Percepción social de los servicios de transporte, caso de estudio Universidad Autónoma del Estado de México

Social perception of transport services: case study at the Autonomous University of Mexico State

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Abstract

This study analyzes the social perception of the mobility system at the Autonomous University of Mexico State. The survey categorizes findings into five key dimensions: accessibility, jobs, mobility and connectivity, safety and public health, and livability. About accessibility (transport services, stops and financial means), the analysis reveals a significant reliance on urban transport 39%, and the Potro Bus service 22%, and perceived efficiency and cost-effectiveness; the stops of mobility service on University community was 1 or 2, and the cost of daily travel was 1.50 USD. The mobility and connectivity (level of satisfaction, punctuality and average distance), around 29% acknowledge the efficiency of the transportation system and economic viability, because is free for students. Safety and public health (accidents, carbon footprint and inclusivity), with 78 % reporting no accidents, and 43% praising the inclusiveness. Moreover, 70% are interested to learn about their carbon footprint associated with transport. The livability (University projects, Urban mobility plans and Technological tools), involves actively educating and engaging in sustainable transportation initiatives with technological and environmental point of view. Additionally, the research introduces the application of Social Life Cycle Assessment methodologies to evaluate the environmental and social impacts of mobility services, aligning with ODS.

Keywords: **Environmental impacts, Mobility University, Social life cycle assessment, Survey, Urban mobility plans.**

Resumen

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Este estudio analiza la percepción social del sistema de movilidad en la UAEMEX. La encuesta clasifica los resultados en cinco dimensiones: accesibilidad, empleo, movilidad y conectividad, seguridad y salud pública, y habitabilidad. En cuanto a la accesibilidad (servicios de transporte, paradas y medios financieros), el análisis revela una dependencia significativa del transporte urbano (39%) y del servicio de Potro Bus (22%), con una percepción de eficiencia y rentabilidad; las paradas del fueron 1 o 2, y el costo del viaje diario fue de 1.50 USD. La movilidad y conectividad (nivel de satisfacción, puntualidad y distancia media), el 29% reconoce la eficiencia y su viabilidad económica, ya que es gratuito para los estudiantes. Seguridad y salud pública (accidentes, huella de carbono e inclusión), con un 78 % expresaron ningún accidente y un 43% destaca la inclusión. Además, el 70% está interesado en conocer su huella de carbono asociada al transporte. La habitabilidad (proyectos universitarios, planes de movilidad urbana y herramientas tecnológicas), se necesita educar y participar en iniciativas de transporte sostenible. Además, la investigación introdujo a la evaluación del Análisis de Ciclo de Vida Social para ajustar los impactos ambientales y sociales de los servicios de movilidad, alineados con los ODS.

Palabras clave: Análisis de ciclo de vida social, Encuesta, Impactos ambientales, Planes de movilidad urbana, Planes de movilidad universitaria..

Introduction

Mobility facilitated by transportation, engenders social, economic growth and environmental domains, alleviates poverty, and enhances quality of life (Andrade et al., 2024). Enhanced transportation enables market access, supports productivity, fosters trade, and promotes regional and global integration. The existing transportation system and shortcomings in urban planning have led to cross-cutting impacts on sustainability, influencing the environmental, social, and economic spheres. Addressing this issue requires a paradigm shift in urban planning and mobility (Centro Mario Molina, 2014). Sustainable mobility must have the four attributes summarized in equitable, efficient, safe, and climate-responsible, considering climate change and reducing air and noise pollution (Finck Carrales, 2023).

The sustainability of "Mobility as a Service" (MaaS), proposed as a tool for promoting sustainable mobility and increasing the share of public transport trips in urban areas; integrated mobility solutions based on user requirements, represented by the younger generations (Zoomers, Homeland Generation and Millennials), they are mostly students at universities and colleges (Santos & Nikolaev, 2021; Shaheen & Cohen, 2018).

The concept "sustainable mobility" was introduced five years after that (European Commission, 1992), the overarching goal linked to sustainable transportation is defined as, "Ensuring that our transportation systems fulfill the economic, social, and environmental requirements of society while minimizing their adverse impacts on the economy, society, and the environment" (Council the European Union, 2006). Economic activities produce externalities that have adverse effects on urbanization, particularly given that 56 % of the global population (4.4 billion inhabitants) resides in urban areas (Nations, 2018). In addition, several environmental concerns around the cities are being addressed, such as the significant increase in energy consumption, the surge in greenhouse gas (GHG) emissions, pollutants in the air, vibrations, traffic congestion, encroachment on public spaces, accidents, harm to buildings and monuments, deteriorating air quality, noise from traffic, congestion-related stress, fatigue, and aggression collectively contribute to health and environmental concerns (Gallo & Marinelli, 2020). To address climate change and reduce the environmental impact of transportation, while also promoting fairness, effectiveness, and inclusivity in urban communities, there is a growing need for innovative mobility solutions centered around shared usage. This shift aims to enhance the overall quality of life in cities.

Considering the negative impacts on different environmental aspects, embracing sustainable mobility solutions emerges as a vital tactic for transitioning towards resilient and eco-friendly urban environments, in line with the Smart City concept (Casas et al., 2020; Gallo & Marinelli, 2020) . Moreover, evidence from developed countries shows that safety, public transport quality, transportation costs, air pollution, and accessibility function as contextual indicators that are also applicable to developing nations (Shiddiqi et al., 2022).

The Mobility Law of the State of Mexico is a legislation that regulates transportation and mobility in the State of Mexico, Mexico. It establishes norms and provisions to ensure a safe, efficient, sustainable, and accessible transportation system for all citizens; on article 9 it is referred, that is necessary studies on vehicle traffic to achieve better utilization of roads and corresponding means of transportation, aiming for the most effective protection of human life, environmental preservation, safety, comfort, and traffic flow (Gobierno del Estado de México, 2015). The Toluca Metropolitan Zone, ranks as the fifth largest city nationwide, boasting a population exceeding two million and standing as the most densely populated urban area in the State of Mexico. Notably, the Toluca and Mexico City corridor witnesses a substantial daily traffic volume, comprising 500,000 automobiles and 20,000 buses (CONAPO, 2012). The Sustainable Mobility strategy for the Toluca Metropolitan Zone addresses five identified trends in terms of mobility and urban development: 1) urban structure tending towards expansion, 2) increase in travel time and distance, 3) promotion of inefficient

transportation modes, 4) fragmentation of public management of mobility, and 5) rise in the use of private cars (Centro Mario Molina, 2014).

The social perception, attitudes, and other internal factors of urban mobility, refers to how the population in a city perceives and experiences transportation and mobility systems within their human behaviour in transportation (Leontev, 2023). Analysing and understanding this perception is important for designing transportation policies and projects that align with the needs and preferences of the community, thus promoting more efficient, safe, and sustainable urban mobility (Brůhová Foltýnová et al., 2020). Assessing the social perception of mobility systems entails examining how these factors influence various segments of society, including marginalized groups, inequality and striving to mitigate detrimental effects while fostering beneficial outcomes (Campos-Vazquez et al., 2022), on the SARS-CoV-2 pandemic, the reduction in overall travel, and the decline in the use of public transportation present a significant challenge for urban mobility (Figueirôa-Ferreira et al., 2023; Stan et al., 2023).

Few studies have adequately addressed a crucial aspect of the planning process, namely the indicators of sustainable mobility within University campuses. There is limited understanding of the social perception of mobility systems in University settings, as evidenced by discussions on social media platforms concerning their environmental and social implications (Alanis et al., 2022; Metastasio et al., 2024). Previous research has examined measures of sustainable mobility within University contexts (Rodrigues da Silva et al., 2024) with campaign of fostering a more sustainable travel behavior (Pedreira Junior et al., 2022), about the infflence factors of the economy and traffic impacts on roads adjacent to universities (Obregón Biosca, 2020; Pedreira Junior et al., 2022), and models to identify the most efficient measures based on user perception of mobility patterns (Klimi, 2022).

The primary objective of this study is to systematically analyse the social perceptions related to the University mobility system within the Autonomous University of the State of Mexico. This analysis focuses on five key performance measures: accessibility, employment opportunities related to mobility, overall mobility and connectivity, safety and public health, and livability. By evaluating these dimensions, the study aims to identify the strengths and weaknesses of the current mobility system from the standpoint of the University community, including students, faculty, and staff. This comprehensive assessment seeks to inform targeted improvements that can enhance the efficiency, inclusiveness, and sustainability of transportation services within the University setting.

Methodology

The mobility services in Autonomous University State of Mexico, University City, located in Toluca campus, is the largest campus with which the University has a total area of 367,065 m2, an enrollment of 23,271 students and 2,250 (employers and academics), housed in 80 buildings of which ten are faculties, figure. 1, (PRDI, 2021). The stakeholder's group representative from University: academics, students and employers in ten University spaces (Architecture and Design, Arts, Political and Social Sciences, Accounting and Administration, Laws, Economics, Geography, Humanities, Tourism and Gastronomy, and Engineering).

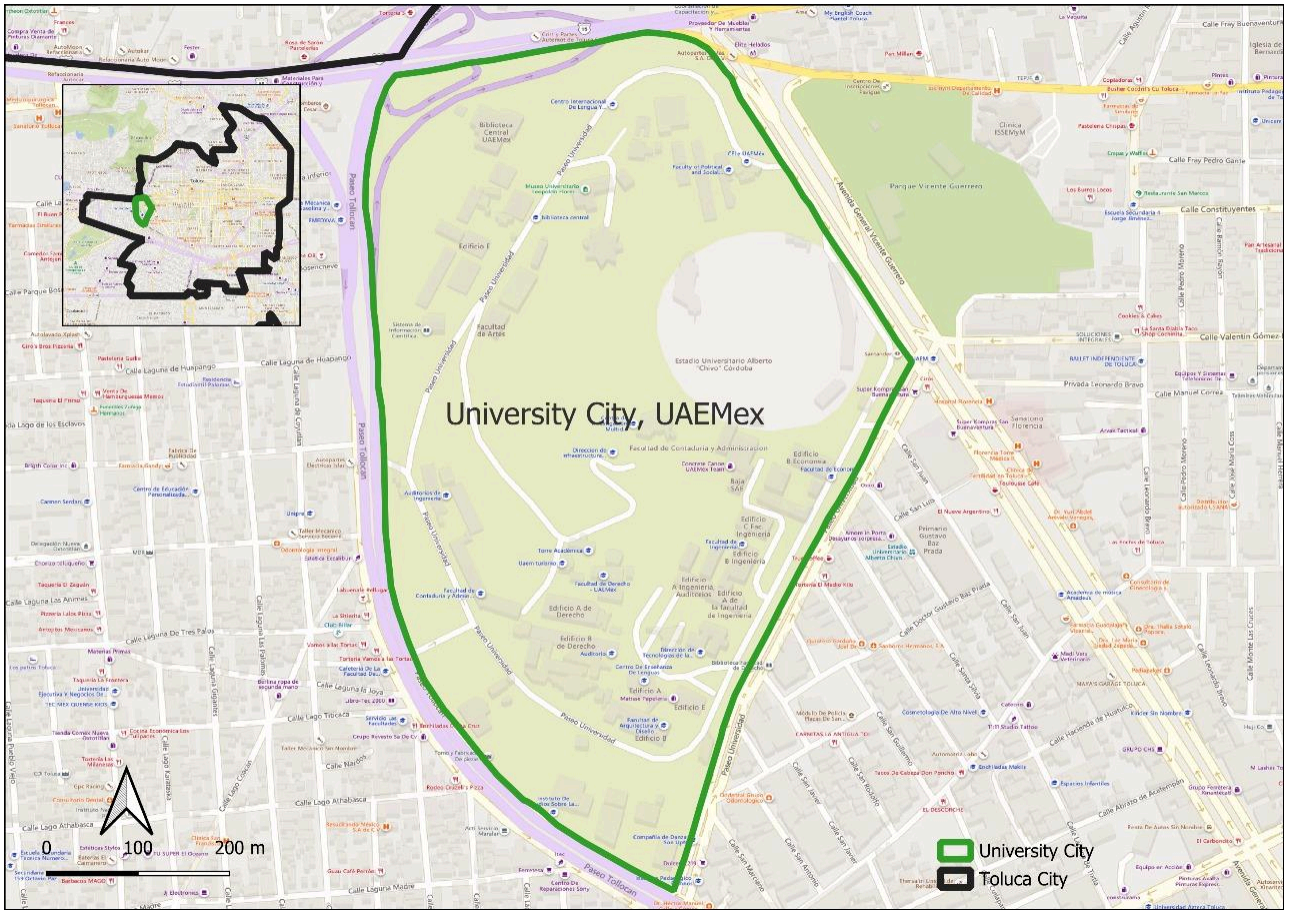

Figure 1.
Geographic boundaries of Autonomous University State of Mexico, central campus.
Source: Google maps.

The survey was structured by Sóstenes Flores, (2024), around origin-destination data, shed light on commuting behaviors to and from the University, enabling a detailed analysis of factors like travel duration, purpose, and transportation services used. Participants received the questionnaire through Google Forms. Interviewees were selected based on criteria including pertinent work background, knowledge of sustainable mobility, and familiarity with university dynamics. Guided interviews, conducted with academics, students, and employers across various University settings, followed a structured questionnaire tailored specifically for this study.

To gather more organic feedback from individuals capable of reflecting the viewpoints of a specific demographic, thereby ensuring the neutrality of the data and uncovering insights that might have been overlooked during the initial design of the interview, the questionnaire and survey were developed drawing from previous studies on mobility systems, such as the work conducted by Gompf et al., (2022) and Osorio-Tejada et al., (2020).

To obtain the stratified sample size, the data reported in the Statistical Agenda was used (UAEMEX, 2023a), as shown in (1), resulting in 372 individuals divided into ten academic spaces (Table 1), reported by Rodríguez G., (2017).

$$n = \frac{z^2 pqN}{(N-1)e^2 + z^2 q} \qquad (1)$$

Where:

N = Total population
n = Sample size
z = Confidence level: 95 %
p = Probability of success
q = Probability of failure
e = Margin of error corresponding to 5 %

Table 1
Total surveys for each academic space of University

Academic spaces	Academics and employers	Students	Surveys	%
Architecture and Design	409	1979	37	10.3
Arts	107	622	12	3.1
Political and Social Sciences	239	1347	25	6.8
Accounting and Administration	512	5935	103	27.7
Laws	373	3109	56	15.0
Economics	201	1931	34	9.2
Geography	123	558	11	2.9
Humanities	208	1160	22	5.9
Engineering	364	2684	49	13.1
Tourism and Gastronomy	165	1245	23	6.1
Total	2701	20,570	372	100

Source: Adapted to (Sóstenes Flores, 2024).

The proposed framework incorporates social performance indicators across five categories: accessibility, employment opportunities, mobility/connectivity, safety/public health, and livability (Ostovar, 2023). These categories (Table 2), serve to assess the comprehensiveness, coherence, and applicability of the findings. Recognizing the necessity of gathering data from primary sources, fieldwork has been carried out at the central campus to ensure accuracy and relevance.

Table 2
Social performance measures on University surveys.

Selected category	Surveys
Accessibility	What means of transportation do you frequently use to get to your University space?
	Why do you prefer this means of transportation?
	Do you use Potro Bus?
	Is your route linear or do you make any intermediate stops and/or transfers?
	If you use a private car, what make, and model (year) is it?
	Does the execution of the Mexico-Toluca Interurban Train bring improvements in your University mobility?
	How much money do you spend a day to get around?
Jobs	Have had any accidents in the operation of transport units?
	Do they have medical service?
	How many hours of work do they use to operate the transport units?
Mobility and connectivity	Do you consider that your level of satisfaction using this mobility service is?
	How long on average does it take you to transfer (home-faculty)?
	What is the average distance you travel by your means of transportation per day? How do you rate the mobility service you use in terms of punctuality?
Safety and public health	How many accidents have you suffered in your mobility service during the year? Would you be interested in knowing your carbon footprint derived from the use of transportation? How do you consider the type of transport you use in terms of inclusivity (aging, people with different abilities, pregnant women, gender equality)?
Livability	Do you know the University project on sustainable mobility and the urban mobility hierarchy pyramid? Do you think that the implementation of these plans has improved your mobility? The means of transportation you use, does it have a technological tool to track its real-time location? And if it does, how useful is it?

Source: Adapted to (Sóstenes Flores, 2024 and Ostovar, 2023).

The proposed methodology of the social performance measures (Ostovar, 2023), provide comprehensiveness about the Univeristy mobility, fig. 2, chosen mobility system for various transportation alternatives, including the Potrobus (powered by diesel and natural gas) as a direct and indirect options such as urban bus, car passenger, motorcycle, taxi, pedestrian on foot or bicycle and compare their respective social and environmental impacts. The accessibility category in University mobility refers to the ease on with which individuals can access transportation services. It encompasses factors such as the availability of transportation options and the proximity of transportation stops or stations to people's origins and destinations, as well as the availability of transportation linked to financial resources.

The jobs categories refer to accidents in transfer, medical services, hours to work and occupations or positions within employees of the University that are involved in or affected by mobility systems, this category typically includes administrative staff, whose work or daily activities may require mobility within or around the University campus. The mobility or connectivity refers to the level of satisfaction, punctuality and average distance of access within the University campus and its surrounding areas. The safety and public health

category assesses the well-being, inclusivity, and security of individuals (accidents) using transportation systems on and around university campuses, supporting the creation of a healthy environment. This includes aspects like the carbon footprint, aiding in the shift toward low-carbon modes or, at the very least, a lower-carbon economy (Duan et al., 2015; Ghate & Qamar, 2020) achieving national mitigation targets (SEMARNAT & INECC, 2022). And finally, the livability on transportation system, enhance the quality of life for contribute to include considerations such as accessibility to amenities and services, availability of diverse transportation options, designing transportation infrastructure and policies that prioritize the needs and preferences of the University community, and inclusive campus environment, promoting sustainable mobility practices.

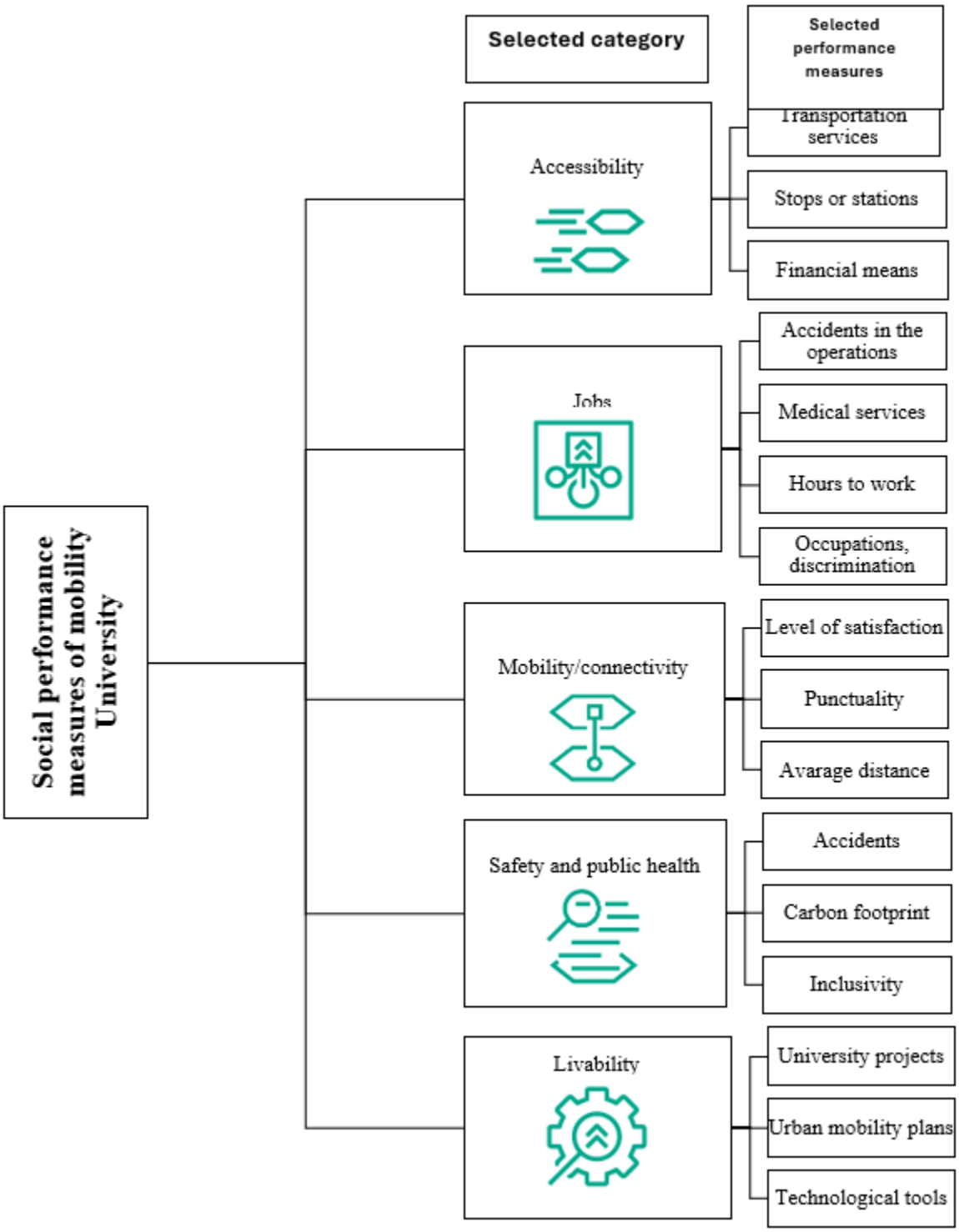

Figure 2.
Social performance measures selected of mobility University.
Source: Adapted to (Ostovar, 2023)

Results and discussion

Accessibility

Accessibility refers to the ability to acquire opportunities and resources to facilitate the fulfillment of various daily life activities, University trips, primarily through mobility, by enhancing individuals' mobility potentials in proximity (Finck Carrales, 2023), to improve the interaction between the community and the institution (Rodrigues da Silva et al., 2024). During the SARS-CoV-2 pandemic, there was an increase in the use of private cars and ride-sharing services, accompanied by a decrease in the use of public transportation modes (Figueirôa-Ferreira et al., 2023), however, the modal split following the pandemic does not follow the same pattern.

According to the mobility perception survey, reported by Sóstenes Flores, (2024), figure 3, conducted during this study, 52.7 % were women and 42.9 % were men, of which 91 % were students; academics and employers were the rest; which demonstrate that women have a higher perception of transportation services of mobility University, compared to men (Pourhashem et al., 2022). The assessment of accessibility includes transportation services, stops or stations, and financial means. The results of the means of transportation frequently used by three sectors were: 39 % urban transport or public transport, 22 % Potro Bus (diesel), 20 % private car, and 9 % walking, choosing these modes to adapt to their needs, save money, and for convenience. The Potro Bus is a service for the student community, designed to provide safe, efficient, and affordable transportation within and around the university campus. This service aims to enhance the mobility of students, allowing them to access academic facilities. The Potro Bus operates on a fixed schedule and designated routes, ensuring timely arrivals. By reducing the need for private vehicles, it not only alleviates traffic congestion but also promotes environmental sustainability by lowering the campus's carbon footprint (UAEMEX, 2023b).

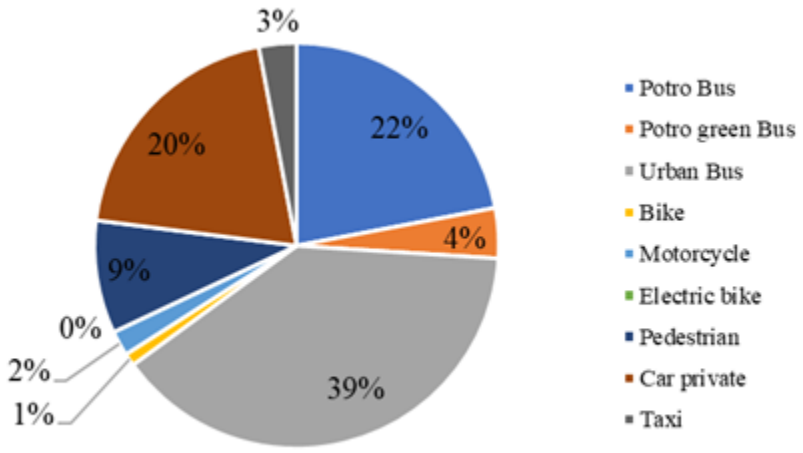

Figure 3.
Inclination of transportation services of mobility University.

Mobility services, as defined by Loubser et al., (2021), encompass transportation alternatives that fulfill user's needs, facilitated through a service provider interface, allowing seamless travel from point A to B. The number of stops or stations of mobility service on University community was 1 or 2 (81 %), bus stops represents challenges that people with reduced mobility experience each day (Andrade et al., 2024), given that they do not have to transfer between various modes of transportation or take more than one mode to reach the academic space, it can be inferred that there is good road development as there are routes in the Toluca area that lead to the University, also to access the service, students must present to the operator their current University. The University mobility system aims for buses to incorporate measures that facilitate accessibility; however, bus stops pose daily challenges for individuals with reduced mobility. The relationship between this measure (stops or stations) is the indicator proposed by Rodrigues da Silva et al., (2024),defines accessibility to

availability and location of parking spaces for the elderly and users with mobility constraints quality of pedestrian paths (inside and to access the campus).

Likewise, according to the mobility service, private cars are the most used mode of transportation by academics, with a travel time ranging from 16 to 30 minutes. In the case of administrative staff, the majority chose 45 minutes or more using public transportation (bus), although most of them traveled distances of 21 to 40 km. Students have also opted for the option of 45 minutes or more, and in this case, the service with the highest votes is public transportation (bus), followed by the Potro Bus. These results are similar of Obregon Biosca, (2020), who reported that on Autonomous University of Queretaro, Mexico, 73 % of trips are mainly made by Urban bus of extension length 21 km. The average distance traveled is over 60 km, indicating a relationship between the time and distance covered. The cost of daily travel represents 39 % of students, with urban transportation (bus) being the most chosen means of transportation, spending between 0 and 1.50 USD, followed by 1.26 to 3 USD by academics and administrative staff; also considering it`s the most economical, and being low according to what the students reported spent more than 2.47 USD per day (Obregon Biosca, 2020).

Mobility and connectivity

The level of satisfaction that they have when choosing a mobility service is mainly 29 % adapt to their needs and 28 % savings, without leaving behind 18 % comfort, 13 % travel time, and 11 % safety, considering that their satisfaction level is good, as shown in Figure. 4, being a principle that if carried out in the Road Safety and Mobility University program (UAEMEX, 2024).

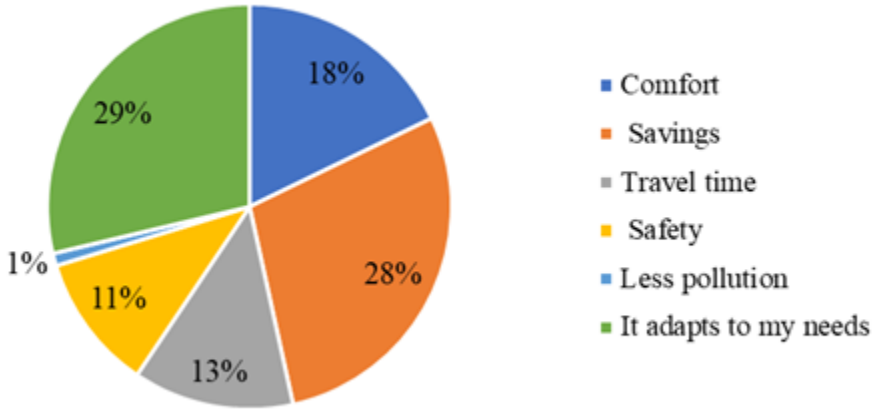

Figure 4.
Preference for choosing mobility service.

In the timeliness of the mobility services offered by the University, 52 % consider them good and 24 % indifferent, being a compliance to rights and obligations of students using the Potro Bus, to board and descend in a timely manner and only at the designated locations of the units, as well as to refrain from moving in the unit in progress. The Potro Bus will be addressed in accordance with the official schedules and at the designated locations. On average the distance they travel is 45 minutes or more by 46 %, being that the University community who live in areas far from their place of study and whose family economy requires support.

The relationship between intelligent mobility for transportation systems and connectivity dynamics, creates social, economic, and environmental challenges, which includes traffic congestion, accident of vehicle,

pollution, increasing cost, etc. (Manohar et al., 2024). Several key aspects come into play, firstly, intelligent mobility technologies rely heavily on connectivity to function effectively. For instance, connected vehicles leverage real-time data exchange and communication with other vehicles, infrastructure, and traffic management systems to enhance road safety and operational efficiency. Connectivity dynamics influence the development and adoption of intelligent mobility solutions. The availability of high-speed internet and widespread connectivity infrastructure enables the deployment of advanced transportation technologies such as autonomous vehicles, predictive maintenance systems, and smart traffic management systems, influencing more efficient, sustainable, and connected mobility solutions.

Safety and public health

In relation to the safety, the number of accidents they have had in the mobility service that most frequents the University community, 78 % mentioned that none, Figure. 5, which determines the quality of life of a community, so it should represent well-being in terms of safety, efficiency and comfort. It is subject to sanction and/or denial of service to users who smoke, introduce or consume alcoholic or enervating beverages within the Potro Bus, as well as, address the unit under the effect of such substances, also, it is subject to punishment: mistreating the unit, scratching, painting or damaging seats, windows, handholds, handrails and structure, as well as littering inside the unit, by the vents or in the whereabouts, as well as placing information or propaganda in any area of the Potro Bus.

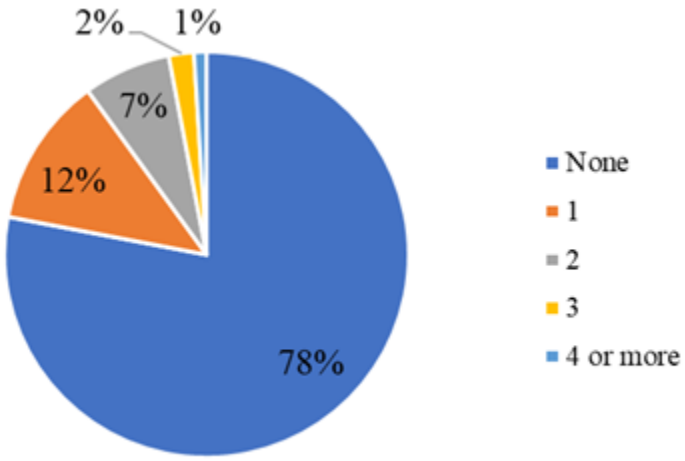

Figure 5.
Percentage of the number of accidents in mobility services.

The inclusivity on mobility service, principally considers the answer that is good (43 %) and indifferent (24 %), having pink Potro Bus which is used exclusively for women; recently deliver two units of Potro Verde Bus that operate with natural gas and have ramps for wheelchairs, in addition, are equipped with racks to transfer bicycles. Users will board and occupy the seats of the Potro Bus according to the order of arrival at the whereabouts, with priority to students with disabilities. For no reason will seats be set aside inside or outside the Potro Bus.

The educational coverage in the state territory with academic spaces are in areas with higher population index, decreasing and shortening the displacement of the University community. The relationship between public health and carbon footprint in mobility is significant, because the carbon footprint refers to the amount of GHG, primarily carbon dioxide, emitted directly or indirectly by transportation. High carbon emissions

from vehicles contribute to air pollution, which can have adverse effects on public health. In the case of students, 70 % chose "yes" in response, being interested in learning more about their carbon footprint.

Embracing alternative services of transportation presents a promising avenue for mitigating air pollution, enhancing health outcomes, and elevating overall quality of life while concurrently decreasing carbon footprint and improve energy efficiency (Pandey, 2024). By opting for eco-friendly services of travel such as cycling, walking, or using public transit, individuals can significantly curb emissions of harmful pollutants, thereby ameliorating air quality and reducing the risk of respiratory illnesses and other health issues associated with pollution exposure. Additionally, the shift towards sustainable transportation options fosters physical activity, leading to improved fitness levels and overall well-being. Moreover, by reducing reliance on conventional vehicles powered by fossil fuels, communities can effectively diminish their carbon footprint, contributing to global efforts to combat climate change. This transition not only promotes environmental sustainability but also cultivates more livable and resilient urban environments, ultimately enhancing the overall quality of life for the community.

Livability

The sustainable and inclusive urban mobility prioritizes people over vehicles, ensuring free transit, the hierarchy of urban mobility, promotes modes of transport that enhance equity, social benefit and environmental paths (UAEMEX, 2023b). As part of the Road Safety and Mobility program and University mobility projects, 54 % do not know them and 40 % yes. Universities, as knowledge centers, and their campuses, akin to compact small cities, provide an optimal environment for pioneering, implementing, and assessing policies and tools aimed at innovative mobility solutions, these initiatives can later be expanded to diverse contexts (Tormo-Lancero et al., 2022). About urban mobility plans, 43 % agree that the University contributes to actions that promote safe and sustainable mobility for citizens, for example with the Competency Management Board for Safe and Sustainable Mobility in Public and Private Transport of the State of Mexico (Gobierno del Estado de Mexico, 2023)

The Interurban Train started partial operations in September 2023, at the four stations of the section that corresponds to the State of Mexico. The service schedule is from 06:00 to 23:00 hours and the tour is completed in approximately 16 minutes. Of the 17 % of students who answered that bring them some benefit. The Figure. 6, responded with 62 % of students that it is the reduction of transfer time the greatest advantage, which the advantage of distance and cost.

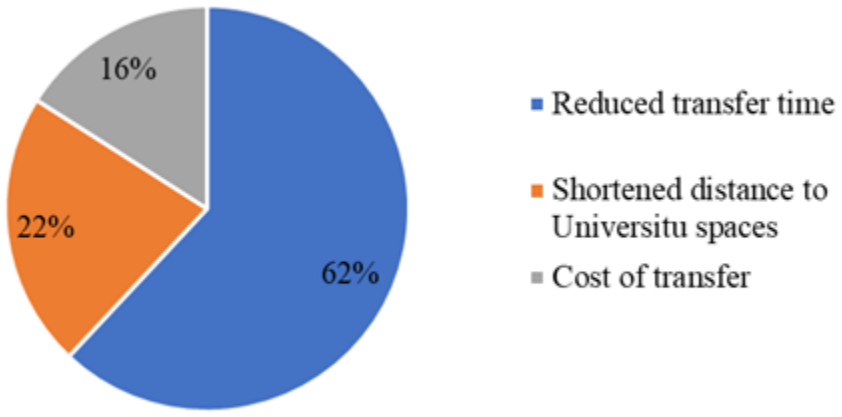

Figure 6.
Percentage of advantages that the Interurban Train on University community.

Since 2016, the technological tool offers to users of the Potro Bus more information and communication elements, with the aim of increasing the efficiency of the use of the University Transport System, but 52 % don't know, considering that it is a good tool. Improving livability through urban mobility plans involves actively educating and engaging the University community in sustainable transportation initiatives with technological and environmental point of view (Gallo & Marinelli, 2020; Metastasio et al., 2024). The introduction of technological solutions, such as mobility applications, plays a crucial role in promoting sustainable transportation. For instance, a University could develop or support an application that facilitates bike-sharing among University community. Another example could be an application that provides real-time updates on public transportation schedules, encouraging more efficient travel planning and increasing public transportation usage.

The environmental initiative to improve positive impact on campus livability, to implement programs can significantly increase participation in sustainable mobility practices. A University could offer rewards, such as discounts at the campus to individuals who regularly use eco-friendly modes of transportation such as cycling, walking, or carpooling (Shaheen & Cohen, 2018). This approach not only supports environmental sustainability but also enhances the overall quality of life on campus.

Jobs

The operator interviews were not accessible, due to the reliability of information on accidents in the operation, medical service and hours of work to operate, however recently published a news about the training and certification of operators, which will be through professionalization through workshops to have a professional profile of transport management, as part of the fulfillment of the Mobility Program of the State of Mexico (Gobierno del Estado de Mexico, 2023).

After receiving training, the plan is to conduct interviews with the workers. Additionally, the "Moovit app" can be installed on any electronic device with internet access, providing information on travel times, schedules, and costs for various modes of transportation, to explore the correlation between Google search popularity and the percentage of workers who commute using public transportation (Santos & Nikolaev, 2021). Furthermore, the study examines relevant social impact indicators for the University and proposes subcategory indicators for workers, including safety, income, social insurance, education, and training, and working hours, based on a review of project reports and financial statements. The reliability of the data was verified by conducting an on-site questionnaire survey of the workers (Yang et al., 2022).

Recommendations and future studies

In the quest for more sustainable and mobility systems, it is imperative to extend the evaluation framework beyond the social perspective of transportation to include a wider array of social aspects and the entire supply chain. This comprehensive approach not only amplifies the scope of impact assessment but also aligns with the increasing environmental consciousness and the need for holistic sustainability models. The integration of Social Life Cycle Assessment (S-LCA) and Life Cycle Assessment (LCA) methodologies offers a robust tool for this purpose, facilitating a detailed examination of both the social and environmental footprints of mobility systems. These methodologies enable the identification of key impact areas, from the direct emissions of school transport to the indirect effects of the broader transportation infrastructure, including private cars, urban transport, and non-motorized options. By broadening the assessment to encompass the full supply chain and incorporating a variety of social factors, we can achieve a more nuanced understanding of the impacts associated with University transportation systems. This expanded approach not only aids in pinpointing areas for improvement but also ensures that the voices of all stakeholders are considered in the

development and operationalization of mobility solutions, thereby fostering a more inclusive and sustainable mobility landscape.

In the literature, the LCA and S-LCA have similarities such as the steps in ISO 14040, the objective data to facilitate assessment and the pre-evaluation tool for decision making and the geographical characteristics of the data; the differences are between impacts categories, inventory analysis object and method evaluation (Yang et al., 2022). The scientific databases for mobility literature, Figure. 7, such as Science direct, Web Science, Directory of Open Access Journals and Scopus using the keywords sets “LCA”, “social life cycle assessment”, “social indicators”, “social sustainability”, “S-LCA”, “sustainable mobility” and “transportation”, among others.

Figure 7.

Most reported environmental and social keywords by the scientific mobility literature analyzed.
Source: Word Cloud Generator.

The selection of categories for social performance measures in the study served as an initial step toward developing S-LCA performance indicators, ensuring that the final set of measures is sufficiently comprehensive (Ostovar, 2023). The S-LCA methodology focus on collect information to evaluate actual or potential social impacts throughout the life cycle of use phase on University Mobility System. Social impacts, as defined, are outcomes of positive or negative pressures on social endpoints, such as the well-being of stakeholders (UNEP, 2020) Critics point out inconsistencies and contradictions in the search for standardization, which hinder the production of clear, trustworthy, and comparable results. Additionally, the S-LCA method is not integrated with social sustainability goals such as the Sustainable Development Goals (SDG). To implement S-LCA as a method for enhancing inclusivity in the design and operationalization of sustainable transportation measures, ensuring that the perspectives of all stakeholders are acknowledged and equally valued in the planning of mobility services (Osorio-Tejada et al., 2020; Woodcock et al., 2021) . In the context of growing environmental awareness and the imperative need for more sustainable mobility models, University transportation emerges as a key area for the exploration of practices that not only optimize logistical efficiency but also minimize their social and environmental impact. Student mobility, intricately tied to University life, encompasses various modalities, ranging from school transport with direct emissions to more indirect options such as private cars, urban transport, bicycles, on foot, and motorcycles.

Based on the results of applying S-LCA and LCA methodologies across various sectors, it can be observed that, unlike conventional LCA which focuses on guiding sustainable direction (Haddad et al., 2023; Mancini & Sala, 2018; Papo & Corona, 2022; Wang et al., 2022) , S-LCA highlights both negative impacts (such as poor working conditions, accidents, human rights abuses) and positive impacts (such as royalties, job creation, infrastructure improvements, tax payments) when conducting sustainability assessments. S-LCA utilizes both generic and site-specific data and can be conducted in a quantitative, semi-quantitative, or qualitative manner. It serves as a complement to LCA and life cycle costing (LCC) (Ramos, 2024).

Incorporating SDG could enhance its widespread applicability, as it provides a standard for interpreting individual performance, thereby increasing its appeal (Hannouf et al., 2023; Pollok et al., 2021) . The Mobility University System, figure 8, have connections with SDG 3 (Health and well-being), target 3.2, aims to halve the number of road traffic deaths and injuries worldwide, target 3.9, the number of deaths and diseases caused by hazardous chemicals and air, water and soil pollution must be reduced. On the other hand, SDG 11 (Sustainable cities and communities) target 11.2 mentions that safe, affordable, accessible and sustainable transport service should be provided in addition to improving road safety by expanding public transport, for all, but paying special attention to the vulnerable groups. About SDG 13 (climate action), target 13.2, focus on integrating climate change measures adopting policies that favor low-carbon growth, and contribute to global efforts to reduce GHG emissions, helping to slow down global warming. The results of this SDG in 2019 show that only half of the world's urban population had convenient access to public transport. The alignment with these goals is to promote low-carbon urban transport and achieve carbon neutrality at the University, provides a standardized method using historical data to analyze global urban transport CO2 emissions and identify transition phases towards low-carbon transport (Li et al., 2022), and find significant policy implications for urban sustainability and transportation planning.

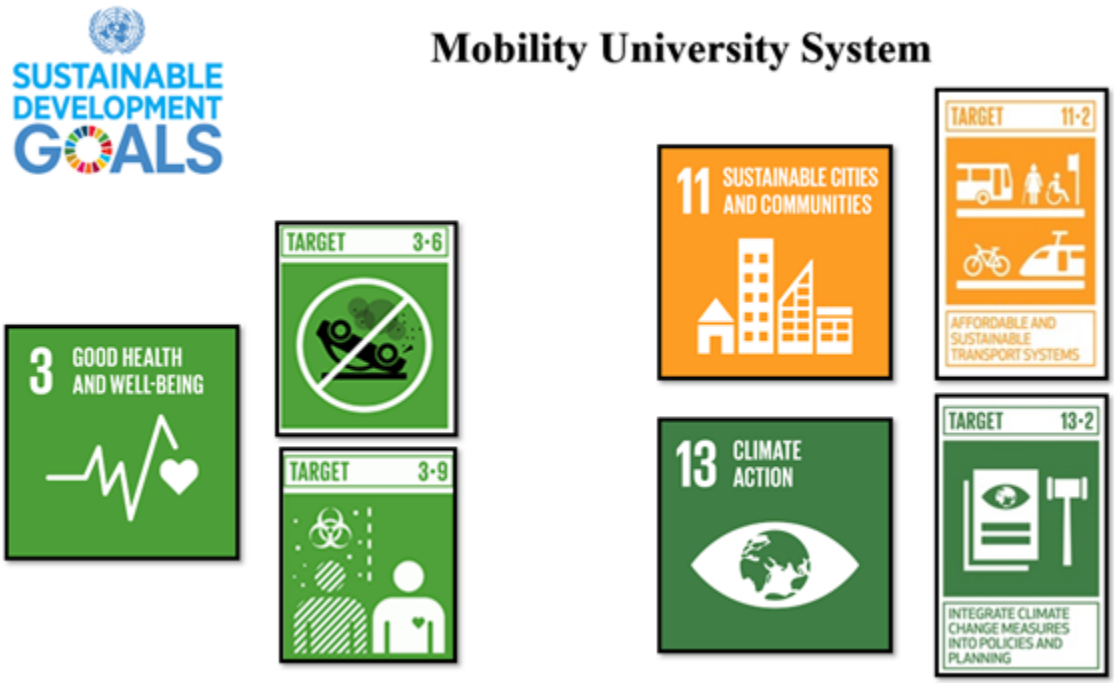

Figure 8.
Mobility University System connections with SDG and targets.
Source: Adapted to (Hannouf, et al., 2023)

Conclusions

The social perception about the mobility system in the Autonomous University of Mexico State, had an important participation of the University community, considering a representative sample in the campus. To measure the social performance of the University mobility service, the survey questions were divided into five categories: accessibility, jobs, mobility and connectivity, safety and public health, and livability. Regarding accessibility, the topics of transport services were addressed, which were 39 % urban transport, 22 % Potro Bus (diesel), 20 % private car, and 9 % walking; the Potro Bus being the mobility service of the student community to which they referred the most throughout the survey. On mobility and connectivity, 29 % consider that the transport system adapts to their needs, considering that it is timely and providing broad and economic coverage. About safety and public health, 78 % have had no accidents in transport units and 43 % consider it to be inclusive transport for women and disabled users, resulting in the provisions of the user decalogue; in relation to public health, 70 % are interested in learning more about the carbon footprint generated by University transport from an environmental education program. In terms of feasibility, 54 % don't know the various urban programs that have been published, recognizing that the University is contributing to actions to promote safe and sustainable mobility, 62 % think it will be an advantage to reduce their transfer times to the University; 52 % also believe that technological tools have not been valued within the University.

Finally, about jobs, it is known that operators will receive a certification to meet a professional profile in the management of transport. Furthermore, the application of Life Cycle Assessment and Social Life Cycle Assessment methodologies to the transport sector remains underexplored. This study marks a step towards filling this gap by offering a holistic view of both the social and environmental impacts of University mobility services. This approach not only aligns with Sustainable Development Goals: 3, 11, and 13, but also underscores the potential of University transport systems to contribute to global sustainability targets, specifically targets: 3.6, 3.9, 11.2 and 13.2. This research paves the way for future research and the development of sustainable mobility solutions that cater to the needs of the university community while contributing to broader sustainability goals.

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Abbreviations

LCA (Life Cycle Assessment)
S-LCA (Social Life Cycle Assessment)
MaaS (mobility as a service)
GHG (greenhouse gas emissions)
SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2)
UAEMEX (Autonomous University of Mexico State)
SDG (Sustainable Development Goals)

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