Use of Technology for Better Understanding of Cities

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Abstract

The transformation of cities is key to achieve the Sustainable Development Goals (SDG) in the near future. The worsening climate crisis urges to long-term solutions which orientate the development of cities to be more sustainable and livable spaces. Urban planning remains as a complex task and, therefore, benefits from the use of technology to better assess the actual needs of cities and find the best way to conjugate the already existing resources towards smarter and more accessible places. Hence, this study focuses on the implementation of UrMoAC, a tool developed by the German Aerospace Center, to obtain useful data about the San Francisco Bay Area which in return can be utilized to shape and guide planning processes oriented to promote urban accessibility and the SDG. The results demonstrate that the urban areas of San Francisco Bay Area have good accessibility levels to public primary schools and help to understand the dynamic environment of the cities involved and plan accordingly to create smart mobility.

Keywords
Climate change, urban analysis, technology, UrMoAc, smart mobility.

1. Introduction
Cities around the world need immediate transformation to meet the Sustainable Development Goals (SDG), defined by the United Nations. The SDG are an urgent call for action from all countries as a result of a global partnership. They provide a shared blueprint for peace and prosperity for people and the planet, now and into the future (United Nations 2015). Therefore, immediate changes need to be made in the way cities are planned and structured. Planning plays a significant role in both climate change mitigation and adaptation. Two of the largest contributors of greenhouse gases - transportation and buildings - are influenced by planning decisions and policies (American Planning Association 2021).

However, to design and plan a city is necessary to know how the city operates. Since information and communication technology affects positively urbanization and directly improves urbanization levels and efficiency (Wang, 2021), technology should be used as a new methodology for urban analysis and transformation This paper presents Urban Mobility Accessibility Computer (UrMoAc); it is a scientific tool for computing accessibility measures, supporting aggregation, variable limits, and intramodality (Krajzewicz et al. 2017) developed by the Institute of Transport Research of the German Aerospace Center. It allows to know in a quantitative and empirical way the performance of a city, considering the urban structure of the city, the urban morphology, the transport modes, the different destinations, and the variability of traffic depending on the time in which it is transited. This tool is easy to use, so cities all over the world can make use of it, as well as make analysis at different scales (metropolitan areas, counties, cities, etc.). Knowing the accessibility of a city is a step forward towards smart mobility and it can help the decision makers to have a guide of what needs to be done to improve the urban environment for citizens, in terms of security, air quality, economic opportunities, etc.

In this study, we will analyze the usefulness of the UrMoAc tool to visualize variables such as travel time and distance to essential destinations, such as an elementary school, and how they can influence climate change, since longer travels imply greater CO_2 emissions.

1.1 Objectives

This paper will analyze the use of technology to plan and design cities in a sustainable way. It will also analyze the UrMoAc as a tool to know the operability of a city considering its urban structure, morphology, transport modes and destinations.

2. Literature Review

Climate affects nearly every aspect of our lives, from our food sources to our transport infrastructure, from what clothes we wear, to where we go on holiday. It has a huge effect on our livelihoods, our health, and our future (National Centre for Atmospheric Science 2020). Unfortunately, in the past years we have observed that global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years. Additionally, temperatures during the most recent decade (2011–2020) exceed those of the most recent multi-century warm period, around 6500 years ago (0.2°C to 1°C relative to 1850–1900). It is unequivocal that human influence has warmed the atmosphere, ocean, and land. For this reason, rapid and widespread changes have occurred in the atmosphere, ocean, cryosphere, and biosphere (Allan et al. 2021).

For years, the focus on the world's response to climate change has been on nation states, which have been mostly unsuccessful in brokering comprehensive agreements or acting (Rosenzweig et al. 2010). Cities, by contrast, are preparing risk assessments, setting greenhouse-gas emission reduction targets, and pledging to act. Urban areas of cities, home to more than half of the world's population, are emerging as the 'first responders' in adapting to and mitigating climate change (Rosenzweig et al. 2010).

According to the European Commission (2013) the definition of smart cities is those which best use modern, integrated technology services and infrastructure in energy, transport, and ICT to respond to the social and economic needs of society. The development of smart cities offers benefits on the environment, climate change and people's quality of life as they align with the SDGs. Some benefits are security, environment and transportation, home energy management, educational facilities, tourism, and citizens' health (Khatoun 2016)

The concept of smart mobility emerged with the popularity of smart cities. Some of the essential factors of smart mobility are a reduction in traffic congestion and new route optimizations with reduced ecological footprint (Paiva et al. 2021). Although, mobility is one of the most difficult topics to face in large metropolitan areas. It involves environmental, social, and economic aspects and needs both high technologies and virtuous people behaviors (Benevolo et al. 2015).

For this reason, urban planning plays a critical role in the designs of cities. Urban planning is recognized as an interaction between the state and society, which aims to articulate public policies in the territory, facilitating their administration in favor of greater development and well-being of society. However, this interaction becomes complex because consumption demands increase, and the carrying capacity of the urban ecosystem to supply them is exceeded, hindering its sustainable functionality (Ramirez et al. 2021).

Technology has always played a significant role in shaping cities, because when urbanism interacts with technology, it is not only about the outcoming products but also new forms of systematic thinking (Yang 2020). One technology that has been developed recently that can help with many of these issues is UrMoAc. This software is a command-line tool for calculating so-called contour accessibility measures at a very fine level of detail, taking into account individual buildings and the transport network. (Krajzewicz et al. 2017). It has been used as a high-performance routing program to achieve more accurate results on average travel distances for each zone based on all potential destinations for the city of Berlin, Germany, and Mexico City, Mexico (Heinrichs 2021). Also, to measure accessibility to main destinations using walking and cycling as the main transport modes in the city of Monterrey, Mexico (Gaxiola-Beltran et al. 2021).

3. Methods

The methodology to make use of the UrMoAc tool is first the acquisition of data since it is essential to have all the information to make the calculations. The necessary data are the origins (blocks or urban blocks), the destinations (schools, hospitals, stores, etc.) and the road network. Some benefits and features that UrMoAc offers for data inputs are（Krajzewicz et al. 2017）:

- Input is read from databases or files (CSV);
- Variable sources / destinations;
- Variable aggregation options;
- Weights for sources and destinations;
- Flexible limits for search: max. time, max. distance, max. number, max. seen value, nearest only;
- Support for different transport modes, as well as intermodal accessibilities;
- GTFS-based public transport accessibility computation;
- Possibility to read time-dependent travel times (for motorized individual traffic);
- Support for data preparation and visualization.

The data we collected for this study is from the San Francisco Bay Area, United States. This region contains 101 cities that are in nine counties on approximately 7,000 square miles of land. Ranked by population, the Bay Area is the fourth largest metropolitan area in the United States, with 7.7 million residents (Metropolitan Transportation Commission, 2021). The nine counties comprising the San Francisco Bay Area are: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma (Metropolitan Transportation Commission, 2021). More information of the data gathered can be found in section 4 "Data collection" in Table 2.

There are other parameters that must be specified by typing them directly when running the program, such as the transport modes, the routing time (time where the measurement is done), and the map projection. In this study, the transport mode used is motorized individual transport (cars and motorcycle) with a speed corresponding to the maximum limit of the road, and the geometry is EPSG:3857, which uses the meter as the base unit. More information about this criterion is in Table 1 in the data collection section.

Next, it is required to perform a pre-processing of this information before running UrMoAc. It is necessary to define the area of interest and upload all the information into a database, the use of PostgreSQL is recommended, so that the tool can access it.

Then, make all UrMoAc calculations deemed necessary. There are several ways to obtain the results, some options are average distance, average travel time and average number of collected destinations, depending on the study's needs. More information can be found in Table 6 in the "Numeric Results" section. In this study, the motorized individual transport (cars or motorcycles) to the nearest public school will be analyzed, considering a travel speed equal to the road limit, because there is no public data on the average speed per road by time of day, to obtain the average distance and travel time.

Finally, visualize the results with the help of applications such as QGIS. Maps should be generated to facilitate the understanding of the results and observe trends within the defined area. It is suggested to represent the data with an adequate level of aggregation such as Block Groups or basic statistical unit areas.

4. Data Collection

As mentioned before, certain datasets are needed to run UrMoAC successfully. Table 1 describes the minimum data required as well as examples and the file extension where the data should be saved.

Table 1. Data description.

Data (Krajzewicz 2017)	Description	Examples	File extension
A list of (at least one) origin, read from a database	From these places the program will perform all the calculations.	Blocks for Mexico or urban blocks for United States	.csv or .shp
A list of (at least one) destination, read from a database	Economic entities (hospitals, schools, stores, businesses, etc.)	National Statistical Directory of Economic Units (DENUE for its acronym in Spanish) for Mexico	.csv or .shp
A road network, read from a database	All the streets to be considered for the calculations.	It's recommended to use information from OpenStreetMap website	.osm recommended

The mode of transport to use, defined on the command line	The mode of transport to be considered for the calculations	Motorized individual transport, bicycle, walk, public transport, intermodal, etc.	GTFS (if public transport is used)
The routing time, defined on the command line	Data will be considered at this time.	28800 (8:00 AM represented as seconds passed since the beginning of the day. It is considered because is the "peak hour")	-
The map projection, defined on the command line	The geometry considered for the calculations	EPSG number	-

Table 2 shows information of the databases used in this study, the institutes that published them, and the URLs.

Table 2. Information of the databases used for this study.

Variable	Database	Institute	URL
Blocks	2020 Census Redistricting Data	United States Census Bureau	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Block groups	2020 Census Redistricting Data	United States Census Bureau	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Counties	2020 Census Redistricting Data	United States Census Bureau	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Road network	OpenStreetMap	OpenStreetMap	https://download.geofabrik.de/north-america/us/california/norcal.html
Public elementary schools	California schools 2020-21	California State Geoportal	https://gis.data.ca.gov/datasets/CDEGIS::california-schools-2020-21/explore

Before using any database, it is important to corroborate that it satisfies the specific format requested by UrMoAc. For the road network, if OpenStreetMap's file is used, the tool has scripts for preprocessing this data according to the specific format required and the delimited area of study.
The format for the origins, destinations, and aggregation areas (if required) must contain an ID and specific geometry to locate the place. More information is explained in Table 3.

Table 3. Format required in the UrMoAc tool for origins, destinations, and aggregation areas (Krajzewicz et al. 2017).

Default column came	Type	Purpose
gid	int/long	Names the object.
the_geom	PostGis-Geometry	Defines the object position in space.
N/A*	double	Weights the object.

*Optional for origins and destinations, not required for aggregation areas.

The format for the road network is that each entry is a road that must have an ID, the specific geometry, where the street starts and ends, the mode of transport that can be used, the maximum speed limit and the length of the road. More information can be found in Table 4.

Table 4. Format required in the UrMoAc tool for the road network (Krajzewicz et al. 2017).

Column name	Type	Purpose
oid	string	The name of the road.
the_geom	PostGis MultiLineString	The shape of the road.

nodefrom	long	The ID of the node the road starts at.
nodeto	long	The ID of the node the road ends at.
mode_walk	boolean	Whether the road can be used by the mode "walking"/"foot"
mode_bike	boolean	Whether the road can be used by the mode "bicycling"/"bike"
mode_mit	boolean	Whether the road can be used by the mode "motorized individual traffic"/"passenger"/"car"
vmax	double	The maximum speed allowed on this road in km/h
length	double	The length of this road

The average travel time when riding a vehicle depends on the current situation on the roads. Thereby, it is not sufficient to use the maximum allowed velocity. Instead, one should as well load speed timelines. Each entry in this data describes the average/current/maximum velocity at a road for a certain time span (Krajzewicz et al. 2017). The format that is necessary for the speed timelines consists of the time interval, the name of the road and the speed, as explained in Table 5.

Table 5. Format required in the UrMoAc tool for the speed timelines (Krajzewicz et al. 2017).

Column name	Type	Purpose
Ibegin	float	The begin of the time interval in seconds.
Iend	float	The end of the time interval in seconds.
Eid	string	The name of the road as defined in the "oid" field of the road network.
speed	float	The average/current/maximum speed at this road.

5. Results and Discussion

5.1 Numerical Results

With the use of UrMoAc we can obtain several results: Output, extended output, statistics output, output for public transport, interchanges output, edge use output and direct output. The description of each is found in Table 6.
The tool offers flexible limits of search: max time, max distance, max number, max seen value and nearest only (Krajzewicz 2017).

Table 6. UrMoAc output description (Krajzewicz 2017).

Name	Description
Output	Main measures for each origin-destination: average distance, average travel time, average number of collected destinations, average value of the collected destinations
Extended output	Includes some additional measures, such as the average velocity, consumed energy in kcal, the average price, access, and egress times, etc.
Statistics output	Extends the plain output by some statistical measures, such as the mean, median, min and max values and their 15 percentiles.
PT (public transport)	Measures concerning PT trips, such as average waiting time, average number of interchanges, average travel time, etc.
Interchanges output	Measures about using interchanges like the name of the halt, the name of the line that was left, the name of the line that was entered, etc.
Edge Use Output	Measures the usage of edges in the given network like the number of times the edge was used, the sum of the sources, etc.
Direct Output	For each origin-destination pair, the complete path including the geometry is given, like edge, line, mode, travel time, geometry, etc.

5.2 Graphical Results

With the outputs obtained by the UrMoAc, we can use tools such as QGIS to visualize the data. In this paper, the following maps correspond to the San Francisco Bay Area.

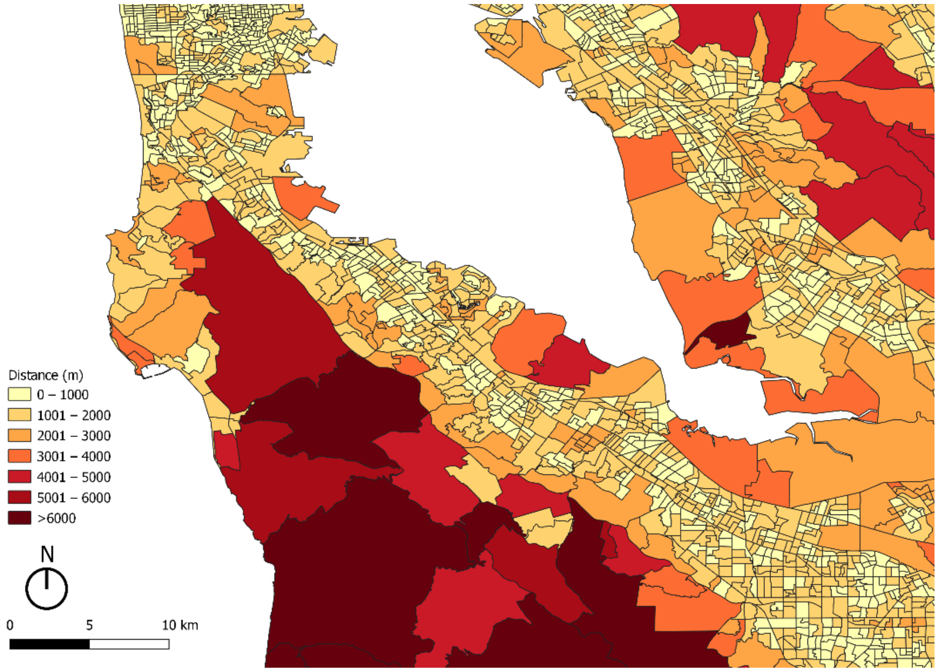

Figure 1. Distance from the urban blocks to the closest public elementary school.

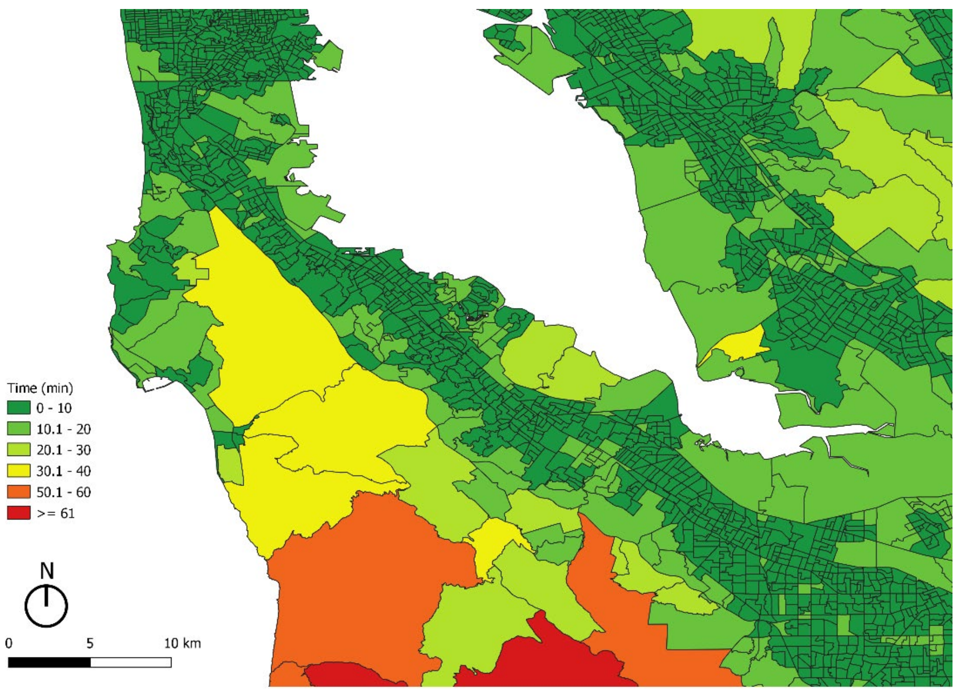

Figure 2. Time from the urban blocks to the closest public elementary school.

It can be observed in Figure 1 and 2 that in urban areas the trend of the distance and the time to be traveled to the nearest public elementary school using motorized individual transport is less or equal to 3 km that corresponds to less or equal to 30 minutes. However, if moving away from urban areas the distance and the travel time increases considerably up to more than 6 km or one hour producing more co-pollutant emissions. These results were calculated with the speed limit of each street.

5.3 Proposed Improvements

The versatility of the UrMoAc tool makes it possible to use it in different applications. In this study, the specific case of co-pollutant generation depending on distance and travel time was analyzed. However, an interesting application for future research is the comparison between cities with different urban development and main transport modes. For example, a city which main transport modes is the bicycle or the electric car, versus another one which uses more individual motorized transportation, or public transportation. This comparison can help identify trends in cities with less pollution and implement them in cities with more pollution.
The tool also allows for easy visualization of the information obtained, which can facilitate the identification of the city's distribution that could help the government recognize the areas of opportunity for development. For instance, the tool can detect places with a lack of green areas, or where access to schools and hospitals is scarce, to design and plan the necessary improvements.

5.4 Validation

A similar analysis was made for the article "Assessing Urban Accessibility in Monterrey, Mexico: A Transferable Approach to Evaluate Access to Main Destinations at the Metropolitan and Local Levels" developed by researchers from Tecnologico de Monterrey (Gaxiola-Beltrán et al. 2021). The study focuses on the analysis of accessibility at metropolitan level (Monterrey Metropolitan Zone), and at local level (Distrito Tec area) in the surroundings of Tecnologico de Monterrey. It demonstrates with the use of UrMoAc tool, that at the city of Monterrey, Mexico the levels of accessibility at the metropolitan level are divergent depending on the desired destination from different areas of the city. At the local level, the Distrito Tec area was analyzed to diagnose to what extent it could be considered a 15-minutes city. The results showed that it does not meet the desired parameters, but that there is a considerable increase in accessibility when bicycles are used as the main mode of transportation. It was possible to observe trends that this city is following as well as to mention some recommendations that could be made when planning an improvement in the accessibility and sustainability of the city (Gaxiola-Beltrán et al. 2021).
With this application, we can validate the use of UrMoAc tool as an aid to understand the operation of the city and be able to know some trends that help to plan the cities of the future.

6. Conclusion

In conclusion, changes must be implemented in cities to make them more sustainable aligned with the SDGs. Therefore, the use of technology emerges as a great help to understand the operation of the city and thus apply the necessary improvements depending on each situation. With the results obtained by applying the UrMoAc tool, we can confirm its usefulness and versatility since it allows to know in a very fine level of detail the operability of a city considering its urban structure, morphology, transport modes and destinations. These characteristics make it a valuable tool for designing and planning the cities of the future. Moreover, it is an easy-to-use tool that can be adapted to the needs of different places to develop smart mobility all over the world.

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Biographies

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Ana L. Gaxiola-Beltrán is a mechatronics engineer from Tecnológico de Monterrey. She has experience in experiment design and data visualization using LABVIEW and MATLAB, as well as English and German language certifications, TOEFL ITP 613 (2019), German B1 Certification Goethe Institute (2019) and CSWA SolidWorks certificate (2020). Gaxiola Beltran studied one year in Germany at the Frankfurt University of Applied Sciences and completed an internship at Liebherr Aerospace, where he oversaw magnetic field analysis and worked in the component design department. She has knowledge of Python, C and has interest in control theory, electronics, and research. During 2019-2020 he participated in the Campus City project where he performs Urban Mobility research on the Monterrey Metropolitan Area and did internship in the engineering center of John Deere Mexico.

Jorge Narezo-Balzaretti is an Urban Planner from the Universidad Nacional Autónoma de México and completed a year of academic exchange at the Technische Universität Berlin. In her professional career she worked for the German Aerospace Center (DLR), in the Department of Urban Development and Mobility, where her research topics focused on accessibility, mobility and urban structure. He also collaborated at the National Commission for the Efficient Use of Energy (CONUEE), an agency that is part of the Mexican Ministry of Energy, in the mobility and transportation department. Here his work focused on researching and proposing energy efficient transportation systems, participating in the formulation of the commission's roadmap, as well as training and dissemination of recommendations and best practices for the transportation sector. He collaborated with the Tecnológico de Monterrey, CampusCity Initiative, as a specialist in urban accessibility to develop a preliminary study on urban accessibility levels at the metropolitan (Monterrey Metropolitan Area) and local (Tec District) levels. Currently, Jorge is a transportation consultant for the Inter-American Development Bank (IDB), where his work consists of developing sustainable transportation public policies for Mexico and the rest of the Latin American and Caribbean region.

Mauricio A. Ramírez-Moreno. received his Bachellor in Mechatronics Engineering in 2010, and his MS and PhD in Biomedical Engineering in 2015 and 2019 in Cinvestav Monterrey (Mexico) respectively. In 2019, he started teaching university level courses in the Biomedical and Mechatronics Engineering Programs in the School of Engineering and Sciences at Tecnologico de Monterrey (Mexico). He also became enrolled in collaborative research activities with students and professors. His main research interests include Brain-Computer Interfaces, neuroengineering, robotics, biomechanics, smart cities and machine learning; and has published five journal papers, three conference papers, and one book chapter in the fields of smart cities and neuroengineering. Since the summer of 2020 he is a postdoctoral researcher, and the Program Manager of Campus City Smart Mobility and the IUCRC BRAIN TEC initiatives; where coordinates research projects with academic and industrial partners.

Ricardo A. Ramirez-Mendoza received his Ph.D. degree in Automation and Production from Grenoble Institute of Technology, France (1997) and his MSc degree in Control from the Tec de Monterrey (1991). He has published over 500 papers in journals, conferences, books, chapters, and patents, and he has mentored over 40 graduate students, postdocs, research engineers and research scientists who occupy leading positions in academia & industry. His research lines include Automotive Control, Active Control, Vehicle Dynamic Control, Mechanical Vibrations, Brain-Computer-Interface, and Biomedical Signal Analysis. Has an appointment from the National System of Researchers level 2 of the Mexican government. Currently, he is Dean of Research and Graduate Studies at the School of Engineering and Sciences and Professor of Mechatronics & Mechanical Engineering in Tecnologico de Monterrey.

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