Estimating Climate Impacts: Case Study - Bicycle Sharing Schemes in Colombia
the use of the bicycle has emerged as an effective greenhouse gas emissions. In this context, strengthening deaths and injuries, deteriorating air quality and rising increased motorisation, stagnant traffic, preventable road Colombians cities are facing a mobility system crisis, with several Colombian cities have demonstrated significant progress. Although several Colombian cities have made great efforts to promote cycling, these have focused specifically on the construction of bicycle infrastructure, which has increased the number of cyclists with little impact on motorised trips, particularly short-distance trips that could be done in active modes. Thus, BSS are a great opportunity to increase the modal shift and reduce the number of motorised trips. Because bikeshares reduce some barriers to cycling, for example encouraging the use of bicycles by women, by facilitating travel over short distances which women perform more frequently, and reaching population in low income areas to gain easier access to public transport, it can quickly boost the number of cyclists on the road. This in turn, generates an increase in cycling modal share from cars, thereby contributing to climate change mitigation by reducing individual car use and improving the overall quality of life with citizens experiencing improved air quality, access to mobility, and reduced accident rate associated to motorized modes. Citizens can expect to see improved health, a better quality of life, reduced congestion throughout the city and reduced road infrastructure costs.

Local context
Local governments around the world have taken a leading role in improving conditions for urban cycling and almost all of Colombia’s major cities have goals and mobility plans that project increased cycling trips, extensions of the cycle-infrastructure network, implementation of public bicycle systems and promotional activities. While this support exists, the current state of conditions for urban cycling is not encouraging, and cycling is estimated to be in decline in several cities due to poorly designed cycle-infrastructure networks and worrying figures of rises in deaths and injuries in several cities in the country. Despite ambitions and several pilot projects, the only urban-scale public bicycle system in operation is Encicla in Medellin. In order to make bicycle use more widespread and to guarantee user safety and comfort, there is an urgent need to carry out quality projects, expanding and improving infrastructure and providing efficient and useful public bicycle systems. The Bogotá portion of the project will consist of approximately 2,300 bicycles in 200 stations, while Bucaramanga, Cali and Montería will respectively consist of about 583, 1088 and 690 bicycles.

Objectives of the project
Cycling cities are facing a mobility system crisis, with increased motorisation, stagnant traffic, preventable road deaths and injuries, deteriorating air quality and rising greenhouse gas emissions. In this context, strengthening the use of the bicycle has emerged as an effective sustainable transport strategy, and several Colombian cities have demonstrated significant progress.

The C40 Cities Finance Facility (CFF) supported a cluster of public Bike Sharing Systems (BSS) projects, in the Colombian cities of Bogotá, Cali, Medellin and Bucaramanga. Public bike sharing systems bring a convenient and affordable means of transportation to a city, significantly increasing the share of cycling and its corresponding benefits within the city. Public bike sharing systems are a key component of transportation plans of the participating cities and their long-term vision for strengthening cycling and non-motorized transport modes. At the national level, a policy has been designed to promote active transport, within the framework of the Colombian Nationally Appropriate Mitigation Actions (NAMA) for Active Transport and Demand Management - NAMA TanDem. This NAMA has defined 8 measures among which is the implementation of BSS, with a high potential to reduce motorized trips and reduce greenhouse gas (GHG) and air pollution emissions.

General methodological considerations
The emission mitigation potential for a project is determined by comparing the difference in GHG emissions generated in the baseline scenario and the project scenario. The baseline scenario is calculated using parameters that describe the context conditions assuming the planned intervention (the cycle hire scheme in this case) is not implemented. The project scenario reflects any changes in conditions that the planned intervention will create. For cycle hire scheme projects the baseline scenario emissions for a given year are calculated from the emissions that would have been created by the cycle scheme passengers if they continue to use their current mode of transport instead of the bicycles. The definition of the baseline starts by estimating the number of passengers that will use the bicycles and the mode of transport they currently use. Then, the number of annual passenger kilometres travelled for each mode of transport is calculated, using the community’s average bicycle trip distance for each city. The emissions are then calculated by applying an emissions factor (amount of emissions per unit of fuel used) to each mode of transport.

The project scenario emissions for a cycling project are zero, as human powered bicycles do not consume any type of fuel.

The methodology used is based on the UNFCCC Clean Development Mechanism (CDM) methodology on “Baseline emissions for modal shift measures in urban passenger transport” (Tool 18). Baseline emissions are calculated using the emissions that would have been caused by cyclists if they had not changed modes of transportation. Emissions are calculated using the share of passengers shifting to the proposed project, emission factors per passenger-km for each vehicle type, the average cycle trip distance travelled and daily cycling ridership. Project emissions for the PSS are assumed to be zero.

More detailed documentation and discussion of the methods used in the calculation (including equations definition of terms) can be found in the document 'Estimating Climate Impacts - A Methodology for Estimating GHG Emission Mitigation Potentials of Infrastructure Projects'.

Baseline scenario data
For the Colombian public bikeshare scheme projects, the baseline scenario assumes that the daily BSS users would continue their normal forms of transport instead of the public bicycles.

To estimate mode shift towards cycling for the Colombian cities, a variety of sources were used:
• For Bogotá, values were provided by the city’s transport experts’ consultation panel which forecasted the mode shift towards the Quinto Centenario Bikenway project.
• For the other cities, as project-level data was not available mode shift was extrapolated from regional proxies and local mode share data.

The community’s average trip distance for Bogotá and Cali are taken from the NAMA TanDem study, where it is reported that the average length of a cycling trip with public bicycles is 5.5 km for a big size city (Bogotá or Cali).

The community’s average trip distance for Montería and Bucaramanga are taken from the results of the pilot studies of the BiSuru Montera cycle hire scheme and the Metropabi Bucaramanga cycle hire scheme, where it is reported that the average length of a cycling trip with public bicycles is respectively 315mm and 38km.

Two other important factors are the fuel share distribution (e.g. percentage of gasoline or diesel) and the fuel efficiency of the baseline vehicles. These parameters are assumed to evolve between 2021 and 2030 and then are held constant afterwards due to a lack of detailed technology trend forecasts beyond that point. The values used are based on a mid-range scenario of GHG savings, developed for the Ciclo Alameda Medio Milenio (CAMI) cycle highway project during a workshop of transport city experts hosted by the CFF in Bogotá that aimed to support city officials to assess emission reductions from the CAMI project. Vehicle fuel share and vehicle fuel efficiency are considered as city or country-specific therefore these values can be used in all the BSS project with confidence.

Lastly, in order to calculate the emissions, baseline travel data is multiplied by vehicle and fuel specific GHG emission factors. The emission factors used for this evaluation come from the Factores de Emisión de los Combustibles Colombianos (FECOC), 2016 Calculator, a tool by developed by the mercantile stock exchange and the environmental business corporation organisation, which reports factors relevant to the Colombian energy market.
Project scenario data

As previously mentioned, the projects will include the installation of approximately 2,300 public bicycles in Bogotá, 1,088 in Cali, 583 in Bucaramanga and 690 in Montería. The number of bicycles per system was estimated by evaluating the average distance between bicycle system stations of several similar size cities with bike-sharing systems, the average number of bicycles per station and the area selected for the bike-sharing service in each city.

To forecast the daily demand of the systems for each city, data from similar size cities and their BSS were used:

• For Bogotá, a factor of 5.3 trips per day per bicycle is used.
• For Cali, a value of 3.27 trips per day for each bicycle in the system was used based on other large cities’ BSS.
• For cities of similar size to Montería, the average number of bicycles is around 3.9 trips/bicycle, which is compatible with the ITDP’s minimum reference value of 4 trips/bicycle.
• For cities of similar size to Bucaramanga, the average number of bicycles is around 3.3 trips/bicycle.

These fleet’s utilisation factors lead to approximately 12,790 BSS users per day in Bogotá, 3,558 in Cali, 2,760 in Montería and 1,924 in Bucaramanga.

Daily ridership is annualised using a factor of 365.25. It is also assumed that bicycles will be used both for commuting on weekdays as well as for leisure over the weekend. An important assumption is also that with the installation of this BSS, the demand for public bicycles is met in 2021 and does not changing significantly, apart from modest population increases. Figures are therefore projected in the years beyond 2021 using Colombia’s population growth index.

Results and emission reductions

This sub-section provides an overview of the GHG emissions impact for each project. The calculations are completed for each year of operation from 2021 (the assumed initiation year) to 2050 (the final horizon year for the analysis). Table 1 describes the estimated emission mitigation values for each Colombian cycle hire scheme project.

The cumulative mitigation impact for 2021 to 2050 is 34,481 tCO₂e for the Bogotá BSS, 8,960 tCO₂e for Cali’s BSS, 1,949 tCO₂e for Bucaramanga and 4,867 tCO₂e for the Montería, which demonstrates the projects’ total potential to reduce GHG emissions and contribute to global climate protection efforts.

The magnitude of the GHG mitigation impact is influenced by the project’s implementation parameter and context conditions. For the Colombian cities’ projects, the mitigation potential is primarily dependent on the number of bicycles available in the BSS, their relative ridership, the baseline transport modes and their fuel share.

The emission savings are limited by the smaller fleets implemented in Cali, Bucaramanga and Montería. Bogotá, having the biggest fleet procured and highest forecasted bicycle utilisation factor has bigger emission savings due to the higher levels of anticipated ridership.

It is also important to note that the mitigation impact of all the projects is heavily influenced by the riders’ origin mode, which for every BSS has a very high percentage of non-motorized transportation (38% on average) and a high percentage of public transportation (27% from buses, 20% from BRT). Targeting specific citizens and sectors and achieving a higher portion of mode shift from passenger automobiles (currently at an average of 8%), taxi (10%) and motorcycle (12%) would increase the GHG savings potential of these projects.

<table>
<thead>
<tr>
<th>Project</th>
<th>2021 Annual Reduction</th>
<th>2050 Annual Reduction</th>
<th>Average Annual Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogotá</td>
<td>1,230 tCO₂e/year</td>
<td>1,232 tCO₂e/year</td>
<td>1,149 tCO₂e/year</td>
</tr>
<tr>
<td>Cali</td>
<td>365 tCO₂e/year</td>
<td>283 tCO₂e/year</td>
<td>299 tCO₂e/year</td>
</tr>
<tr>
<td>Bucaramanga</td>
<td>87 tCO₂e/year</td>
<td>61 tCO₂e/year</td>
<td>65 tCO₂e/year</td>
</tr>
<tr>
<td>Montería</td>
<td>169 tCO₂e/year</td>
<td>184 tCO₂e/year</td>
<td>162 tCO₂e/year</td>
</tr>
</tbody>
</table>

Table 1 - GHG mitigation impacts of the bicycle sharing systems
Challenges and lessons learned

In this section, a summary of the process of the GHG assessment is presented highlighting the challenges encountered and the solutions adopted which could be utilised by other practitioners.

Preliminary estimates

The biggest challenge encountered in the GHG assessment of the BSS projects was the data collection process. When the preliminary calculations were developed, most projects were still in the design phase which meant that project specific data, such as size of bike fleets, average distance cycled, and mode shift was not available. Bogotá was the exception to this, where extensive data was available because of ongoing support from the CFF for the Ciclo Alameda Medio Milenio (CAMM) project and higher quality of data already available to the city.

To complete the preliminary estimates for Cali, Montería and Bucaramanga, many assumptions had to be made:

- For the preliminary estimate, the overall community transport mode share was used instead of using data specific to BSS users’ origin (pre-project) mode. In the final estimate, global proxy data regarding the typical origin of BSS users, reported in the NAMA TanDem study, was used;
- The size of the bicycle fleet for each city was estimated using the cities’ population and a proxy value from the NAMA TanDem study that suggests a value of 2.6 public bicycles per 10,000 inhabitants;
- The average distance cycled was sourced using proxy data from the NAMA TanDem study, as a function of cities’ size;
- The fuel share of the transport modes used was the Colombia average, from the C40 Pathways database;
- The fuel emission factors used were IPCC standard values.

The lack of project specific data for the above parameters, created a low level of confidence in the early estimates. This demonstrates how performing a GHG assessment before key design parameters are defined is a lengthy and less accurate process.

Update of the data collected

Pilot BSS studies in the cities of Montería and Bucaramanga helped refine the data used for the initial estimates, providing project-specific data for both cities and in some cases, proxy data for Cali.

However, project level data was not available for all data items. Those gaps were filled with proxy data from a diverse range of sources. The existence of the NAMA Framework on cycling projects in Colombia proved very useful in providing that default data, in particular for average trip distance.

Mode shift

Mode shift, or the share of trips from origin modes, is a critical parameter in determining the impact of the project. Outside of Bogotá, no community/project-specific data was available, and this parameter had to be approximated from a mix of city data and characteristics from other cycling projects in the region.

The analysis was performed in three steps:

1. Determining the attraction factor per origin mode, i.e. how the share of trips that will be diverted to the cycling project relative to the modes of transportation currently used in the city. This attraction factor represents a change of behaviour effected by the project. It was assumed that this attraction factor would be broadly similar across Latin America and extrapolated from other cycling projects in Mexico City and Guadalajara;
2. Obtaining baseline mode share data for each target city (Bucaramanga, Cali and Montería), representing current trips being taken in the city;
3. Applying the attraction factor to the mode share for each of those modes used in the baseline.

Average distance travelled

A Latin American regional proxy for the average distance travelled for BSS trips was initially used for this analysis. Regional proxies can often serve as an acceptable source of information when local data is unavailable. However, in this case, the data source was relying heavily on Brazilian cities, which often have different city structures, sizes, and environmental characteristics (e.g. topography) compared to Colombian one.

The collection of city specific data for Montería and Bucaramanga showed that use of the proxy data was leading to the underestimation of the average distance travelled by 20% and 50% respectively.

Given this significant variation, the data used for Cali and Bogotá, was taken from the NAMA studies. This was justified because proxies outside of Colombia would be unlikely to reflect the behaviour of Colombian bike-sharing systems and a country specific study would be more representative of the two biggest cities’ values.

Ridership

Ridership, or trips taken per day for a bike sharing system, is often difficult to estimate. Estimation requires extensive surveys of the targeted population and projections can often vary from real post implementation data.

In this case, the ridership was calculated from the number of bikes in service, using the ratio of trips taken to bikes in service from an analysis of global bike-share systems. This analysis spanned a wide diversity of cities, with varying climates, fleet sizes and cycling behaviours and is therefore not necessarily representative of the Colombian context.

However, the data provided did take into account the size of cities considered, giving some level of granularity to the analysis.

When using proxy data, especially if it is not country or region specific, it is always useful to test it against comparable cities to check its accuracy for the analysis. For those projects, this data was compared to ridership data for Medellín, which is the only Colombian city for which ridership data was reported for public bike-sharing systems. This analysis showed that the values used (2 to 5.3 trips/day/bicycle) were conservative when compared to ridership in Medellín (8 trips/day/bicycle).

In summary, accurate estimation of project GHG mitigation potential relies on the availability of project-specific data. Ex ante estimates should ideally be conducted at later project design stages when the system is defined well enough to provide the necessary data. When project-specific data is not available then careful consideration of proxy values must be made.

Acknowledgements

This report was written by Laura Frasconi and Antoine Jallet, of the C40 Cities Climate Leadership Group. Others who provided suggestions on the structure and content of this report include Culley Thomas & Oliver Walker.
