UNIVERSIDAD POLITÉCNICA SALESIANA

SEDE CUENCA

CARRERA DE INGENIERÍA AUTOMOTRIZ

SUSTAINABLE MOBILITY IN HIGHER EDUCATION INSTITUTIONS: CASE OF SALESIAN POLYTECHNIC UNIVERSITY CUENCA CAMPUS

Trabajo de titulación previo a la obtención del título de Ingeniero Automotriz

AUTORES: ANDRÉS OSWALDO CELI FLORES
ADRIÁN JOSÉ LAVANDA CARRIÓN
TUTOR: ING. JAVIER STALIN VAZQUEZ SALAZAR

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Atentamente,

Andrés Oswaldo Celi Flores
1150207346

Adrián José Lavanda Carrión
150046009

Sustainable Mobility in Higher Education Institutions: Case of UPS

1st Andrés Oswaldo Celi Flores
Automotive Engineering Career
Universidad Politécnica Salesiana
Cuenca, Ecuador
acelif@est.ups.edu.ec

2nd Adrián José Lavanda Carrión
Automotive Engineering Career
Universidad Politécnica Salesiana
Cuenca, Ecuador
alavanda@est.ups.edu.ec

Abstract—This document delves into the realm of sustainable mobility in Cuenca, Ecuador, specifically centering on the commuting dynamics of students and collaborators from the Universidad Politécnica Salesiana. The focus is on leveraging existing mobility systems, such as tram and urban bus services, while introducing novel modes, such as shared bicycles and electric scooters, into the transportation landscape. The com- prehensive analysis addresses both challenges and opportunities within urban parishes, contributing to the development of a sustainable mobility plan designed to improve the transportation experience for students and collaborators. The proposed plan integrates established systems, such as trams and urban buses, with the introduction of innovative shared modes, fostering a multimodal approach to accommodate the diverse needs of users. The strategic framework encompasses seven pillars across the domains of vision, policy, and implementation, ensuring the seamless incorporation of these diverse mobility solutions for a more sustainable and user-centric transportation system for students and collaborators.

Index Terms—sustainable mobility, transportation, shared bi- cycle, scooter, university, student

I. Introduction

Mobility stands out as a fundamental element in shaping the dynamics of a city, playing a crucial role that profoundly influences the quality of life of its residents, especially impacting the day-to-day experiences of those associated with educational institutions. The efficiency and accessibility of the urban transportation system not only affect the functionality of the city but also serve as key factors in improving the effectiveness of daily activities for students and members of various institutions in the locality. Effective design and management of mobility options not only ensure smooth connectivity, but also contribute significantly to the creation of more inclusive and sustainable urban environments. [1] [2]

Sustainable mobility is particularly relevant in specific environments, such as higher education institutions. Firstly, universities are expected to lead cities in their efforts toward sustainable mobility. In addition, universities function as small cities within a city. They are unique communities where people with different lifestyles, backgrounds, beliefs, and ages coexist and share spaces for studying and working. [3] [4]

This paper consists of two main parts. The first challenges two underlying principles of conventional transportation planning: trips as derived demand and minimization of travel costs. It suggests that the existing paradigm should be more flexible, especially if the sustainable mobility agenda is to become a reality. The second part argues that there are policy measures available to enhance urban sustainability in terms of transportation, but the main challenges are related to the necessary conditions for change. These conditions depend on the high-quality implementation of innovative plans and the need to gain public trust and acceptability to support these measures through active participation and action. [5] [6]

II. Theoretical Framework

Sustainable mobility in university settings has been a recent subject of research attention. The implementation of sustainable mobility systems is crucial for reducing the environmental footprint of academic institutions. Furthermore, Azzali and Sabour [3] emphasize the importance of adequate infrastructure, such as bike lanes and charging stations for electric vehicles, to support and evolve the mobility system to a more sustainable mode.

According to Banister [5], complaints about the time it takes to move from one place to another are prevalent, and many studies are conducted with the aim of reducing travel time. Vehicular congestion is the primary issue hindering timely mobilization. [7]

Shields [8] focuses on the displacement of students to higher education institutions (HEIs) and its impact on climate change. The study examines the influence of the distance between student and collaborator residences and educational institutions on the choice of transportation mode. The findings highlight the importance of understanding the specific challenges students face in accessing sustainable transportation options. The relationship between public transportation availability and student mobility is analyzed, emphasizing the need for institutional policies favoring sustainability in commuting to HEIs. [9]

Regarding current trends and approaches, Cappelletti [10] highlight the growth of vehicle sharing programs, improved public transportation, safe walking paths, and bicycle facilities, with a specific analysis for their application at the University

of Foggia, Italy. There is a shift towards comprehensive approaches that combine sustainable transportation policies with awareness initiatives, examining the causes or benefits of implementing these proposals on the environment.

Banister [5] suggests that policy measures can be applied to change transportation modalities, with the aim of reducing car usage. Promotion of human-powered transportation is encouraged by reducing the space and speed of urban traffic, reallocating it to public transportation. This approach creates greater difficulty for private vehicle mobilization, reallocating space not only to public transportation but also to eco-friendly modes such as wider pedestrian and cyclist areas.

In the university context, institutions such as the University of California, Davis, the University of Oregon, Leiden University, the University of Oviedo, the University of Colorado, Boulder and the University of Cambridge lead the promotion of cycling as a sustainable means of transportation. They implement measures such as bike lanes, improved bike parking, bike rental programs, and incentives for cycling within their campuses. [11] [9] [12] [4]

III. Methodology

A. Detailed Survey Design Description

In the context of sustainable mobility, the survey is designed to gather information from students and collaborators with a focus on commute patterns to the Universidad Politécnica Salesiana. The survey addresses the following key questions:

1) Home Address: Collects the specific residential address of students and collaborators.

2) Parish: Identifies the parish in which the student and collaborator reside.

3) City: Captures the city of residence for complete understanding.

4) Transportation Mode: Inquire about the type of transport used for the daily commute.

5) Estimated Travel Time: Obtain information on the approximate time spent on the daily commute.

6) Estimated Distance:: The purpose of this paper is to determine the estimated distance between the residence of the student and the collaborators and the Universidad Politécnica Salesiana to propose the means or the transportation.

The survey is designed to explore mobility patterns, taking into account the challenges and strengths of transportation. The target population comprises around 6,000 students and 500 collaborators from the Universidad Politécnica Salesiana. Students and collaborators predominantly use private vehicles, with instances of single occupancy. In addition, a significant portion relies on public transportation options like buses and trams. Some students and collaborators, who live close to the university, opt for sustainable modes of transport, such as bicycles or walking.

To analyze commuting patterns, each student's address is geolocated on a city map using a coordinate system. This allows for the calculation of the distance each student needs to cover to reach the Universidad Politécnica Salesiana. The mapping process also facilitates the identification of specific challenges and circumstances that some students may encounter during their commute.

Fig. 1. Cuenca road network. Source: Authors

This survey is crucial for understanding and promoting sustainable mobility practices within the student population, providing valuable insights for addressing transportation weaknesses and fostering a more environmentally friendly and efficient transportation system for the Universidad Politécnica Salesiana community.

B. Statistical Sample Size

In the context of the research conducted at the Universidad Politécnica Salesiana, it is essential to determine an appropriate sample size for reliable results. The university's combined population of students and collaborators, with 6000 students and 500 collaborators, respectively, becomes a focal point in estimating specific characteristics with a high level of confidence.

For the student population, a targeted 96 % confidence level and a 4 % margin of error lead to a calculated sample size (n) of approximately 556 students.

$$\frac{N \cdot z^2 \cdot p \cdot q}{e^2 \cdot (N - 1) + p \cdot q}$$

$$\frac{6000 \cdot 2.05^2 \cdot 0.5 \cdot 0.5}{0.04^2 \cdot (6000 - 1) + 0.5 \cdot 0.5}$$

$$n \approx 556$$

Simultaneously, for the collaborator population, a targeted 96 % confidence level and a 4 % margin of error result in a calculated sample size (n) of approximately 174 collaborators.

$$\frac{N \cdot z^2 \cdot p \cdot q}{e^2 \cdot (N - 1) + p \cdot q}$$

$$\frac{500 \cdot 2.05^2 \cdot 0.5 \cdot 0.5}{0.04^2 \cdot (500 - 1) + 0.5 \cdot 0.5}$$

$$n \approx 174$$

C. Obtaining Distances for Transportation

The acquisition of precise distance metrics from the residence of each student and collaborator to the Universidad Politécnica Salesiana involved a rigorous geospatial methodology using ArcGIS software. The initial step encompassed the geolocation of survey-provided addresses, utilizing geocoding processes to transform textual representations into spatial coordinates. ArcGIS, a sophisticated Geographic Information System (GIS), was used for its robust capabilities in spatial analysis and visualization.

Fig. 2. Cuenca road network and starting points for each student. Source: Authors

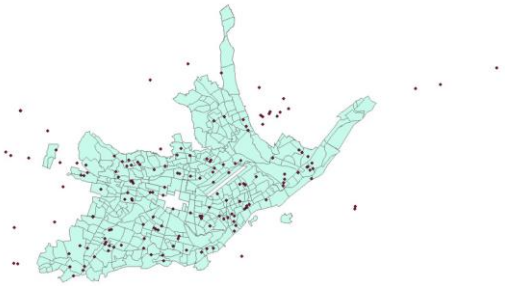

Fig. 3. Starting point of each collaborator. Source: Authors

Subsequently, the establishment of centroids within every parish and neighborhood of Cuenca ensued, strategically positioned to encapsulate the geographic centers of these regions. The precision of the geolocation was paramount to ensure an accurate representation of the spatial distribution of student residences throughout the city. This meticulous approach facilitated a comprehensive understanding of the geographic spread of the student demographic.

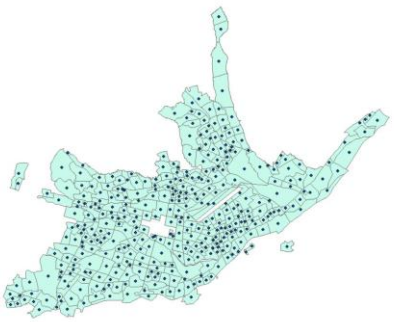

Fig. 4. Centroid of each neighborhood. Source: Authors

The resultant spatial data set enabled the creation of distance matrices, quantifying the geographic separation between each centroid and the university campus. This quantitative representation was instrumental in delineating spatial patterns and identifying potential areas of concentration or dispersion in student and collaborator residences.

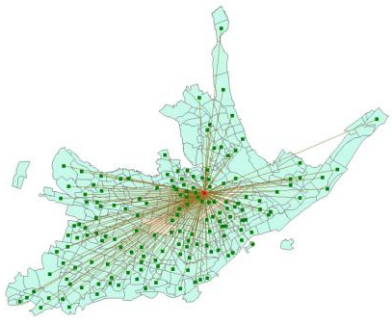

Fig. 5. Lines of desire from each neighborhood towards the UPS . Source: Authors

Moreover, this geospatial analysis allowed for the identification of optimal routes and transportation corridors, providing insights into the most frequented pathways students and collaborator undertake to reach the university. The ArcGIS geospatial analysis not only served as a tool for distance measurement but also as a robust framework for spatial modeling and visualization, enhancing our capacity to discern intricate spatial relationships.

Ultimately, this comprehensive geolocation and distance analysis form the basis for informed decision making about sustainable transportation solutions. By leveraging this geospatial data, the university can tailor mobility initiatives to the specific geographic needs of its student and collaborator population, fostering efficient, environmentally conscious, and accessible commuting options.

IV. Analysis of Results

In examining the transportation patterns among students, an insightful analysis emerges, shedding light on prevalent mobility trends within the university community. The predominant modes of transportation include public buses, walk-by trains, and private vehicles, each offering distinct advan-

tages and presenting unique challenges. This analysis aims to investigate the dynamics of these transportation choices, emphasizing the overarching goal of fostering sustainable mobility practices while addressing the diverse needs of the student population. By comprehensively understanding the advantages and challenges associated with public transportation, walking commutes, and private vehicle usage, we can formulate strategic recommendations to enhance the overall sustainability and efficiency of student mobility within the university environment.

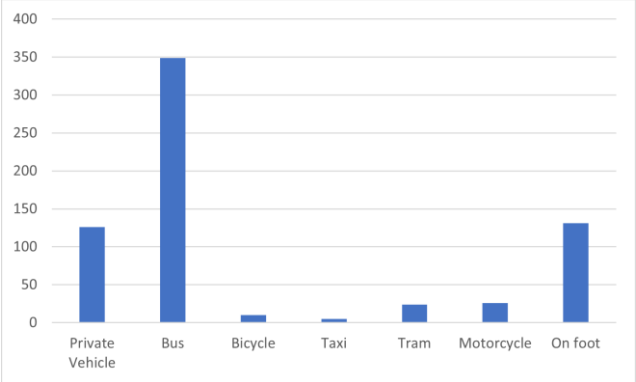

Fig. 6. Type of transportation used by Students. Source: Authors

A. Public Transportation (Bus):

1) Advantages: The prevalence of public transportation use among students signifies increased accessibility and cost effectiveness. The extensive reach of bus services ensures that a large student population can conveniently access the campus, fostering inclusivity. Moreover, the economical nature of public transportation aligns with sustainability goals, making it an environmentally conscious choice.

2) Challenges: However, challenges remain within the realm of public transportation, particularly with regard to possible delays and longer travel times. These issues may affect the overall efficiency of the commute and could impact the reliability of this mode of transportation for students with time-sensitive schedules.

B. Walking Commute:

1) Advantages: The inclination towards walking commutes reveals a commitment to health-conscious and sustainable practices among students. The act of walking not only promotes physical well-being, but also aligns with environmental goals by minimizing carbon emissions. For students residing in close proximity to the campus, walking serves as a convenient and sustainable mode of transport.

2) Challenges: However, challenges arise when students must navigate impractical distances on foot. The feasibility of walking as a primary mode of transportation may be limited for those living farther away from the university, requiring complementary transportation options to ensure universal accessibility.

C. Private Vehicles:

1) Advantages: The use of private vehicles provides students with unparalleled flexibility, allowing them to tailor commute schedules and destinations according to individual preferences. This mode of transportation also offers a level of comfort and privacy not readily available with other options, providing a personalized and convenient travel experience.

2) Challenges: However, challenges emerge with private vehicle usage, including the potential for increased traffic congestion and the demand for on-campus parking. These challenges not only contribute to environmental concerns, but also pose operational difficulties in managing vehicular flow within the university infrastructure, necessitating a careful balance between convenience and sustainability.

D. Classification of distances

Within the analysis of distances, a classification of four has been determined based on the distances traveled by certain groups of students.

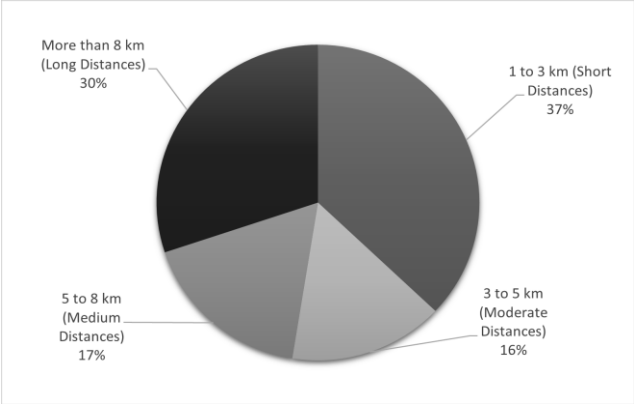

Fig. 7. Percentage of Students According to the Distance to Travel. Source: Authors

1) Short Distances (1 to 3 km):: 37 % of the respondents have a relatively short distance to travel, indicating that a significant portion of the population lives close to the university. This might suggest that a considerable number of students or faculty can walk or use short commutes, which can be beneficial in reducing transportation costs and promoting a healthier lifestyle.

2) Moderate Distances (3 to 5 km):: 16 % of the respondents have distances ranging from 3 to 5 km. This suggests that there is a moderate-sized group of individuals who have a somewhat longer commute compared to the first group but still within a reasonable distance. Depending on the location and transportation options, these individuals might use bikes, public transport, or cars for their daily commutes.

3) Medium Distances (5 to 8 km):: 17 % of the respondents have distances between 5 and 8 km. This indicates that there is a notable portion of the population with a relatively longer commute to the university. People in this group may have to rely more on motorized transportation, and factors such as traffic and commute time become more significant for them.

4) Long Distances (More than 8 km):: 30 % of the respondents have distances greater than 8 km, which represents a substantial proportion of the population. - Individuals in this group likely face longer commute times, potentially requiring more advanced transportation options, such as cars or public transit.

V. Discussion

The analysis of results reveals significant trends in student mobility, highlighting the predominant use of public buses, walking commutes, and private vehicles, each with distinct advantages and challenges. To propose a sustainable mobility plan for the university, the following recommendations can be considered:

A. Conventional Bikes (1 to 3 kilometers):

For short distances of 1 to 3 kilometers, conventional bikes are an ideal choice. Their advantages include low energy consumption, requiring only human power, and zero emissions. Biking for these distances is not only environmentally friendly but also promotes physical activity, contributing to healthier lifestyles. Additionally, biking often allows for quicker point-to-point travel, especially in congested urban areas, and requires minimal infrastructure investment.

B. Electric Bikes (3 to 5 kilometers):

Electric bikes become advantageous for distances ranging from 3 to 5 kilometers. They offer the combined benefits of traditional bike and electric assistance capabilities. With low energy consumption and minimal emissions, electric bikes provide an eco-friendly alternative for slightly longer distances. The electric assist feature reduces travel time and makes cycling more accessible to a wider range of people. Electric bikes require less effort from riders, making them suitable for various fitness levels. In addition, the infrastructure needed for electric bikes, such as charging stations, is relatively simple and cost-effective.

C. Advantages of Electric Scooters (5 to 8 kilometers):

For distances of 5 to 8 kilometers, electric scooters present a practical solution. Their advantages include low energy consumption, with efficient electric motors, and zero emissions, which contributes to environmentally sustainable transportation. Electric scooters offer a faster and more convenient option for mid-range distances, reducing travel time compared to traditional modes of transportation. Their compact design allows for easy parking and storage, requiring minimal infrastructure investment. Additionally, electric scooters can navigate through urban traffic efficiently, providing a time-saving and eco-friendly alternative for commuting.

D. Options for Distances Over 8 Kilometers:

1) Private Electric Vehicles: Private electric vehicles offer the convenience of personalized transportation with the added benefits of low energy consumption and reduced emissions compared to traditional internal combustion engine vehicles. They provide flexibility in travel routes and timings, contributing to a comfortable commuting experience. [13]

2) Electric Motorcycles: Electric motorcycles are suitable for longer distances, offering a balance between energy efficiency and speed. They provide a faster mode of transportation while maintaining lower emissions and reduced environmental impact. Electric motorcycles can navigate through traffic efficiently, making them a practical choice for urban commuting.

3) Electric Public Transport: Electric-powered public transport, such as buses and trains, serves as a sustainable option for longer distances. These modes of transportation contribute to the reduction of emissions and congestion. Electric public transport systems are often well-established, providing a reliable and cost-effective means of commuting for a larger population.

4) Electric Taxis: Electric taxis combine the convenience of on-demand transportation with the environmental benefits of electric propulsion. They are suitable for individuals who prefer a door-to-door service, providing a comfortable and efficient option for longer-distance travel. Electric taxis contribute to reducing air pollution and noise levels in urban areas.

5) Promotion of Tram Usage: Trams offer a sustainable and efficient mode of public transport for longer distances within urban areas. They operate on electric power, resulting in zero emissions during travel. Trams contribute to reducing traffic congestion and provide reliable and punctual service. Promoting the use of trams aligns with sustainable urban mobility initiatives and promotes a greener transportation system.

VI. Conclusion

In conclusion, the analysis of transportation patterns among students and collaborators at the Universidad Politécnica Salesiana in Cuenca, Ecuador, reveals the prevalence of public buses, foot traffic, and private vehicles as the main modes of transportation. The analysis highlights the advantages and challenges associated with each mode of transport, highlighting the need for a sustainable mobility plan that addresses the diverse needs of the student and collaborator population. The proposed plan integrates established systems, such as trams and urban buses, with the introduction of innovative shared modes, fostering a multimodal approach to accommodate the diverse needs of users. The strategic framework encompasses seven pillars across the domains of vision, policy, and implementation, ensuring the seamless incorporation of these diverse mobility solutions for a more sustainable and user-centric transportation system. By implementing the recommendations outlined in this document, the university can enhance the overall sustainability and efficiency of student and collaborator mobility within the university environment, fostering a more environmentally friendly and inclusive transportation system for the Universidad Politécnica Salesiana community.

VII. Recommendations

A. Enhance Public Transportation

Increase the frequency and efficiency of public transport not only within the university campus but also in its surrounding areas. This involves expanding the public transport network,

B. Promote Walking Commutes

Extend campus design strategies beyond university borders to create pedestrian-friendly pathways connecting surrounding neighborhoods. By collaborating with local authorities, the university can contribute to the development of safe sidewalks, pedestrian zones, and bike lanes in the areas adjacent to the campus, encouraging sustainable and healthy commuting practices.

C. Sustainable Alternatives for Private Vehicles

Collaborate with local communities to promote sustainable alternatives for private vehicles in the vicinity of the university. This includes advocating for ridesharing programs, incentivizing the use of electric or hybrid vehicles, and working with local authorities to implement shared transportation initiatives that benefit both students and residents in the surrounding areas.

D. Integration of Shared Mobility Options

Extend the integration of shared mobility options, such as bike-sharing and electric scooters, to cover routes leading to the university from nearby neighborhoods. By fostering partnerships with local transportation providers, the university can contribute to a seamless and sustainable multimodal transportation network for both students and the local community. E. Education and Awareness Extend educational and awareness campaigns to encompass not only university students but also residents in the surrounding areas. Workshops, seminars, and campaigns should emphasize the collective benefits of sustainable transportation practices, encouraging a broader community engagement in adopting eco-friendly commuting habits.

E. Education and Awareness

Extend educational and awareness campaigns to include not only university students but also residents of the surrounding areas. Workshops, seminars and campaigns should emphasize the collective benefits of sustainable transportation practices, encouraging the participation of the larger community in the adoption of environmentally friendly commuting habits. [16]

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