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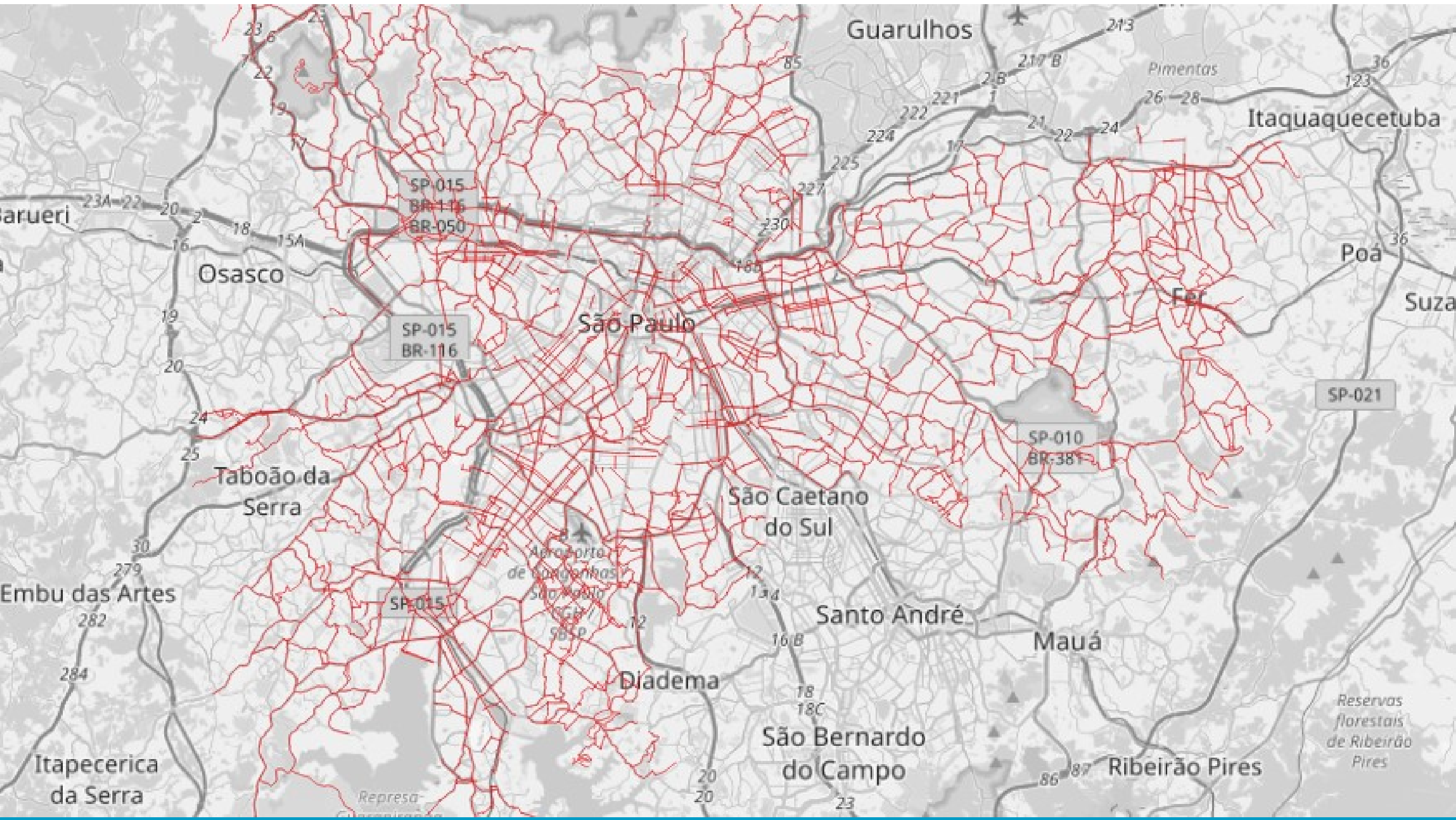

The World Bank

Social Cost Benefit Analysis São Paolo Cycle Network

Final, 18th of March 2022

Economic Consulting

DECISIO

Title

Social Cost Benefit Analysis São Paolo Cycle Network

Date

18th of March 2022

Status rapport

Final

Assigned by

The World Bank

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1. Introduction

1.1 São Paulo Municipality Cycle Plan

One of the objectives in the São Paolo mobility policy is to prioritize the most sustainable modes, such as cycling. In recent years, the municipality of São Paulo (PMSP: Prefeitura Municipal São Paolo) has intensified the implementation of several policies and initiatives to promote cycling in the city, including the construction of nearly 500 km of cycling infrastructure. Among these initiatives, a new version of the São Paulo Municipality Cycle Plan was announced in December 2019. The main objective of the plan is to recognize the bicycle as a mode of transport and includes the elements of urban infrastructure for circulation, parking and the provision of shared bicycles, and complementary communication and education actions.

The city of São Paolo is supported in this by the World Bank through technical analysis that will complement, improve and implement the cycle plan, in order to promote cycling as a mode of transport in the city, consolidating a comprehensive, safe and integrated cycling network. This analysis includes a social costs and benefit analysis (SCBA) which is an important tool to determine the effects of the bike plan and the social return of investments. It can help to gain support from relevant stakeholders. Decisio has a vast experience in applying economic analysis like SCBA to bike projects around the world.

1.2 Social cost benefit analysis

A SCBA is a systematic and cohesive method to assess all the impacts caused by an investment project or other policy measure. It comprises not just the financial effects (investment costs, direct benefits such as profits, taxes and fees, et cetera), but all the social effects related to pollution, environment, safety, travel times, spatial quality, health, indirect (i.e. labor or real estate) market impacts, legal, etc.

The main aim is to help policy-makers to make informed and rational decisions about different courses of actions by systematically and cohesively comparing the costs and the benefits of different alternatives. To ensure comparability, effects are expressed in the same unit (i.e. they are monetized). The prized effects reflect the value a society attaches to the project effects.

For this specific project, Decisio has carried out a SCBA of the cycle network. This approach synergizes with the aims of the World Bank, by providing scientifically backed estimations of the total costs and benefits of the subject of analysis. This provides the basis for well-informed policy decisions. This SCBA is a useful start, especially for the city of São Paulo, which is at a critical point when it comes to transport management infrastructure. The upward pressure of population and income growth on motorized transport usage, can be curbed to a degree with a targeted policy intervention.

The results of a SCBA offer the possibility to:

1. An integral assessment of various effects. All relevant costs and benefits of an investment project are considered and quantified as much as possible. Effects that cannot be expressed in money are listed separately. This effects remain outside the financial return figure, but are described and included qualitatively.
2. Attention for the distribution of costs and benefits. Infrastructure projects like a cycle network may cause inconvenience to some (e.g. some shops and residents), while the benefits are initially for the users.
3. Comparing project alternatives. The social cost-benefit analysis is well suited for a systematical comparison of different project alternatives and to provide information regarding the trade-offs between alternatives.
4. Mapping uncertainties and risks. Different methods are used to take economic uncertainties and risks into account. The SCBA must support a policy decision based on a "calculated risk".

2. Background

2.1 Problem analysis

Mobility is of crucial importance for São Paulo, as for any fast growing urban area. Yet, at this time accessibility is low since São Paulo is the fifth most congested city in the world[1]. According to the Inter-American Development Bank (IADB), São Paulo's citizens lose on average 32 hours to congestion, which is equal to US$ 2 billion, This is equivalent to 1.1 percent of São Paulo's GDP. To get a proportion of what these losses represent: The direct cost of congestion in São Paulo is equivalent to what the city spends on health care[2]. The level of congestion is also linked to productivity losses, GHG emissions, and local air pollution.

In order to improve urban mobility, PMSP prepared the Urban Mobility Plan in 2015, including an ambitious plan to expand exclusive or segregated bus lanes and Bus Rapid Transit (BRT) corridors as well as cycling infrastructure. The objectives of the plan include, among others, (i) promoting universal access (facilities for people with disabilities) for public transit; (ii) improving accessibility to the municipal urban transport systems; (iii) promoting non-motorized modes; (iv) reducing the number of traffic accidents and deaths; (v) reducing average travel time; (vi) expanding the use of mass transit; (vii) reducing vehicle emissions; and (viii) contributing to reducing social inequalities. In order, to promote the use of bicycles and reduce road safety risks for cyclists, the 2019 Municipal Bicycle Plan aims at expanding the cycle network from 506 kilometer to 1,800 kilometer by 2028[3]. In order to support the investment that this network requires and to see if the benefits outweigh the costs, a social cost benefit analysis was conducted.

2.2 Project alternatives

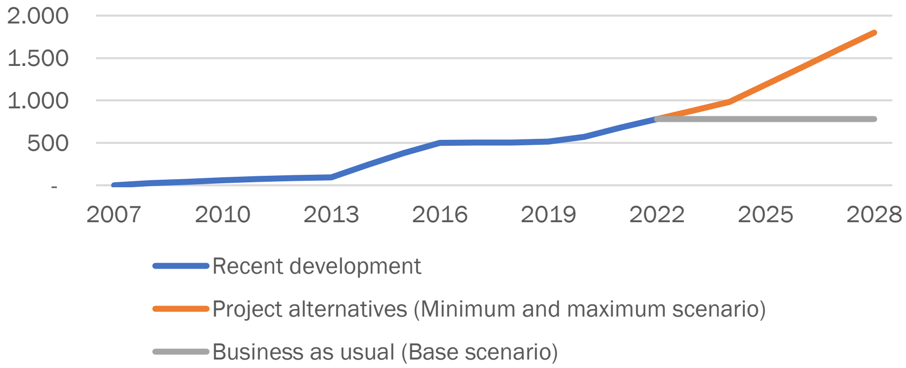
The World Bank is supporting the city of São Paulo to develop a Cycle plan, including a safe and comfortable network of cycling infrastructure that connects different geographical points with the greatest potential to generate or attract potential new bicycle trips. In order to meet this objective, a network of approximately 1,800 kilometers of cycling infrastructure is planned (see Figure 2.1 and 2.2) The future cycle network adds in total around 1,100 kilometers to the network compared to 2021.

1 NRIX 2018 Global Traffic Scorecard (http://inrix.com/scorecard)

2 IADB (2021). Urban road congestion in Latin America and the Caribbean: characteristics, costs, and mitigation

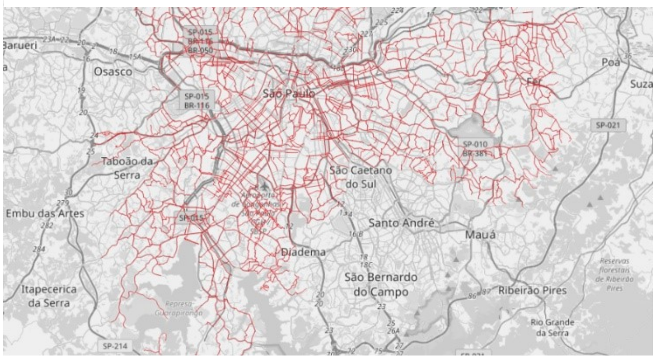
3 World Bank (2019). Project information document: São Paulo Aricanduva BRT Corridor

Figure 2.1 The cycle network expansion in terms of length between 2007 and 2028



Source: project team World Bank

Figure 2.2 The entire cycle network of the city of São Paulo in 2028



The main input for the SCBA is the expected modal shift from various modes to cycling as a result of the cycle network expansion. As the future is uncertain, two scenarios have been used that sketch the lower and upper end of the bandwidth of the potential benefits:

- Minimum scenario with an increase of modal share of cycle use from 0.9 percent to 1.6 percent in 2028;
- Maximum scenario with an increase of modal share of cycle use from 0.9 percent to 6.7 percent in 2028;

In both scenarios, the growth in bicycle usage leads to a decrease of the use of cars (in 43 percent of the trips), public transport (35 percent) and walking (16 percent).

Furthermore, the passenger demand for mobility is expected to continue to grow with 1 percent annually, there will be a slight increase in cycling speed (about one percent faster) and the cycle network becomes safer in both scenarios. See chapter 3 for more detailed information.

Estimation of the cycle use in the Minimum and Maximum scenario

In order to estimate the potential modal shift in São Paulo as a result of the cycle network expansion, two different approaches have been applied in the Minimum and Maximum-scenario:

- **Minimum scenario:** A linear growth of kilometers of cycleways and cycle use, extrapolating growth from recent years to 2028. On the basis of the period 2007-2017, it is found that every additional kilometer cycle network attracted 132 extra bicycle trips per day (included a correction for population growth). With more than thousand extra kilometers cycle network, this would translate into a modal share of 1.6 percent in 2028. This would be the lower end of the bandwidth. This scenario is considered rather conservative, because an expansion of the existing network makes a much bigger part of São Paulo reachable for cyclist. Which would more likely lead to an exponential growth rate than a linear growth with the constructed kilometers of cycling infrastructure.
- **Maximum scenario:** A comparison between the cycle network density of Bogota and the proposed cycle network density in São Paulo is made to estimate the maximum modal shift. Bogota is with a cycle use of 9 percent regarded as the cycling capital of South America. It has currently about a third more cycle network per square kilometer than what São Paulo will have in 2028. Therefore it is assumed that the proposed cycle network expansion, the maximum modal share of cycling will be 6.7 percent in 2028.

2.3 General assumptions

This study is a so-called quick scan SCBA. This means that it has been carried out on the basis of unit values and that no in depth research has been done into, for instance, effects on noise, nature, the environment or road safety. The main purpose of this SCBA is to identify what effects will result from the implementation of the cycle network.

The calculations are based on the following assumptions:

- The traffic effects were based on estimates made by the World Bank project team and the Decisio project team using available statistics.
- The cost indicators are based on estimates from the World Bank project team.
- Start year of construction is 2022. The duration of the investments (construction period) is seven years (2022-2028).
- The new infrastructure will be built over the course of seven years. Therefore effects start occurring increasingly over the construction period from 2022 to 2028. The effects of the full network are included from 2028 onwards.

- The full cycle network does not come at the expense of road infrastructure or parking space. In other words, the SCBA does not take into account conversion of car lanes and parking spots into cycling infrastructure.
- The unit values used in this SCBA are based on the Handbook on the external costs of transportation of the European Commission[4], valuation of the social effects of cycling[5] en *Werken in Beweging*[6]. Numbers are converted to Brazilian price levels, using corrections for differences in prices, income and specific characteristics of externalities based on World Bank Open Data.
- The World Bank project team provided various statistics on the cycle network, accidents, modal split, average travel distances, generalized transport costs, gas emissions and forecasts on population and economic growth. It shared origin-destination matrices (OD) of the city of São Paulo as well.

Net Present Value

An issue in comparing the costs and benefits, is the difference in time in which the effects occur. The investment costs are incurred at the start of the project, while the benefits occur afterwards. However, these benefits will occur for many years in the future. To be able to compare the effects, the Net Present Value (NPV) of the future costs and benefits must be calculated using a discount rate. As a result, today's value (present value) is calculated which makes the effects over time comparable.

In order to determine the net present value, the following principles are assumed:

- The NPV is calculated for the year when construction starts: 2022.
- Effects are calculated for a period of 100 years from the start of construction. This corresponds to a theoretical "infinite" period, meaning that the cycle network is a permanent intervention.
- The discount rate used for the calculation is 4 percent as suggested by Lopez (2008)[7].
- Monetary values are stated in 2021 price levels.
- All costs and benefits are expressed in market prices (including VAT), unless stated otherwise.

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[4] European Commission (2019) Handbook on the external costs of transport

[5] Decisio (2017) Valuation of the societal effect of cycling. SCBA Bicycle: state-of-the-art valuation key figures

[6] Decisio (2021) Estimation of monetary value health effects of exercise by employees

[7] The World Bank - Lopez (2008) The Social Discount Rate: Estimates for nine Latin American Countries. World Bank Policy Research Working Paper 4639

3. Traffic analysis

The main goal of the expansion of the cycle network is to prioritize the most sustainable modes in São Paulo. To determine the effects on accessibility (and also the related social effects), insight is needed into the current and future traffic flows. In other words: What is the modal split today? How many trips could be affected by the expansion of the cycle network? To which extent will there be a modal shift to bicycle usage? Which modality were the new cyclists previously using? What is the effect of the cycle network on travel time and distance? In this chapter, these questions will be discussed.

The traffic inputs are the base for calculating the social effects of accessibility (Chapter 4).

3.1 Existing trips

The cycle network expansion incorporates the city of São Paulo. Therefore the total number of trips with a origin and destination within this region are considered: per day nearly 23 million trips in 2017. The number of trips per day for different modes of transport in 2017 were estimated as shown in Table 3.1.

Table 3.1 Trips per day for different modes in the city of São Paulo (2017)

Travel mode	Daily trips (mln)	Modal share
Rail	0.8	3.6%
Metro	0.7	3.1%
Bus	6.0	26.2%
Car	6.2	27.1%
Motorcycle	0.5	2.2%
Taxi	0.4	1.5%
Walking	8.1	35.4%
Cycling	0.2	0.9%

Source: OD 2017, adjusted by Project team World Bank and Decisio

The modal shift to bicycle leads to a decrease of the number of trips by other modalities. But not all trips are likely to be substituted by the bicycle. A cyclable trip is assumed to have a length of at least 1.25 kilometers, but not more than 7.5 kilometers. On a daily basis, there are about 7.5 million cyclable trips in 2017. Of course, some people will prefer to cycle distances less than 1.25 kilometers or more than 7.5 kilometers , but for this study walking is assumed to be the preferred modality below 1.25 kilometers, while other modalities than the bicycle are used for distances longer than 7.5 kilometers. The number of trips per day for different modes of transport in 2017 (see table 3.2), will be used to determine the shift from various modalities to the bicycle between 2022 and 2028.

Table 3.2 Daily trips with a length between 1,25 and 7,5 kilometers for different modes in the city of São Paulo (2017)

Travel mode	Daily trips (mln)	Modal share
Rail	0.0	0.3%
Metro	0.3	3.7%
Bus	2.3	30.9%
Car	3.2	42.5%
Motorcycle	0.2	2.4%
Taxi	0.2	2.7%
Walking	1.2	15.8%
Cycling	0.1	1.80%

Source: OD 2017, adjusted by Project team World Bank and Decisio

Traffic growth was around 1 percent per year between 2007 and 2017[8] and is expected to continue with 1 percent annually as well since population size and GDP per capita are expected to grow too[9].

3.2 Modal shift

In collaboration with the project team of the World Bank, a modal shift towards cycling due to the expansion of a safer and more comfortable cycle network is estimated. In 2017 0.9 percent of all trips was made by bike. In the Minimum scenario, this modal share is estimated to increase to 1.6 percent in 2028; In the Maximum scenario, it is estimated to increase to 6.7 percent in 2028. In both scenarios, the growth in bicycle usage comes mainly at the expense of the car, public transport and walking.

[8] Pesquisa Origem Destiono 2017 50 anos: A mobilidade urbana da regiao metropolitana de Sao Paul em detalhes.

[9] Historical data and forecasts on population and economic growth, provided by the World Bank project team

Table 3.3 Modal shift per day for different modes in the municipality of São Paulo (2028)

Travel mode	Modal share	Minimum scenario Daily trips shifted (mln)	Minimum scenario New modal share	Maximum scenario Daily trips shifted (mln)	Maximum scenario New modal share
Rail	3.6%	-0.00	3.6%	-0.00	3.6%
Metro	3.1%	-0.01	3.0%	-0.06	2.8%
Bus	26.2%	-0.06	26.0%	-0.47	24.4%
Car	27.1%	-0.08	26.8%	-0.65	24.6%
Motorcycle	2.2%	-0.00	2.1%	-0.04	2.0%
Taxi	1.5%	-0.00	1.5%	-0.04	1.4%
Walking	35.4%	-0.03	35.3%	-0.24	34.5%
Cycling	**0.9%**	**0.18**	**1.6%**	**1.50**	**6.7%**

Source: OD 2017, adjusted by Project team World Bank and Decisio

In the concluding section, a sensitivity analysis is given on the basis of a larger modal shift from bus and walking than from car.

3.3 Effect on travel time

Cyclists are expected to cycle faster when additional cycling infrastructure is installed. On the basis of the OD (2007), cyclists were estimated to cycle with an average speed of 15.4 kilometers per hour in 2007. In the OD (2017), cyclists were estimated to cycle with an average speed of 15.5 kilometers per hour. A slight increase in cycling speed in ten years time: 0.4 percent. After the installation of additional cycling infrastructure, it is likely that the average cycling speed will increase. In order to estimate this, the change in cycling speed in the period 2007-2017 is extrapolated on the basis of the total additional length of the cycle network: around 1,300 kilometers. From this, a cycling speed of 15.7 kilometers per hour is derived. On an average cycle trip length of 4.2 kilometer, this means a marginal saving of around 10 seconds per cycling trip.

On the one hand, with reduced road space available, prioritization of cyclists at junctions, the installation of speed bumps and potential replacement of parking space, motorized traffic (car, taxi and bus) is expected to experience a small decrease in average speed per trip. On the other hand, when the modal shift results in less motorized traffic on the street, this effect will be mitigated due to less congestion and improved traffic circulation. It is therefore assumed that the average speed of car traffic remains stable at an average of 29.4 kilometers per hour.

Pedestrians and passengers of public transport will not experience changes in travel time.

3.4 Effect on travel distance

Cyclists may be able to use a more direct route with the new bike infrastructure in place on roads where it was impossible to cycle before. This means that the distance of their trip could be shorter and that they can save time and costs of travel. On the other hand, a traffic engineering principle called the *BREVER/Marchetti's-law* implies that a person always spends an almost constant amount of time travelling per day. This means people do travel longer distances when the speeds of transport is increasing because of improved infrastructure. In this study, it is unknow to which extent this effect will occur and therefore the effect on travel distance is assumed to be zero.

Other modalities such as cars, taxi's and public transport may start to take detours, because the cycle network expansion could make their current route less attractive. If so, they will travel longer, create more pollution and congestion. But this could be counteracted by improved traffic circulation. Because it is also likely that there will be new cycling infrastructure on the potential detour route, since the cycle network will be constructed throughout the whole city. Therefore, the effect is assumed to be zero.

4. Social costs and benefits

In this chapter we describe the effects that occur when the cycle network is completed. The effects are compared to the reference situation in which no cycle network will be built, but investments in public transport still occur as planned.

4.1 Financial effects

Construction costs

The construction and maintenance costs per kilometer cycling infrastructure were estimated by the project team of the World Bank.

Estimation of the total construction and maintenance costs

Information from the municipality of São Paulo on construction and maintenance costs was not available. Instead, the estimation is based on official municipal information on the financial costs of the bicycle plan 2019-2020:

- Average construction cost per km: R$ 556,819
- Average maintenance cost per km: R$ 490,822

Note, the maintenance cost per kilometer is relatively high in comparison to the construction cost. It is important to note that there is no continuous policy of cycling infrastructure maintenance in São Paulo. In practice, the maintenance projects have rebuilt the cycling infrastructure. As this is the case, an average is calculated for the construction costs per kilometer and the maintenance costs are derived from a standard mark-up:

- Initial construction cost per km: R$ 514,462
- Maintenance cost per km per year: R$ 7,717

The result is presented in table 4.1.

*Table 4.1 Construction costs (NPV, *1 million BRL)*

	Minimum	Maximum
Construction costs	-R$ 502	-R$ 502

Maintenance costs

Maintenance costs are assumed to be 1,5 percent of the investment annually. The result is presented in table 4.2.

*Table 4.2 Maintenance costs (NPV, *1 million BRL)*

	Minimum	Maximum
Maintenance costs	-R$ 191	-R$ 191

4.2 Accessibility effects

Travel time

Chapter 3 explains to what extent cyclists using the expanded cycle network have a shorter travel time, while the average speed of cars, taxis and buses is expected to remain stable. To convert these values to a monetary value the daily trips were incremented to yearly trips and multiplied by an average value of time of R$ 10.72 per hour[10]. Table 4.3 shows the results in NPV.

*Table 4.3 Effect on travel time (NPV, *1 million BRL)*

Travel mode	NPV in mln	
Bicycle	R$ 159	R$ 471
Car	-	-
Taxi	-	-
Public transport	-	-
Walking	-	-
Total	R$ 159	R$ 471

Congestion

As stated before, congestion is mainly caused by motorized traffic as cyclists require less space. So when trips currently made by car, taxi or bus are exchanged for trips by bike, there is less congestion on the roads for other traffic. In a highly congested city like São Paulo this is of major importance. To value this effect we applied marginal external unit values per kilometer[11]. The results in Net Present Value are presented in table 4.4.

*Table 4.4 Congestion effect (NPV, *1 million BRL)*

	Minimum	Maximum
Congestion	R$ 2.821	R$ 23.280

Travel time reliability

Congestion and travel time have an impact on the reliability of the traffic network. The lower the capacity of the network, the greater the chance of delays during a trip and uncertainty in travel time. Congestion mostly applies to motorized traffic as cyclists experience no congestion or to a minimum extent. The reliability of travel time for cyclists will mainly improve when waiting time at junctions are reduced and

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[10] Calculations Decisio based on Decisio (2017) Waarderingskengetallen MKBA Fiets: state-of-the-art, adjusted to Brazil

[11] European Commission (2019) Handbook on the external costs of transport

cyclists are segregated from other traffic. A rule of thumb of 25 percent of travel time gains is applied[12]. The results in Net Present Value are presented in table 4.5.

*Table 4.5 Effect on travel time reliability (NPV, *1 million BRL)*

Travel mode	NPV in mln	
Bicycle	R$ 39	R$ 116
Car	-	-
Taxi	-	-
Public transport	-	-
Walking	-	-
Total	R$ 39	R$ 116

4.3 Health effects

There are various scientific studies that show that people who cycle regularly are physically and mentally healthier than non-cyclists. It appears, for example, that cyclists live longer and suffer less from illness such as obesity, depression and heart disease. In addition, it appears that cyclists are twice as happy as car drivers, public transport travelers and pedestrians. These positive effects on physical and mental health result in higher labor productivity, lower health care costs, reduced burden of disease, higher life expectancy and generally higher quality of life.

It should be noted however, that the effects depend on the kind of people who start to cycle. People who are less active in their daily lives experience greater health effects with an increase in physical activity than people who are already reasonably active in daily life. In this analysis we only assess the effects conservatively, because we only take into account health effects for those who do not meet the physical activity guideline.

The unit values in this study come from a literature study of Decisio[13] and are adjusted to Brazilian price levels.

Labor productivity
Regular cycling and walking increases both physical and mental fitness. Research shows that the degree of fitness of employees influences their level of productivity

[12] Decisio (2012). Maatschappelijke kosten en baten van de fiets, quickscan
[13] Decisio (2021) Estimation of monetary value health effects of exercise by employees

when working[14] [15]. Active employees are therefore more productive in the hours they work than their less active colleagues. It is an important effect: According to the studies, productivity can increase with 4 to 18 percent when employees are regularly physically active. As the band with is wide, we cautiously assume a maximum productivity growth of 3 percent for people who do not meet the physical activity guideline. This means a productivity gain of R$ 0.05 per kilometer cycled in São Paolo.

Also, people who travel by bicycle are less often ill and relatively fitter, wherefore they are more productive. Research shows that people who cycle to work are on average 1.3 days less ill per year than non-cyclists[16]. A lower number of sick days has various positive effects: lower costs for the employer, a reduction in healthcare costs for society and for the individual time gains and improved quality of life by not being ill. We cautiously assume that people who do not meet the physical activity guideline become 1.3 days more productive when they start to cycle to work. This means a productivity gain of R$ 0.01 per kilometer cycled in São Paolo.

Both unit values account for the employed share of the population.

Healthcare costs

More exercise leads to less disease and thus less healthcare costs[17]. If everyone would exercise enough, billions euros per year in healthcare costs related to dementia, coronary heart diseases and strokes could be saved in the Netherlands. Dividing the saved amount of health care costs by the number of kilometers that must be cycled in order to meet the exercise guideline, results in an average health care cost saving per kilometer cycled. It is assumed that extra kilometers cycled by people who meet the physical activity standard do not contribute to a reduction in healthcare costs. This means a saving in healthcare costs of R$ 0.02 per kilometer cycled in São Paolo.

Burden of disease

Analogous to the estimate of the effect on healthcare costs, we can estimate the burden of disease. In other words, the quality of life increases. As discussed in the previous section, a certain degree of physical activity has a positive effect on certain

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[14] TNO. (2003). TNO Arbeid rapport. Retrieved from: https://www.10000stappen.nl/uploaded/TNO%20Arbeid%20rapport.pdf

[15] Ecorys (2017). The socio-economic value of sports and exercise.

[16] TNO (2010). Cyclists cycled a minimum of 18 kilometres to and from work during the week, non-cyclists a maximum of 6. Other cycling activities have not been included.

[17] Ecorys (2017). The socio-economic value of sports and exercise.

disease states. If everyone would exercise enough, billions euros per year in terms of YLD (Years lived with disability, a measure of the burden of disease) could be saved as well[18]. Dividing the saved amount of YLD by the number of kilometers that must be cycled in order to meet the exercise guideline results in an average health care cost saving per kilometer cycled. It is assumed that extra kilometers cycled by people who meet the physical activity standard do not contribute to a reduction in burden of disease. This means a reduction in burden of disease of R$ 0.09 per kilometer cycled in São Paolo.

Life expectancy

More exercise leads to longer healthy lives. At least three factors influence life expectancy for cyclists: physical activity, inhaling polluted air and traffic accidents. In this section the effects of traffic accidents are not considered because traffic safety is a separate effect. Despite a life expectancy reduction of days due to the inhalation of polluted air, the increase in physical activity leads easily to an increase in life expectancy of multiple months on average[19] [20]. The net increase in life expectancy by replacing car journeys by bike journeys is equal to a certain amount of DALY (Disability-adjusted life years). The calculation is rather conservative and assumes that people need to cycle for an average of 40 years to achieve this effect and this benefit only applies to people who do not yet meet the physical activity standard. This means a health benefit of R$ 0.02 per kilometer cycled in São Paolo.

Pedestrians

When someone starts cycling (more), this is often at the expense of other forms of physical activity. For example when pedestrians start cycling. In this study, about 18 percent of the new cyclist were previously cycling. Cycling the same distance instead of walking results in a saving of travel time, but also in less time of physical activity. According to the literature study cycling generates half the health benefits of the same distance.

[18] Ecorys (2017). The socio-economic value of sports and exercise.
[19] Den Hartog et al. (2010). Do The Health Benefits Of Cycling Outweigh The Risks?
[20] Den Hartog et al. (2013). Health advantages of cycling many times greater than the health risks.

The results in Net Present Value are presented in table 4.6.

*Table 4.6 Health effects (NPV, *1 million BRL)*

Mode	Minimum	Maximum
Productivity	R$ 213	R$ 1,760
Sick days	R$ 52	R$ 429
Health costs	R$ 96	R$ 795
Burden of disease	R$ 365	R$ 3,015
Life expectancy	R$ 86	R$ 713
Total	R$ 813	R$ 6,712

4.4 Traffic safety

In this section two types of effects for traffic safety are distinguished: objective safety and subjective safety. In other words: how many accidents and casualties occur (objectively) and how do people feel about traffic safety (subjective).

Objective safety

When looking at objective traffic safety, the current situation needs to be taken into account. In the period 2016-2020 there were approximately 2.5 thousand accidents involving cyclists in São Paulo[21]. These have led to deaths (180) and injuries (2.5 thousand) of which just a proportion happened on cycling infrastructure:

- 7 percent of cycling accidents occurred on cycling infrastructure;
- 7 percent of cycling accident with injuries as result, happened on cycling infrastructure;
- 3 percent of cycling accidents with fatalities as result took place on cycling infrastructure.

On the basis of total distance cycled or driven in a motorized vehicle, the number and type of accidents and the external accident costs per casualty for 2017, we determined the external accident costs per passenger kilometer in 2017. This is valued using external costs for different types of accidents (fatal, serious injury and slight injury) consisting of human costs (costs of pain and suffering), production loss, medical costs, administrative costs and damage to private and public goods[22].

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21 Prefeitura Municipal São Paolo (2021). Retrieved from: http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx

22 IPEA Traffic accidents report 2003

Table 4.7 The external accident costs per passenger kilometer in 2017

	Bicycle	Motorized
External accident costs	R$ 0.45	R$ 0.10

Source: IPEA (2003) and World Bank project team, adjusted by Decisio

The following effects need to be taken into account for the future situation. First, it will be safer to cycle when the cycle network expansion has been installed. Second, there is a lower risk of severe accidents when there is less motorized traffic on the roads due to a modal shift towards the bicycle, because most severe accidents are caused by motorized traffic. Third, research shows that motorists are less likely to hit cyclists and pedestrians when there are more people cycling or walking. It appears that motorists adjust their behavior in the presence of people cycling. Therefore a greater proportion of cyclists in the city leads to a lower chance of an accident for cyclists and pedestrians. This is called *safety in numbers* [23]. Fourth, and contrary to the others, new cyclists are more vulnerable in traffic and are more likely to have severe injuries when an accident occurs than was the case with their previously used modality (bus, car, etc.).

Predicting the future road safety situation is hardly possible. Nevertheless, to estimate the effects of the new cycle network on objective traffic safety, we assume a 50 percent risk reduction for cyclists. Safety risks per kilometer driven by motorized traffic (car, taxi and bus) are assumed to remain the same. Thus the external accident costs per passenger kilometer will be R$ 0.23 for cyclists, whereas the motorized passenger kilometers remains R$ 0.10. Nevertheless, it will be generally more dangerous to cycle than to travel in a car or bus. Existing cyclists profit from the safer cycle environment. The same applies for new cyclists, but compared to their previously (motorized) means of transport, it becomes more unsafe.

Table 4.8 The external accident costs per passenger kilometer in 2028

	Bicycle	Motorized
External accident costs	R$ 0.23	R$ 0.10

Source: IPEA (2003) and World Bank project team, adjusted by Decisio

In the Minimum scenario, there will be a net benefit for traffic safety. The traffic safety is assumed to improve by half for the existing cyclists in São Paolo. As a

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23 https://ecf.com/resources/cycling-facts-and-figures/safety-numbers

result, there will be less accidents among them. Even though the newly attracted cyclists in the Minimum scenario also profit from the improved road safety, their previously means of transport is safer. This results in more accidents amongst them. But importantly, the reduction in accidents among existing cyclist is higher than the increase in accidents among the new cyclist. In terms of the SCBA, the benefits of the existing cyclists exceed the costs of the newly attracted cyclists, wherefore there is net benefit in the Minimum scenario.

In the Maximum scenario, however, there will be a net cost for traffic safety. This is because the modal shift in the Maximum scenario will be four times as big. In other words, it attracts four times more new cyclists and therefore more accidents. As a result, the costs of the new cyclists will exceed the benefits for the existing cyclists. This creates a cost in the Maximum scenario. The result in NPV is shown in table 4.9.

*Table 4.9 Objective traffic safety (NPV, *1 million BRL)*

	Minimum	Maximum
Traffic safety	R$ 883	-R$ 5,673

In the concluding section, a sensitivity analysis is given on the situation wherein there is no improvement in road safety at all.

Subjective value of safety

Subjective safety is about how people experience safety. A feeling of unsafety can cause people to cycle less pleasantly, avoid certain routes or stop cycling at all and take the car, taxi or bus instead. No indicators exist to quantify the effect on subjective safety. We therefore include this effect qualitatively with a ‘+’ to represent a positive effect in the SCBA.

4.5 External effects

External effects are the effects imposed on others by the behavior of the traveler. When cars are driving, they pollute the air, emit CO2 and cause noise disturbance.

Noise

A modal shift can lead to changes in the noise nuisance for the surroundings. A decrease in motorized traffic leads to less noise pollution. In highly populated area like São Paulo effects are greater than in more rural areas. To value this effect we used marginal external cost values per kilometer[24]. The results in Net Present Value are presented in table 4.10.

*Table 4.10 noise effect (NPV, *1 million BRL)*

	Minimum	Maximum
Noise	R$ 52	R$ 427

Air pollution and climate change

Traffic and transport are often accompanied by emissions of harmful substances, such as CO2 emissions and particulate matter, nitrogen and sulfur oxide. CO2 emissions contribute to climate change and global warming, while particulate matter and other emissions contribute to the quality of air and health. When less kilometers are driven by motorized traffic due to the modal shift (and therefore less fuel is used), the emissions are reduced. To value this effect we used marginal external cost values per kilometer[25]. The results in Net Present Value are presented in table 4.11.

*Table 4.11 Air pollution and climate change (NPV, *1 million BRL)*

	Minimum	Maximum
Air pollution	R$ 99	R$ 821
Climate change	R$ 106	R$ 872
Total	R$ 205	R$ 1.692

4.6 Indirect effects

Indirect effects due to the modal shift are the expenditures (investments and subsidies) on public transport and fuel taxes for motorized traffic.

Expenditures

The public transport system is affected when passengers start using bicycles instead of the bus, metro or train. The magnitude of this effect depends on the question if the same schedule of operation will be maintained and whether investments in infrastructure can be avoided (or delayed):

- The low modal shift from the metro and train and the expectation for further growth in metro (see box). mean that these systems will keep operating in the same manner. Operation costs and subsidies from the government will stay the

24 European Commission (2019) Handbook on the external costs of transport
25 European Commission (2019) Handbook on the external costs of transport

same, but income from tickets sales will be reduced. On the other hand, passengers will benefit from a higher chance on a seat and a more comfortable trip because the trains will be less crowded.

- Based on the relatively high modal shift coming from buses, we expect it will reduce bus services. This means that they have less income from passengers, but they also have lower costs of operating the system. Passengers that are still using the bus experience a negative effect, because they have less options to travel. On the other hand, the government contributes less to the bus systems through public transport subsidies since the level of services will be reduced. In addition, because the cycle network has potentially more effect on the number of travelers by bus (usually people travel 7 kilometers per bus trip), we expect an effect.

Passenger demand in public transport

The passenger demand on public transport has been stable over the last decade. Yet, the overall public transport ridership over the past decade masks two opposite trends: from 2007 to 2017, the number of passengers in metro and suburban rail systems have increased by more than half, whereas bus ridership has decreased by nearly 9 percent. Furthermore, the passenger demand for mobility is expected to continue to grow with 1 percent annually[26]. Therefore it is assumed that metro and suburban rail systems continue to grow as well. This growth is not expected for bus services. Partly because metro and suburban rail systems are substitutes to bus services.

The comfort of passengers and the extent to which investments in public transport can be delayed or saved in a fast growing city like São Paulo are not known and therefore not included in this SCBA. However, the effects related to the decreasing number of bus passengers are taken into account. This effect may be one of the following two:

1. On bus services with a low occupancy rate where the decrease in bus passengers is high. We assume the bus services will be adjusted to the decreasing demand (i.e. lower frequencies). This leads to a reduction of the subsidies to these bus services.
2. On bus services with a high occupancy rate (more likely in São Paulo). The effect of the decreasing number of passengers will be a benefit to the remaining passengers. As it means buses are less crowded, they have a higher chance to have a seat inside the bus and the chance decreases that passengers have to wait for the next bus when a bus is full. As the value is of this effect is unknown, the subsidy per passenger paid by the authorities is taken as proxy.

[26] World Bank (2019). Project information document: São Paulo Aricanduva BRT Corridor

The Municipal Government of São Paulo (PMSP) have significantly increased the subsidies to the public transport. Despite continuous tariff increases over the last decades, the municipality had to increase its subsidies from R$ 588 million in 2006 (adjusted by inflation) to R$ 3.02 billion in 2017. This is equal to an average of R$ 0.12 per kilometer travelled by public transport; R$ 0.87 per bus trip.

*Table 4.12 Expenditures (NPV, *1 million BRL)*

	Minimum	Maximum
Subsidies	R$ 412	R$ 3,403

Taxes
Because more trips will be made by bike, fewer kilometers are driven by car, taxi or bus on an annual basis. Where less motorized traffic has a positive effect on noise, air quality, road safety and fuel costs, it has a negative effect on the revenues of the São Paulo State Government. After all, the majority of fuel costs consist of excise duties.

The Net Present Value of losses in excise fuel taxes are stated in table 4.13.

*Table 4.13 Excise fuel taxes (NPV, *1 million BRL)*

	Minimum	Maximum
Taxes	-R$ 1,119	-R$ 9,235

4.7 Qualitative effects

Comfort
Besides savings of travel time, existing cyclists experience more comfort while travelling on dedicated cycling infrastructure. Comfort is for new cyclists a variable considered when choosing the mode. There are various elements that influence the degree to which a cycling route is more comfortable. This includes width of cycling infrastructure, lighting, signposting, (feeling of) safety, priority, quality of paving, protection against wind and rain etc. These effects are likely to improve with the implementation of the cycle network. However, there are no indicators to value the effect on comfort. Therefore we include it qualitatively in the SCBA using a '+' in the resulting table.

It should be noted that there is a relation between the value of travel time and the value of travel comfort i.e. a more comfortable journey can influence the valuation of travel time. In fact the value of travel time on a comfortable route is lower than the travel time rating on a less comfortable route.

Quality of public space

A better connection for cyclists and pedestrians can lead to a higher quality of public space. For example infrastructure and traffic have an impact on social cohesion. With physical or psychological barriers, places can become disconnected. This affects the quality of life. An increase in bicycle traffic can reduce the barrier effect of busy roads and increase accessibility. This can have an effect on the social interactions, property values and gentrification.

According to Jacobs (1961)[27], measures that lead to "more eyes on the street" reduce the risk of crime. More social interaction is discouraging for criminals. Cycling infrastructure projects that lead to more bicycle traffic may lead to a more (objective and/or subjective) feeling of safety. However, it is possible that reducing crime in one area may lead to higher crime rates elsewhere. Then the problem will be relocated and the effects cancel out.

There is little research on indicators to value the higher quality of public space. This effect will therefore be included only qualitatively.

Equality

Offering affordable resources to a large group of people contributes to more equality in society. This applies to mobility when enabling people to cycle safely has advantages for the society, such as:

- Providing transport modes to access basic needs such as healthcare, schools, work, supermarkets, etc.
- Creating economic opportunities for people with a lower income

Making affordable mobility available on a large scale leads to a higher participation in social activities, less social exclusion and creation of social capital.[28] No quantitative research has yet been done into the relationship between cycling and the effect on economic equality. Therefore this effect cannot be quantified and is qualitatively included in the SCBA.

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[27] Jacobs (1961). Life & Death of Great American Cities.

[28] Martens (2013). The role of cycling in limiting transport poverty in the NL.

5. Bike SP plan

In order to stimulate the use of bicycles in São Paulo, the municipality of São Paulo can incorporate financial incentives. The following measures could be considered: contributions towards the purchase of a bicycle, sponsorship and advertising on the bicycles and reimbursement of kilometers travelled by bicycle. This paragraph provided input for the discussion with regard to the reimbursement on the basis of unit values related to cycling. The starting point is a shift from car to bicycle.

There are several advantages if a person chooses the bicycle instead of the car:

- Accessibility (i.e. congestion): When a traveler opts for the bicycle instead of another mode of transport, this has an effect on this other mode of transport. It becomes quieter on the road. We analyze this by means of a reduction in congestion (effects on journey time and reliability). The effect on travel time and travel costs of the traveler is not included in this analysis. The traveler himself chooses a certain mode and in making this choice he takes into account travel time and travel costs. These aspects are already included in the choice of modality and are therefore not included as a welfare effect.
- Health: Health effects can also be included if, as a result of a measure, more kilometers are cycled. In this case this partly concerns commuters switching from car to bicycle or e-bike and partly commuters and non-workers. We distinguish five types of health effects: productivity, sick days, health care costs, burden of disease and life expectancy.
- Safety: Measures that make people cycle more and/or use their cars or public transport less, each have their own impact on traffic safety. These effects can be determined on the basis of an average accident probability per kilometer.
- External effects: Traffic usually involves emissions of harmful substances, such as CO2 and emissions of fine dust, nitrogen and sulphur oxides. A modal shift may also lead to changes in noise pollution for the surrounding area. A decrease in car traffic leads to less noise pollution.

Table 5.1 The marginal benefit per additional kilometer cycled instead of the car (in BRL)

Effect	Unit value
Accessibility	
Congestion	R$ 0.52
Traffic safety	
External accident costs per casualty	R$ 0.37
Health effects	
Productivity*	R$ 0.09
Sick days*	R$ 0.02
Health care costs	R$ 0.02
Burden of disease	R$ 0.09
External effects	
Air quality	R$ 0.01
Climate change	R$ 0.02
Noise	R$ 0.01

* Only applicable on those who work

Source: European Commission (2019), Decisio (2017; 2021), project team World Bank

The Brazilian price level adjusted unit values are shown in table 5.1. These unit values are based on Dutch and European unit values and data provided by the World Bank project team. The unit values show an average. In reality, each unit value can therefore deviate largely. For instance because of the degree of road congestion in case of accessibility, the physical and mental health of the population, the perceived road safety and the environmental friendliness of the car fleet.

These unit values are evidence based but, nevertheless, surrounded by uncertainty. Therefore a more in-depth study is suggested to each of the unit value. For instance the unit values of health are rather large. An in-depth analysis can narrow down the bandwidth, can be specified to certain target groups and to modality (the healthiness of an e-bike). Also an important issue: excise duties. Will this be incorporated?). So, more in depth study to the local context is crucial. Nonetheless, the table with unit values provides insights in the marginal benefits for each kilometer cycled instead of car usage and can be used for first discussions on the Bike SP plan. For which effects will São Paulo reimburse travelers who were once driving the car and now cycle? Will only the external effects (congestion, noise, air quality and CO2) be reimbursed or also the health effects which are also reaped by the individual and company the person works for? Or will the company also participate in the Bike SP plan?

6. Results SCBA

An analysis of the costs and benefits of the cycle network expansion in São Paulo has been carried out in a quick scan manner. Since the future is uncertain, two scenarios have been used that sketch the lower and upper end of the bandwidth of the potential benefits. These scenarios mainly differ in terms of modal shift: whereas the Minimum scenario is based on a small modal shift (the share of cycle use in the total shifts from 0.9 to 1.6 percent), the Maximum scenario is based on a substantial modal shift (towards 6.7 percent). In addition, it has been assumed that in both scenarios road safety for cyclists improves and cycling speed increases slightly. In this analysis both financial and economic and social effects of the two scenarios have been considered for a period of 100 years.

*Table 6.1 Overview of results (NPV, *1 million BRL)*

	NPV in mln	
	Minimum	Maximum
Financial effects		
Construction costs	-R$ 502	-R$ 502
Maintenance costs	-R$ 191	-R$ 191
Accessibility effects		
Travel time	R$ 159	R$ 471
Travel time reliability	R$ 39	R$ 116
Congestion	R$ 2,821	R$ 23,280
Health effects	R$ 813	R$ 6,712
Traffic safety	R$ 883	-R$ 5,673
External effects		
Noise	R$ 52	R$ 427
Air pollution	R$ 99	R$ 821
Climate change	R$ 106	R$ 872
Indirect effects		
Subsidies	R$ 412	R$ 3,403
Taxes	-R$ 1,119	-R$ 9,235
Qualitative effects		
Comfort	+	+
Quality of public space	+	+
Equality	+	+
Results		
Total costs	-R$ 693	-R$ 693
Total benefits	R$ 4,266	R$ 21,193
Balance	R$ 3,572	R$ 20,500
B/C-ratio	**6.2**	**30.6**

In both scenarios the benefits more than outweigh the costs consisting of the one-off investments and the annual management and maintenance. These costs amount to almost R$ 0.7 billion. in both Minimum and Maximum. In contrast, the benefits amount to more than R$ 4 billion in Minimum and more than R$ 21 billion in Maximum. This is due to the much larger modal shift from car and public transport to cycling. In both scenarios this leads to considerably less congestion, subsidy savings and improved quality of life (less noise and air pollution; less CO2 emissions). On the other hand, there is a substantial 'cost' in terms of excise duties because less fuel is consumed. Nevertheless, the benefit-cost ratio for Minimum and Maximum is 6.2 and 30.6 respectively. In fact, this means that for every real invested in the cycle network, society gains R$ 6.2 and R$ 30.6. In reality it will most likely be somewhere in between, depending on the implementation of the project, the cultural change required and flanking policies such as subsidies. Bases on the sensitivity analysis in the paragraph 6.1, these positive benefit-cost ratios prove to be robust, yet traffic safety remains a focal point.

Subsidy scheme: Bike SP Plan

In order to stimulate the use of bicycles in São Paulo, the municipality of São Paulo can incorporate financial incentives such as the reimbursement of kilometers travelled by bicycle instead of the car. There are several reasons for this – as shown in the SCBA as well – related to accessibility, traffic safety, health effects and external effects. This report has provided first insights in the components of such a subsidy scheme, but more in depth study is essential. Nonetheless this is food for discussion and can become more accurate as soon the scope and goals of the subsidy scheme is clearer.

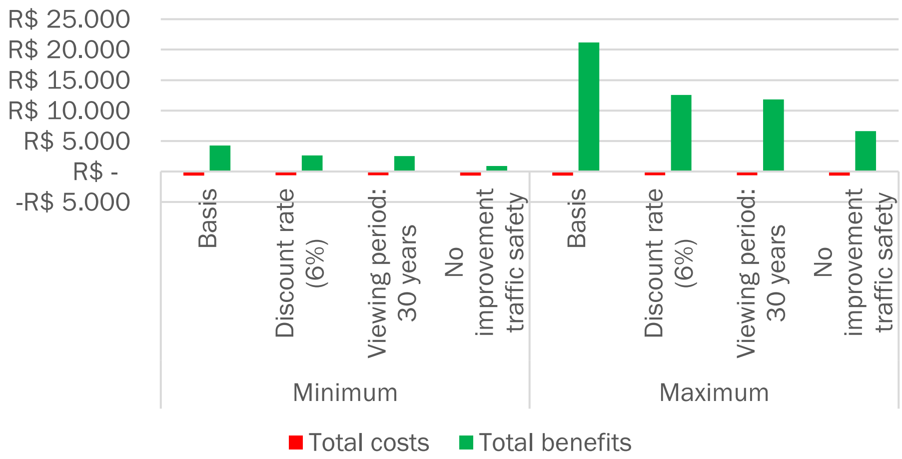
Although both scenarios are positive, differences are noticeable. The Minimum scenario is clearly more moderate due to the small modal shift to cycling. The Maximum scenario shows much higher benefits (or costs in the case of excise duty) for almost every SCBA-effect. There is one exception, namely road safety. This is positive in the Minimum scenario, whereas it is negative in the Maximum scenario. This is despite the assumption that the risk of bicycle accidents is reduced by the cycle network expansion. Existing cyclists profit maximally from this improvement, whereas new cyclists actually lose out. After all, previously they travelled by car or bus and the figures show that these are safer means of transport. In the Minimum scenario the number of new cyclists, and thus the negative road safety, remains relatively limited. As a result the positive road safety for existing cyclists is greater than the negative effect for new cyclists. This is in contrast to the Maximum scenario: due to the large number of new cyclists, and thus the negative road safety effect, the positive effects for existing cyclists evaporate. This is an argument in why investments in a safe cycle network for all is a must. If this is not done, the social benefits will be reduced significantly model wise (see sensitivity analysis on traffic safety below), and in reality fewer people would cycle.

6.1 Sensitivity analysis

The sensitivity of the outcomes in the SCBA – both for the Minimum as Maximum scenario – were analyzed for a number of effects and assumptions. These are:

- **Discount rate**: In the basis, a discount rate of 4 percent is used. Since the current economic situation is uncertain due to the pandemic and the war Ukraine, a 6 percent discount rate is applied. The benefit-cost ratio slightly decreases in comparison with the result in table 6.1, yet it remains positive: 4.4 in the Minimum scenario and 21.1 in the Maximum scenario.
- **Viewing period**: In the basis, a viewing period of 100 years is used. In order to test robustness, a viewing period of 30 years is applied as well. The analysis for the shorter viewing period is carried out with the discount rate of 4 percent. The benefit-cost ratio slightly decreases in comparison with the result in table 6.1, but it remains positive: 4 in the Minimum scenario and 18,8 in the Maximum scenario.
- **Traffic safety**: In the basis, an improvement of traffic safety for cyclists is assumed. It is however uncertain to which extent this will be achieved. Therefore an analysis without any traffic improvement is carried to test the robustness of the outcomes. This analysis is carried out with the discount rate of 4 percent and a viewing period of 100 years. The benefit-cost ratio significantly decreases in comparison with the result in table 6.1, but remains positive: 1.3 in the Minimum scenario and 9.5 in the Maximum scenario.

*Figure 6.1 Overview of results sensitivity analyses discount rate, viewing period and traffic safety (NPV, *1 million BRL)*



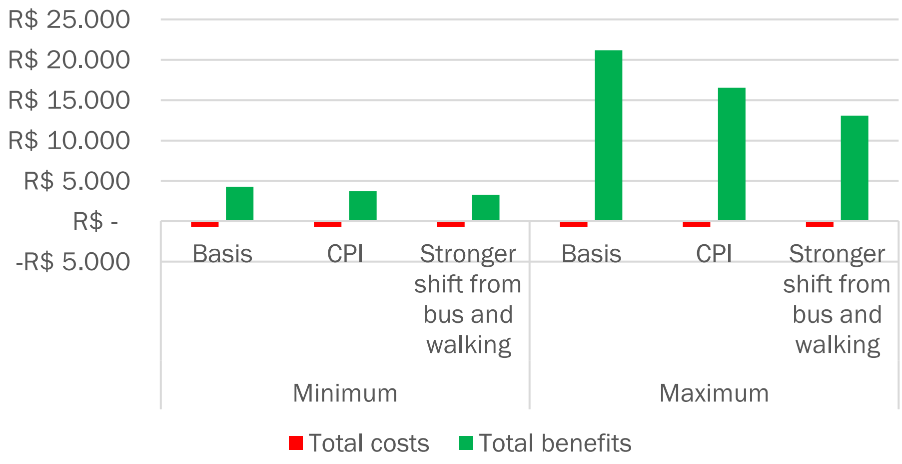
- **Modal shift**: In the basis, a modal shift from mainly car to cycling is assumed. It is however uncertain to which extent this will be achieved. Therefore two analyses with mainly a shift from bus and walking to cycling are carried out: (1.) with the modal split of the CPI and (2.) with an even stronger emphasis of a shift from bus and walking rather car (see table 6.2 for the used modal split). This analysis is carried out with the discount rate of 4 percent and a viewing period of 100 years.

Table 6.2 Modal shift: the previously used modality of the new cyclists

Modal split	Basis	CPI	Stronger shift from bus and walking
Rail	0%	0%	0%
Metro	4%	5%	4%
Bus	31%	35%	46%
Car	43%	34%	22%
Motorcycle	2%	3%	2%
Taxi	3%	2%	3%
Walking	16%	22%	23%

As is visible from figure 6.2, the total benefits slightly reduced as the modal shift from car to cycling is decreasing. Nevertheless, the benefit-cost ratio remains positive: 4.7 in the Minimum scenario and 18.9 in the Maximum scenario.

*Figure 6.2 Overview of results sensitivity analyses modal shift (NPV, *1 million BRL)*



Literature

- Calculations Decisio based on Decisio (2017) Waarderingskengetallen MKBA Fiets: state-of-the-art, adjusted to Brazilian price levels
- Decisio (2012). Maatschappelijke kosten en baten van de fiets, quickscan
- Decisio (2017) Valuation of the societal effect of cycling. SCBA Bicycle: state-of-the-art valuation key figures
- Decisio (2021) Estimation of monetary value health effects of exercise by employees
- Den Hartog et al. (2010). Do The Health Benefits Of Cycling Outweigh The
- Risks?
- Den Hartog et al. (2013). Health advantages of cycling many times greater than the health risks.
- ECF Road Safety. Retrieved from: https://ecf.com/taxonomy/term/511/type/facts_figures_
- Ecorys (2017). The socio-economic value of sports and exercise.
- European Commission (2019) Handbook on the external costs of transport
- Historical data and forecasts on population and economic growth, provided by the World Bank project team
- IADB (2021). Urban road congestion in Latin America and the Caribbean: characteristics, costs, and mitigation
- IPEA Traffic accidents report 2003
- Jacobs (1961). Life & Death of Great American Cities.
- Martens (2013). The role of cycling in limiting transport poverty in the NL.
- NRIX 2018 Global Traffic Scorecard (http://inrix.com/scorecard)
- Pesquisa Origem Destiono 2017 50 anos: A mobilidade urbana da regiao metropolitana de Sao Paul em detalhes.
- The World Bank - Lopez (2008) The Social Discount Rate: Estimates for nine Latin American Countries. World Bank Policy Research Working Paper 4639
- TNO. (2003). TNO Arbeid rapport. Retrieved from: https://www.10000stappen.nl/uploaded/TNO%20Arbeid%20rapport.pdf
- World Bank (2019). Project information document: São Paulo Aricanduva BRT Corridor
- World Bank. Project team