Towards a sustainable mobility plan for Engineering Faculty, Universidad de la República, Uruguay

Silvina Hipogrosso[0000−0003−2124−7267] and Sergio Nesmachnow[0000−0002−8146−4012]

Universidad de la República, Montevideo, Uruguay,
{silvina.hipogrosso,sergion}@fing.edu.uy

Abstract. This article presents an analysis of the current situation regarding sustainable mobility in Engineering Faculty, Universidad de la República, Montevideo, Uruguay. Sustainable mobility is a relevant issue in transportation within the novel paradigm of smart cities. The presented analysis is oriented to provide specific recommendations towards developing a sustainable mobility plan for Engineering Faculty and the surrounding neighborhood. The case study is analyzed considering the main concepts from related works and well-known quantitative and qualitative indicators. An empirical study based on questionnaires performed in the zone is introduced, providing interesting information for the study. The main results are discussed, including the motivations and issues that prevent users to move towards sustainable transportation modes. Specific suggestions are formulated to develop and improve sustainable mobility in the studied zone.

Keywords: sustainable mobility; public transportation; smart cities

1 Introduction

Mobility is a crucial component of modern smart cities, which allows people to efficiently perform daily activities on urban areas [17]. Mobility is also part of the great environmental challenges existing nowadays. Related to this last issue, the main concepts of sustainability and sustainable development have been applied to conceive new models to guarantee the movement of people with minimal environmental impact, in order to not compromising the ability of future developments in this regard.

Sustainable cities in the twenty-first century are expected to prioritize people by integrating transport and urban development, in order to create vibrant, low-carbon cities where people want to live and work. Sustainable mobility is one of the big challenges of this twenty-first century. Sustainable mobility is defined as the ability to "meet the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future" [21].

Sustainable mobility works under three interconnected pillars: environmental, social, and economic. These pillars can be applied to make mobility sustainable, accessible to more people, and integrated in multimodal ecosystems for higher overall efficiency. Sustainable mobility solutions must respect the three pillars to contribute positively to the communities they serve and also the collaboration across public and private players, along with citizens, is a necessary requirement to develop sustainable mobility by the people and for the people.

Sustainable mobility also requires a mind-shift: one where citizens, administrators, and decision-makers move from carbon-intense modes of transport to more sustainable solutions, like electric vehicles, car sharing, the expansion of bicycle and pedestrian lanes, as well as an overall shift from road to rail freight. With the rapid urbanization and increase of the environmental awareness and concerns, urban development have resulted in an urgent need and opportunity to rethink how we built and manage our cities to create climate-safe cities and ensure a better quality of life to citizens. However, governments should endeavour to move beyond simply pledging to reduce carbon emission to a specific level by a certain year it is necessary to adopt a sustainable mobility plan that could be developed for the future of our communities. There is a urgent need for replanning the correct type and mix of transport modes to provide people efficient transport solutions to get to their activites.

In Montevideo, Uruguay, few initiatives have been proposed towards sustainable mobility. Most of the recent steps were focused in the public transportation, e.g., with the introduction of electric buses in the system. On the other hand, a few initiatives to promote sustainable private mobility have been developed in the last years (e.g., a leasing plan to acquire electric vans for last mile distribution of people and goods. However, no concrete mobility plans have been conceived for specific zones of the city. In this line of work, this article presents a study oriented to characterize the mobility demands of a specific zone of Montevideo, namely the surroundings of Engineering Faculty in Parque Rodó neighborhood. Besides analyzing infrastructure and specific conditions of the transportation modes available in the zone, an empirical approach is followed to consider subjective opinions, based on personal questionnaires to people traveling from/to the area. The resulting data are processed and analyzed following a urban data approach, in order to extract useful information and elaborate specific suggestions towards a sustainable mobility plan in the studied zone.

The article is organized as follows. Next section introduces the main concepts regarding the sustainable mobility paradigm. A review of the main related work is presented in Section 3. The analysis of the current situation in the studied zone is reported in Section 4. The suggestions and recommendations for developing and improving sustainable mobility in Engineering Faculty are described in Section 6. Finally, Section 7 presents the conclusions and the main lines for future work.

2 Sustainable mobility

In the last thirty years, sustainability has been a major concern of modern society. The concept of sustainable development, referring to development to fulfill important roles of nowadays, but without compromising the future, has been promoted as crucial to build more equitable, environment friendly, and inclusive model of society.

The sustainable mobility paradigm integrates many relevant concepts, including those related with their impacts on environment and society [2]. Overall, the main idea is to consider mobility as a valued activity regarding environmental, social, and economic concerns [12]. One of the most studied aspects has been the impact of mobility on the environment, with the main idea of conceiving new transportation paradigms accounting for cleaner means, accessibility, and integration of people. Other important aspects have also been analyzed, including the impact on economy, and the overall quality of life (safety, health, etc.).

Raising awareness and involving citizens are key aspects for sustainabe mobility. In turn, technology has been identified as one of the most valuable tools to help developing environmental friendly sustainable mobility. Different methods and indicators have been proposed to analyze means of transportation [6] and other important issues related to sustainable mobility.

3 Related work

Several articles in the related literature have proposed initiatives towards sustainable mobility. Litman and Burwell [10] stated that the lack of holistic plans for transportation lead to poorly effective policies. They proposed that a sustainable transportation plan must be conceived from a broad point of view, considering several aspects (e.g., energy efficiency, health, economic and social welfare, etc.) and their and interrelated impacts. The authors formulated a paradigm shift for rethinking transportation, considering different integrated solutions for sustainable transportation systems.

The importance of developing a correct strategic plan for sustainable urban mobility was highlighted by Banister [2]. Such a plan must include several actors, and stakeholders must play a major role for the implementation of specific initiatives. Similar conclusions were extracted by Miller et al. [16], who elaborated about the role of public transportation regarding sustainability and proposed recommendations for for developing sustainable public transportation systems, based on several case studies.

The proposal by Gudmundsson at el. [6] introduced a framework for sustainability transportation evaluation and two real-world cases in Europe were studied. The importance of quantitative and qualitative assessment using indicators for decision-makers and operators was highlighted. Other relevant case studies in developed countries include the analysis of the impact of transportation in an integrated urban model of California by Johnston [9], and the empirical analysis for designing innovative sustainable innovative mobility solutions in three urban areas in Copenhagen [5].

In Latin America, Rodrigues et al. [19] studied the development of sustainable urban mobility in several Brazilian cities, regarding several dimensions of sustainability. The analysis allowed identifying key elements to be included in the proposal of public policies for improving sustainable mobility. Lyons [11] studied the actions for economic and social sustainability, and environmental protection in Bogotá, Colombia, emphasizing on the importance of the integration between transportation and social planning. The authors concluded that the main concepts of the case study regarding sustainable transportation can be replicated in other developing countries.

In Uruguay, project 'Public transportation planning in smart cities' [18] studied diverse features of sustainable public transportation in Montevideo and proposed interesting lines of works for improving bus lines in the city [4]. The analysis of sustainable mobility in the public transportation of Montevideo was addresed in our previous conference article [8] and later extened with sustainable mobility recommendations [7]. This article elaborates on the previous proposal, including a in-depth analysis of the situation and main motivations for developing a sustainable mobility plan for Engineering Faculty.

4 Sustainable mobility analysis for Engineering Faculty, Montevideo, Uruguay

This section describes the analysis of sustainable mobility developed for Engineering Faculty, Montevideo, Uruguay.

4.1 Motivation and objectives of the study

The main motivation of the study is to understand the mobility demands to Engineering Faculty and from Engineering Faculty surroundings to other zones of the city. This is a relevant case study, which includes several interesting features: is located in a residential area, but having other high education centers, a shopping center and several health centers nearby, among other relevant services.

The main objectives of the study include identifying, analyzing, and characterizing the current mobility situation in the studied zone, to extract useful information for elaborating a sustainable mobility plan for Engineering Faculty. In 2020, Engineering Faculty has more than 10 000 students, 1 000 professors, and 200 administrative employees. In addition, students and professors of other faculties also assist to lectures in Aulario Massera. All these persons have specific mobility demands to access to the institution. The study is based on a survey, and the opinions of interviewed people are taken in consideration.

The analysis of the current mobility situation provides useful information for developing a sustainable mobility plan in the studied zone. This is a relevant result considering some actions taken by Engineering Faculty to promote sustainable mobility (e.g., the creation of a program to promote the use of bicycles between students and professors, and joint works with the city administration of Montevideo to create bike lanes in a circuit connecting faculties of Universidad de la República).

4.2 Methodology

The proposed study is based on two main methodological stages: a first stage applying urban data analysis approach to characterize the current reality of mobility in the studied area, and a second stage based on a survey to capture the experiences, opinions, and feelings of people traveling from/to the studied area. This way, the proposed methodology combines quantitative and qualitative elements and analysis to provide an holistic view of mobility demands, and also perceptions and perspectives of sustainable mobility in Engineering Faculty and the surrounding neighborhood. The main details of the applied methodology are described next.

Methodology for data collection. Two main sources of data were considered. In the first stage, the study gathered operational data (e.g., bus lines that operates in the zone, timetables, etc.) and also information about the available infrastructure (e.g., bus stops, bicycle lanes, parking facilities, etc.) either from open data sources or by personal inspection.

In the second stage, a survey was performed in-situ in the studied area, to gather the data for the analysis. A total number of 617 persons were interviewed: 538 commuting from other zones of the city and 79 living in the area. Four relevant groups of people were identified: students of Engineering Faculty and other faculties that shares Aulario Massera, professors and employees of Engineering Faculty, people who live in the neighborhood, and people who work on the neighborhood. The survey considered not only Engineering Faculty, but also the surrounding neighborhood to capture a more holistic view of mobility demand from/to the studied area.

The survey was focused on gather relevant mobility information of the studied groups of people, including: frequency of travel, origin/destination of trips, relevant aspects of transportation mode(s) used for commuting, willingness to switch to a more sustainable transportation mode, and issues that prevent changing to a more sustainable transportation mode. The questionnaires were performed during 15 November–15 December 2019, from Monday to Friday, from 8:00 AM to 7:00 PM. Weekend trips were not considered in the analysis because they are significantly lower than working days trips. People who already commute in sustainable transportation modes were not asked if they would be willing to change towards a more sustainable transportation.

Indicators. The analysis considers quantitative and qualitative sustainable mobility indicators proposed by the World Business Council for Sustainable Development:

- *Coverage* (quantitative) defined as the ratio of the area covered by each sustainable mobility service (ci) and the total urbanized area studied (ta), $coverage = ci/ta$. The total urbanized area for the case study in this article is considered to extend for 0.52 km^2.

- *Affordability* (*af*, quantitative), defined as the mobility expenses as a percentage of the income, considering the cost of each transportation mode and socio-economic data (middle income, according to values reported for 2019 by National Institute of Statistics [3]): $af = nt \times p/i$, where nt is the number of trips, p is the cost of a single trip, and i is the income per capita.
- *Access to mobility service* (*am*, quantitative), defined as the share of population with appropriate access to a sustainable mobility service $am = \sum_i PR(i)/nh = 1 - \overline{PR}/nh$, where nh is the number of citizens and $PR(i)$ is the percentage of people living within 400 meters from a transportation stop. Service area is limited to 400 meters, as the maximum distance that a person considers to walk to use a public transportation service [1].
- *Origin and destination of trips* (quantitative), which account for the specific zones that originate trips to the studied zone and also the destination of trips that initiate in the studied zone.
- *Commuting travel time* (quantitative), defined as the average time spent by a person when traveling from/to the studied zone. The average walking speed is assumed to be 5 km/h. For bus, the commuting travel time includes the time for a person to walk to the bus stop and the time waiting for the bus to arrive. For bicycles, the average speed is 13.5 km/h.
- *Travel distance* (quantitative), accounting for real distances that people travel, considering origin and destination of trips to/from the studied zone.
- *Mobility preferences: transportation modes* (qualitative/quantitative), transportation modes used for commuting to/from the studied area.
- *Mobility preferences: relevant aspects for mobility* (quantitative), accounting for those features of mobility and transportation modes that are most regarded by people commuting to/from the studied area.
- *Willingness to use or change to more sustainable transportation modes* (qualitative), accounting for the opinion of people about sustainable mobility and sustainable transportation modes.

Methodology for data analysis. The study applies a urban data analysis approach [13,14] to evaluate global characteristics of mobility demand in the area. Well-known mobility indicators are used (e.g., coverage and commuting travel time) and other relevant aspects related to sustainable mobility are analyzed (e.g, modal-choice preferences for trips, which is linked to affordability, travel time, comfort, accessibility, and sustainability).

A specific focus of the analysis is public transportation, which is a major component of sustainable mobility. Public transportation is a rational alternative to private transportation modes with high impact in the environment (automobiles, motorcycles) due to emissions of air pollution and greenhouse gases [16].

The approach for computing affordability and access to mobility service is the same applied for Montevideo in our previous article [8]. For the case study considered in this article, we take in consideration that most of the interviewed people have middle/high income and trips from/to low income zones of the city are below 8%. The quality service of transportation modes from/to the studied zone is also analyzed, according to the preferences of users while commuting.

5 Practical approach for analysis and implementation of a sustainable mobility plan for Engineering Faculty

This section describes the sustainable mobility research for Engineering Faculty.

Description of the studied area. The studied area includes the surroundings of Engineering Faculty, Universidad de la República, Uruguay, located in Parque Rodó neighborhood (South of Montevideo).

The studied area covers $0.52\,\mathrm{km}^2$ and includes three main avenues: Herrera y Reissig, where Engineering Faculty is located, Sarmiento, and Sosa. Nearby the Engineering Faculty is Aulario Massera, a large classroom building shared with other faculties. The main features of the studied area include:

- *Public transportation stops*: the studied zone includes ten public transportation stops. Six of them are located at less than 200 m of Engineering Faculty. Only one bus stop correspond to the electric bus service.
- *Bicycle lanes*: an exclusive lane for bicycles was projected to be built in the studied zone, continuing the one existing in Herrera y Reissig and reaching Engineering Faculty. However, this lane has not been built and the local administration has no plans to build it in the near future.
- *Parking facilities*: Engineering Faculty has two parking lots with parking capacity for about 140 vehicles. The building also has bicycle parking (open from 7:00 to 23:00 from Monday to Saturdays) with security monitoring and a parking capacity of 330 bicycles. The bicycle parking has restrooms with showers and lockers to promote students using their own bicycles for traveling. This facility is under current norms for bicycles parking in public institutions, according to the administration of Montevideo. No other parking facilities are available in the studied zone.
- *Sidewalks, illumination and urban furniture*: the studied zone is properly equipped with modern illumination and urban furniture. Sidewalks are built in all roads in the studied area, but some segments are deteriorated, making it difficult to walk for elder and impaired people. Curb cut have been recently installed at street intersections for wheelchair users, also benefiting pedestrians using canes and baby carriages.

Analysis of results

Coverage. The studied area is fully covered by the public bus service, since all locations are within the 400 m range of a bus stop. Six bus lines operate in the zone: 117, 199, 300, and 405 (all of them have stops in both Engineering Faculty and Aulario Massera), 174 (the nearest stop is on Bulevar Artigas, 350 m from Engineering Faculty), and E14 (the nearest stop is on Sarmiento Avenue, 400 m from Engineering Faculty). However, just one line (E14) is operated by an electric bus, since July 2020. The total coverage of the public bus transportation service in the zone is 100%, while electric bus only covers 80% of the studied area. The public bicycle system does not cover the studied zone. The local administration has proposed a plan for extending the area of service to include Parque Rodó neigborhood and other areas, but it has not been implemented yet.

Affordability and access to mobility service. The affordability index was computed considering a trip length of 30 minutes, which is close to the commuting time for trips in Montevideo [15] and also from/to the studied zone. A medium level of income per capita in Montevideo (USD 691) is considered, according to the profile of most people commuting from/to the studied zone. Buses apply a flat rate for standard one-hour trips (0.85 USD/trip), allowing one transfer. A trip using a private bicycle is considered free, but the amortization cost of a bicycle accounts for 0.20 USD per trip. The public bicycle service is free up to 30 min, and it costs 0.74 USD after that. A car trip is about 2 USD, considering amortization and fuel costs as for July, 2020. According to the results, most of the interviewed people (97%) can afford a bicycle and almost all (99%) can afford a bus ticket. On the other hand, less than 15% of the people can afford a private motorized mean (car or motorcycle).

Mobility preferences: transportation modes. Table 1 reports the number of trips from/to the studied zone, using each transportation mode (listed from more sustainable to less sustainable).

Table 1: Transportation modes used for commuting to/from the studied zone.

transportation mode	*#trips*	*percentage*
walking	83	13.0%
bicycle	40	6.3%
bus	361	56.4%
more than one	69	10.8%
motorcycle	9	1.4%
car	78	12.2%
total	640	100.0%

Results reported in Table 1 indicate that less than 20% of the trips to/from the studied zone currently use sustainable transportation modes. The analysis also shows that the bus is the preferred mode for commuting, accounting for more half of the trips. In turn, other non sustainable transportation modes sum 13.6% of the trips, most than people that walk to the studied area. Most of the surveyed people agreed that they use bus because it is the most accessible and affordable transportation mode, especially for medium/large distances. Results also show that the potential of using bicycle is not properly developed, as only 6.3% of the people use this mean of transportation. These are relevant results to consider when developing a sustainable mobility plan in the zone.

Travel distances. Table 2 reports the number of trips (using any transportation mode) according to their travel distances from/to the studied zone. The percentage and the accumulated percentage are also reported.

The analysis of travel distances reported in Table 2 indicates that a significant number of people travel from/to near locations. One-third of them travel between 2 to 3 km, and 60% of the surveyed people commute from a maximum distance of 5 km. This is a relevant result to consider in a sustainable mobility plan, as short instances allow implementing specific strategies to promote the use of

Table 2: Number and percentage of trips according to travel distance ranges

distance	*#trips*	*percentage*	*accumulated*
0–1 km	41	6%	6%
1–2 km	33	5%	11%
2–3 km	127	20%	31%
3–4 km	103	16%	47%
4–5 km	80	12%	59%
5–6 km	44	7%	66%
6–7 km	13	2%	68%
7–8 km	52	8%	76%
8–9 km	19	3%	79%
9–10 km	5	1%	80%
$>$ 10 km	125	20%	100%

sustainable transportation modes. Of the 125 trips from/to more than 10 km, 84% of them have origin/destination from outside Montevideo, mainly in the nearby department of Canelones. Fig. 1 geographically presents the accumulated percentage of trips according to the distance to Engineering Faculty.

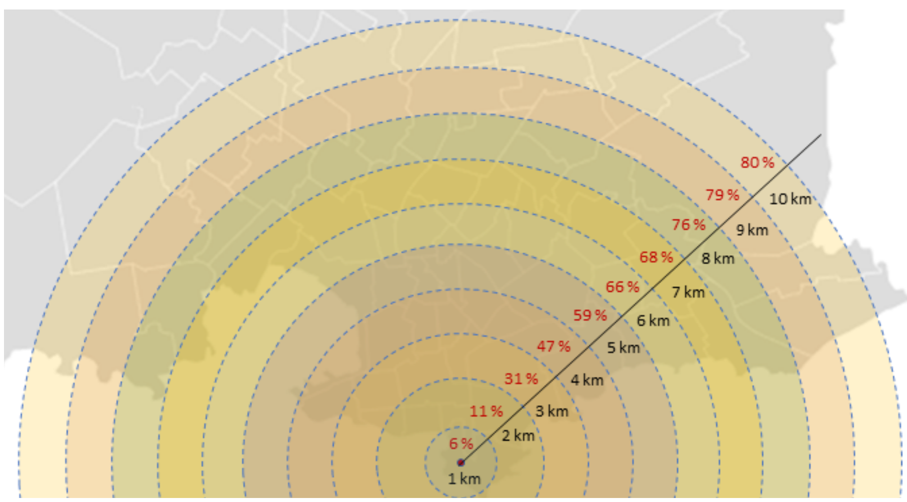

Fig. 1: Travel distances to the studied zone.

Another relevant result is that 95% of people make a round trip and more than 90% commute from/to the same location at least three times a week. Thus, the regularity of mobility demands in the studied zone supports the proposed data analysis approach based on patterns detection for mobility characterization.

Mobility preferences: transportation modes by distance. Table 3 reports the summary of transportation modes by distance.

The analysis of results reported in Table 3 indicate that most of the people that walk from/to the studied area travel less than 3 km. In turn, bus is preferred by people that travel from 2–3 km and more, and completely dominates in the range of 4–9 km. Most of the people that use bicycle travel 2–4 km. Private vehicles are used by people that travel more than 2 km.

Table 3: Transportation modes by distance

distance	*walking*	*bus*	*bicycle*	*motorcycle*	*car*	*bus and other*
0–1 km	24	6	2	0	1	7
1–2 km	18	2	6	0	4	2
2–3 km	26	60	17	1	8	12
3–4 km	13	49	9	0	12	11
4–5 km	2	57	4	1	9	5
5–6 km	0	32	1	1	7	2
6–7 km	0	7	0	0	3	3
7–8 km	0	39	1	1	8	3
8–9 km	0	15	0	1	3	0
9–10 km	0	4	0	0	1	0
$>$ 10 km	0	90	0	4	22	7

Origin and destination of trips. Fig. 2 graphically reports the origin of trips to the studied zone. The discretization level is given by the 63 neighborhoods identified by the National Statistical Institute in Montevideo. In turn, Fig. 3 graphically reports the destination of trips starting in the studied zone.

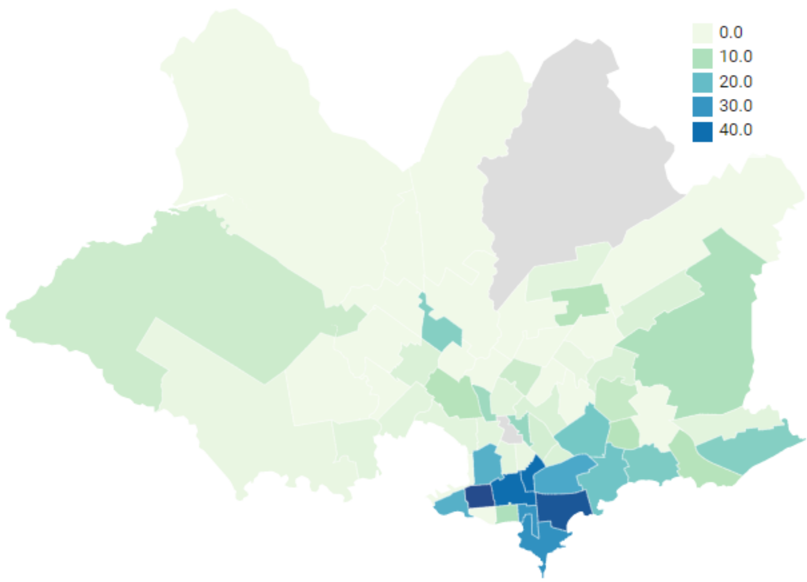

Fig. 2: Origin of trips to the studied zone.

The analysis of Fig. 2 and Fig. 3 demonstrate the regular pattern followed by origin and destinations, according to the regularity of mobility demands commented in the previous paragraph. The neighborhoods that contribute the most as origin/destination of trips to Engineering Faculty are Centro and Pocitos (as origin) and Centro, Pocitos, and Cordón (as destination). Both maps also demonstrate that most of trips come from/go to central neighborhoods of the city, and neighborhoods located in the East also contributes to the demand.

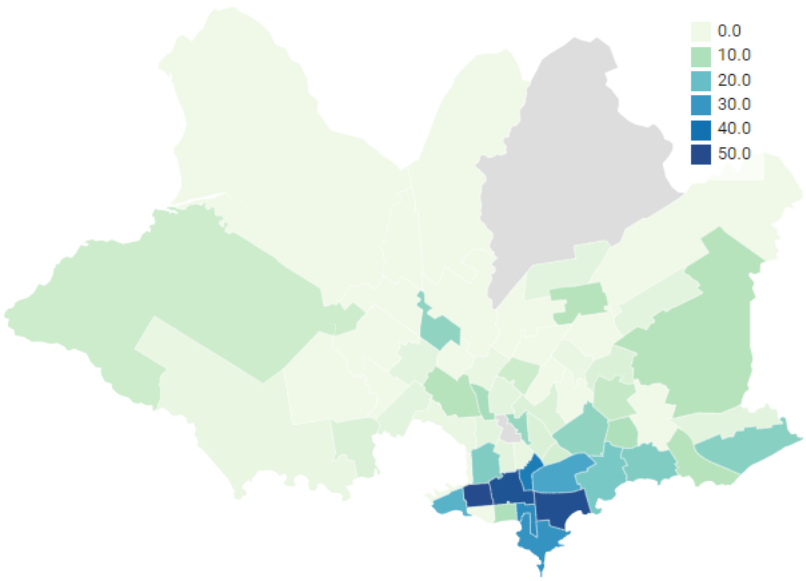

Fig. 3: Destination of trips from the studied zone.

Commuting travel time. The average travel times from/to the five most demanded origin/destination of trips to/from the studied zone are reported in Table 4. Bicycle is the fastest transportation mode for travels up to 3.5 km, where most of the people travel from/to. For distances between 3 km and 8 km, car has similar travel time than bicycle, and always lower than bus. Walking is not a reasonable option, regarding travel times, for travels larger than 2 km.

Table 4: Commuting travel time to Engineering Faculty from the most frequent neighborhoods as origin/destination of trips.

neighborhood	*distance*	*bus*	*bicycle*	*walking*	*car*
Parque Rodó	1.0 km	-	4.4 min	12.0 min	5.7 min
Cordón	2.5 km	18.9 min	11.0 min	30.0 min	12.0 min
Tres Cruces	3.0 km	21.2 min	13.3 min	36.0 min	15.2 min
Pocitos	3.5 km	28.4 min	15.5 min	42.0 min	17.0 min
Centro	3.7 km	24.4 min	21.4 min	44.4 min	20.8 min
Prado	8.0 km	44.4 min	35.5 min	-	28.8 min

Willingness to change to more sustainable transportation modes. Almost all people (93.2%) that use non-sustainable transportation modes stated that they would be willing to change to a more sustainable transportation mode. Table 5 reports the sustainable transportation modes users will be willing to change to. 62% of the people would be willing to change to electric public transportation, and 31% to bicycle. The main reasons for changing are the mitigation of environmental damages, energy efficiency, and avoiding health issues. 49 people that use automobile and 151 that use bus would change to electric public transportation. In turn, 149 people would change to bicycle as transportation mode. Most bus travelers would use a public bicycle system if it was operative in the area.

Table 5: Sustainable transportation modes users will be willing to change to.

transportation mode	*#trips*	*percentage*
electric public transportation	298	48.3%
bicycle	149	24.1%
electric motorcycle	8	1.3%
walking	7	1.1%
scooter	6	1.1%
use sustainable transportation	113	18.3%
would not change	36	5.8%

The survey also recognized the reasons why people do not change to electric bus and bicycle. The main reasons for not changing to bicycle included: poor safety conditions (29.6%), no bicycle parking (22.2%), cost (19.7%), poor public bicycle system (18.5%), bad climate conditions 6.2%). The main reasons for not changing to electric bus include: slow, many stops (50.5%), not direct (21.9%), uncomfortable (13.3%), inefficient (7.6%), low frequency (4.8%).

Safety and the lack of infrastructure are the main reasons that prevent users from changing to bicycle. In turn, reasons why people do not change to electric bus are related to characteristics of the bus system in Montevideo, which is perceived as slow, with many stops, and not providing direct connections. These results are related to the most relevant aspects for mobility to the studied area. Almost half of the people (44%) prioritize speed. Comfort is the second most regarded aspect (22%) and cost the third (17%). Sustainability is not perceived as a relevant feature for mobility (6%).

6 Recommendations for a sustainable mobility plan in Engineering Faculty

The analysis of results are a useful input to conceive specific recommendations for developing a sustainable mobility plan in Engineering Faculty. The mobility characterization is a valuable first input to elaborate suggestions. Since mobility demands follow a regular pattern, plans can have an important impact on all people commuting from/to the zone. In turn, the very large number of people (93.2%) willing to change to sustainable mobility options should encourage to take actions on this regard.

Any plan toward promoting sustainable mobility must consider the inherent features of the studied zone and the transportation system of Montevideo. In this regard, a relevant issue to address is the poor development of bicycle, which provides the cleaner and faster option for short and medium-distance trips. Furthermore, bicycles are also the most affordable transportation mode, although interviewed people do not In this line, one of the first suggestions is to take strong actions to promote the use of bicycles for traveling from/to the studied zone. This action will effectively aim at the large universe of people that travel from/to distances up to 5–6 km, i.e., about 60% of the commuting people. Of course, such actions must be coordinated with other institutions because the survey revealed that infrastructure changes are needed, such as building the exclusive line for bicycles to Engineering Faculty, and also extending the public bicycle system to cover the studied zone. In turn, safety should be addressed too, as it is one of the main concerns of possible users of this sustainable transportation mode. It is not enough to signal bicycle lines on the street or sidewalks, but to provide a physical separation for safety of cyclist and pedestrians. Thus, introducing bicycle stations, improving parking facilities, and designing an articulated network of exclusive lanes are a must to improve sustainable mobility in the zone.

The development of electric public transportation is also another major line of work to improve sustainable mobility in the zone. The coverage of the electric bus must be expanded, by including at least one line directly connecting Engineering Faculty and the South of the studied zone with relevant origin/destinations in the city. This is a relevant issue that will require the participation of local authorities and the main bus companies. However, extending coverage is not enough. The study confirmed that people will not change to electric public transportation if the service does not improve. A throughout review of routes, bus stops, and travel times must be considered. This suggestion extends to the whole city, because the redesign of the bus network must be be performed from an holistic view. A specific suggestion is to introduce lines with fewer stops and higher frequencies than the current service, to allow commuters to travel faster. In turn, bus companies should focus on offering a better travel experience. Some suggestions related to improve travel conditions and comfort include appropriate dimensioning of vehicles according to the demand, provide air-conditioning, guaranteeing universal accessibility, providing accurate real-time information via mobile applications, and improve bus stops facilities. Another specific suggestion, in this case for the city administration, is defining preferential lanes for buses, which are currently not available in the zone. Some avenues in the zone (e.g., Herrera y Reissig and Bulevar Artigas) can take advantage of preferential lanes to avoid traffic congestion and speed up public transportation.

Another relevant result of the research is that sustainability is not regarded by people as a relevant aspect for mobility. This is a consequence of the poor development of the concept in Montevideo, where just isolated and limited sustainability mobility initiatives have been developed. Engineering Faculty and Universidad de la República should assume an active role in formation and dissemination about this topic, in joint works with local and national governments.

Improving infrastructure is not an easy task, mainly due to the lack of a proper urban planning. In this regard, specific initiatives should be conducted following the Transit-Oriented Development (TOD) [20] paradigm for urban planning and development to create a revitalized and environmentally friendly neighborhood. Initiatives oriented to reduce automobile utilization (e.g., pedestrianization or limiting private traffic) must be implemented, jointly with the promotion of sustainable mobility. Applying the TOD principles should certainly help to achieve that goal. In turn, Engineering Faculty can also contribute by limiting the access to private car parking only to shared vehicles, and improving the bicycle parking.

Another relevant suggestion is to develop/improve intermodal connectivity in the area. Combining bicycle and bus is a worth idea for people commuting from/to long distances, e.g., from outside Montevideo. This idea has been proposed to the local administration to improve the access and connection to the main large-distance bus terminal in the city using bicycle. The proposal will certainly contribute to improve quality, safety, accessibility, and cost-effectiveness of the mobility system in the studied zone and Montevideo.

The reported results, descriptive statistics, main findings of the survey, and suggestions are very valuable to design an effective sustainable mobility plan in the studied area. To conceive such a plan, the main concepts of sustainable mobility must be taken into account, to satisfy the mobility needs guaranteeing a better quality of life. These concepts include developing an integrated approach, considering strategic objectives and coordinating policies between sectors (transportation, territorial, social, environment, energy, etc.). In turn, initiatives must be carefully planned and its performance properly assessed via a systematic monitoring and long-term evaluation plan. Any of the proposed suggestions must be implemented by actively involve citizens, stakeholders, administrators, operators, and other relevant actors, accounting for their needs and opinions.

7 Conclusions and future work

This article presented an analysis of the current mobility reality in Engineering Faculty, Universidad de la República, Montevideo, Uruguay.

A methodology applying quantitative and qualitative indicators was applied to characterize the mobility demands, including subjective opinions from people commuting to/from the studied area. A survey was performed to gather information about origin/destination of trips to/from Engineering Faculty, mobility preferences, willingness to change to more sustainable transportation modes, the main reasons why people do not change, and other relevant aspects for mobility.

The main findings of the analysis are the universal affordability of sustainable transportation and that 93% of the people would be willing to change to a more sustainable transportation mode. According to the analysis, 60% of the people commute a maximum distance of 5 km, which suggest that implementing specific strategies to promote the use of sustainable transportation modes is viable. The high acceptance of sustainable transportation modes is highlighted and it sets a solid base for developing a sustainable mobility plan in the zone.

Based on the results of the analysis, specific recommendations are provided to develop a sustainable mobility plan for Engineering Faculty, mostly focused on improving traffic efficiency and accessibility, which is a direct contribution, as no previous similar studies have been developed in Montevideo.

The main lines for future work are related to extend the analysis including other relevant issues (e.g., private vehicles and traffic in the city, environment and pollution, etc.). The analysis of other mobility needs is also important to assess the impact of sustainable mobility in the studied zone. The proposed methodology can be applied to characterize mobility demands and sustainable mobility on other relevant neighborhoods in the city.

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