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SISTEMA INTELIGENTE DE GESTION DE TRANSPORTE (SIGT)

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ABSTRACT

The proposed system aims to strengthen information management through the use of digital technologies that facilitate communication between transportation providers and passengers. Its implemeThis research presents an overview of the implementation of an Intelligent Transportation Management System (ITMS) as a technological strategy to improve the management and accessibility of public transportation information. The study focuses on the need to enhance the quality of transportation services by providing users with reliable and timely information, thereby supporting better decision-making and improving the overall travel experience.

The proposed system aims to strntation is expected to contribute to greater operational efficiency, improved service quality, and enhanced user satisfaction, while supporting sustainable urban mobility and regional development.

KEY WORDS: Intelligent Transportation Management System, public transportation, urban mobility, digital technologies, information management.

1. INTRODUCTION

Mobility is one of the fundamental pillars of economic, social, and territorial development, as it facilitates access to essential services, employment opportunities, education, healthcare, and commercial activities. In this context, public transportation plays a strategic role by enabling the daily movement of millions of people and contributing to the integration of cities and regions. However, rapid urban growth, increasing mobility demand, and digital transformation have created new challenges for transportation systems, particularly in the efficient management of user-oriented information (United Nations [UN], 2015; National Institute of Statistics and Geography [INEGI], 2023).

In response to these challenges, many countries have implemented Intelligent Transportation Systems (ITS), which integrate information and communication technologies to optimize transportation operations, improve resource management, and provide users with real-time information on routes, schedules, estimated arrival times, service disruptions, and operating conditions. The implementation of these systems has demonstrated significant benefits, including reduced travel uncertainty, improved passenger experience, and enhanced operational efficiency in public transportation services (Ministry of Infrastructure, Communications and Transportation [SICT], 2024; Mexican Institute of Transportation [IMT], 2021).

In Mexico, the digitalization of mobility services has gained increasing importance in recent years as part of national strategies

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aimed at modernizing public transportation and improving customer service. Nevertheless, the adoption of technological tools remains uneven, as many bus terminals continue to rely on traditional methods of providing information, such as ticket counters, printed notices, and verbal announcements. This situation limits timely access to information regarding schedules, platform changes, service delays, and trip availability, negatively affecting travel planning and users' perception of service quality (Ministry of Agrarian, Territorial, and Urban Development [SEDATU], 2024; SICT, 2024).

The Pachuca Bus Terminal, located in Pachuca de Soto, Hidalgo, presents similar conditions. Based on direct observation and a preliminary assessment, it was identified that users experience difficulties in obtaining accurate and up-to-date information regarding departure and arrival schedules, trip availability, platform assignments, and operational changes. This issue is consistent with the findings of the 2023 National Survey on Government Quality and Impact (ENCIG), which reported that only 31.9% of public transportation users in Hidalgo had access to information about bus schedules, highlighting important opportunities to improve information management and dissemination within the transportation service (INEGI, 2023). Consequently, passengers spend additional time seeking information at ticket counters, increasing waiting times, creating uncertainty, and reducing the perceived quality of the service.

Given this situation, the incorporation of technological tools represents a viable alternative for strengthening communication between transportation companies and users while facilitating immediate access to reliable and updated information. However, ensuring the effective operation of a technological solution requires the implementation of evaluation and continuous improvement mechanisms capable of monitoring system performance and supporting ongoing adjustments. In this regard, the Plan–Do–Check–Act (PDCA) cycle, developed by W. Edwards Deming, is a widely recognized methodology for planning, implementing, evaluating, and continuously improving processes through quality indicators and systematic feedback (Deming, 1986; Hernández-Sampieri et al., 2022).

Based on the above, the objective of this research is to design a mobile application supported by an Intelligent Transportation Management System (ITMS) for the Pachuca Bus Terminal in Hidalgo, Mexico. The proposed system is intended to provide real-time information on schedules, departures, arrivals, trip availability, and platform locations. Furthermore, the study proposes integrating the PDCA continuous improvement cycle as a management strategy to evaluate system performance, optimize information management, enhance the user experience, and contribute to greater operational efficiency in public transportation services.

2. GENERAL OBJETIVE

To design a proposal for an Intelligent Transportation Management System (ITMS) for the Pachuca Bus Terminal in Hidalgo, Mexico, through the integration of digital tools that enhance information management, optimize the user experience, and improve the efficiency of public transportation services in the region.

3. METHODOLOGY

3.1. Design and instrument

A structured questionnaire of 20 questions was applied through a digital form. The instrument includes demographic variables (age, sex), questions about frequency and usage behavior, perception scales (ease of information, sufficiency, waiting times), 5-point Likert satisfaction scales, questions about current use of transport applications, interest in a new app, priority functions (multiple option), items of agreement/disagreement on clarity of information and usefulness of an app in real time (items 13-16), service recommendation, and open item on aspects to be improved.

3.2. Sample and data processing

107 initial records were obtained. After debugging (deletion of 2 practically empty rows and review of inconsistent or misaligned values), the final analytical sample was at N = 105 valid responses. Frequency and percentage analysis was used for categorical variables, averages and standard deviations for ordinal/interval variables (Likert), and the Cronbach Alpha coefficient to evaluate the reliability of multi-item scales. For the open question, a thematic content analysis was carried out.

Software used: Python (pandas, numpy) for cleaning, descriptive statistics and reliability calculation.

Figure 1. Shows a simulation of the use of BusGo in a bus terminal, where users consult routes, schedules and arrival times in real time through the mobile application, facilitating mobility and planning of their trips.

4. Reliability Analysis

The reliability or internal consistency of the scales was evaluated by the Cronbach Alpha coefficient. Values of $\alpha \geq 0.70$ are considered acceptable, ≥ 0.80 good and ≥ 0.90 excellent.

4.1. Scale of Perception of Information and Usefulness of the Application (Items 13-16)

The following items were grouped, all measured on a scale of 1 (totally disagree / very low) to 5 (totally agree / very high):

1. Item 13: The information on schedules, destinations and rates provided by the Central de Autobuses is clear and easy to understand.
2. Item 14: I believe that information on delays, platform changes and availability of runs should be updated in real time.
3. Item 15: A mobile application with real-time information would improve the quality of service at the Pachuca Bus Station.
4. Item 16: I would use a mobile application that would allow me to check schedules, rates, platform location and notifications of changes or delays.

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Scale	N of complete cases	Cronbach´s Alpha (α)
Perception Information + App (4 ítems)	101	0.871
Satisfatoón (Personal + General)	~103	0.227
Interpretation	—	Excellent / Low (different items)

Explanation of the Reliability Table: Cronbach's Alpha coefficient of 0.871 for the four items related to the clarity of current information and the perception/utility of a real-time application indicates excellent internal consistency. This means that the items consistently measure the same underlying construct (the positive assessment towards the improvement of information through technology). The inter-item correlations were moderate to high (especially between items 15 and 16, r ≈ 0.89), which supports the one-dimensionality of the scale. On the contrary, the satisfaction scale composed of only two items (staff satisfaction and general service satisfaction) yielded a very low alpha (0.23), which is expected because they measure relatively independent facets of the service; therefore they are reported separately in descriptive analyses.

5. Descriptive Results

5.1. Characteristics of the Sample

Table 1. Distribution by Age

Age group	Frequency	Percentage
18-25 years old	63	60.6%
26-35 years old	17	16.3%
Under 18 years old	11	10.6%
More than de 45 years	8	7.7%
36-45 years old	5	4.8%
Total valid	104	100%

Explanation Table 1: The sample is predominantly composed of young users (60.6% between 18 and 25 years old). This is relevant because this age group usually has greater technological adoption and greater expectation of digital information in real time. Those over 45 years of age represent only 7.7%.

Table 2. Distribution by Sex

Sex	Frequency	Percentage
Feminine	58	55.2%
Masculine	45	42.9%
I prefer not toy say it	2	1.9%
Total valid	105	100%

Explanation Table 2: There is a slight predominance of women (55.2%). The distribution is relatively balanced, which allows generalization of findings to both sexes without serious biases of representation.

Table 3 Frequency of use of the Central.

Frequency of use	Frequency	Porcentage
Occasionally	47	44.8%
Weenkly	21	20.0%
Diary	20	19.0%
Monthly	16	15.2%
Total valid	104	100%

Explanation Table 3: Almost half of the respondents (44.8%) use the terminal occasionally. However, a significant percentage (39%) uses it with high frequency (daily or weekly). This implies that both frequent and sporadic users would benefit from improvements in information.

5.2. Access and Quality of Current Information

Table 4. Ease of obtaining information about schedules

Ease	Frequency	Percentage
Regular	55	52.4%
Easy	25	23.8%
Difficult	10	9.5%
Very difficult	8	7.6%
Very easy	4	3.8%
Total valid	102	100%

Explanation Table 4**:** More than half of users (52.4%) qualify as 'Regular' the ease of obtaining schedule information. Only 27.6% consider it Easy or Very Easy, while 17.1% perceive it as Difficult or Very Difficult. The approximate average is 3.07 on a 1-5 scale, which indicates a barely neutral-low perception. There is a clear margin for improvement in the accessibility of information.

Table 5. Have you experienced problems due to a lack of information about delays or platform changes?

Answer	Frequency	Percentage
Yes	62	61.4%
No	38	37.6%

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Total valid	100	100%

Explanation (Table 5): A total of 61.4% of respondents reported experiencing problems due to insufficient information regarding delays or platform changes. This represents one of the most significant findings of the study, indicating that most users have encountered inconveniences caused by outdated or unavailable information. Daily passengers reported an even higher incidence of these problems (approximately 79%).

Table 6. Is the information provided at the bus terminal sufficient?

Answer	Frequency	Percentage
Percentage	61	58.1%
Sometimes	25	23.8%
Almost always	8	7.6%
Never	5	4.8%
Almost never	4	3.8%
Total valid	103	100%

Explanation (Table 6): Only 27.6% of respondents considered the information provided at the terminal to be sufficient ("Almost Always" or "Always"). The majority (58.1%) stated that the information is only sufficient "Sometimes," reinforcing the perception that the current information services are inadequate.

Table 7. Waiting Time to Receive Information at the Ticket Counter

Waiting time	Frequency	Percentage
5-10 minutes	57	54.3%
Less than de 5 minutes	30	28.6%
11-20 minutes	15	14.3%
More than de 20 minutes	1	1.0%
Total valid	103	100%

Explanation (Table 7): Although 28.6% of users waited less than five minutes, the majority (54.3%) reported waiting between five and ten minutes, while approximately 15% waited more than ten minutes. These waiting times suggest room for improvement, particularly through the implementation of digital information services.

5.3. Satisfaction with the Service and Staff

Table 8. Satisfaction with Customer Service Provided by Staff

Nivel de satisfacción	Frecuencia	Porcentaje
3. Ni satisfecho ni insatisfecho	49	47.1%
4. Satisfecho	37	35.6%
2. Insatisfecho	11	10.6%
5. Muy satisfecho	5	4.8%
1. Muy insatisfecho	1	1.0%
Total válido	103	100%

Explanation (Table 8): Customer satisfaction with staff was predominantly neutral (47.1%). Only 40.4% of respondents reported being satisfied or very satisfied, while 11.6% expressed dissatisfaction. The estimated mean score was 3.33 out of 5, indicating opportunities for improvement through customer service training.

Table 9. Overall Satisfaction with the Service

Statistic	Value
Mean (1–5 scale)	3.59
Standard Deviation	1.06

Explanation (Table 9): Overall satisfaction reached an average score of 3.59 out of 5, slightly above the midpoint of the scale. Approximately 50.9% of respondents reported being satisfied or very satisfied, while a considerable proportion remained neutral or dissatisfied. The standard deviation (1.06) indicates variability in user perceptions.

5.4. Interest and Perceived Usefulness of a Mobile Application

Table 10. Current Use of Transportation Applications and Interest in a Dedicated Mobile App

Variable	Yes	No
Do you currently use transportation apps?	43.3%	56.7%
Would you like a dedicated app for the Pachuca Bus Terminal (real-time schedules, fares, delays, and platform information)?	90.1%	9.9%
Perceived usefulness of the app	Very Useful 58.1% + Useful 28.6% = 86.7%	Regular/Low 13.3%

Explanation (Table 10): Although only 43.3% of respondents currently use transportation applications, 90.1% expressed interest in having a dedicated mobile application for the Pachuca Bus Terminal. Furthermore, 86.7% considered such an application useful or very useful. This represents the strongest evidence supporting the development of the proposed technological solution.

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Table 11. Most Important Features Desired in a Mobile Application

Feature	Mentions	Approximate Percentage
Updated schedules	81	77%
Fares	59	56%
Delay notifications	44	42%
Routes and destinations	43	41%
Platform locations	35	33%
Ticket purchasing	3	3%
Other (restaurants, tourist attractions)	3	3%

Explanation (Table 11): The most requested features were those related to real-time operational information, including updated schedules, fares, delay notifications, routes, destinations, and platform locations. Ticket purchasing and complementary services received minimal interest, suggesting that the application should initially prioritize reliable and up-to-date information.

Table 12. Mean Scores of Likert Scale Items Regarding Information and Mobile Application (1–5 Scale)

Item	Mean	SD
Clarity of current information	3.11	1.17
Delay and platform information should be updated in real time	3.83	1.31
A real-time mobile application would improve service quality	3.92	1.33
I would use an app with schedules, fares, platforms, and notifications	3.91	1.38
Importance of this aspect for service quality	3.82	1.33
Overall satisfaction with the service	3.59	1.06

Explanation (Table 12): The clarity of current information obtained the lowest mean score (3.11), confirming users' perception of insufficient information. Conversely, items related to real-time updates (3.83), service quality improvement through a mobile application (3.92), and intention to use such an application (3.91) received considerably higher scores. These findings indicate that users clearly recognize the current problem and strongly support the proposed technological solution.

6. Qualitative Analysis: Areas for Improvement (Open-Ended Question)

A total of 67 valid responses to the open-ended question regarding service improvements were analyzed using inductive thematic analysis.

Table 13. Main Improvement Themes Identified

Theme / Category	Approximate Frequency	Representative Examples
Information / Schedules / Delays / Mobile App / Notifications	18	Immediate notifications, mobile app, updated schedules, delay information
Customer Service / Staff / Attitude / Ticket Office	16	Better customer service, staff attitude, ticket office assistance
Vehicles / Cleanliness / Maintenance / Air Conditioning	8	New buses, cleanliness, mechanical maintenance, air conditioning
Drivers / Departure Times / Organization / Efficiency	6	On-time departures, improved organization, faster service
Positive Comments	4	Everything is fine, good service
Others (Safety, Stops, Miscellaneous)	15	Passenger safety, better organization, various suggestions

Explanation (Table 13): The two most significant improvement areas identified were information management (including schedules, delays, and digital tools) and customer service provided by staff. These qualitative findings support and enrich the quantitative results, confirming that the demand for a mobile application is part of a broader need for effective communication and user-centered service.

7. Conclusions and Recommendations

7.1. Main Conclusions

1. The sample was primarily composed of young users (60.6% aged 18–25), a population with a high level of technological affinity.
2. Users perceived significant deficiencies in the current information system. Approximately 61% reported problems caused by insufficient information regarding delays and platform changes, while the clarity of available information obtained the lowest average score (3.11).
3. Satisfaction with staff was moderate to low (mean = 3.33), and overall service satisfaction was moderate (3.59).
4. Interest in a real-time mobile application was remarkably high. 90% of respondents expressed interest in such an

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application, 87% considered it useful or very useful, and the intention-to-use score averaged 3.91.

5. The most requested application features were updated schedules, fares, delay notifications, routes and destinations, and platform locations.
6. The four-item perception scale regarding information quality and the proposed mobile application demonstrated excellent internal consistency (Cronbach's α = 0.871).
7. Qualitative findings confirmed two major priorities: improving information management through digital solutions and enhancing customer service quality.

7.2. Recommendations

1. Develop and implement a mobile application and/or improve digital information displays at the bus terminal to provide real-time schedules, fares, platform locations, and push notifications regarding delays and platform changes.
2. Prioritize operational information features before incorporating ticket purchasing or additional services.
3. Provide customer service training for ticket office personnel and frontline staff to improve communication, professionalism, and user experience.
4. Strengthen visual and audio communication within the terminal regarding delays and platform changes as a complement to the mobile application.
5. Evaluate operational aspects such as vehicle maintenance, cleanliness, and departure punctuality as part of a comprehensive quality improvement strategy.
6. Conduct a post-implementation evaluation to measure changes in user satisfaction and the effectiveness of the new information system after the mobile application has been deployed.

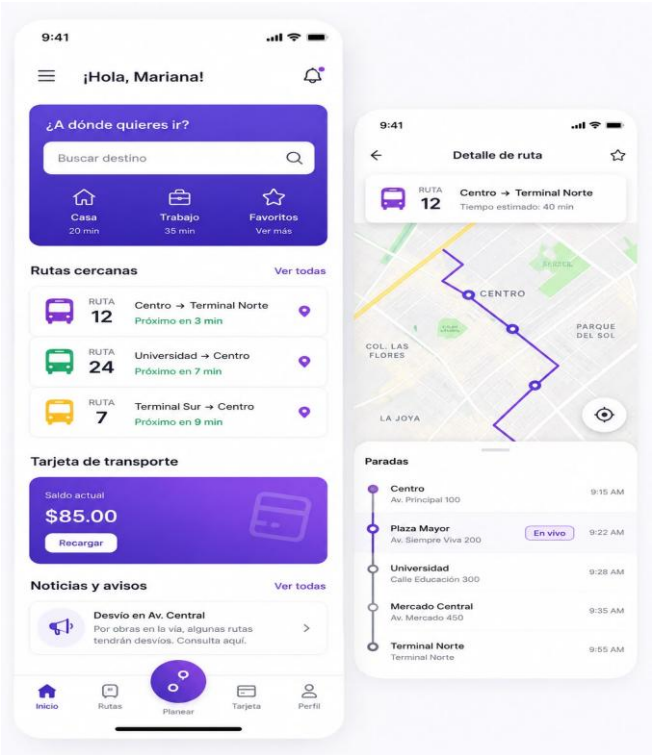

Figure 2. BusGo is a fictional mobile application designed to facilitate the use of public transport. It allows you to check routes, locate nearby stops, know the arrival of trucks in real time and manage the balance of the transport card, offering a quick and easy way to plan the transfers of users.

CONCLUSION

The research findings revealed that, although users of the Pachuca Bus Terminal generally perceive the service positively, there is a clear need to improve access to up-to-date, reliable information regarding schedules, vehicle locations, delays, platform changes, and service availability. These shortcomings create uncertainty, increase wait times, and negatively impact the passenger travel experience.

Survey data indicate broad support for implementing an Intelligent Transport Management System (ITMS), as the majority of participants expressed interest in using a mobile app that provides real-time information. This confirms that technological tools offer a viable alternative for optimizing mobility, facilitating trip planning, and boosting user confidence in the public transport service.

Furthermore, the results support the achievement of the established objectives by identifying key user needs and demonstrating the feasibility of a technological solution based on the PDCA (Plan-Do-Check-Act) continuous improvement cycle. Implementing this proposal would not only enhance information management and operational efficiency at the Pachuca Bus Terminal but also increase user satisfaction by providing a more modern, accessible service tailored to their needs. In this regard, the ITMS represents an innovative strategy with the potential to improve public transport quality and foster more efficient, reliable mobility.

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