's economy. In particular, the plan aims to integrate cycling with public transport, encouraging the acceptance of cycling as a realistic transport mode for short trips and promoting multimodal trips for longer distances.

Challenges

- Though the region's cycle network plan is ambitious, gaps remain. In Recife, areas that are seriously underserved by transport are not covered by the cycle lane network. Cycle lanes are instead concentrated in higher-income neighborhoods, exacerbating deep social inequalities that exist in the city.

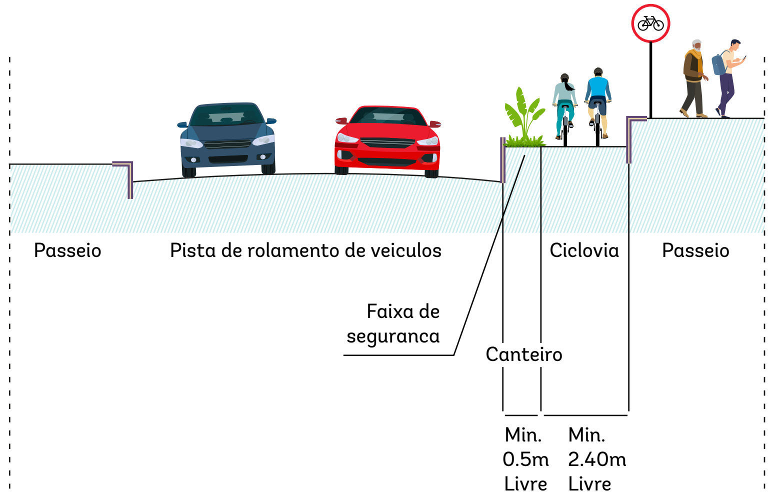
- Maintenance of existing cycle lanes also poses a challenge, as limited municipal funding is made available for this.

Project Overview

The City of Recife had been advancing cycling even before the Cycling Masterplan was developed at the metropolitan level in 2014. Recife's Transport and Mobility Master Plan (2011) and Redes Cicláveis report (2010) recognized cycling as a way to generate economic, environmental, and social benefits for the city.

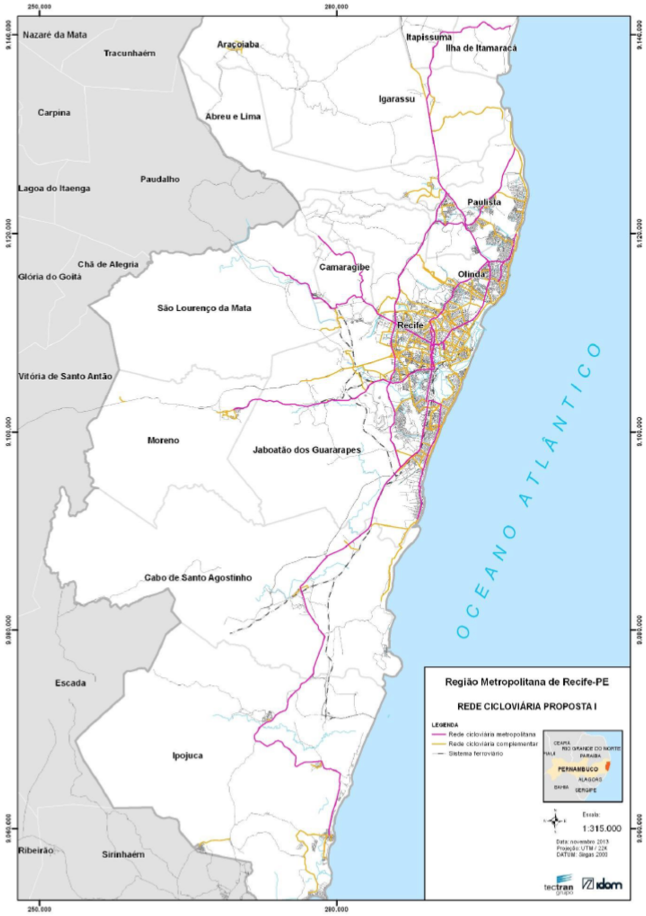
The Cycling Masterplan covers the 14 cities which comprise the Recife metropolitan area, proposing a cycle network of 591 km. The planned network is divided into "metropolitan" and "supplemental" networks. The 245 km metropolitan network is under the State's responsibility and 346 km of supplemental lanes are under each City's responsibility. Within the City of Recife, the "metropolitan" network accounts for 71 km of protected cycling infrastructure. There are 178 km of "supplemental" lanes, which includes 156 km of protected lanes, 4.2 km of ciclofaixa (a design common in Brazilian cities with small reflective delineators along the lane), and 18.4 km of unprotected lanes.

Figure 4.2. Example of street section with bidirectional, segregated cycle lane



Source: Tectran/idom, 2013.

Map 4.9. Cycle lane map



Source: Tectran/idom, 2013.

Recife's cycle network plan consists of long-distance corridors and shorter direct routes. For both types, there is a particular focus on connecting public transportation hubs with the cycle lane network, to promote multimodal trips over using private vehicles. The metropolitan corridors are meant to promote inter-municipal trips within the broader metropolitan region. While mainly implemented alongside public transport corridors, some streets are proposed to be exclusively composed of cycle lanes to further enhance the safety and comfort of cyclists. The complementary network, on the other hand, aims to facilitate trips within each municipality in the region. It connects the metropolitan network to public transport terminals and other points of interest like universities, schools, shopping malls, among others.

Results

The CyclingMax tool was applied only to the 156 km of protected cycle lanes that make up the "supplemental" network of local routes funded and maintained by the City of Recife.

EIRR
91.52%

NPV
US$ 593.73 MN

SAFETY
Number of prevented fatal and serious crashes per year
21.55

HEALTH
Number of reduced mortalities through increased physical activities per year
24.29

EMISSIONS
CO_2 emissions per year
5,147.79 tons avoided

TRAVEL TIME
Travel time saved per year
1,246,608.45 hours

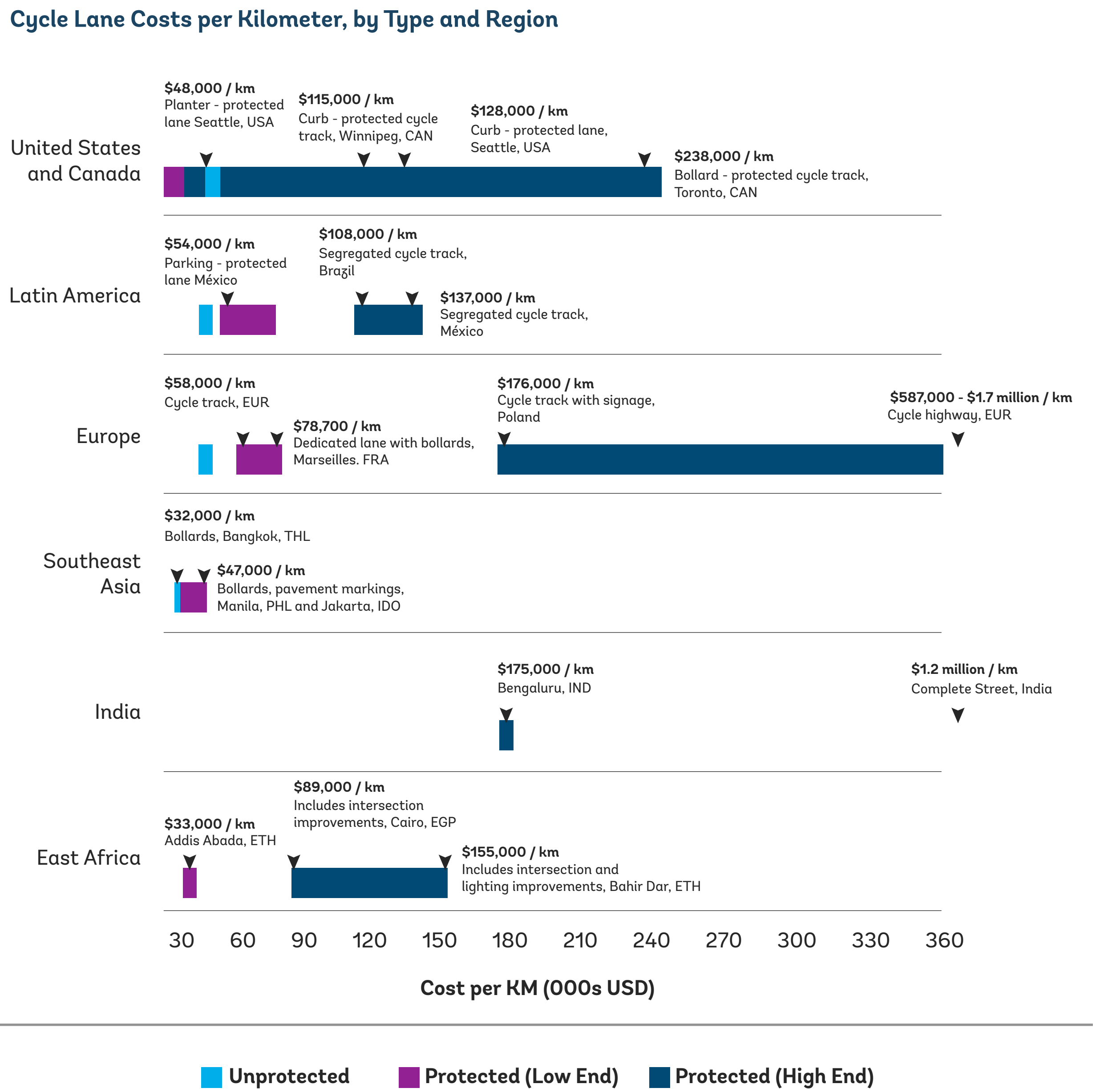
5

Inside the CyclingMax Tool

Deep dive into the tool to understand its core components: from its mathematical models to its input and output modules. Learn how the tool processes diverse inputs to generate robust cost-benefit ratios and actionable investment insights. Understanding these mechanics helps planners and decision-makers better interpret results and customize analyses for their specific urban contexts.

The cost of a cycling facility includes two major components: the *initial construction* cost incurred before the facility opens to traffic and the *annual maintenance cost*, which is incurred each year for maintenance since the facility opens to traffic. This construction cost can vary significantly according to the local costs of construction materials and labor. Several studies have surveys of the costs of cycle lanes, providing reference values for estimating cost. As users typically have an estimate of the project cost, the construction and maintenance costs are requested as inputs from the user in the input module. Figure 5.1 illustrates the cost of per kilometer for construction of cycle lane in a report by ITDP.

Figure 5.1. Cost of cycling lane per kilometer



Source: ITDP. (2022). Making the Economic Case for Cycling [online] Available from: https://www.mobiliseyourcity.net/sites/default/files/2022-08/Making-the-Economic-Case-for-Cycling_6-13-22.pdf.

5.1. Cycling demand modeling

The demand for cycling traffic serves as critical input for assessing the benefits of cycling infrastructure. The volume of bicycle trips and their cumulative distance directly influence the benefits of a cycling facility, including the environmental, safety, and health benefits. Cycling demand is influenced by the location, type, and density of land use both along and within a specific radius of the bicycle facility. Various factors can lead to significant variations in cycling demand, including the following:[Ref-x]

1) Cycling facility type: cycling lane (with or without a physical divider between the cycling lane and the lane for motor vehicles), exclusive cycling lane, on-street cycling route, etc.
2) Existing transportation modes and demand
3) Existing local economic development and land use around the cycling facility

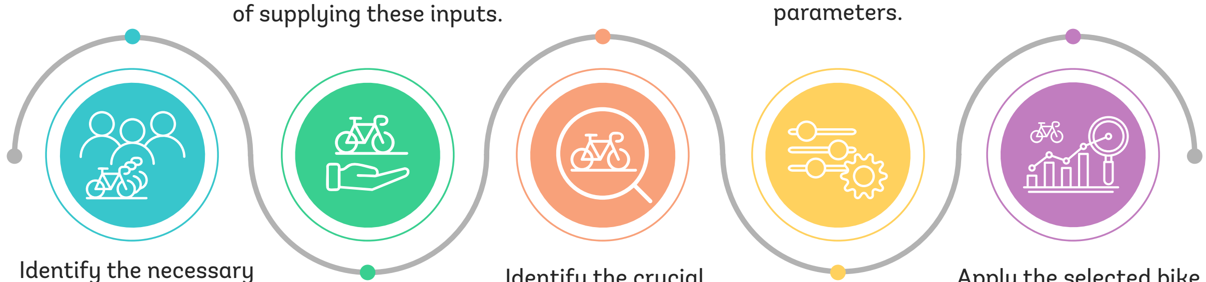
Travel demand forecasting is well studied, and multiple methods for demand forecasting have been developed. In general, these demand forecasting models can be grouped into three general categories:

- *Trip-based four-step trip generation models*. These models predict traffic demand based on a sequence of tasks that includes trip generation, trip distribution, mode choice, and route assignment. This is the industry standard for forecasting future demand. However, this method requires extensive input and complex modeling. The inputs require surveys, comprehensive coefficient selection, network development for trip distribution and route assignment, and sensitivity analysis. Thus, forecasting using the four-step model is typically carried out through dedicated consulting efforts for each project.
- *Activity-based travel demand models*. These models improve upon the trip-based models by incorporating constraints related to time, space, and the linkages among activities and travel. Activity-based travel demand models have been increasingly adopted in recent years.
- *Strategic planning and sketching-planning models*. These models are based on high-level estimates of trip rate per individual, population size, percentage of shift from other traffic modes, etc. Strategic planning and sketching-planning models typically require less information and less intensive modeling processes than trip- and activity-based models.

Although trip- and activity-based models show potential for cycling demand forecasting, both modeling approaches require significant investment for data collection, traffic network construction, utility function development, and model calibration. The associated costs are often prohibitively high for cycling demand forecasting. Consequently, most cycling infrastructure cost-benefit analyses employ variations of strategic planning and sketch-planning models, which require less information and less burdensome modeling.

However, as for trip- and activity-based models, the outcomes are sensitive to the chosen parameters. Therefore, identifying accurate parameter values is essential for precisely estimating cycling demand. Another challenge arises from the fact that the targeted users for a project may lack access to sources for the key parameters. Therefore, providing reasonable default values is critical. A suggested approach based on strategic-planning and sketch-planning models is illustrated in Figure 5.2.

Figure 5.2. Approach for forecasting cycling demand



Source: World Bank.

The CyclingMax tool estimates demand based on the population affected along the new cycling facility. A simple linear regression is used to estimate the total induced travel distance resulting from the new cycling facility.[Ref-xi] Based on a sample of eight Latin American cities. This regression model ($R^2 = 0.88$) concluded that for every person living within 300 m of a protected bicycle lane, roughly 315 km are cycled on protected lanes every year.

$$\textit{Induced Biking Length} = \textit{Population} * 315 \; (\textit{km per year}), \qquad (1)$$

where *Population* is the population within 300 meters of the cycling facility.

According to a study by the National Institutes of Health (NIH) installing new bicycle lanes will induce increases in bicycle use by 59 percent (trips) and 88 percent (total distance traveled) relative to the situation without bicycle lanes.[Ref-xii] Therefore, the existing cycling length is:

$$\textit{Existing Biking Length} = \frac{\textit{Induced Biking Length}}{0.88} \; (\textit{km per year}) \qquad (2)$$

5.2. Benefit modeling

The CyclingMax tool includes four categories of benefits: safety, health, environmental, and travel time saving. During the development of the CyclingMax tool, several existing tools were reviewed. The CyclingMax incorporates the most valuable and project-relevant benefit categories from existing tools. Additional modeling modules were added to demonstrate these benefits effectively. Benefits requiring further research or parameters typically unavailable in developing countries were omitted. This section details the calculation methods for all benefits included in the CyclingMax tool and explains the rationale behind each analytical approach. Note that all the parameters/variables discussed in this section are also listed in the Appendix. The reference number (*ref #*) of each parameter/variable indicated in the following sections is indexed in the Appendix for ease of identification. The rule of a half needs to be applied when assessing the impacts of induced traffic.[Ref-xiii]

Safety benefits

The CyclingMax tool considers the safety benefits of a cycling facility in two parts:

1) Benefit from shifting modes from cars to cycling. In existing cost and benefit analyses of cycling facilities, the safety benefits are typically calculated based on the amount of traffic that shifts from cars to cycling. The mode shift from car to cycling enhances safety by avoiding potential car crashes. The associated benefit is estimated from the average cost of crashes, crash rate, and the total amount of induced cycling distance that is diverted from car travel. The calculation formula is similar to those applied in the CALTRAN and Australia models.[Ref-xiv] Note that a single car is likely to have more than one occupant; thus, *Vehicle Occupancy* is included as a parameter in the calculation to reflect the total number of cars instead of total number of cycling riders:

*Safety Benefit from Mode Shift = Induced Cycling Length * (Trip Purpose Composition[1] + Trip Purpose Composition[2]) * Diversion from Cars / Vehicle Occupancy * Crash Rate * Average Serious Crash Cost * (Induced Benefit Factor),* (3)

where:

- *Induced Biking Length* can be calculated from Equation (1)
- *Trip Purpose Composition*[1] is the percentage of commuting in cycling traffic (ref 1)
  Trip Purpose Composition[2] is the percentage of cycling traffic other than commuting and recreational trips (ref 1). Following common safety benefit calculation practice, recreational trips were not included as recreational bike trips are elastic demand and may expose to less risk
- *Diversion from Cars* is the percentage of newly induced cycling trips that were originally taken by cars (ref 15)
- *Vehicle Occupancy* is the average number of people in each car (ref 3)
- *Crash Rate* is the motor vehicle traffic crash rate per billion vehicle KM traveled (ref 7)
- *Induced Benefit Factor*[3] adjusts for the effects of unaccounted factors and is given a value of 0.5
- *Average Serious Crash Cost* is the cost per crash in USD (ref 5), which can be calculated as:

$$\text{Average Cost of Serious Crash} = (p_{fatal} * \text{Cost per Fatal Crash} + p_{injury} * \text{Cost per Serious Injury Crash}) / (p_{fatal} + p_{injury}), \quad (4)$$

where:

Cost per Fatal Crash = 70 * per capita GDP, and (5)

Cost per Serious Injury Crash = 17.5 * *per capita GDP* (6)

based on World Bank estimates,[Ref-xiv] and p_{fatal} and p_{injury} are the proportions of fatal and serious injury crashes, respectively.

Along with the calculation of burden of road crash in LMICs in the iRAP's model, the safety benefit that will be calculated only includes fatal and serious injury based on a meta-analysis in LMICs.

[3] In the majority of situations, the calculation of the user benefit associated with induced traffic is relatively straightforward and relies on the "rule of the half" methodology: P. Mackie et al. (2005). *Treatment of Induced Traffic.* [World Bank Transport Notes Series]. http://hdl.handle.net/10986/11796

The Global Road Safety Facility study suggested that the ratio of fatal to serious injury crashes is 1:15 at country level. However, as a logical assumption, this could vary by road infrastructure length. Suggested ratios could be: 1:2 for very short sections, 1:5 for short sections, 1:10 for medium-length sections, and 1:15 for long sections. The CyclingMax tool uses 1:15 as the default value, but users can adjust this ratio according to the specific project.

Fatal crash rates per billion kilometers traveled by cars are available for limited counties. These data are only available for two developing counties: Mexico (27.5 fatal crashes per billion km traveled) and Malaysia (16.2 per billion km traveled). Most developed counties have low rates — between 3 and 9 fatal crashes per billion km traveled.

The CyclingMax tool estimates the default fatal and serious injury crash rates as follows:

a) The default fatal crash rate is set to 20 fatalities per billion km traveled by cars based on the average of the statistics available for Mexico and Malaysia.

b) The estimated rate of fatal and serious-injury crashes is set at 16*20=320 per billion km traveled. The factor 16 comes from the 1:15 ratio of fatal to serious-injury crashes derived from World Bank research.

2) Benefit for existing cycling traffic. A second component of safety benefit (that is, the safety benefits of the cycling facility for existing cycling traffic) was incorporated into the CyclingMax tool in consideration of previous safety-related research conducted based on the Highway Safety Manual (HSM). This benefit reflects the reduction in cycling crashes in existing cycling traffic due to the newly built cycling facility. Similar to the calculation method of the HSM, the CyclingMax tool calculates this benefit based on the existing cycling distance, existing crash rate, average cost of cycling crashes, and CMF of the newly built cycling facility:

*Safety Benefit for Existing Cycling = Existing Cycling Length * Existing Cycling Crash Rate* (1-CMF) * Cost of Cycling Crashes*, (7)

where:

- *Existing Cycling Length* is calculated using Equation (2)
- *Existing Bike Crash Rate* refers to the crash rate between cycling and motor vehicles in mixed traffic conditions (ref 7)
- *Cost of Cycling Crashes* is the average cost of crashes (ref 6)
- *CMF* is the crash modification factor (ref 9), which ranges from 0.41 to 0.92 based on existing studies, implying a reduction of 59 percent to 8 percent in crash rate

The World Bank has suggested the CMFs shown in Table 2.1, which are also adapted in the World Bank's Transport GP assessment models.

The fatal and serious injury cycling crash rate is a critical parameter when determining the safety benefit. Unfortunately, virtually all availably cycling crash rates are for developed countries, and no fatal and serious-injury crash rates are available, even for developed countries. We derived the default value for developing countries using the following logic:

a) In United Kingdom, the fatal cycling crash rate is 36.8 per billion km traveled (23 per billion miles traveled) and fatal car crash rate is 4.8 per billion km traveled.[Ref-xv,xvi]

b) The ratio of the rate of fatal cycling crashes to the rate of fatal car crashes is 36.8/4.8.

c) The default value for the rate of fatal car crashes is 20 per billion km traveled, as discussed above in the "Benefit from shifting modes from cars to cycling" section.

Assuming a constant ratio between the rates of fatal cycling crashes to car crashes, the fatal cycling crash rate should be 20*36.8/4.8=153 per billion km traveled. The corresponding fatal + serious injury crash rate should then be 16* 153=2,448 per billion km traveled.

Health benefits

Cycling facilities improve health by inducing exercise when users shift from car travel to bicycle travel. The calculation of health benefits in the CyclingMax tool involves the value of a statistical life, percentage of cycling (aged 16–64) in the population, percentage of induced cycling traffic, and the reduction in mortality due to exercise. The modeling method used combines features of the CALTRAN model and WHO HEAT model.

However, instead of estimating the population affected by cycling exercise based on the estimated number of trips per traveler and average cycling distance of each trip, the CyclingMax tool asks users to provide the population as a direct input variable. This approach is more accurate and direct since the local population and the percentage of cyclists are both known parameters in most areas of the world; it is much more difficult to estimate the number of cycling trips and cycling distances.

*Health Benefit =Population within 300 meters of the cycling facility*Percentage of Cyclist in the Population*(Induced Cycling Length) / (Induced Biking Length +Existing Cycling Length)*Annual Reduction of Mortality *Allcause Mortality*Value ofa Statistical Life*(Induced Benefit Factor),* (8)

where:

- *Percentage of Cyclist in the Population* is the percentage of the population aged 16–64 (ref 4)
- *Annual Reduction of Mortality* is reduction in all-cause mortality due to cycling exercise (ref 11)
- *All-cause Mortality* is the local mortality rate (ref 10)
- *Induced Benefit Factor*: 0.5, which is a *discount* factor to adjust for the effect of unaccounted factors[4]
- *Value of Statistical Life* = 70 * per capita GDP (ref 12)

[4] In the majority of situations, the calculation of the user benefit associated with induced traffic is relatively straightforward and relies on the "rule of the half" methodology: P. Mackie et al. (2005). *Treatment of Induced Traffic.* [World Bank Transport Notes Series]. http://hdl.handle.net/10986/11796

Environmental benefits

The CyclingMax tool calculates environmental benefits in terms of the amount of carbon dioxide that would have been used by cars if that amount of traffic did not switch from cars to cycling. The emission per car distance traveled is aggregated with the cost of emissions. The formula used to calculate the environmental benefit is similar to the method used in the CALTRAN model. However, rather than using a simple compound increasing rate to calculate the cost of emissions from year to year, CyclingMax uses a more accurate emission cost based on multiple previous studies with multiple years of data. The emission benefit in CyclingMax is calculated as:

Emission Benefit = (Induced Biking Length)(Trip Purpose Composition[1]+ Trip Purpose Composition[2])*Diversion from Cars / Vehicle Occupancy* (Emission Cost * Vehicle Emission Rate) * (Induced Benefit Factor)* (9)

where:

- *Trip Purpose Composition*[1] is the percentage of commuting in cycling traffic (ref 1) *Trip Purpose Composition*[2] is the percentage of cycling traffic other than commuting and recreational trips (ref 1). Following common environmental benefit calculation practice, recreational trips were not included by default. For example, the Australian model does not include recreational trips, while California allows users to choose whether they should be included, which is likely due to the elastic nature of recreational bike demand.
- *Diversion from Cars* is the percentage of newly induced cycling trips that were originally taken in cars (ref 15)
- *Vehicle Emission Rate* is the parameter (ref 14)
- *Induced Benefit Factor*: 0.5, which is a discount factor to adjust for the effect of unaccounted factors[Ref-viii]
- *Emission Cost* can be found in the lookup table (Table 4.1 below) from the World Bank, which provides lower and upper bounds of dollar per tonnage for present until 2050. Based on these data, the carbon cost is set to between US$40 and $80 in 2020 and increases to US$50 to $100 by 2030.

Table 4.1. Price of carbon for the estimation of environmental benefits

Year	Lower Bound ($/ton)	Upper Bound ($/ton)
2022	42	84
2023	43	86
2024	44	87
2025	45	89
2026	46	91
2027	47	94
2028	48	96
2029	49	98
2030	50	100
2031	51	102
2032	52	105
2033	53	107
2034	55	109
2035	56	112
2036	57	114
2036	58	117
2038	60	120
2039	61	122
2040	63	125
2041	64	128
2042	65	131
2043	67	134
2044	68	137
2045	70	140
2046	71	143
2047	73	146
2048	75	149
2049	76	153
2050	78	156

Note: The price adjustment using the Consumer Price Index (CPI) involves recalculating the shadow price of carbon from a past year to reflect current prices may be needed in case the inflation is extensive.

Source: World Bank. (2017). Shadow price of carbon in economic analysis. [Guidance note]. https://thedocs.worldbank.org/en/doc/911381516303509498-0020022018/original/2017ShadowPriceofCarbonGuidanceNoteFINALCLEARED.pdf

Travel time savings benefits

The CyclingMax tool considers travel time savings derived from a traveler switching from walking to cycling. The tool also considers increases in travel time resulting from mode shifts from cars or public transit to cycling. The travel time savings is calculated as the sum of all changes in travel time resulting from diversions from cars, walking, and public transit to cycling. The diversion rates and average travel speeds of these modes are advanced parameters that must be input by users. The modeling method used in CyclingMax is modified from the M4 method,[Ref-iv] which calculates the travel time savings for existing cycling trips before and after a cycling facility is built. We believe that the time savings for such trips should not be significant if the travel distance is the same. In contrast, the difference in travel time resulting from switching to cycling from other modes will be significant given the different average travel speeds of these modes. Travel time savings (TTS) is calculated as follows:

*TTS = Value of Time * [(Induced Cycling Distance * Diversion Rate from Walk / Average Walk Speed – Induced Cycling Distance * Diversion Rate from Walk / Average Cycling Speed) + (Induced Cycling Distance * Diversion Rate from Car / Average Car Speed – Induced Cycling Distance * Diversion Rate from Car / Average Cycling Speed) + (Induced Cycling Distance *Diversion Rate from Transit / Average Transit Speed – Induced Cycling Distance * Diversion Rate from Transit / Average Cycling Speed)] * (Induced Benefit Factor),* (10)

where:

- *Induced Cycling Distance* is the induced total cycling distance due to the newly built facility and can be calculated from Equation (1)
- *Diversion Rate from Cars* is the percentage of newly induced cycling trips that were originally taken in cars (ref 15)
- *Diversion Rate from Walk* is the percentage of newly induced cycling trips that were originally taken by walking (ref 15)
- *Diversion Rate from Transit* is the percentage of newly induced cycling trips that were originally taken by walking (ref 15)
- *Average Cycling Speed* is the average speed of cycling (km/h) (ref 16)
- *Average Car Speed* is the average speed of driving (mph) including time spent on looking for parking, walking from parking to final destination, etc. (ref 16)
- *Average Transit Speed* is the average speed of traveling by public transit including transfer and waiting time (km/h) (ref 16)
- *Induced Benefit Factor*: 0.5, which is a discount factor to adjust for the effect of unaccounted factors[Ref-xiii]
- *Value of Time* is calculated using Equation (11): $\text{Value of Time} = e^{-4.191} * \text{per capita GDP}^{0.696}$ (11)

5.3. Cost-benefit cashflow metrics

The tool calculates the annual cash flow based on the costs (for example, construction and maintenance costs) and monetized benefits, as illustrated in Figure 5. NPV is then calculated using the following equation:

$$\boldsymbol{NPV} = \sum_{n=1}^{20} \frac{Cash\ Flow_n}{(1 + interest\ rate)^{n-1}} \tag{12}$$

where:

- $Cash\ Flow_n = Benefit_n - Construction_n - Maintenance\ Cost_n$.
- EIRR is estimated by solving the following equation:

$$\sum_{n=1}^{20} \frac{C_t}{(1+IRR)^t} = C_0, \tag{13}$$

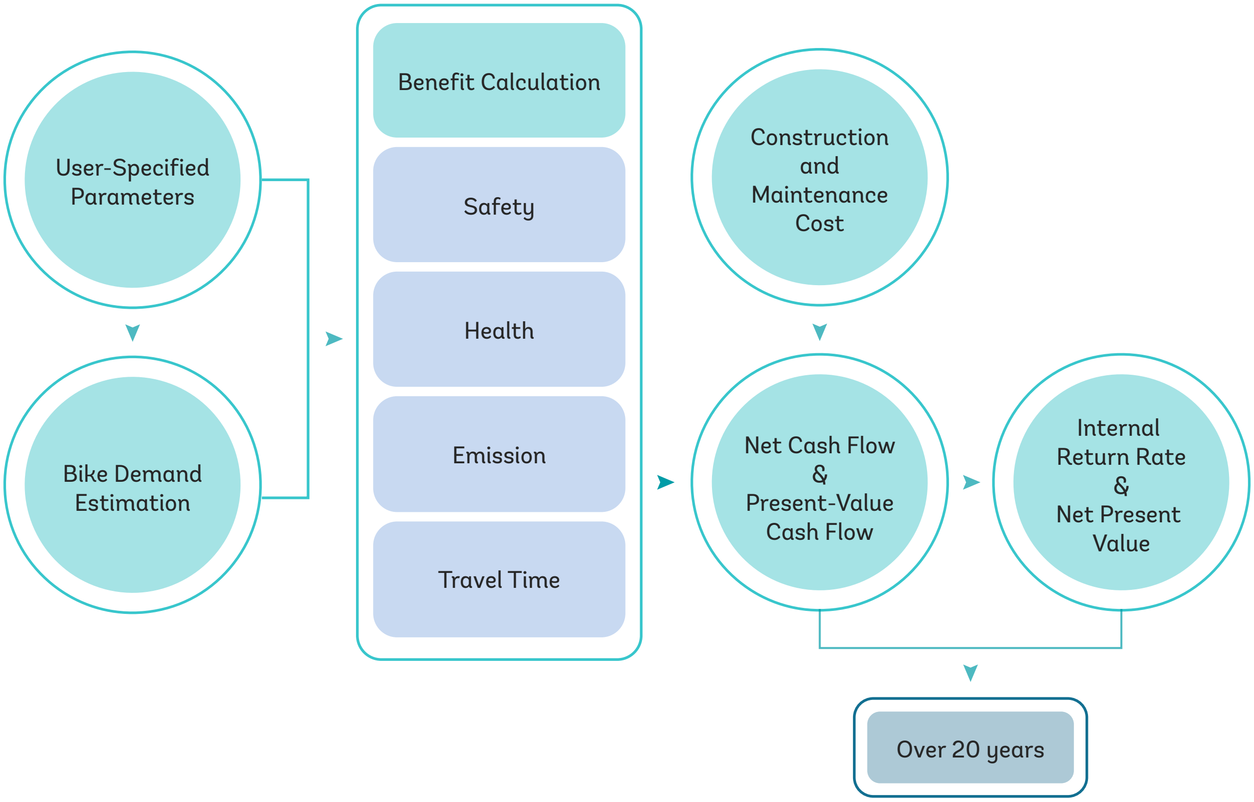
where C_t is the cash flow at year t (not including the initial construction cost), and C_0 is the initial construction cost. EIRR is the value when the NPV is equal to zero.

5.4. Modules in the tool

The CyclingMax is an online tool that includes three primary modules (as shown in Figure 5.3):

- Input Module
- Background Calculation Module
- Output Module

Figure 5.3. High-level structure of the World Bank CyclingMax tool



Source: World Bank.

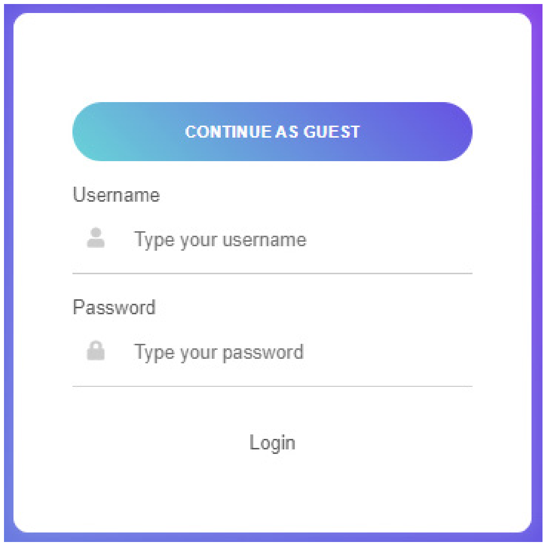
Input module

The input module (Figure 5.4) is the first interface that users encounter when accessing the tool. Users can select "Continue as a guest" or input login credentials. If users select "Continue as a guest", the webtool will allow users to select default parameters from dropdown menus, or input customized parameters, and calculate the benefits. If users input login credentials as an administrator, the webtool will allow users to add input parameters to the dropdown menus as candidate parameters for future users. Following this page is the introduction page as shown in Figure 5.5. The users will be directed to the basic input information page after that (Figure 5.6). The input module requests three main inputs from the user:

1) **Select project location and input project name**. The input module first asks the user to select a project location for the new cycling facility. The project location is used by the tool to identify default values for location-specific parameters required for the benefits calculation, including the per capita GDP, the value of time (VOT), value of statistical life (VSL), and the cost of crashes. The tool then extracts these parameters from an online database (Figure 5.6).
2) **Input basic project information**. The input module requires the user to input basic information about the cycling facility (for example, the length of the facility, construction cost, maintenance cost, population, etc.). The data entered by the user in this section is used to estimate cycling demand. For now, the construction is assumed to be accomplished within one year before the project opens to traffic (Figure 5.6).

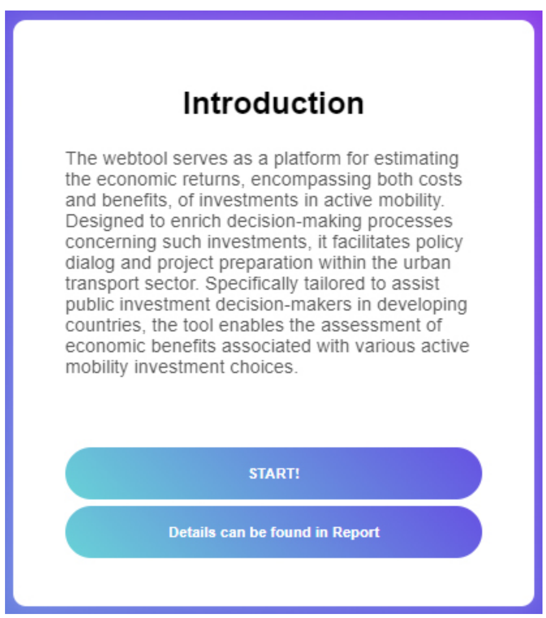
3) **Click on "Next Step" to enter the parameter input interface**. Once the user clicked on the "NEXT STEP" button, the input module directs the user to a different interface (Figure 5.7) where they can define the values of the input parameters. This option empowers advanced users with more flexibility in determining the input variables.

Figure 5.4. Landing page of the World Bank CyclingMax tool



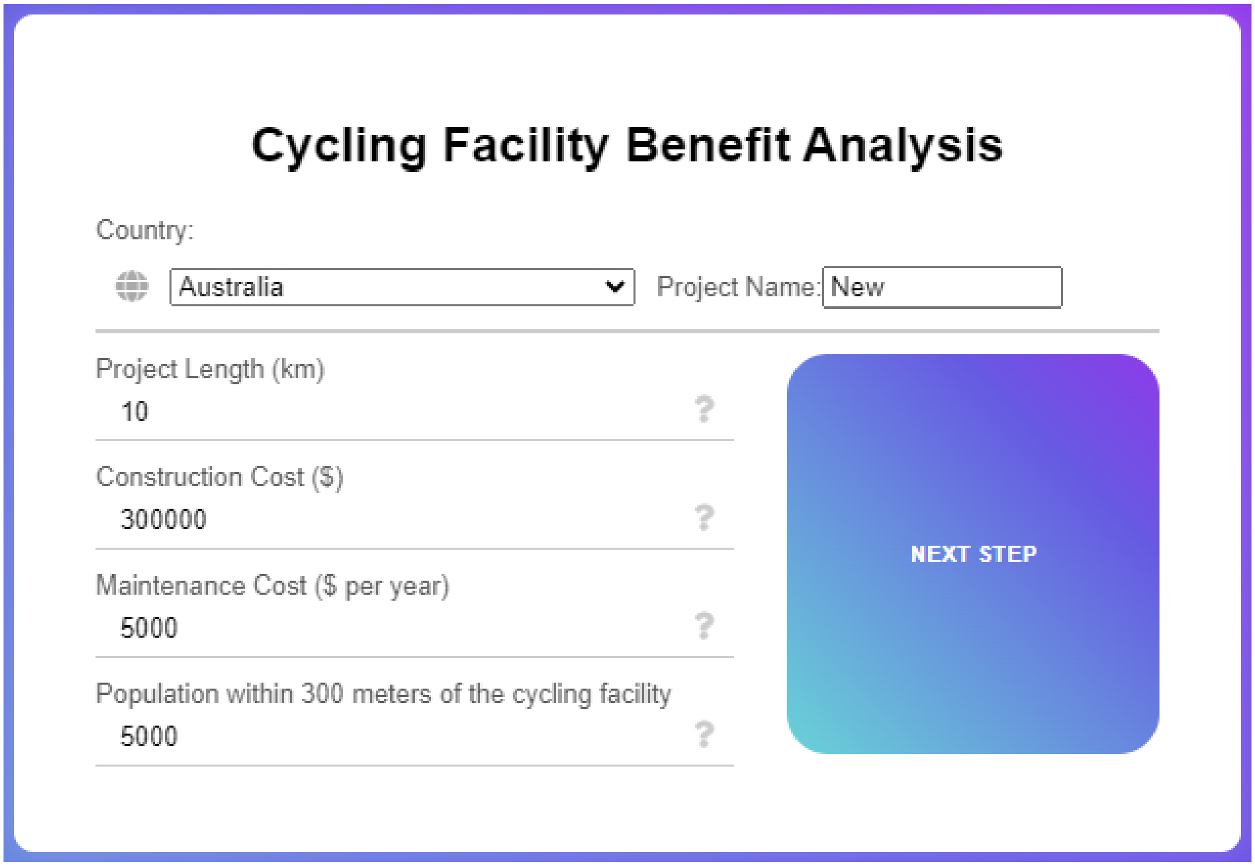
Source: World Bank.

Figure 5.5. Introduction page of the World Bank CyclingMax tool



Source: World Bank.

Figure 5.6. Image of the input module, which is the second interface encountered by the user when accessing the tool.

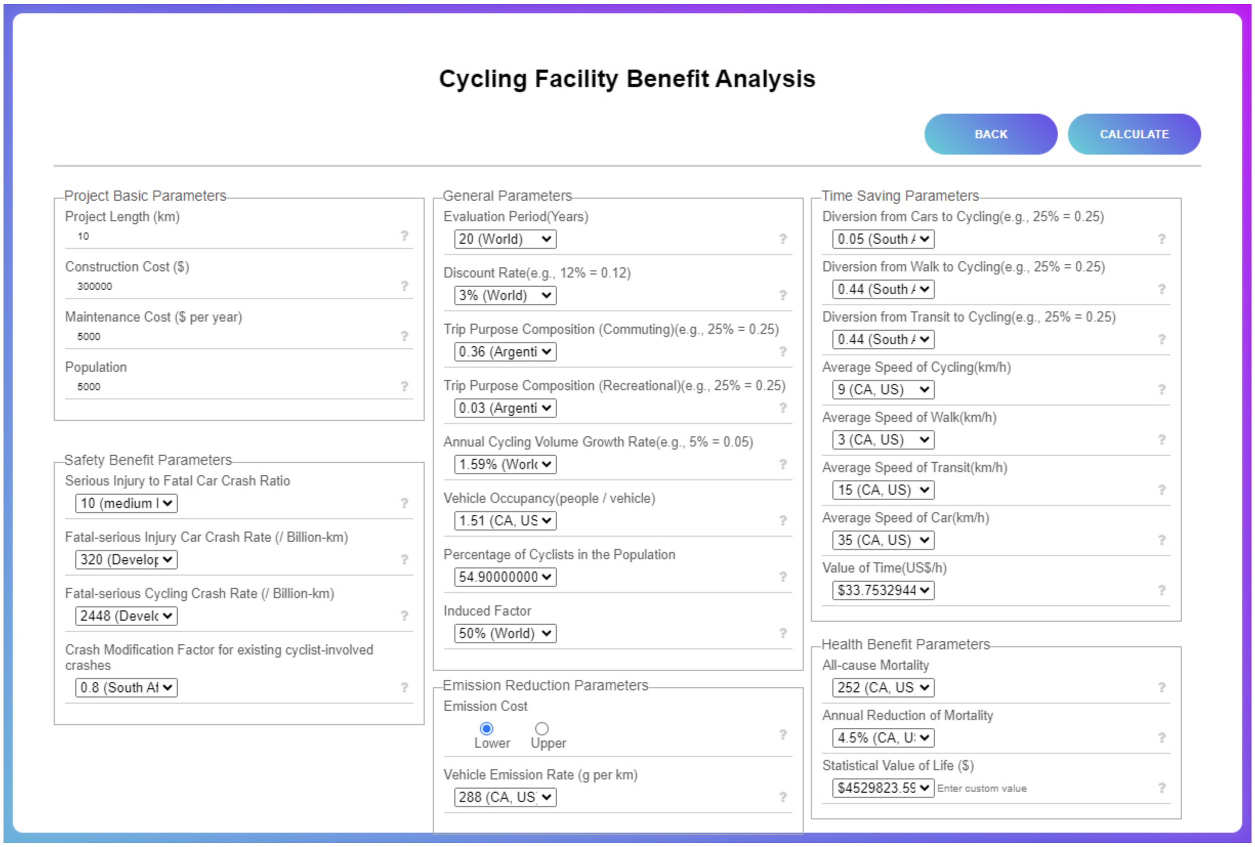


Source: World Bank.

As shown in Figure 5.7, the input parameters included on the advanced scenario interface have pulldown menus with suggested values. The sources of the suggested values are listed in the Appendix. The sources of these suggested values are either existing cost and benefit analyses reported by various research institutes around the world or case studies conducted by the World Bank from different geographic locations worldwide. If these suggested values are not suitable for a specific project, CyclingMax allows users to input values for any parameter. Thus, if users choose to, they can specify the values for all the input parameters to best suit their local situation.

Note that the number of available suggested values varies from parameter to parameter. Studies that comprehensively collect and evaluate all the parameters considered in the CyclingMax tool are very limited. The current parameter selections in the tool represent all the relevant parameters identified in our review of the literature. If future users wish to provide other suggested values, they can use the “Advanced scenario” option and/or update the dropdown menu to include other candidate parameters.

Figure 5.7. Interface for the advanced scenario where users can define the values of the input parameters

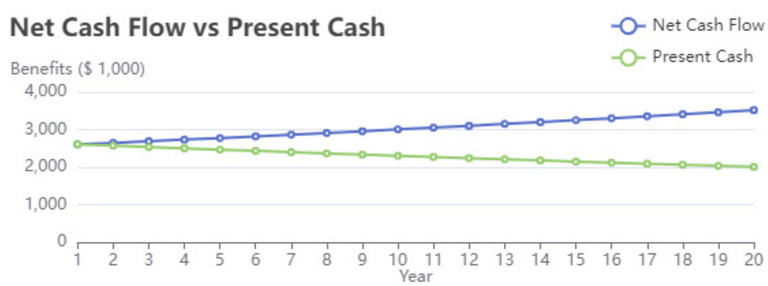


Source: World Bank.

Output Module

The CyclingMax tool calculates the annual cash flow associated with the cycling facility based on the cost, including both the construction and maintenance costs, and monetized benefits. The outputs (Figure 5.6) are provided as the net cash flow, present value cash flow, net present value (NPV), and economic internal rate of return (EIRR). Net cash flow is the difference between monetized benefits and cost by specific years. Present value cash flow is the current worth of a future cash flow discounted at a specific rate. NPV is the sum of the present values of incoming and outgoing cash flows over 20-year evaluation period. EIRR is the discount rate that makes the NPV of all cash flows from a particular project equal to zero. The EIRR and NPV provide a high-level summary of the overall benefit of the project.

Figure 5.8. Output of the CyclingMax tool



Impact Results:

NPV: $ 4558532.08

IRR:867.40%

PRINT

DOWNLOAD

BACK

Cost Streams and Indicators:

Year 0, Construction Cost: $ 300.00 (Unit: $ 1,000)

Year Since Operation	Maintenance	Safety Benefit	Health Benefit	Emission Benefits	Travel Time Saving	Net Cash Flow	Present Cash
1	5.00	796.65	620.43	0.22	1194.01	2606.31	2606.31
2	5.00	809.32	630.29	0.23	1213.00	2647.84	2570.71
3	5.00	822.19	640.31	0.24	1232.28	2690.02	2535.60
4	5.00	835.26	650.49	0.25	1251.88	2732.88	2500.97
5	5.00	848.54	660.84	0.26	1271.78	2776.41	2466.81
6	5.00	862.03	671.34	0.27	1292.00	2820.64	2433.11
7	5.00	875.74	682.02	0.28	1312.55	2865.58	2399.88
8	5.00	889.66	692.86	0.29	1333.42	2911.23	2367.09
9	5.00	903.81	703.88	0.30	1354.62	2957.60	2334.76
10	5.00	918.18	715.07	0.31	1376.16	3004.71	2302.86
11	5.00	932.78	726.44	0.32	1398.04	3052.58	2271.40
12	5.00	947.61	737.99	0.33	1420.26	3101.20	2240.37
13	5.00	962.68	749.72	0.35	1442.85	3150.59	2209.76
14	5.00	977.98	761.64	0.36	1465.79	3200.77	2179.57
15	5.00	993.53	773.75	0.38	1489.09	3251.76	2149.79
16	5.00	1009.33	786.06	0.39	1512.77	3303.55	2120.42
17	5.00	1025.38	798.55	0.41	1536.82	3356.16	2091.45
18	5.00	1041.68	811.25	0.42	1561.26	3409.61	2062.87
19	5.00	1058.25	824.15	0.43	1586.08	3463.91	2034.68
20	5.00	1075.07	837.25	0.45	1611.30	3519.08	2006.88
		30.55 %	23.79 %	0.01 %	45.79 %		

Number of Reduced Fatal and Serious Crashes per year	Number of Reduced mortality per year	Reduced Tons of CO2 per year	Hour of travel time saved per year
0.09	0.16	0.67	41264.06

Source: World Bank.

5.5. The future of CyclingMax

The CyclingMax tool is a straightforward tool that is readily available for use by users who may or may not have all the needed parameters to calculate benefits and costs of cycling facilities. It needs to be noted that there are several aspects that the tool can be improved in the future if more resources become available to improve the tool. This includes e-bikes as well as more sophisticated demand modeling method and sensitivity analysis to model the impacts of varied demands of cycling.

A

Appendix

Appendix: Parameter Values and Sources

Table A1. General Parameters

Ref#	Parameter	Description	Suggested Value	Location	Source
1	Trip Purpose Composition	The composition of the cycling traffic in [commute, others, and recreational]	[0.186, 0.353, 0.461]	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
			[0.36, 0.61, 0.03]	Argentina	Case study (Buenos Aires in 2024)
2	Cycling Volume Growth Rate	The trip growth rate due to the newly built facility	1.59%	Multiple countries	Case study (Buenos Aires in 2024)
			6%	Peru	A study reviewed
			11.5%	Argentina	Case study (Lima in 2023)
			2%	China	WB ICR (Tianjin in 2023)
3	Vehicle Occupancy	The average number of people in each car	1.51	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
4	% of population ages 16-64	The percentage of cyclists among the population involved	54.9%	CA, US	Reviewed tools (UCDAVIS and CALTRAN)

Source: World Bank.

Table A2. Accident Prevention Parameters

Ref#	Parameter	Description	Suggested Value	Location	Source
5	Average Cost of Car Crashes	The average cost per crash including fatal and serious injury crashes	US $126,400 (including all crashes, including property damage only crashes)	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
			(70 * per capita GDP + 17.5 * per capita GDP * 15) / 16 [in USD]	Low- and middle-income countries	World Bank, GRSF
6	Average Cost of Cycling Crashes	The average cost per crash including fatal, injury, and property-only crashes	$126,400	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
		The average cost per crash including fatal and serious injury crashes	(70 * per capita GDP + 17.5 * per capita GDP * 15) / 16 [in USD]		
7	Crash Rate	Default *Fatal and Serious Injury* crash rate per billion km traveled	320	Developing countries	See estimation on Methodology chapter Safety Benefits section
8	Cycling Crash Rate	Fatal and Serious injury crash rate per billion km traveled.	2,448	Developing countries	See estimation on Methodology chapter Safety Benefits section
9	CMF	Segregated cycling path or physically protected on-road cycling lane	0.41	Low- and middle-income countries	World Bank, CMF memo
		Dedicated cycling lane on roadway from no lane	0.82	Low- and middle-income countries	World Bank, CMF memo
		Crash modification factor from no build	0.92	China	WB ICR (Tianjin in 2023)

Source:

Table A3. Health Benefit Parameters

Ref#	Parameter	Description	Suggested Value	Location	Source
10	All-cause mortality for cycling population	The rate of all-cause mortality per 0.1 million people	252	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
			446	India	Reviewed tools (WHO, HEAT)
			340	Argentina	Case study (Buenos Aires in 2024)
11	Annual Reduction of Mortality	The reduced percentage of all-cause mortality due to exercise	4.5%	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
			21%	France	A Systematic Review
			5.2%	Argentina	Case study (Buenos Aires in 2024)
12	Value of Statistical Life	The statistical value of life	70 * per capita GDP [in USD]	Low- and middle-income countries	

Source:

Table A4. Emission reduction parameters

Ref#	Parameter	Description	Suggested Value	Location	Source
13	Emission Cost	The cost per ton of CO_2	Look up table (*Table 4.1. Price of carbon for the estimation of environmental benefits*)	Low- and middle-income countries	
14	Vehicle Emission Rate	The per-vehicle CO_2 emissions by driving cars	207 [in g/km at 40km/h]	CA, US (Model 2024)	Reviewed tools (UCDAVIS and CALTRAN)
			303 [in g/km]	Peru	Case study (Lima in 2023)
			251 [in g/km]	Argentina	Case study (Buenos Aires in 2024)
			294	USA	ITDP PBLPC tool
			167	Europe	
			155	China	
			100	India	
			151	Brazil	
			168	Other Americas	
			139	Africa	
			117	Other Europe	

Source:

Table A5. Time Savings Parameters

Ref#	Parameter	Description	Suggested Value	Location	Source
15	Diversion Rates	From cars to cycling	0.05	East Africa	ITDP case studies (Dar es Salaam, Addis Ababa)
			0.15	Argentina	Case study (Buenos Aires in 2024)
			0.36	Peru	Case study (Lima in 2023)
			0.5	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
			0.29	China	WB ICR (Tianjin in 2023)
			0.049	Bogota	ITDP PBLPC tool
			0.016	Guangzhou	ITDP PBLPC tool
		From walking to cycling	0.44	East Africa	ITDP case studies (Dar es Salaam, Addis Ababa)
			0.27	China	WB ICR (Tianjin in 2023)
			0.32	Bogota	ITDP PBLPC tool
			0.57	Guangzhou	ITDP PBLPC tool
		From public transit to cycling	0.44	East Africa	ITDP case studies (Dar es Salaam, Addis Ababa)
			0.6	Argentina	Case study (Buenos Aires in 2024)
			0.64	Peru	Case study (Lima in 2023)
16	Average Speed (Cycling, Walk, Car)	The average speed of different modes	(14,5.3,40) [in km/h]	CA, US	Reviewed tools (UCDAVIS and CALTRAN)
			(14,5.3, --) [in km/h]	Argentina	Case study (Buenos Aires in 2024)
			(16.5,3.6,-) [in km/h]	Peru	Case study (Lima in 2023)
			(22.3,--, --) [in km/h]	China	WB ICR (Tianjin in 2023)
17	Value of Time	General cost of time/cost for business trips	$e^{-4.191}$ * per capita $GDP^{0.696}$ [in USD/hour]	Low- and middle-income countries	World Bank, Meta-analysis of the value of time

Source:

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