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Abstract	Upon identifying the troubled system of public transportation in the Northern-border City of Juarez, Mexico, this research adopts an exploratory approach to address such problem and provide a plausible path to solve it. Urban mobility has become one of the main challenges for the Smart City. The latter concept is a global tendency to achieve competitive edge via adopting technological development regarding public mobility. Juarez system of public transportation experiences lacks of modernity infrastructure, which results in pollution due to obsolete vehicles, delays, passenger saturation during heavy hours, traffic accidents and users' inconveniences. Although many proposals arose in the past to deal with the prevailing situation, to date the city experiences no improvements whatsoever. This paper examines what the scenario would be if the City embarked in the endeavor of adopting high-tech vehicles for public transportation. Particularly, the paper transits through the sate-of-the-art literature to provide in-sights regarding modern transportation alternatives that not only are environmental-friendly, but also financially viable, promoting productive chaining and local benefits. The proposal centers in buses powered by electricity. The paper discusses financial figures and possible scenarios; it also highlights the need for future urban infrastructure improvement and reconfigurations, especially pavement and transportation routes redesign to allocate charging stations.

Keywords (separated by '-')	Urban public transportation - Smart city - Urban mobility - High-tech transportation vehicles - Urban infrastructure

Public Urban Transportation in the Smart City: An Exploratory Study in the Northern México

Arturo Montoya, Aida Yarira Reyes Escalante, Diego Adiel Sandoval Chavez, and Carlos Alberto Ochoa

Abstract Upon identifying the troubled system of public transportation in the Northern-border City of Juarez, Mexico, this research adopts an exploratory approach to address such problem and provide a plausible path to solve it. Urban mobility has become one of the main challenges for the Smart City. The latter concept is a global tendency to achieve competitive edge via adopting technological development regarding public mobility. Juarez system of public transportation experiences lacks of modernity infrastructure, which results in pollution due to obsolete vehicles, delays, passenger saturation during heavy hours, traffic accidents and users' inconveniences. Although many proposals arose in the past to deal with the prevailing situation, to date the city experiences no improvements whatsoever. This paper examines what the scenario would be if the City embarked in the endeavor of adopting high-tech vehicles for public transportation. Particularly, the paper transits through the sate-of-the-art literature to provide in-sights regarding modern transportation alternatives that not only are environmental-friendly, but also financially viable, promoting productive chaining and local benefits. The proposal centers in buses powered by electricity. The paper discusses financial figures and possible scenarios; it also highlights the need for future urban infrastructure improvement and reconfigurations, especially pavement and transportation routes redesign to allocate charging stations.

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1 Smart City

The term Smart City conveys the idea of a sustainable urban setting that improves citizens "quality of life" at the time that does not threat the environment. To do so, Smart City management promotes the adoption of Information and Communication Technologies (ICTs) for urban development [1]. In the late 2000s, IBM coined the term "smarter planet" with the idea of configuring the Smart City, a division of hardware, software and digital services conceived to help local government authorities to promote sustainability in their cities. Applications include monitoring transportation water and energy consumption and other diverse urban activities.

Smart City concept included a series of indicators that look for the use of technology in diverse realms of the city, such as: public institutions, public space, education infra-structure and many more [2]. These indicators gave place to categories and levels, which drove the assessment and presentation of results.

The Annual Report of Institute of Higher Business Studies (IESE) Business School University of Navarra includes a Cities in Motion Index (CIMI), the advance and progress in intelligent cities. IESE ranked London in first place when it comes to implementation of intelligent strategies and tactics. The runner up was New York, while Mexico City ranked 133th., [3].

A city is intelligent if the appellative "intelligent" accompanies its economy, people, mobility, environment, governance and living. As stated before, ITCs are fundamental to achieve competitive edge and to assure a sustainable future [4].

Expected benefits derived from transforming cities into intelligent entities may go far beyond than originally realized. In 2018 was estimated that the global market value of intelligent cities will be higher than US $ 1 billion by 2020 and US $2.5 billion by 2025. It will also promote a higher interaction and participation among government, private sector and stakeholders, aiming to promote wellbeing, life transformation and safety of citizens [5].

Global cities such as San Francisco, Barcelona, Amsterdam, Montreal, Dublin or Singapur, followed London and New York in approving legislation and documents that seek for the establishment of an integral strategy for the adoption of intelligent guidelines for cities [6]. It is also a tendency to widespread the strategy to reach all levels of citizens. It is now common for government officials of intelligent cities to integrate people's initiatives to benefit common people and small business [7].

A Smart City plan must include the development of a strong bandwidth network to support digital applications so that connectivity is present citywide and available for citizens. The communications infrastructure may be conformed for a mix of technological options, such as data network, cable, optic fiber, state-of-the-art WiFi. Optic fiber is by far the technology that provides whit the fastest connectivity and supports Wi-Fi and other related options, which support a great variety of devices [8].

Mobile intelligent phones technology is a crucial element in the Smart City. These phones serve as a distribution channel of information as well as an intelligent sensor hooked to a global network of information and communication [8].

2 Intelligent Urban Public Transportation

Urban sprawl has affected citizen interaction worldwide. Now people need to commute long distances to arrive to work, school, hospitals, and public offices, or simply to go shopping. The mobility in cities worsen due to an inefficient system of public transportation, which increases the dependency on automobiles, causing traffic congestion and stress.

Besides the negative effect of an inefficient transportation system on mobility, other factors also contribute to affect it. Lack of normative or enforcement on land usage, or even particular interest, which overlooks impacts on mobility, may be worsening the problem. An immediate negative impact of poor public transportation reflects in the environmental conditions, which suffers from massive emissions that contribute to air pollution. By contrast, Smart Cities keep an agenda focused in improving mobility in public transportation by reconverting the powering of vehicles from fossil-based combustibles to clean options, such as gas or electricity. This movement motivated commuters to consider an economic and clean alternative to the use of automobiles, giving place to share rides [9].

On the other side, many solutions have reached the implementation stage. Gassman et al. [10] point out that projects included traffic system guides, sensor-based parking lots (which allowed on-line monitoring), traffic congestions predictors via intelligent traffic lights, and systems for sharing automobiles and bicycles, as well as autonomous transportation, both public and private. Intelligent mobility initiatives pursued the following objectives:

a. To ensure innovative and sustainable transportation systems.
b. To promote access to diverse transportations options.
c. To guarantee citywide availability.
d. To include no-motorized transportation.
e. To integrate ICTs into public transportation system,

According to Gasmman et al. [10] there is no need for a large-scale transformation to improve public transportation; sometimes, big achievements derive from timely, well-implemented small changes using technology. Intelligent solutions in an efficient urban public transportation discourage the use of private vehicles in favor of public commuting. An intelligent transportation option may be innovative, increasing quality service, enhancing accessibility and reducing transportation costs [7].

Public transportation may improve a great deal in the future with the idea of smart systems, to the extent that citizens will not use automobiles, transforming cities into trafficless spaces. Reductions in the use of energy, a byproduct of the process of improving public transportation is a value-added benefit that protects the environment.

Recent evidence reinforces the idea modern public transportation is a topic of interest that has achieved high acceptance among urban population, particularly the adoption of automated vehicles. In their work Bernhard, et al. [11] emphasizes that studies in Germany used IoT to address public transportation considering autonomous vehicles. Other evidence points towards usability and reliability of vehicles. The interest resided on how these factors affected deterioration and performance, providing better framework to establish maintenance policies [12].

Another application study, to optimize public transportation, Panovski and Zaharia proposes a methodology to integrate situational context (including public events, planned interventions and citizen notifications) in the analysis of public transport data, and develop diverse sceneries using data collections [13]. In addition, the research of the new payment technologies for public transport are considered data from smart cards is given as a source of information about transportation movements on public transport [14].

In a very sound approach, Poltavkaya built on the popularity of electronic payment by cards to trace and monitor trip characteristics in public transportation. Panovsky report additional efforts to optimize public transportation, especially to integrate situational contexts, such as public events, planned interventions and citizen notifications [13].

Using open innovation platforms in the public transport, that study develop by Lusikka, Kinnunen and Kostiainen [15] proposed the innovation platforms allow businesses to develop new, better and more personalized services to citizens like an air quality, passenger counting, platform for testing, sensoring and monitoring, and others. Other research has offered alternative improvements for public transport, for example: optimization, vehicle automation, transport sustainability, automatic vehicles, and more. The Table 1 presents a collection of studies related to the development of innovative technologies applied to public transportation.

3 Context of Public Urban Transportation in Juárez

With the exception of Mexico City, in other important cities of the country, there are severe deficiencies in the metrics related to digital infrastructure and connectivity.

The "Global Innovation Index" shows that in Mexico there is a big gap in terms of science, technology and innovation, ranking at the 56th position at global level. The budget as a percent of the GNP destined to science and technology is only 0.5%. An important number a variety of challenges in the areas of economics, social cohesion, transportation and sustainability in general, prevail [27].

Juarez, México, is the largest city of the State of Chihuahua. It is worldwide know that in Juarez prevails a series of negative factors, such as political differences, lack of long term planning, territorial conflicts, violence and insecurity (5th in perception at National level, 72% of the population feels insecure, according to INEGI), corruption, as well as poor coordination among government levels [28]. According to a report from an independent entity, people grade a 15-year old public transportation in Juarez with 5.97 out of 10 and only 23.5% of the people use it. This low grading reflects on the massive use of the automobile, that reaches 46.9% [29]. Public transportation faces an adverse scenario: old vehicles, unpaved roads, high insecurity for passengers

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Table 1 Examples of modern public urban transportation research 2019

Piotr Kisielewski, Mariusz Danda, Marek Bauer [16]	Optimization of rosters in public transport
Marcin Koniak, Andrzej Czerepicki [17]	Autonomization of public transport vehicles
Nistha Nakarmi, Sangeeta Singh [18]	Smart infrastructure for sustainable public transportation
Nistha Nakarmi [19]	Smart infrastructure for sustainable public transportation
Manohar Kumar, Neha Kumari, Suryanshu Tomar, Tarun Kumar [20]	Smart public transportation for smart cities
Anatoly A. Zaitcev [21]	Socialization of public transport in the new technological paradigm
Oded Cats, Alex Vermeulen, Martijn Warnier, J.W.C. Van Lint [22]	Modelling growth principles of metropolitan public transport networks
Andreas Lauber, Eric Sax, Markus Wiedemann [23]	Autonomous driving in public transportation depots
Jessica R. Lazarus, Susan A. Shaheen, Stanley E. Young, […], J. Sam Lott [24]	Shared automated mobility and public transport
Andrés Monzón, Sara Hernandez, Andres Garcia-Martinez, Francesco Viti [25]	Public transport in the era of ITS: ITS technologies for public transport
Thomas Holleczek, Liang Yu, Joseph K. Lee, […], Patrick Jaillet [26]	Detecting weak public transport connections from cellphone and public transport data

Fuente: own elaboration

and other commuters, mainly cyclists and pedestrians [30]. Public transportation in Juarez mobilizes an estimate of 420,000 people daily [31].

Juarez network of public transportation encompasses 26 routes privately operated. It also includes a massive-use, lane-dedicated route named Eco-Bus (see Fig. 1). However, coverage in not complete along the city, there are many zones without formal service. In these zones, private parties provide informal service to transport people to nearby places [31].

The cost for a single one-way trip is $8.00 (50% discount for seniors). Payment options confine almost to cash for all lines, with the exception of Eco-Bus, which only accepts prepaid cards. Service hours vary for each route, but in general they operate from 4:30 AM to 9:00 PM. Not all the bus stops are equipped, some lack benches, signals, boots or sunshades. Some are informal and unequipped.

With the exception of the study of Bouskela, Casseb, Bassi, Cristina De Luca, Marcelo Facchina [8] which provided insights for Chihuahua City to approach the condition of a Smart City in terms of public transportation, no work could be found addressing public transportation from the standpoint of the Smart City.

Fig. 1 Juarez urban área. Fuente: Google. (s.f.). [Mapa de Ciudad Juárez, Chihuahua Mx. en Google maps]. Recuperado el 5 de febrero del, 2015, de: https://www.google.com/maps/@31.6905492,-106.46087,12.25z?hl=en

4 Method

The methodology was development in two steps:

a. The method consisted in an exploratory studying adopting a data collection instrument (survey) previously designed and validated. The survey included 26 routes; data collection includes the following categories: route, environmental impact, technology. The treatment of data was descriptive and relational, using SPSS v.23. In addition, Weka 3.9.2 and Tableau 15.0 completed the relational analysis (Table 2). AQ1

b. Envisioning an intelligent alternative for the public transportation in Juarez. Proposal steps.

5 Results

a. An exploratory studying

Out of 26 routes, 18 (69%) start their way in the downtown zone, the remaining six have a different starting and ending point, but their routes includes some parts of the downtown within a diameter of 1470 m. (see Table 3). The 31% of the routes have a unique path, very well known by users. The remaining have two or more paths, not always known by users due for a lack an of a route map, either printed or digital (Fig. 2).

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Table 2 Transportation routes in Juarez, Mexico

Route	Name
1	1-A Morelos
2	1-B Express
3	2-A
4	2-B
5	2-Lazaro
6	3-A
7	3-B
8	4
9	5-A colectivos
10	5-B
11	7
12	8-A
13	8-B
14	10
15	Línea Industria
16	Juárez Aeropuerto
17	Juárez oasis
18	Juárez Zaragoza
19	Mercado de Abastos
20	Oriente Poniente
21	Permisionarios Unidos
22	Poniente Sur
23	Transportes urbano
24	Universitaria
25	Valle de Juárez
26	Ecobus

Resource: own elaboration

Results show that up to 850 buses operate daily. Even though more than 1200 concessions are active, many of them do not operate due to diverse reasons, such as obsolesce and poor maintenance. In average, a route has 33 buses circulating, Table 4 show the number or busses by route.

In regards to frequency of routes, 19 (73%) lines have a waiting time between 5–10 min, which route controllers monitor considering bus number and time schedule. 11% fall. In the range of 10–15 min, while 12% do in the range of 16–20 min. Only one line reported a waiting time longer than 20 min.

With the exception of Eco-Bus, which operates buses of models 2017 o newer, school bustype vehicles cover the other routes. The average model is 2005, that is, they have been operating for at least 15 years. These diesel-powered buses (96%)

Table 3 Terminales de las líneas de transporte

#	Route	Final point
1	1-A Morelos	Termoeléctrica
2	1-B Express	Fracc. Sierra vista
3	2-A	Colonia Insurgentes
4	2-B	Colonia Chihuahua
5	2-Lazaro	Montada
6	3-A	Escobedo
7	3-B	Montada
8	4	Hipódromo
9	5-A colectivos	KM 20
10	5-B	Pánfilo Natera
11	7	Parque Ind. gema
12	8-A	colonia zapata
13	8-B	Seguro Nuevo
14	10	Anapra
15	Línea Industria	Smart Ponciano
16	Juárez aeropuerto	sanlorenzo
17	Juárez oasis bu	Fracc. oasis
18	Juárez Zaragoza	Zaragosa
19	Mercado de abastos	Los ojitos
20	Oriente Poniente	las misiones
21	Permisionarios Unidos	las palmas
22	Poniente Sur	KM20
23	Transportes urbano	mariano Escobedo
24	Universitaria	Ciudad Universitaria
25	Valle de Juárez	San Francisco
26	Ecobus	Tierra Nueva

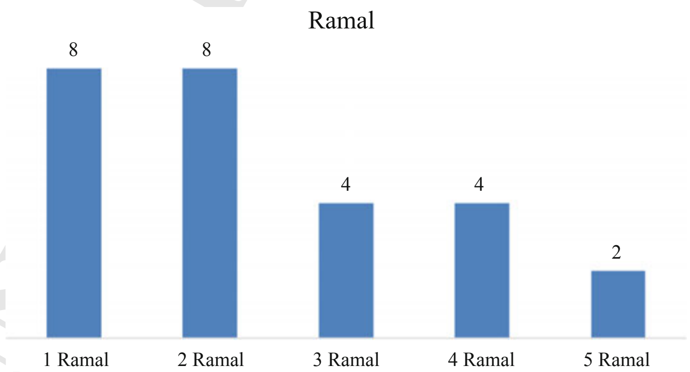

Fig. 2 Total Ramal terminal

Table 4 Busses and routes

Route	Quantity busses
1-A Morelos	50
1-B Express	40
2-A	21
2-B	18
2-Lazaro	43
3-A	45
3-B	25
4	10
5-A colectivos	52
5-B	38
7	8
8-A	38
8-B	31
10	40
Línea Industrial	14
Juárez aeropuerto	73
Juárez Oasis bu	20
Juárez Zaragoza	50
Mercado de abastos	16
Oriente Poniente	50
Permisionarios Unidos	14
Poniente Sur	40
Transportes Urbano	10
Universitaria	57
Valle de Juárez	30
Ecobus	17

Fuente: Elaboración propia con datos de la encuesta

-most of them imported to Mexico already used- lack of adequate maintenance. It is very common to operate buses under extreme climate conditions –lacking A/C (in only 8% A/C is available), full of people to overcapacity and over rough-unpaved roads.

By City's ordinance, all drivers must attend a driving course in the facilities of the Department of Public Transportation. It is questionable how and who designed the course and how reliable it is. Moreover, an extra fee may waive the course. Additionally, all drivers must have an adequate license driver to operate public transportation buses. Results showed only two lines provide drivers with extra training as a part of their organizational educational program.

Table 5 Factors affecting maintenance frequency

	Option 1	Option 2
Unpaved roads or damaged pavement	19	3
Transport polices	3	2
High cost of spare parts	1	11
Credit restrictions	1	2
Vandalism and incivilities	1	7
Traffic issues	1	1

When it comes to unit maintenance, 85% of concessioners provide service in their own mechanic shop, while some do so in informal or improvised shops, or even outdoors, in the public space. Only three reported to maintain units in private-owned certified shops.

The most frequent period of maintenance is weekly (62%), followed by monthly (38%). Maintenance include fluid levels and reposition of worn parts, as well as occasional failures. Very often, these maintenance actions derived from circulating in un-paved roads, damaging suspension and tires. Factors affection the frequency of unit maintenance is the high cost of spare parts, misconduct of users (vandalism and incivilities), see Table 5.

In the case of intelligent options, only one unit reported to have free WiFi (unavailable to users). Technological features concentrate in a GPS system to locate the unit, without keeping a database. Results revealed that, traffic controllers, messaging and phone calls continue in use. Sensing technologies only appeared in four units (15%).

None of the concessioners provide with electronic itineraries. A private initiative created a Facebook page named "Mapas de Ruteras de Ciudad Juárez" (@RuterasJrz · Sistema de transporte público).

b. Envisioning an intelligent alternative for the public transportation in Juarez.

The proposal is to increase the quality of public transportation services via adopting a strategy based upon the implementation of information technologies. That is, to increase public mobility incorporating Smart City's tactics while the environment is not harmed. Three stages compass this proposal: (a) replacing actual unit with modern vehicles; (b) adopting information technologies; (c) developing of an App for the use in the public transportation system of Juarez.

We propose to replace old out-of-times buses with modern state-of-the-art electricity-powered units, equipped with satellite-based location devices, front and rear cameras, users monitoring, passenger on-off and bus stoppage monitoring, WiFi, general use monitoring, emergency alerts and electronic payment devices, among others.

Electrical buses are cleaner and healthier, at the time that bring savings in fuel and maintenance. They are silent and easy to drive, do not emit toxic gases that pollute the environment, but they are nor exempt of disadvantages.

Fig. 3 Electrical Buss BYD model K9 [32]

There are advantages and disadvantages in adopting electric vehicles [32]. The advantages include zero emissions, 50–100% reduction in greenhouse effect gases (depending on the way generation process of electricity), reducing life cycle costs of batteries, low levels of noise, among others. On the other hand, disadvantages include capital-intensive investment to provide for infrastructure, such as rapid chargers, high price of units, limited options for financing and high operating costs.

The proposal consists in replacing the old fleet with electrical units equipped with energy-storage batteries. The reference is the unit BYD Model K9 [33]. BYD is a China-based company that is the top seller of electrical buses. Recently, BYD expanded operations by opening a manufacturing plant in California. According to BYD's website, the buses operate on a Ferrum-based (Fe) battery, which last for 155 miles at full charge. The recharge time is approximately one hour; the battery has a useful life up to 4000 recharge cycles (see Fig. 3).

To adopt electrical technology implies the need for space to accommodate chargers in the operations base. For this project, we propose the acquisition and installation of at least 60 charge stations located at functional terminals (see Fig. 4).

All intelligent equipment will be integrated into the unit, this refers to tangible services of comfort for the passenger, such as comfortable seats, and intangible services such as monitoring of passengers and driver, WiFi services, emergency signals, cameras, among others, see Fig. 5.

Battery-equipped buses do not have exhaust pipe; instead, electrical cells produce water steam only. Buses' emissions depend upon how previous productive chain links generate electricity and hydrogen fuel. If renewable energies generate the electricity and hydrogen, then there will be no emissions at all [34].

Fig. 4 Station reload [32]

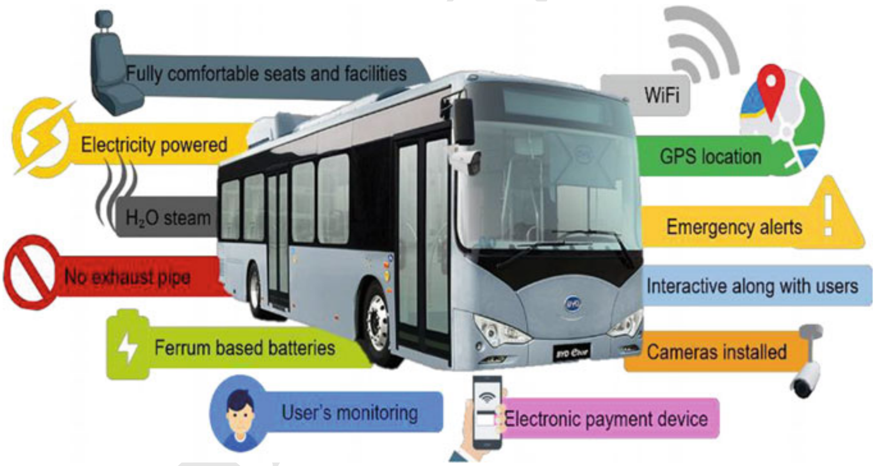

Fig. 5 Intelligent bus

The proposal includes the development of an App. The use of apps goes in line with the adventment of innovations in information technologies, such as intelligent phones and tablets.

The app would interact with the main social networks and user's email. The user will be able to search for the status of routes in real time, as well as for departing and ending points, and transships. The app accepts electronic payments and keep record of the trip history, providing statistics about frequency, distances and favorite routes.

The trip planning platform will allow the user to introduce destine details, providing information about nearest bus stop, waiting times, trip times, traffic status, transship options and available transportation lines Users will be able to buy, via credit card or electronic wire transfer, passage for one or more days, up to a month. The app will send to the smart phone o tablet a QR code, which validates when getting on the bus (Fig. 6). The app will also enable the user to report bus conditions and driver behavior, thus controlling unit's condition and driving irregularities.

Proposal pilotage will require an initial investment of MX$280 million, which cover the acquisition of 60 buses at a unit cost of MX$7.5 million. Proper intelligent equipment technology for buses would cost an extra MX$20 million for the whole project (see Table 6).

Even in a pessimistic scenario in which the project requires high investment, the proposal sound because it thrives to overcome the prevalent poor and costly service.

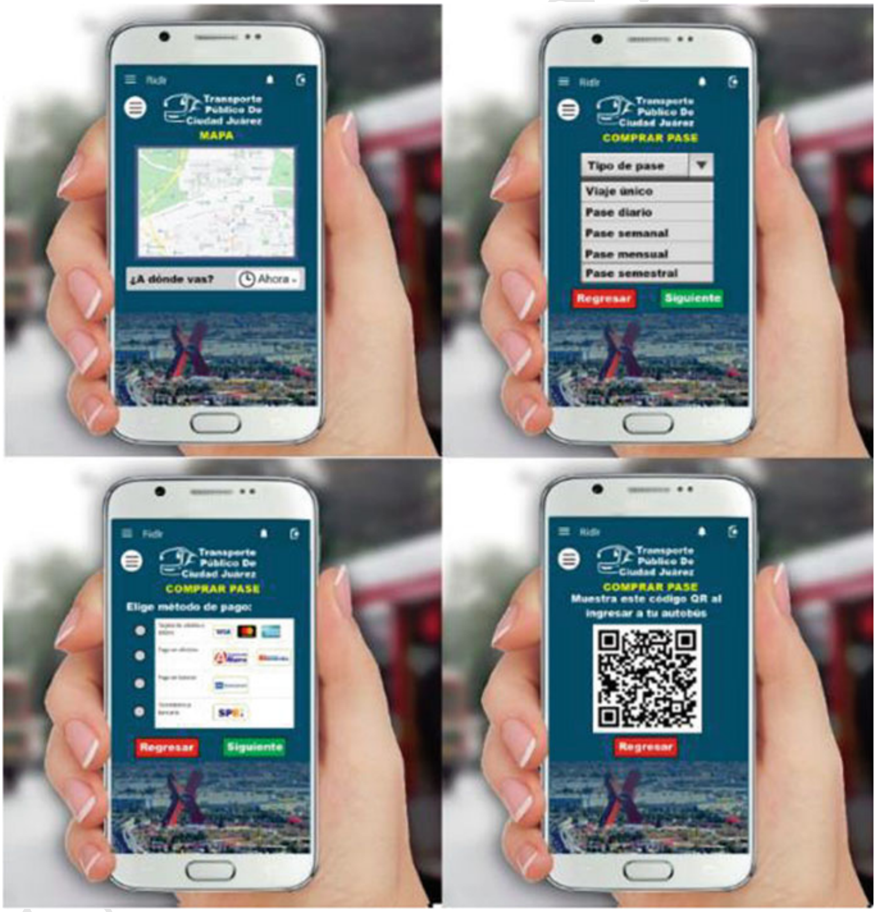

Fig. 6 Mobile app for public transportation

Table 6 Proposal general cost

	Proposal cost
Elements	Cost
Unit cost K9	$7,500,000.00
Number of units	60
Total units cost	$450,000,000.00
Chargers cost	$250,000.00
Number of chargers	60
Total cost of chargers	$15,000,000.00
Pavement route de transp.	$280,000,000.00
Other intelligent equipment	$12,000,000.00
App development	$5,000,000.00
Total	$762,000,000.00

The objective aims to keep up with modernity, to avoid extra costs for users and to decrease the use of private automobiles. Then, the proposal suggests a better option for transportation, searching into the buses' market, focusing on sustainability and modernity.

6 Concluding Remarks

This paper envisioned a plausible solution for the prevalent inefficient public transportations service in Juarez, Mexico. By reconfiguring the existing fleet, which is obsolete and expensive to maintain, the city may aspire to have an excellent transportation service. The Smart City promotes the adoption of intelligent, environmental-friendly strategies to offer safe and reliable public services. Electricity-powered buses, fully equipped with state-of-the-art technology, may revamp the transportation services, improving urban sustainability while lowering operative costs.

Although the proposal sounds, it is imperative for the City to improve the roads and streets, to improve and enforce public transportation ordinances and to promote civil education regarding the use of new technologies.

To review the actual conditions of the buses allowed justifying the need to modernize this service. By interviewing, the concessioners revealed the negative scenario the actual transportation system faces: out-of-times, deteriorated buses, as well as archaic management and maintenance practices. This made clear the need to modernize the fleet to provide a better service.

With this proposal, it is easy to visualize the need for an update in the units, as well as in the routes, existent or New-AI this gives place to modern forms of route management.

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Chapter 10

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