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SYSTEMIC MODEL FOR MANAGING ELECTRIC CHARGING STATIONS IN THE VALLEY OF MEXICO

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Abstract
Currently, when discussing the cessation of fossil fuel use for human mobility, the immediate thought is the utilization of renewable energy sources stored in batteries to power vehicles. In the specific context of cities, we refer to automobiles using clean technologies for propulsion. This trend is known as electric mobility, which gradually replaces internal combustion vehicles. This contributes to reducing the ecological footprint generated during our daily transportation for various activities. To achieve a complete transition to electric mobility in Mexico, a significant push is required to motivate users, producers, investors, and entrepreneurs to adopt electric cars. Additionally, a technical infrastructure supporting their usability and applying analytical and systemic tools to establish an efficient management model for charging stations is necessary. The systemic model proposes tools to address the current energy management challenges of charging stations in the Valle de México region.

Keywords
Charging stations car, management, energy, systemic model, Systems Science.

Introduction

The Valley of Mexico, one of the country's largest and most populated metropolitan areas, is in the middle of a transformation process towards more sustainable mobility. In this context, electric charging stations or charging stations for electric vehicles play a fundamental role in promoting and transitioning towards electromobility. The objective of this electromobility trend is to become an alternative that gradually replaces internal combustion vehicles. This benefits in reducing the ecological footprint that we produce when moving to carry out our activities. Since the beginning of 2015, only 1.5% of mobility has been with emerging and purely electric technologies, while close to 60% continues with internal combustion transportation (IEA, 2020).
To carry out the transition to full electric mobility in Mexico, a significant push is needed to motivate users, producers, investors, and entrepreneurs to use and produce electric cars and develop a technical infrastructure that supports their utility and efficient management to design vehicle charging stations.
The current context in America is that being a continent with countries of vast territorial extent, automobiles need a great range of energy. Cars in the Americas need to be durable and have slightly more power than those used in smaller countries or those with shorter travel distances. Therefore, on this continent, people tend to trust gasoline-powered cars or, in some cases, invest in hybrid cars to save fuel costs and use electric power when necessary. Large-scale electric mobility in America still presents many problems in terms of implementation and investment, including the most important ones (Xiang, 2017).
According to information obtained from agencies in 2020, nearly 50 million cars are in circulation in the country (INEGI, 2020). The sample of private cars in Mexico consists of internal combustion engines. Although the sale of hybrid and electric vehicles has increased since 2017, the use of electric cars in urban areas is still low.
Car brand suppliers and dealerships already establish the parameters for charging stations; they are not universal. Here, they need to start having better supply systems to become compatible with many other car

models. This is where the battery charging capacity and the power of charging stations need to be improved (Sánchez et al., 2021).

Methodology

This article describes how a model is developed for managing electric station energy resources through System Thinking. This approach, through the transdisciplinary approach, postulates, validates, and generalizes in a systemic way the dynamic models of reality systems, which in this case study shows the reality of electric station management systems (Wheeler, 2000).
System thinking is used to seek the understanding, interpretation, and conceptualization of the elements of the system under study. For its treatment, Total Systems Intervention (TSI) is used to study and select in a well-founded manner the most systemic model or methodology adequate, as Jackson suggests, allows us to delve deeper into problematic situations that cannot be understood with a single approach.
Some elements of the TSI are that they operate from the point of view of knowledge of the problem superior to that of the actors involved, that is, from the observation of the subject matter expert, to address the problem a collection of information is generated to take a model to decision making that, supported by the expert's knowledge, will provide an optimal solution on what should be done in the situation (Jackson, 2016) Jackson proposes three levels of knowledge in Systems Thinking to address this type of problem. First, it is interpreted using a systemic approach using different disciplines, such as social sciences, administrative sciences, and physics. At the second level, the study of pure systems is addressed, where the aim is to organize information and problems. And the third level is the solution to these problems.
This methodology is very useful in ensuring the efficient use of energy resources at electric stations since they will be used by people who interact with the site equipment, intervene in the planning and installation process of the charging stations, and finally, influence the cost and final use of energy.
The study of the environment and surroundings in which the activities and functions of electric vehicle charging systems take place is in the urban areas of the Valley of Mexico. The actors and entities related to this system of generation, supply and management of resources are interacting very closely and following objectives that can be both individual and common to each other. Table 1 shows that the system to be studied is complex. Its perspective fluctuates between unitary and pluralistic. Due to the complexity of the management system in the electric stations and the multiple entities and actors involved in the system.

Table 1.-Context matrix Problem of the object of study (Electric Charging Station)

	Unitary	**Pluralistic**	**Coercive**
Simple	Simple Unitary	Simple Pluralistic	Simple Coercive
Complex	**Unitary Complex**	**Pluralistic Complex**	Coercive Complex

This work offers, within the methodology to develop the model, a system of systems methodologies, capturing the interrelation of the entities and elements of the problem context with respect to systems approaches (Jackson, 2013).

Within the TSI proposed by Jackson, other methodologies and systemic tools can be used, and for this object of study of the electric stations in the Valley of Mexico, it has been selected to use the Soft Systems Methodology and the Viable System Model.

Results and discussion

The proposed system's functions, such as modelling, simulation, optimization, and correlation, are governed by energy management concerns. Within the energy management system, key constraints such as power balance are enforced (Patil et al., 2021).
According to Patil et.al, the most recent model for managing a charging station is through his model with the MPA algorithm.
A general model with the emerging infrastructure of the electric stations can be seen in Figure 1.
In this section, the distribution power system is connected to the electric vehicle charging station (EVCS) to provide energy source services to EVs. When an EV arrives at the charging station, it communicates information to the EVCS operator.
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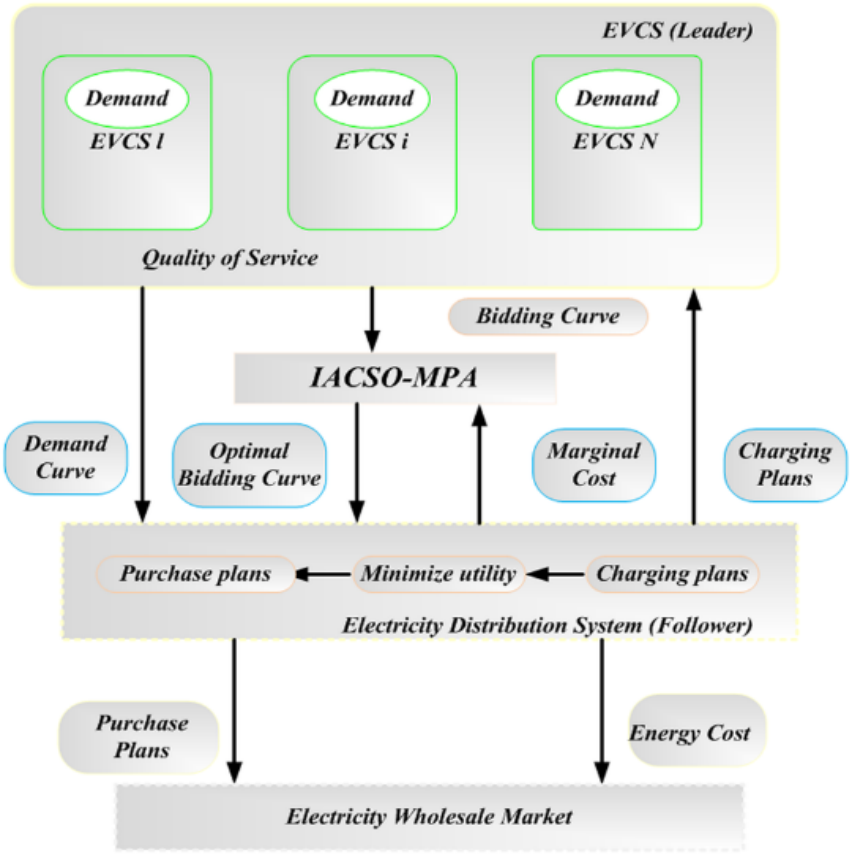
Figure 1. Management System between a station and the power system.



This proposed model minimizes the utility of distribution systems, improves electrical load and energy purchase plans, analysing the behaviour of supply and demand curves (Patil et al., 2020).

Conceptual Model.

Applying the TSI to an electric vehicle charging station system involves addressing the problem holistically, considering all elements and their interactions within the charging system (Jackson, 2016).
First, define the electric vehicle charging station system, identifying all its components and stakeholders, which may include:

- Charging stations (hardware and software)
- Electric vehicles and their users
- Energy providers
- Governments and regulators
- Technology and telecommunications companies
- Local communities
- Electric distribution networks

The implementation of the TSI applied to a station management system, as proposed, provides information on continuous improvement techniques in the field of electricity markets that evolve every day in terms of renewable energies. Figure 2 shows the relationship and interaction within the Ecosystem that an Electric Charging Station represents.

Figure 2.- Ecosystem of a Charging Station for electric cars.

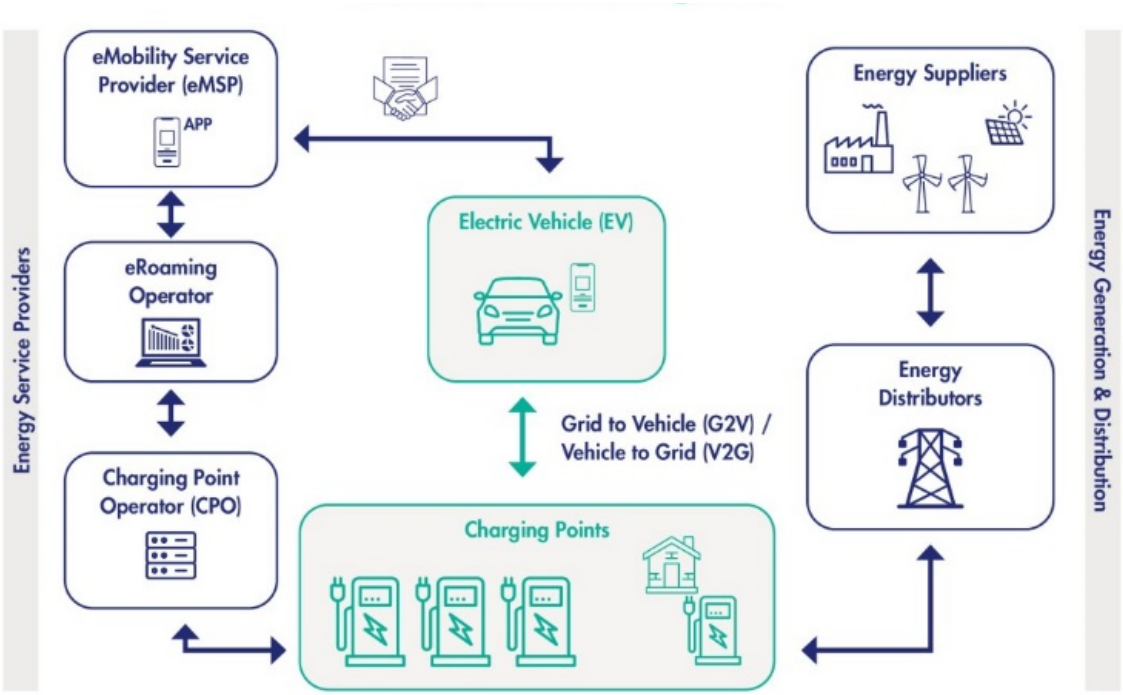
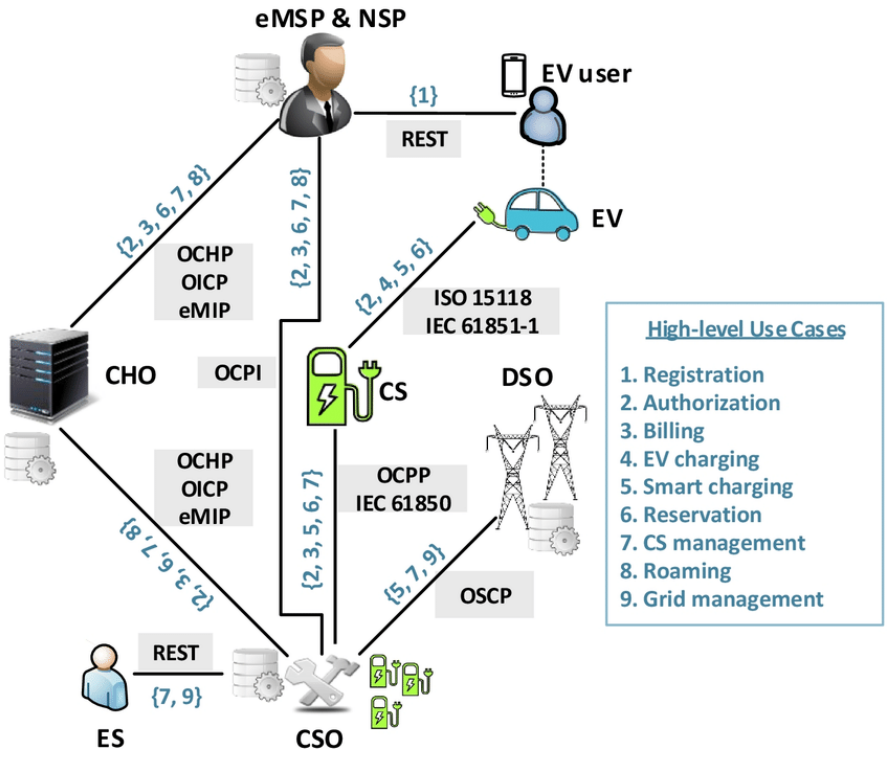


Figure 3 shows the actors involved in an electromobility system, showing the actors and elements that intervene in the areas of Mobility, Energy Supply and Energy Charging (Boucetta et al., 2021).

Figure 3. Actors involved in the Charging Stations.



To better understand the electric vehicle charging system, the system of stations should be visualized as an organization. According to Beer, through systems thinking, the weak points and areas for improvement of the charging system can be highlighted (Beer, 1985).

Starting from the information obtained and compiled to define a management model, starting from the most emerging designs of how an electric station is made up, the design of the systemic model of the energy management of the electric station can be developed in the following way, as follows: poses the TSI:

1.- ***System Diagnosis:***

- Identify all the electric stations in a certain area of the Valley of Mexico.
- Analyse load demand patterns throughout the day and week.
- Assess the power supply available at each location.
- Examine the energy sources used at the electric stations (e.g. grid electricity, solar energy, etc.).

2.- ***Identification of Systemic Problems:***

- Detect peaks in energy demand at certain times of the day that can overload the local electrical grid.
- Consider the energy efficiency of charging stations and their environmental impact.

3.- ***Intervention Design:***

- Implement a demand management system that distributes load more equitably throughout the day and avoids demand peaks.

- Promote the use of renewable energy, such as solar panels, in electric stations to reduce the carbon footprint.

4.- ***Implementation of the Strategies:***

- Introduce a demand management system that regulates the charging speed according to the available capacity in the local electrical grid.
- Install energy storage systems, such as batteries, at selected electric stations.

*5.-****Monitoring and Continuous Evaluation:***

- Monitor the impact of interventions on energy demand, charging efficiency and sustainability.

*6.-****Participation of Interested Parties:***

- Involve electric station owners, energy suppliers, local authorities and electric vehicle users in the decision-making process and feedback.

The interrelationships between actors, entities, and the environment in the context of charging stations reveal a complex network of collaborations crucial for the sustainable development and operation of this infrastructure. The successful implementation of charging stations requires multidimensional collaboration among developers, operators, charging network managers, electric vehicle manufacturers, technology companies, governments, and users (Checkland, 2010). These interactions are essential to address technical, regulatory, and social aspects.

Conclusions

Energy management in the field of electromobility is an important part of the administrative management system of the complete system of the transition towards electric mobility since energy is the useful raw material with which work is done in the stations. The systemic and methodological tools mentioned in this article are useful for dealing with complex pluralistic and/or unitary systems, such as the management system of an electric station. The TSI was used to design a management model since it provides great support for the holistic approach, as observed from the context matrix, which is a complex system with actors and elements that interact with each other.

This methodology allows you to address the system as a whole instead of solving problems in isolation. This is essential to understanding and addressing systemic challenges and ensuring solutions are effective and sustainable. TSI can result in long-term savings. Initial investment in energy storage and renewable energy can reduce operating costs and dependence on fossil fuels, benefiting electric stations and electric vehicle users.

Importance of the Holistic Approach:

- The consideration of environmental factors, such as energy efficiency and the source of electricity, is vital to maximize the ecological benefits of electric mobility. A holistic approach that encompasses everything from energy generation to the operation of charging stations is essential.
- Close collaboration with technology companies and charging equipment manufacturers is essential to drive innovation in charging station management. The implementation of advanced technological solutions contributes to operational efficiency and an improved user experience.

In summary, the successful management of charging stations requires a deep understanding and effective collaboration among all involved actors, considering technical, social, and environmental aspects. The integration of innovative technologies and sustainable practices is key to maximizing the benefits of electric mobility and ensuring a positive impact on the environment.

The design of a model with the Systems Thinking treatise promotes the participation of actors and entities. This includes electric station owners, electric vehicle users, energy companies, local authorities and more. This ensures that solutions fit the needs and expectations of all parties involved.

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This article is supported by Instituto Politécnico Nacional of México by means of Project SIP 20242464 and SIP 20241727 granted by Secretaría de Investigación y Posgrado and Consejo Nacional de Humanidades, Ciencias y Tecnologías of México.

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