



Urban Design Project Impact Tool



Acknowledgment

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The development of the tool was made possible through the support of CNCA and was coordinated by the Planning Office, with the participation of a team of technicians from different departments of the City of Rio, who contributed with technical data, methodological proposals, analyzes and approvals.

We are incredibly grateful to CNCA and to the entire technical team dedicated to the project.

The tool

The tool aims to measure the extent to which specific elements of urban projects can impact the achievement of cities' strategic goals and commitments towards sustainable development, contributing to the search for effective results in reducing GHG emissions, in the heat islands and improvement in air quality.

IMPROve was developed based on the city of Rio de Janeiro, considering local data and the specificities of its different regions, but having the possibility of being used by any other city from configuration settings.



The Planning Office, responsible for the integrated planning of the city, focused on the elaboration of participatory and multisectoral plans and the consolidation of institutional support and partnerships, also seeks to build tools and strategies to achieve better results for the sustainable development of Rio de Janeiro.



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Introduction

The IMPROve tool was developed with the objective of measuring the impact of urban interventions in Rio de Janeiro, in line with integrated planning for sustainable development and climate actions, to achieve the city's strategic goals and commitments and has as one of its characteristics can be used by other cities.

In general, the tool intends to measure the impact of different municipal interventions, allowing the understanding of which elements of each intervention, and which interventions should be prioritized to achieve the most effective goals of sustainable development in the city, and contribute to the design process enabling the identification of priority elements that must be considered to achieve the best results.

For the selected urban intervention projects, through the measurement of the elements of the intervention, the reductions and removals of processed effect gases, improvement of air quality and reduction of local temperature will be estimated.

In this way, the application of the tool will provide the alignment of the projects with the international agenda agreed by the city of Rio de Janeiro, with the objectives of sustainable development, with the fulfillment of the Paris Agreement, and other commitments guided by the municipal macro-planning.



1.1. Problem to be solved

The correct understanding and dimensioning of the benefits and co-benefits related to solutions aimed at coping with climate change are strategic to prioritize the implementation of effective actions.

Considering the complexity of urban contexts, the increasing diversity of the demand of cities and the scarcity of resources, the prioritization of the climate agenda has been a great challenge for public and government managers. Tools that allow better translation of possible results can be great allies for better management of cities.

Thus, in a scenario where environmental issues are increasingly relevant to cities, tools that allow public managers to have information on how to improve their projects so that they offer the best performance from the environmental point of view, become increasingly necessary, allowing for more accurate and effective decisions.

1.2. The solution and its relevance

IMPROVe is a tool for measuring the environmental impacts of urban projects, easy to use for both technicians and public managers working with projects related to sustainable development that should defend the prioritization of projects and their respective components. A tool in Excel, built on usability and ease of reading results. Through this tool, cities will actually be able to predict their impact reduction potential, so that then it is possible to measure them.

The tool is an instrument to help the public administration transform urban spaces by increasing their resilience and serve as catalysts for the urban changes the city needs to meet strategic commitments:

- Climate neutrality in 2050
- Air quality
- Climate resilience
- Sustainable development goals

2. Objectives



Measure the results of an existing intervention



Prioritize actions / projects



Estimate the future results of urban projects focused on sustainability



Encourage the application of techniques and materials of better environmental performance



Support technicians and public managers, who work with projects related to sustainable development, in decision-making on specifications of the elements in new projects of urban interventions.



Generate numbers and information that can be used



Encourage data collection processes so the tool can bring more advanced and reliable features



Mapping potential for reducing environmental impacts related to the urban environment

3. Target audience



Public management technicians and managers working with projects related to sustainable development.

4. Tool limitations

Application limited to specific regions: need for customization according to application area

The tool considers not always accurate data and estimates. It is recommended that such data be always revisited to improve the accuracy of the results.

Because it is a tool with two-dimensional reading, there are also limitations related to thermal sensation in certain locations within the intervention areas. For the same reason, for example, there is no way to consider shadows in these temperature measurements.



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General methodology

First, the types of urban interventions that the tool should be able to quantify environmental impacts were defined. As approved by the city, the projects of urban interventions, such as implementation of low emission zones, square, park, implementation of bicycle paths, closure of wagon able road, among others, will be analyzed under the following aspects:



Use from via

- Reduction/increase of GHG emissions by changing the modal participation of the road;
- Reduction/increase of local pollutant emissions by changing the modal participation of the road.



Vegetation/ Vegetation cover

- Removal of CO2 by increasing the plant area;
- Removal of particulate matter by increasing the plant area;
- Temperature reduction by increasing plant area.



Floor and Roof

- Reduction/increase of temperature evaluated by material characteristics (material type, color and permeability).
- Reduction of GHG emissions by solar power generation (applicable in case of use of solar plate as cover).



Street lighting

- Reduction of GHG emissions by reducing energy consumption.




	 Greenhouse gas emissions	 Air quality	 Heat Island
Change of road use	✓	✓	-
Afforestation	✓	✓	✓
Pavement materials and coverage	-	-	✓
Street lighting and solar panel installation	✓	-	-

Table 1. Environmental impact matrix by urban intervention actions

Source: Own elaboration

For the regionalization of the conditions of each region of the city according to emissions, temperature and air quality, studies on the following data are being considered:

- Car flow by region (CET-Rio)
- Rio bus network
- Ratio of modals (types of means of transport) by region of the city
- List of materials used for flooring and roofing
- List of species used for afforestation (classified by shrub, small, medium and large)
- Green area index of the municipality of Rio de Janeiro
- Air monitoring
- Maps of heat islands
- Initial survey of projects eligible for pilot project

With the above data in hand, we defined those regions of the city that have similar characteristics of temperature, air quality and emissions. Such parameters are used as reference scenarios and considered in the results to be delivered.

It is important to highlight that the tool will not be able to evaluate plant suppression as a type of intervention, because the form of measurement differs from vegetation/vegetation cover and does not appear as an intervention among those considered.

To estimate the impacts of urban intervention projects, some theoretical-methodological approaches are used, which can be refined throughout the project, the main methodologies being:

Removal of GHG Emissions

Estimates of greenhouse gas removals from tree planting based on the IPCC - Guidelines for National Greenhouse Gas Inventories and MCTIC - Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions and Removals - Agricultural Sector.

GHG Emission Reduction

Reduction estimates based on the Climate Action Plan (CAP) of the municipality of Rio Janeiro, Brazilian GHG Protocol Program, *IPCC - Guidelines for National Greenhouse Gas Inventories*.

Temperature characterization by region

By remote sensing analysis of satellite images of the municipality of Rio de Janeiro.

Characterization of average local pollutants by region

By the average obtained by the monitoring carried out by the city and by the IENA at measurement points in the city.

5.1. Mapping the development path

- 1** Preparation of the Project Plan
 - Definition of methodologies
 - Detailing
 - Research
 - Objectives
 - Expected results
 - Tests – pilot project
 - 2** Detailing the regionalization methodology of the different areas of the city, about its characteristics related to:
 - Air quality (pollutants)
 - Temperature
 - Emissions
 - 3** Validation with technical team of the city
 - 4** Request for information necessary for regionalization work
 - 5** Definition and detailing of inputs / information necessary for the use of the tool
 - 6** Validation with technical team of the city
 - 7** Definition and detailing of calculation methodologies related to emission, temperature and air quality criteria
 - 8** Validation of the conceptual structure of the tool
 - 9** Definition of pilot design to be used for tool testing
 - 10** Application of the pilot project and analysis of results
 - 11** Validation with technical team of the city
 - 12** Final adjustments
 - 13** Training
- 

5.2. Workflow / how to use



1 Input and Input Data

The first step is for the user to become familiar with the tool. In the **“Introduction”** tab there is an explanation and a general mapping of the IMPROve tool.

The tool consists of the following tabs:

- In the **“2_Entry_Data”** tab, the user must enter the project information in the blue cells.
- In the **“1.1_Exemple_Use”** tab, the user can refer to an example of filling the tool.
- In the **“1.2_Impact_Matrix”** tab, the user can see the impacts that are evaluated for each type of action in urban intervention projects in the City of Rio de Janeiro.



2 Project results

After input of the project data, the tool presents in the form of tables and graphs the results for greenhouse gas emissions and reductions, air quality, and the variation of the local average temperature before and after the urban intervention project.



3 Project calculations

From the input data, the tool calculates the variations of **“before”** and **“after”** variations of the project of emissions of effect emissions studies (GHG), the concentration of air pollutants and the variation of the average temperature of the region.



Data regionalisation

In order to allow the comparability of the project with a reference scenario, a regionalization of the data in the tool was structured for travel parameters, pollutant concentration and surface temperature. The rational detailing is contained in the Diagnostic Report of the IMPROVe tool and the data used for project calculations can be found in the tabs **"5.1_Database"** and **"5.2_Auxiliary_Data"**:

- Data refresh should be performed only by the administrator user and the update tutorial is described in the **"5.3_Data_Atualization"** tab



Emission Factors

The emission factors used for estimates of process effect gas emissions (GHG), concentration of air pollutants and the variation of the average temperature are available in the **"6_Emission_Factors"** tab.

In order to encourage the use of low-emission materials, a Catalogue of guidance of the footprint of carbon of materials.



Project Scores

In the Results area, each project receives a **"Score"** assigned to each of the 3 parameters analyzed and also a general result of the project. The administrator user of the tool can give weights from 1 to 3 to each parameter individually depending on the criteria to be prioritized in each intervention area.



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Specific methodologies

6.1. Regionalization of the city

In order to allow the comparability of the project with a reference scenario, a regionalization of the data was structured in the IMPROve tool. Thus, the availability of data from the city of Rio de Janeiro was evaluated for each of the environmental impacts to be measured in the tool and an analysis of the databases was performed to identify a common regionalization criterion. The most detailed and up-to-date information for each of the environmental impacts analyzed is listed below:



Greenhouse Gas Emissions

- The consumption of fuels by the transport sector provided by the IPP.
- Average daily flow per track type (structural, primary arterial, secondary arterial, collector and local) provided by CET-RIO.
- Individual matrix year 2016 with Transbrasil with estimates of car trips made available by the city hall.
- Headquarters public transport year 2014 considered between 07:00 and 08:00 in the morning provided by the city.
- Matrix of modal distribution by city region made available by the city hall.
- The number of trips made by each mode of transport in the city, obtained from the Sustainable Urban Mobility Plan - PMUS.(Rio de Janeiro, 2016)
- Opening of data from the Origin and Destination Survey 2011 made available by the city.



Air quality

- Pollutant concentration: 8 air quality monitoring units by the (DATA. RIO, 2020a)city.
- NO_x, NO₂ and MP_{2.5} concentration: measured by INEA stations and consolidated by SMAC.



Heat Island

- Heat island map of the city of Rio de Janeiro shared by the city with average annual temperature in the range of 30x30m (L8_Media_geral.tif).

Based on the data obtained for each impact analyzed, and aiming to ensure the usability and replicability of the tool, it is recommended to accept a single regionalization criterion for the three categories of impact. Thus, the regionalization criterion is the 33 administrative regions of the city of Rio de Janeiro. Eight of these 33 regions will still be subdivided into neighborhoods, because they have different characteristics.

Regionalization of greenhouse gas emissions data

The estimate of greenhouse gas emissions is made from fuel consumption. For the regionalization of the tool, an estimate of the amount of fuel consumed in each mode of transport was made from the data of the modes of transport used in the city, the number of trips and the total fuel consumption.

Fuel Consumption

For fuel consumption, data from the 2017 GHG emissions inventory, made available by the IPP, were used.

Fuel Consumption by Travel Mode

Having, therefore, the modes of transport used in the city, the number of trips and fuel consumption, an estimate of the amount of fuel consumed in each mode of transport was made as detailed below:

Diesel

The modes of road transport that consume diesel are: Bus, Van, Truck and BRT and the mode of water transport that consumes diesel is: Barca.

Gasoline

The modes of road transport that consume gasoline are: Car, Taxi and Motorcycle.

Ethanol and CNG

The modes of transport that consume ethanol and CNG are: Car and Taxi.

Total Number of Trips

The number of trips was used as a reference for the distribution of fuels between each mode of transport in the city.

Based on the most recent Origin-Destination Survey of the city of Rio de Janeiro, according to the PMUS, the modal division of the city of Rio de Janeiro was used for the year 2011. It is noteworthy that the available data do not consider the implementation of BRT and VLT, because they refer to the period prior to these actions.¹(Rio de Janeiro, 2016)

As the data from the Origin and Destination Survey refer to the year 2011, a projection of modal participation for the year 2020 was carried out. For the modes of car, bus, motorcycle, subway, train and VLT, the estimated growth was considered in the "Study on Climate Change Mitigation Scenarios and Analysis of the Potential for Reducing Greenhouse Gas Emissions for the City of Rio de Janeiro". For the bicycle mode, it was considered that there will be growth in the participation of the modal due to the actions of expansion of the cycle path network presented in the PMUS. (PANGEA CAPITAL, 2016)(Rio de Janeiro, 2016)

Regionalization of total travel

The estimate of the modal distribution of trips by region was made from the total travel of the city of Rio de Janeiro (projection of modal participation for the year 2020) and additional data provided by the city.

- Individual matrix year 2016 with Transbrasil with estimates of car trips made available by the city.
- Headquarters public transport year 2014 considered between 07:00 and 08:00 in the morning provided by the city.
- Opening of data from the Origin and Destination Survey 2011 made available by the city.
- Transport modal occurrence matrix by region.

From the analysis of these data, the number of trips per mode of transport for each administrative region was estimated.

¹The Origin and Destination Search is an investigation into the pattern of travel that people make in a region. In addition to information on origins and destinations, the search also raises modes of transport Used.

Additionally, for the standard scenario of the project, the number of trips is obtained from the characteristics of the pathways: track categories (structural, primary arterial, secondary arterial, collector, location); semaphorized or not pathways; track size (number of tracks per track). From the average daily flow per track presented in Table 2 the tool estimates the number of trips according to the category of the road and the number of lanes and estimates, by mode of transport, proportionally to the modal distribution of the administrative region.

Category from street	No traffic lights	With traffic lights
Structural	22.000	19.000
Primary Arterial	17.000	15.000
Secondary Arterial	13.000	10.000
Collector	8.000	-
Local	1.000	-

Table 2. Average daily flow per track (working days)
 Source: Volume and hierarchy table sent by CET-Rio on 11/16/2020

As highlighted by CET-Rio, Table 2 was constructed to establish average values of daily traffic volume per bearing range, thus enabling routes of different dimensions to be evaluated accordingly. The values may vary from the reality and characteristics of each route and each route, but the values presented were based on data from scores and capacity studies. Differentiated values for semaphorized roads or not were also established for the higher categories, since it is a factor that influences the capacity of the road. Lower hierarchy routes do not usually have this variation.

Regionalization of Air Quality Data

The air quality monitoring program of the City Hall of Rio de Janeiro – MonitorAr has 8 fixed stations that monitor daily the concentrations of the following local pollutants: Carbon Monoxide (CO), Nitrogen Dioxide (NO₂), Sulfur Dioxide (SO₂), Ozone (O₃), Particulate Materials (MP₁₀ and MP_{2.5}) and Hydrocarbons (HC). In addition to monitorAr stations, INEA monitors the concentrations of pollutants in the atmosphere in the State of Rio De Janeiro. In the construction of the tool, 4 monitoring stations of Nitrogen Oxide (DATA.RIO, 2020a) and Nitrogen Dioxides (NO₂) and 9 particulate materials monitoring stations (MP_{2.5}).

For the regionalization of the data of the IMPROve tool, the pollutant concentration data from the MonitorAr and INEA stations compiled by the Municipal Department of the Environment of the city of Rio de Janeiro were used. To obtain the data for the other regions of the city from the data of the stations, we used the spatial interpolation method weighted by the inverse of the distance – IDW for the area of the municipality of Rio de Janeiro, obtaining the distribution surface of these pollutants.(Myth & Mitasova, 1999).

Regionalization of Heat Islands data

According to literature data, such as the studies by Poranga and Amarin (PORANGABA and AMORIM, 2019) and Vieira and Machado (VIEIRA and MACHADO, 2018), remote sensing is cited as the technique used to measure surface temperature, as well as the formation of heat islands. Therefore, for the construction of the tool, we used the data obtained by landsat satellite, a satellite model widely used in research on the urban climatic thermal field in Brazil.

The tool was constructed using remote sensing data from the Landsat-L8 satellite that quantifies the radiant surface temperature in a pixel of 30 meters. For the regionalization of the average temperature data, we used the heat island map of the city of Rio de Janeiro shared by the city with annual average surface temperature obtained by landsat-8 satellite on the scale of 30x30m (L8_Media_geral.tif). Using the QGIS software, the average temperature for each administrative region was obtained by crossing the heat island map with the boundary map of the administrative regions.(DATA. Rio, 2020d).

6.2 Methodology for measuring project impacts

6.2.1. Emissions

The method proposed by the GPC - *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* was used to measure impacts on effect gas (WRI, 2014) emissions. The GPC method was designed to account for GHG emissions in a period of one year, so for the calculation estimates in the tool, average annual data were used.

The GPC method seeks to disaggregate emissions data to allow major GHG sources to be identified in a city or region. Among the six different sectors in which the emitting activities can be allocated, the IMPROve tool estimates emissions in the sectors of Stationary Energy, Transportation of AFOLU (Agriculture, forest and land use).

Additionally, for the development of the calculation of emission/removal of effect gases in the IMPROve tool, the following studies were also used:

- Monitoring of Greenhouse Gas Emissions from the City of Rio de Janeiro 2012 to 2017 (Data.Rio, 2019a)
- IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006)
- Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019)
- Specifications of the Brazilian GHG Protocol Program (FGV/ GVCes & WRI, 2011)
- Calculation Tool of the Brazilian GHG Protocol Program (FGV, 2020)
- Calculation Tool for Balance of Greenhouse Gas Emissions in Forests and Agroforestry Systems in Brazil (WRI, 2020a)
- Technical Note – Greenhouse Gas Protocol Calculation Tool for forestry in Brazil (WRI, 2020b)



Estimation of the variation in GHG emissions by the change in road use

The change in the use of the road will result in a variation in GHG emissions and local pollutant emissions if the implemented project promotes:



The change in the type and quantity of trips of the modes used for travel by the road (e.g. bike lane installation results in an increase in the number of bicycle trips);



The change in the type of fuel used by the modes (e.g. replacement of diesel buses by electric bus).

Fuel consumption in each mode of transport is proportional to its frequency of use, represented here by the number of journeys. Therefore, initially, an estimate of the average fuel consumed per trip was performed.

Thus, the calculation of fuel consumption before and after the project is carried out from the variation between the number of trips of each mode of transport before and after the realization of the project.

Knowing, therefore, the consumption of fuels, it is possible, from the emission factor of each fuel, to estimate the impact in terms of GHG according to the following formula:

“i” Index denoting the type of fuel

$$E_i = C_i \cdot FE_i$$

CO₂e missions and attributable to fuel *i*, tCO₂ and.

Fuel consumption *i*, in unit of measurement *u*, being *u* m³, *l* or kg.

CO₂ emission factor and applicable to fuel *i*, in tCO₂ and/*u*.



Estimation of variation in GHG emissions by street lighting

The calculation of GHG emissions from electricity consumption by street lighting is carried out from estimates of electricity consumed according to the following formula:

$$E_{CO_2} = C \cdot FE_{CO_2}$$

CO₂ emissions attributable to the electricity consumption of the national interconnected system, in tCO₂ and.

Electricity consumption of the national interconnected system in MWh.

CO₂ emission factor applicable to electricity from the national grid, in t CO₂/MWh.



Estimation of the variation in GHG emissions by the installation of solar panels

The calculation of reduction of GHG emissions from the installation of solar panels is carried out from the estimates of electricity generated according to the following formula:

$$R_{CO_2} = G \cdot FE_{CO_2}$$

Reduction of CO₂ emissions attributable to electricity generation, in tCO₂ and.

Electricity generation by solar panels, in MWh.

CO₂ emission factor applicable to electricity of the national interconnected system, in t CO₂/MWh.



Estimation of the removal of GHG emissions by urban afforestation actions

The removals of CO₂ from urban afforestation actions were calculated according to the following equation, according to the methodology developed by wri for the Atlantic Forest biome, where the municipality of Rio de Janeiro is located:(WRI, 2020b)

$$R_{CO_2} = n \cdot Vol \cdot D \cdot CF \cdot \frac{44}{12}$$

Removals of CO₂ attributable to tree planting, in t CO₂.

Volume per tree, in m³/unit.

Carbon fraction in dry matter.

Number of seedlings planted, in unit.

Density of wood, in kg/m³.

Conversion factor from C to CO₂.

According to the methodologies of the IPCC and WRI, the removals of CO₂ (IPCC, 2019) (WRI, 2020b) were estimated considering longevity per species. Thus, the volume per tree was estimated from longevity (years) by species type and annual incremental (m³/year) determined by the growth rate of the species (fast, moderate and slow) and density (units/area).

It is important to highlight that the removals of herbaceous vegetation species (herbs, grasses) are not estimated, as the recommendations of the GHG Protocol Agricultural Guidance (GHG Protocol, 2016) were considered, as the biomass associated with this type of vegetation is relatively ephemeral and the reductions in these reserves are rebalanced in a short period.

6.2.2. Temperature

According to the U.S. Environmental Protection Agency (EPA, 2014), *the urbanization process leads to changes in the landscape, such as replacing vegetation with buildings and roads. These changes lead to the formation of urban heat islands that are characterized by more heated urban areas than the less urbanized and rural neighborhood.*

According to literature data, such as the studies by Porangaba and Amarin (PORANGABA and AMORIM, 2019) and Vieira and Machado (VIEIRA and MACHADO, 2018), remote sensing is cited as the technique used to measure surface temperature, as well as the formation of heat islands. Therefore, for the construction of the tool, we used the data obtained by landsat satellite, a satellite model widely used in research on the urban climatic thermal field in Brazil.

According to the study by Giordano and Krüger, the use of materials with higher reflectivity index, or albedo factor, is a strategy for temperature reduction. Albedo is an index of the material's ability to reflect part of the incident solar radiation, ranging from 0 to 1. The higher the albedo, the higher the percentage of incident radiation that is reflected, and therefore, a smaller portion of energy is converted into heat, resulting in lower surface temperatures. (GIORDANO & KRÜGER, 2014)





For the development of the calculation of temperature increase/reduction estimates at the heat island level in the IMPROVe tool, the following studies were used as the basis:

- Urban pavements used in Brazil: Characterization of solar reflectance and temperature verification in the field (Del Carpio & Marinovski, 2016)
- Potential for reduction of surface temperature by increasing albedo in the various Brazilian regions (GIORDANO & KRÜGER, 2014)
- Are urban water bodies really cooling? (Jacobs & Clock, 2020)
- The effects of trees on the urban climate. In: Trees in the 21st Century (BERNATZKY, 1993)
- Vegetation-albedo feedbacks. Climate processes and climate sensitivity (Dickson & Hanson, 1984)

Based on the methodologies mentioned, the tool estimates the increase/reduction of temperature by the reflectivity index of the materials used in pavement and cover and by the actions of afforestation, vegetation and vegetation cover.

It is noteworthy that the reflectivity factors were extracted from the literature, thus being an initial proxy for the calculation of the local mean reflectivity. Shading effects were not contemplated in the tool, since the shading effect depends on other factors such as wind speed, climatic variation over time, intensity of light rays, and arrangement of objects in space, not contemplated in the present study. Also, the effect of heat emitted by combustion vehicles in urban space was also not included in the tool, as it would require a detailed study with traffic data, vehicle flow, peak times and temperature measurement.

Estimated temperature correlation and reflectivity factor

According to the study by Del Carpio and Marinoski, it is possible to estimate a correlation of temperature with the reflectivity factor of the surface. From the temperature data for the administrative regions and the reflectivity factor of the materials used in urban intervention projects, it was possible to estimate a logarithmic correlation between temperature and reflectivity factor according to the following figure and formula:

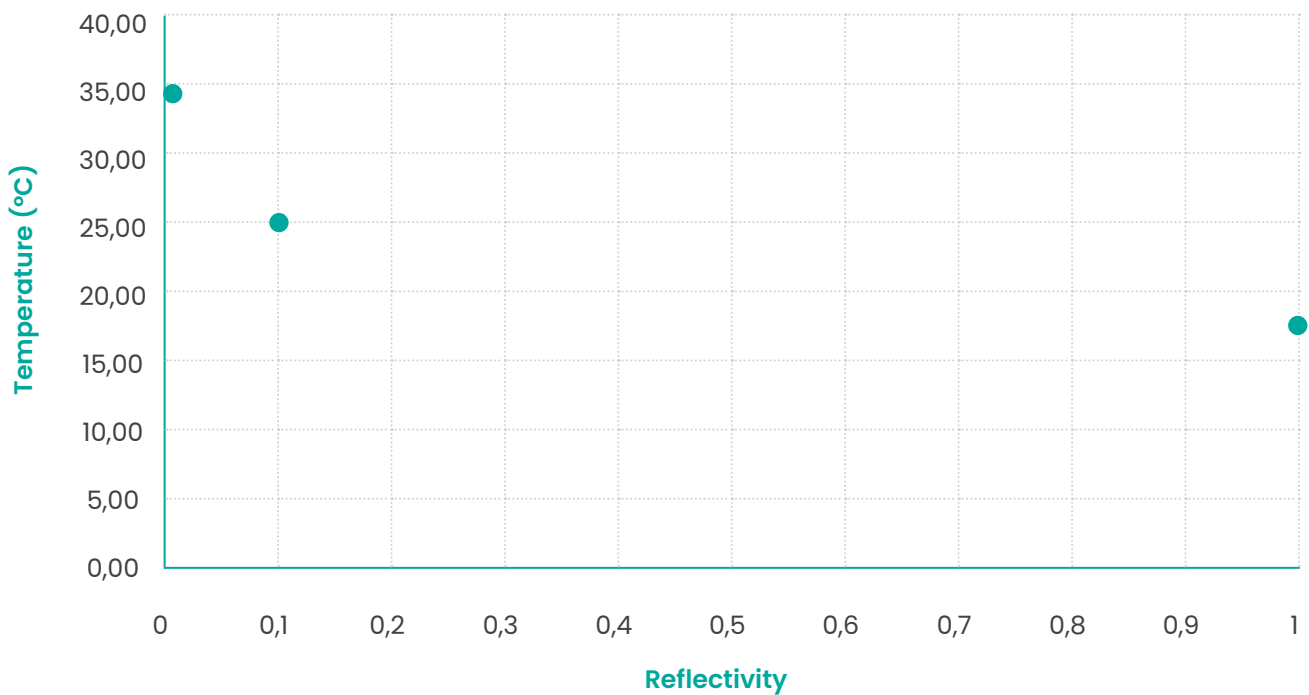


Table 3. Logarithmic correlation between temperature and reflectivity factor for administrative regions

Source: Own elaboration

Estimated temperature in the administrative region from the actions of the project, in °C.

Estimated reflectivity of the area from the actions of the project, dimensional.

$$T_{ra} = -a_{ra} \ln(r) + b_{ra}$$

Constant of the equation calculated for the administrative region, in °C.

Constant of the equation calculated for the administrative region, in °C.

6.2.3. Air quality

According to CONAMA Resolution No. 491/2018, the air quality standard is one of the instruments for air quality management, determined as the concentration value of a specific pollutant in the atmosphere, associated with an exposure time interval, so that the environment and the health of the population are preserved in relation to the risks of damage caused by air pollution (CONAMA, 2018).

The air quality monitoring program of the City of Rio de Janeiro – MonitorAr has 8 fixed stations that monitor the concentrations of the following local pollutants: Carbon Monoxide (CO), Nitrogen Oxides (NO) Sulfur Dioxide (SO₂) Ozone (O₃) Particulate Materials (MP₁₀ and MP_{2.5}) and Hydrocarbons (HC) (DATA. RIO, 2020a). In addition to MonitorAr stations, INEA monitors the concentrations of pollutants in the atmosphere in the State of Rio De Janeiro. In the construction of the tool, 4 monitoring stations of Nitrogen Oxide (NO) and Nitrogen Dioxides (NO₂) and 9 particulate materials monitoring stations (MP_{2.5}).

Among the main sources of emission of local pollutants, the combustion of motor vehicles are very significant sources and to estimate the emissions from the fuel consumption of transport modes were consulted the Inventory Emissions of Vehicle Sources Metropolitan Region of Rio de Janeiro YEAR-BASE 2013 (INEA, 2016) and Vehicle Emissions in the State of São Paulo 2018 (CETESB, 2019).

For the estimates of removal of local pollutants by vegetation, the method proposed by *i-Tree Canopy Air Pollutant Removal and Monetary Value Model Descriptions study was used.*(Hirabayashi, 2014)

In addition, for the development of the calculation of emission/removal estimates of local pollutants in the IMPROVe tool, the following studies were also used:

- A new variable in planning for sustainable urban development: green areas in backyards in the suburb of Rio de Janeiro (Ferreira, 2016)
- Landscaping Guidance for Improving Air Quality near Roadways (Sacramento, 2017)
- Urban woodlands: their role in reducing the effects of particulate pollution (Beckett, Freer-Smith, & Taylor, 1997)

Based on the methodologies cited, the tool estimates the emissions of local pollutants by transport combustion and removal by vegetation.



Estimation of the variation in local pollutant emissions by changing the Use of the Road

Similarly, to the calculation of GHG emissions, from fuel consumption before and after the project, it is possible, from the local pollutant emission factor of each fuel, to estimate the impact in terms of each pollutant according to the following formula:

“i” Index denoting the type of fuel.

“a” Index that denotes the type of pollutant.

$$EP_{i,a} = C_i \cdot FEP_{i,a}$$

Pollutant emissions attributable to fuel i , in pollutant t a .

Fuel consumption i , in unit of measurement u , being u m^3 , l or kg .

Pollutant emission factor to applicable to fuel i , in t of pollutant a/u .

To estimate the impact of variations in local transport pollutant emissions on the concentration of local pollutants, the study *Fine and Coarse Aerosol at Rio de Janeiro prior to the Olympic Games: Chemical Composition and Source Apportionment was used*. (Godoy, 2018) According to the study, vehicle emissions contribute, on average, to $59 \pm 9\%$ of the concentration of $MP_{2.5}$ in the city of Rio de Janeiro. Based on the study, the SMAC - Municipal Secretariat for the Environment estimated vehicle influencing factors in the emission of local pollutants by administrative region of Rio de Janeiro.



Estimation of the removal of local pollutant emissions by afforestation actions

The removals of local pollutants by planting seedlings were calculated according to the following equation, according to the methodology developed by *i-Tree* (Hirabayashi, 2014) Canopy:

“ α ” index that denotes the type of pollutant

$$R_{\alpha} = -n \cdot A \cdot FRP_{\alpha}$$

Number of seedlings planted, in unit.

Removals of pollutant to attributable to tree planting, in t of the pollutant α .

Basal area per tree, in $m^2/unit$.

Pollutant removal factor to applicable, in t of pollutant to α/m^2 .



7

Application example
Pilot project

During project execution, the tool was used for testing. The pilot project selected for the use of the tool was the Neutral District - Presidente Vargas Axis. As the project for the implementation of the Neutral District is under development, the city carried out a simulation of the ideal scenario as a low emission area focused on increasing afforestation, green areas and clean mobility.

The pilot project Simulation - Neutral District - Presidente Vargas Axis has a total area of 94,577.91m² and presents the following actions:



Reduction in the number of roads for vehicles



Widening of sidewalks with application of permeable grass paver



Expansion of central beds with application of ground cover vegetation and pedestrian walk



Implementation of two two-way bike paths



Implementation of flower beds on sidewalks



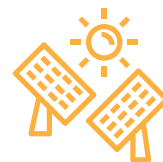
Implementation of rain gardens, water mirrors



Increase in the number of trees



Implementation of pergolate



Application of solar panels on bus shelters

From the project data entered at the simulation, the tool quantifies and consolidates the results by environmental impact as shown in Table 4.




	 Greenhouse gas emissions	 Air quality	 Heat island
Project results	Positive impact High	Positive impact Moderate	Positive impact Low

Table 4. Consolidated project result sorted by impact range
Source: Own elaboration

Legend	Greenhouse gas emissions	Air quality	Heat island
Positive impact High	GHG emissions above 70%	Reduction of concentration of local pollutants above 30%	Temperature reduction above 2°C
Positive impact Moderate	Reduction of GHG emissions by 30 to 70%	Reduction of concentration of local pollutants between 10 and 30%	Temperature reduction between 1 to 2°C
Positive impact Low	GHG emissions reduction by up to 30%	Reduction of concentration of local pollutants up to 10%	Temperature reduction up to 1°C
No impact	No variation in GHG emissions	No variation in GHG emissions	No temperature variation
Negative impact High	Increase in GHG emissions above 70%	Increase in the concentration of local pollutants above 30%	Temperature increase above 2°C
Negative impact Moderate	GHG emissions increase by 30 to 70%	Increase in the concentration of local pollutants between 10 and 30%	Temperature increase between 1 to 2°C
Negative impact Low	Increase in GHG emissions by up to 30%	Increase in the concentration of local pollutants by up to 10%	Temperature increase up to 1°C

Table 5. Legend classification project impact
Source: Own elaboration

As a result of the generation, the project presents:



Greenhouse Gas emissions

Annual reduction of 69,939 tons of CO₂ and, and increased removal of 722.2 tons of CO₂ by afforestation.



Air quality

The project presents an improvement in air quality, with the reduction of the average annual concentration of local pollutants, mainly CO (from 1.801ppm to 1.604ppm) and NO_x (from 53.15µg/m³ to 47.62µg/m³).



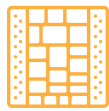
Heat island

The average temperature estimated with the actions of the project varies from 21.83 to 24.21°C, with the previous temperature being 25.63°C.

The pilot project elected by the city hall Neutral District – Presidente Vargas Axis presents the four categories of actions of urban interventions contemplated in the scope for the development of the IMPROve tool:



Change of road use



Materials used in Flooring and Roofing



Afforestation / Vegetation / Vegetation cover



Street lighting and solar panel installation

The pilot project simulation analyzed shows results in an annual **reduction of 69,939 tons of CO₂e, and increased removal of 722.2 tons of CO₂** by afforestation, improvement of air quality, with the reduction of the concentration of local pollutants, (from 1.801ppm to 1.604ppm) and NO_x (from 53.15µg/m³ to 47.62µg/m³) and a **reduction in the average temperature in the range of -1,42 to -3.80°C**. It is important to highlight that the pilot project is only the clipping of an avenue of the Neutral District that is in the development phase, which indicates a great potential for reducing environmental impacts for the Neutral District project.

From the analysis of the results obtained for environmental impacts (reduction /removal of greenhouse gas emissions – GHG; reduction of heat islands; improvement of air quality), it can be concluded that IMPROve – Urban Impacts Tool meets the objective of measuring the impact of urban interventions in Rio de Janeiro and assisting in decision-making of urban projects.



8

Material catalog

For general guidance in material specification, the table below can be used by designers in the search for emission reductions by selecting less emission-intensive materials:

Material	Emission factor (kgCO ₂ e/ unit.)	Unit.	Ecoinvent Process 3.6
Sand	0,00467	kg	sand quarry operation, extraction from river bed sand APOS, S - RoW
Asphalt	0,26134	kg	mastic asphalt production mastic asphalt APOS, S - RoW
Bamboo	2,66609	m	engineered wood joist production joist, engineered wood APOS, S - RoW
Interlocked block	0,22793	kg	lightweight concrete block production, pumice lightweight concrete block, pumice APOS, S - RoW
Recycled rubber	2,84715	kg	synthetic rubber production synthetic rubber APOS, S - RoW
Ceramic	0,76139	kg	ceramic tile production ceramic tile APOS, S - RoW
Metal coverages	3,72507	m ²	zinc coating, coils zinc coat, coils APOS, S - RoW
Concrete	198,90968	m ³	concrete production 20MPa concrete, 20MPa APOS, S - RoW
Eco granite	0,50027	kg	natural stone plate production, cut natural stone plate, cut APOS, S - RoW
Fiberglass	2,99473	kg	glass wool mat production glass wool mat APOS, S - RoW
Permeable granitine	0,50027	kg	natural stone plate production, cut natural stone plate, cut APOS, S - RoW
Apexed granite	0,50027	kg	natural stone plate production, cut natural stone plate, cut APOS, S - RoW
Polished granite	0,97011	kg	natural stone plate production, polished natural stone plate, polished APOS, S - RoW
Metal grate	2,11938	kg	steel production, low-alloyed, hot rolled steel, low-alloyed, hot rolled APOS, S
Wood	2,66609	m	engineered wood joist production joist, engineered wood APOS, S - RoW
Plastic Wood	2,32495	kg	polyethylene production, high density, granulate polyethylene, high density, granulate APOS, S - RoW
Cobblestone	0,97011	kg	natural stone plate production, polished natural stone plate, polished APOS, S - RoW
Portuguese stone	0,50027	kg	natural stone plate production, cut natural stone plate, cut APOS, S - RoW

Material	Emission factor (kgCO ₂ e/ unit.)	Unit.	Ecoinvent Process 3.6
Natural stones	0,75168	kg	natural stone plate production, grounded natural stone plate, grounded APOS, S - RoW
Hail	0,50027	kg	natural stone plate production, cut natural stone plate, cut APOS, S - RoW
Permeable cementitious floor	0,18610	kg	cement cast plaster floor production cement cast plaster floor APOS, S - RoW
Permeable grass paver	0,18610	kg	cement cast plaster floor production cement cast plaster floor APOS, S - RoW
Tactile floor	0,18610	kg	cement cast plaster floor production cement cast plaster floor APOS, S - RoW
Draining floors in general	0,18610	kg	cement cast plaster floor production cement cast plaster floor APOS, S - RoW
Polyester	5,98927	kg	polyester resin production, unsaturated polyester resin, unsaturated APOS, S - RoW
Porcelain	0,18610	kg	cement cast plaster floor production cement cast plaster floor APOS, S - RoW
PVC	2,48665	kg	polyvinylchloride production, suspension polymerisation polyvinylchloride, suspension polymerised APOS, S - RoW
Clay	0,00869	kg	gravel production, crushed gravel, crushed APOS, S - RoW
Soil cement	0,09266	kg	anhydrite floor production anhydrite floor APOS, S - RoW
Shading fabric	2,24830	kg	polyethylene production, linear low density, granulate polyethylene, linear low density, granulate APOS, S - RoW
Ceramic tiles	0,38574	kg	roof tile production roof tile APOS, S - RoW
Ecological tiles (vegetable fibers)	1,29845	kg	fibre cement facing tile production fibre cement facing tile APOS, S - RoW
Ecological tiles (PET)	3,12806	kg	polyethylene terephthalate production, granulate, amorphous polyethylene terephthalate, granulate, amorphous
Glass	1,02718	kg	flat glass production, uncoated flat glass, uncoated APOS, S - RoW

Table A. Guiding catalog of materials
Source: Own elaboration



9

Replicability
Use by other cities

One of the main premises for the development of IMPROve is that it could be adapted to the use of other cities. In this way, all public managers in such cities may receive access passwords that will allow the entry of data relating to such cities. It is important to remember that the work of parameterization of regionalization data will still be necessary because each city may have specific data to parameterize and must be carried out by specialized professionals.

IMPROve brings in the tabs **5.1 – “Database”** and **5.2 “Auxiliary Data”** the clear signaling of all the information necessary for the personalization of such data. Only managers in possession of the password access to the tool will be able to update such data. Detailed guidance on regionalization updates for other cities can also be found in the **5.3 “Data Update”** tab.

Example:

Estimated number of daily trips of residents of Rio de Janeiro by mode and modal division (%) – 2020		
Mode of Transport	Number of Daily Trips	Modal Division (%)
On foot	3.431.664	26,57%
Bicycle	360.685	2,79%
Car	2.736.148	21,18%
Taxi	128.172	0,99%
Motorcycle	86.046	0,67%
Bus	4.223.751	32,70%
BRT	472.903	3,66%
Van	509.413	3,94%
Truck	124.923	0,97%
Subway	503.214	3,90%
Train	270.835	2,10%
VLT	63.242	0,49%
Boat	5.508	0,04%
TOTAL	12.916.505	100%

Source: Own development of travel projection based on PMUS data



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10

Innovation



11

Expected Results
How to Read the Results

The tool was developed with a tab with consolidated results for better user visualization.

As a first result, the tool presents a consolidated of the project result, considering the following evaluation ranges:

	Positive impact			Negative impact					
	High	Moderate	Low	High	Moderate	Low			
Project result	Greenhouse gas Emissions Positive impact High			Air quality Positive impact Low			Heat island Negative impact Low		

Table 6. Consolidated project result sorted by impact range
 Source: Own elaboration

The results are also detailed by impact analyzed in the project as shown in the following figures.

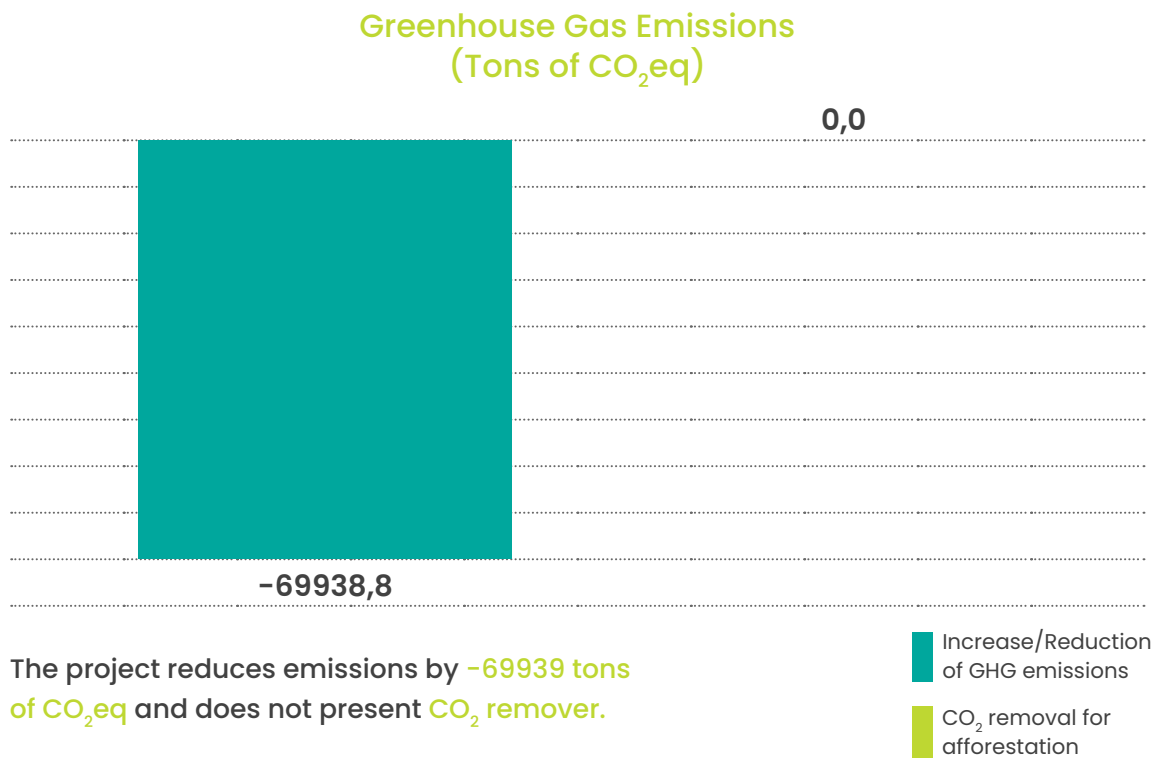


Table 7. Project result in greenhouse gas emissions
 Source: Own elaboration

Air quality

Concentration of local pollutants

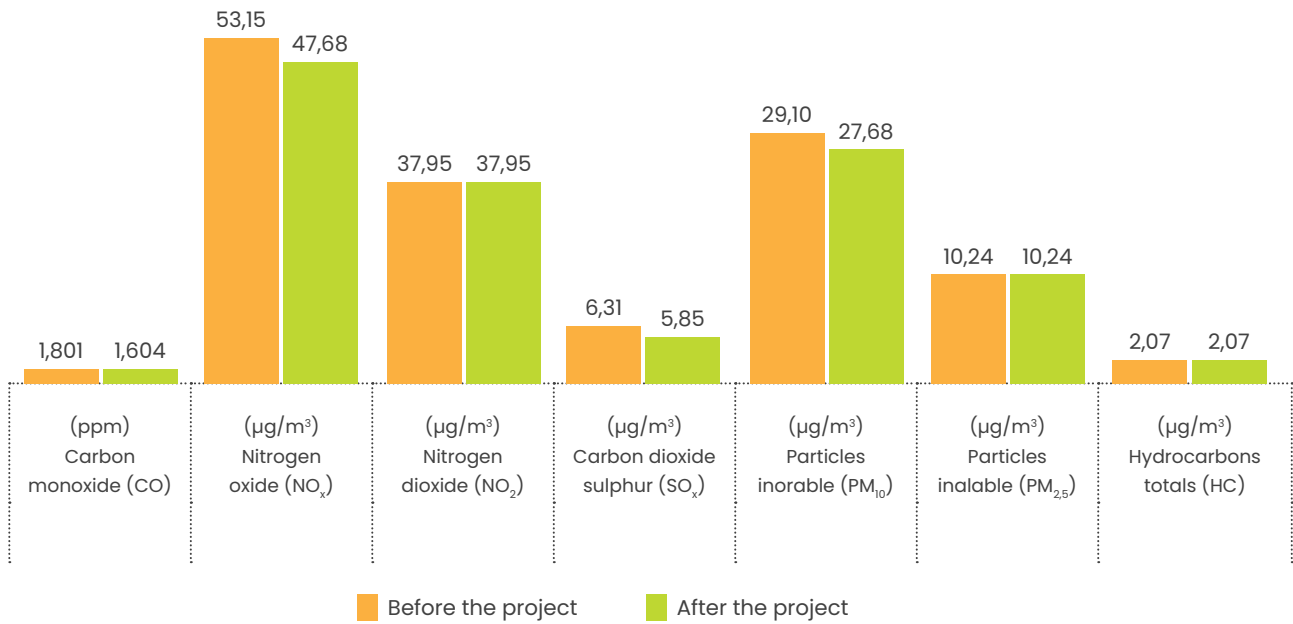


Table 8. Project result in air quality

Source: Own elaboration

For the analysis of results in air quality, the technical recommendations of the SMAC not to consider ozone were followed, because it is a pollutant that is produced through chemical reactions that occur in the atmosphere, not being emitted by a specific source.

Heat Island

Annual Average Temperature (°C)

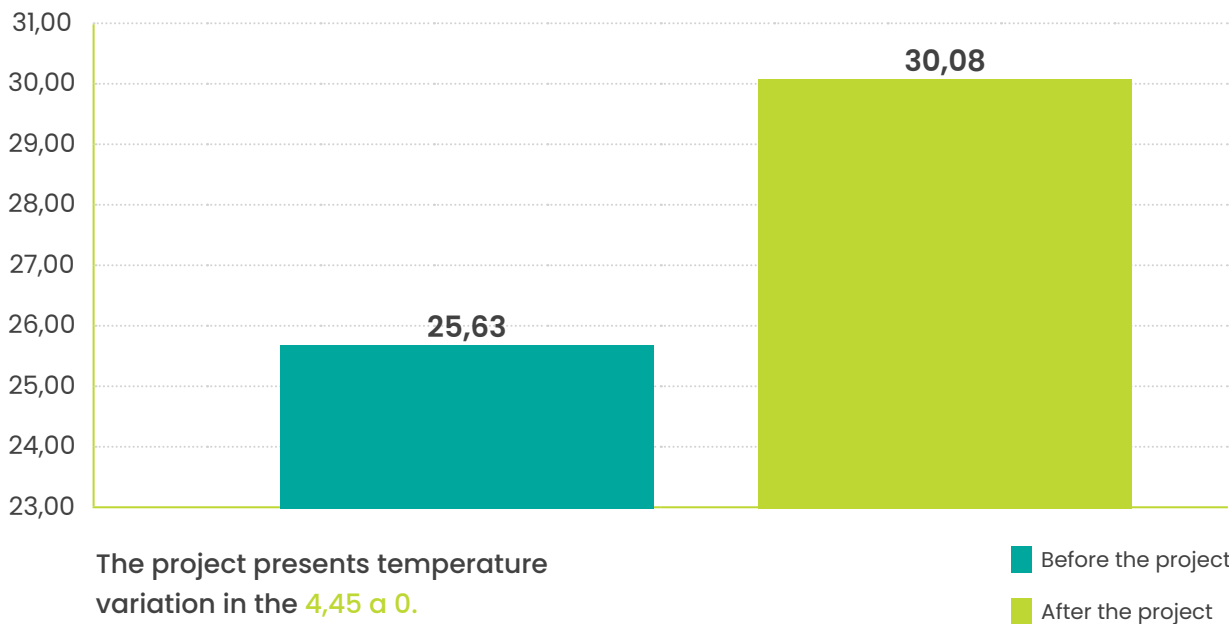


Table 9. Result of the project in Heat Island

Source: Own elaboration



12

Evolution of the project
Next steps

During the development of the IMPROve tool, teams had the opportunity to identify possible features that could be implemented so that the work is constantly improved with improvements and new functionality. Examples:

Permeability

It is possible to think about impacts to be measured by the tool that can affect the permeability of urban areas and reduce flood problems. With inputs on material permeability, green/permeable areas, retention strategies or infiltration it is possible to obtain results that state how much this intervention is contributing positively or negatively to the permeability criterion.

Monitoring / Sensing

During the walk of the work, the importance of data that can safely represent the characteristics and behavior of the city was emphasized. Here is the recommendation for cities to implement strategies for monitoring and storing data that can be accessed and worked on.

Smart cities

One can think of a “Smart Cities” index to be measured by the tool just as it is now able to measure temperature or emissions. Such an index would be powered by information from interventions where, for example, IMPROve asks about number of air quality sensors, vehicle counting, temperature, security (cameras, facial reading, etc.), flooding, connectivity/data networks, among others, before and after the project.

Mobility / electrification

With number of filling stations, lanes or exclusive parking for electric cars, electrified public transport or tolls for combustion vehicles, IMPROve incorporates an electrification index of the intervention area “before x after”

Monitoring of results

It is extremely important that it is possible to check the estimated numbers by the tool! Sensors and measurement strategies should be implemented in the intervention areas so that it is possible to monitor the results and, consequently, calibrate the tool.

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Urban Design Project Impact Tool

