An integrated and comprehensive tool to assess urban mobility strategies

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Abstract. Transport planning is a challenging topic to be addressed in urban areas in order to create sustainable cities, due to the adverse health effects, noise and congestions generated by the transport sector. Therefore, policymakers require technical tools that allow to take regulatory transport decisions, considering environmental and health impacts. This work presents the development of an integrated and comprehensive tool to assess urban mobility strategies called MAITec. The methodology includes the implementation and application of specialized software to estimate health impact by transport emissions. The tool was implemented in a university district in Mexico. Results indicate that in the base scenario, people are exposed to high pollutant concentrations in some sectors of the distric, where traffic pollution claims approximately 9 lives every two years. MAITec was implemented in a free online platform and shared with local governments for its application.

Keywords: sustainable mobility, health impact, air pollution

1. Introduction

Mobility is a key component to achieve sustainable development. Over 55% of people worldwide live in cites and by 2050, it is expected that two-thirds of the world's population will be living in urban areas (United Nations, 2018). In terms of environmental aspects, transportation is the second largest oil consumption worldwide, and it is responsible for 24% of global CO_2 emissions (IEA, 2020). Furthermore, within urban areas, mobile sources have the highest emissions of nitrogen oxides (NOx) and carbon monoxide (CO). The exposure to air pollution causes adverse health effects including morbidity and premature mortality (Nieuwenhuijsen et al., 2017).

The transport sector requires well-designed and efficient urban planning and long-term policies on transport decarbonization to move towards a sustainable mobility. Some the recommended strategies are: lowering energy intensity by introducing electric vehicles, modal shift by increasing investment in public transport, avoiding journeys, among others. Due to sustainable mobility is a multidimensional issue, there are diverse approaches and tools to assess mobility strategies. There are decision support tools focused on the policy selection considering economic and social aspects (Damidavičius et al., 2020; Szimba et al., 2018), and those based on simulators (Horni et al, 2016; Waddell, P., 2011). However, there are few tools that includes environmental and health impacts to evaluate mobility strategies in urban areas.

Considering the need of policymakers to assess mobility policies previous their implementation, including environmental and health impacts as relevant indicators to select the mobility strategies to be implemented, this paper provides an integrated and comprehensive tool called MAITec (Mobility Assessment and Insights from Tecnologico de Monterrey) to assess urban mobility strategies in a full-chain assessment. MAITec is a scenario-planning framework that integrates, for first time, a microsimulation model (SUMO), a vehicle emission model (MOVES), an air quality model (AERMOD), and a methodology to evaluate air quality and health impacts of mobile strategies in urban areas. This tool has been designed to be useful for policymakers, considering pre-defined transport policy measures that can be evaluate by local authorities in order to select efficient mobility policies. MAITec is available in a virtual platform (https://maitec.info/app). This paper shows the developed of MAITec and its application in an university district in Monterrey, Mexico.

2. Methodology

2.1. Tool structure

MAITec consists in two main elements: eight layers that represent the modeling framework and a user interface available via web (https://maitec.info/app). Figure 1 shows the modelling framework to assess the mobility strategies, which have eight layers: location and demography, mobility infrastructure, vehicle fleet and fuels, mobility

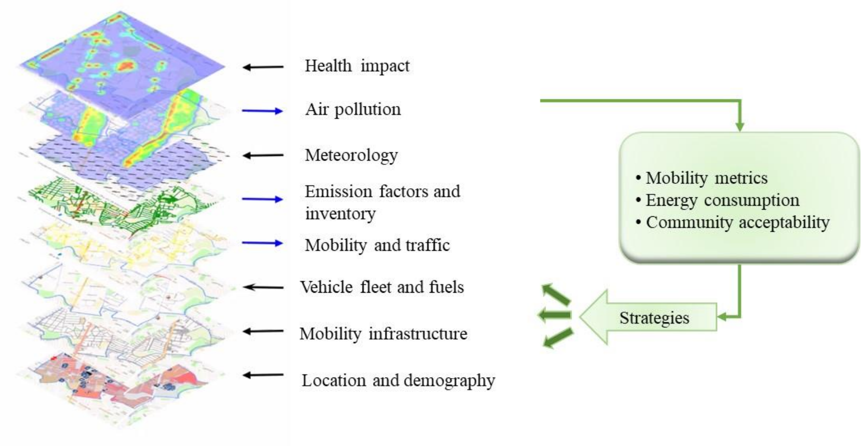

Figure 1. Structure of MAITec

and traffic, emission factors and emission inventory, meteorology, air pollution and health impact. Table 1 describe each of the layers.

MAITec has been designed with pre-defined transport policy measures such as electromobility, bike routes, modal integration of transport and reorganization of public transportation. However, these mobility strategies are still in process to be implemented.

Table 1. Brief description MAITec's layers

Layer	Description
1. Location and demography	Defines the geographical delimitation, the population distribution, and the topography of the area of interest
2. Mobility infrastructure	Comprises a quantitative description of the conditions of the roads based on the next criteria: road coating, pavement conditions, road quality according to the damages observed on the road, signaling, accessibility, traffic lights, and levels of service for road transportation
3. Vehicle fleet and fuels	Reports characteristics of the vehicle fleet based on: i.) the vehicle distribution by vehicle categories ii.) the vehicle activity as a function of the kilometer traveled, and iii.) the fuel quality describing the chemical and physical characteristics of the fuels
4. Mobility and traffic	Comprises three main elements: i.) the driving cycle obtained by micro-trips, ii.) application of the Urban Mobility Index – UMI (Moeinaddini et al., 2015) and, iii.) the implementation of a traffic microsimulation by the Simulator of Urban Mobility (SUMO).
5. Emission factors and emission inventory	The Motor Vehicle Emission Simulator (MOVES) for Mexico was executed to estimate the emission inventory for carbon dioxide (CO_2), carbon monoxide (CO), particulate matter with aerodynamic diameter less or equal to 2.5 µg/m^3 and 10 µg/m^3 ($PM_{2.5}$ and PM_{10}, respectively), hydrocarbons (HC), and nitrogen monoxide (NO). An emission inventory was estimated based on the emission factor adjustment through the NO, CO and HC measures by a Remote Sensing Device (RSD).
6. Meteorology	The Weather Research and Forecasting (WRF) model was implemented to estimate the meteorological conditions during 2019.
7. Air pollution	Includes the execution of two models: AERMOD, a gaussian air quality model suggested to take regulatory decisions (US EPA, 2020) and ANSYS FLUENT v2020 a Computational Fluid Dynamic (CDF) software.
8. Health impact	For the estimation of the health impact by air pollution the suggested probabilistic model by SEMARNAT (2012) was implemented. This model considers the dose-response function defined by Martínez-Muñoz et al. (2020) for Monterrey, which express risk of mortality.

The data collected in layer 1, 2 and 3 was used as input data for the implementation of the traffic simulator SUMO (layer 4). The results of the traffic microsimulation were employed as an input data for MOVES software in layer 5. Likewise, MOVES results were used as emission input data for the AERMOD air quality model (layer 7), which also used as input data the meteorological information of layer 6. Finally, health impact was estimated based on pollutant concentrations, which were the results from the air quality model.

MAITec was implemented in Distrito Tec a university district of Tecnologico de Monterrey, located in Monterrey, the third largest city of Mexico (INEGI, 2014). In this case, it was developed the base scenario, which includes all modes of transportation in Distrito Tec.

3. Results

Location and demography: Distrito Tec is an area of 3882.7 m^2 divided in 24 neighborhoods. This space has a university campus that houses 300 students with a total of 16.962 inhabitants.

Within Distrito Tec, it is estimated 58.345 daily trips. Figure 2. shows the geographical distribution of people within Distro Tec, including places of interest such as bus stations, parking lots, among others.

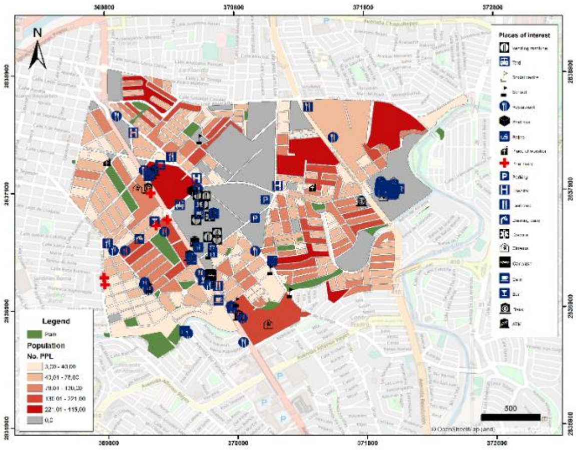

Figure 2. Geographical distribution of people and places of interest in Distrito Tec.

Mobility and infrastructure: Distrito Tec has a total of 142.96 km of roads. The following classes have a higher coverage: residential roads 48.02%, tertiary road 18%, service road 14.36% and trails with 9.09%. The analysis of the road quality showed that 27.8% of the roads requires intervention for their improvement and today, only 40% of the area has access for people with disabilities.

Vehicle fleet and fuels: Within the Monterrey metropolitan area (MMA), the vehicle distribution is led by light-duty vehicles (74%) and with a low proportion of hybrid and electric vehicles (0.026%). In Distrito Tec are registered around 2 million of vehicles with an average age of 13 years. This area has 6 gasoline stations and 2 charging stations for electric vehicles.

Mobility and traffic: The representative driving cycle for MMA was estimated, finding an average speed of 10.94 m/s, a specific fuel consumption of 8.17 l/100km-ton and other 17 characteristic parameters. The UMI reach a value of 24.79, which means that Distrito Tec has a low sustainable mobility, mainly based on private vehicles. Finally, SUMO simulation showed that in Distrito Tec, the average speed of vehicles is 36.7 km/h and 76% of the trips are made by private vehicle, 1% by bicycle, 8% by public transport and 15% by other modes of transport.

Factor emission and emission inventory: Table 2 and 3 show the results of factor emissions for MMA and the emission inventory for Distrito Tec.

Meteorology: During 2019 the prevalence wind comes from the south-east with speed wind between 3.8 and 5.7 m/s. The relative humidity varied between 39% to 65% and the temperature ranged between 16.16 ºC and 29.85 ºC. The wind rose and the monthly average values of relative humidity and temperature can be visualized in MAITec platform (https://maitec.info/app).

Table 2. Factor emissions in MMA

Pollutant	Factor emission (g/km)				
	Type of vehicle				
	Trucks	Buses	Motor cycle	Taxis	Private vehicle
CO	35,3	33,8	17,1	15,8	13,6
NO	7,0	3,1	0,5	2,6	1,2
HC	3,7	7,8	1,6	4,5	2,8
CO2	1246,6	1274,6	327,1	443,6	443,6
PM2.5	0,0119	0,0128	0,0175	0,0135	0,0135
PM10	0,0135	0,0145	0,0197	0,0153	0,0153

Table 3. Emission inventory for Distrito Tec

Pollutant	Emission (ton/year)				
	Total	Private vehicle	Trucks	Buses	Motor cycle
CO	389,73	263,07	87,69	33,13	5,85
NO	36,81	24,85	8,28	3,13	0,55
HC	80,29	54,19	18,06	6,82	1,2
CO2	13053	8811	2937	1109	195,8
PM2.5	0,332	0,224	0,075	0,028	0,005
PM10	0,375	0,253	0,084	0,032	0,006

Air pollution: Results from AERMOD and CDF shows that the higher pollutant concentrations are located near to roads under conditions of low wind speeds and high emissions. The maximum annual concentration of $PM_{2.5}$ was 19.9 µg/m^3 which exceed the annual air quality standard (12 µg/m^3) (Secretaria de Salud, 2014). The pollutant dispersion can be visualized in MAITec platform (https://maitec.info/app).

Health impact: Figure 3 shows the number of relative cases of health impact by $PM_{2.5}$ pollution. It is estimated that in Distrito Tec the traffic pollution claims approximately 9 lives every two years due to respiratory and cardiovascular systems diseases.

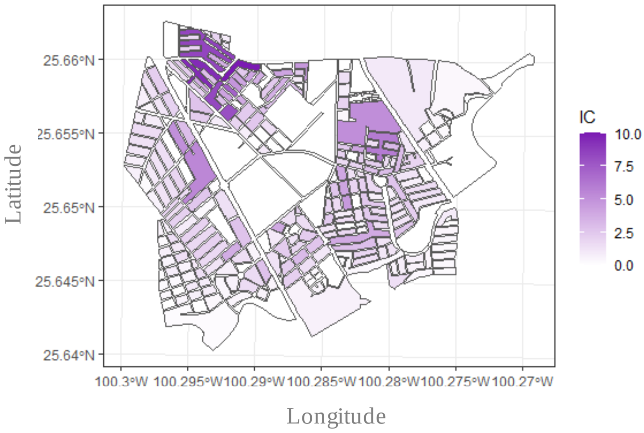

Figure 3. Health risk index (IC) within Distrito Tec by $PM_{2.5}$ pollution. The highest the index the highest the health risk.

4. Conclusions

MAITec is an integrated and comprehensive tool that includes sophisticated models, which allow to assess the health impact of transportation systems at micro and mesoscale level. The structure of MAITec allows to implement diverse mobility strategies and compare their environmental and health effects. Therefore, this tool is an useful and friendly platform that contribute to take regulatory decisions based on scientific knowledge.

MAITec was implemented in Distrito Tec. Results showed that even $PM_{2.5}$ emissions are lower respect to the emissions of other pollutants like CO and NO, the current $PM_{2.5}$ concentration claims approximately 9 lives every two years. It implies that within Distrito Tec there are diverse mobility strategies that could be implemented to reduce the risk of mortality.

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