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Electrification of Madrid Fleet Public Transport Company (EMT): Strategic Analysis And Implementation.

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Abstract Madrid Public Transport Company (EMT) is a property of the Madrid City Council, and it provides the public buses service in the whole city. Madrid, as most of the big cities in the world, is facing problems related to high levels of urban pollution, which directly affects the health and life quality of their inhabitants. EMT, having a fleet of around 2.000 buses, has an impact in the mentioned problem and in the global warming. With the Strategic Plan 2017-2020, many new buses will be acquired, resulting in a fleet of natural gas, hybrid and electric vehicles by the end of 2020. The present study has the goal of being the cornerstone of a future strategic plan of the company. To this end, both external and internal analyses of the company have been conducted, which support that the electrification of the whole fleet is the best option in the long term. Furthermore, a Benchmarking of the state of the public transport in other 25 cities and the technology used in them has been conducted. Last, a model that allows replicability of this strategic assessment is proposed, in order to help other Transport Companies and City Councils to decide which transport fleet is the best to implement in their cities depending on their necessities and resources.

Keywords: Sustainable transport, Electric Buses, Air Quality, Emissions, Benchmarking

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1 Introduction

Nowadays, most of the world's biggest cities are facing a huge problem that affects directly the health and life quality of all their inhabitants, the high levels of urban pollution. Madrid, as the capital of Spain and the biggest city of the country, is one of the cities that suffers this problem the most. Madrid is exceeding occasionally, as most of the large cities of the world, the pollutants concentration level that the World Health Organization considers safe to breathe (World Health Organization, 2005). The most important pollutants that are in the cities' atmosphere are particulate matter (PM), nitrogen oxides (NO_X) and ozone (O_3), all of them are toxic, causing an increase in mortality and numerous cardiovascular and respiratory system diseases. Out of this three, the use of fossil fuels is responsible for two of them, PM and NO_x. Reducing the emissions in the city is in the Air Quality Plan of the City of Madrid (Ayuntamiento de Madrid, 2017).

Each kind of engines produces different pollutants. Diesel buses produces high quantities of CO_2, NO_X and PM. Natural Gas buses slightly increase the CO_2, reduce the NO_X and practically vanish the PM emissions. Electric and hydrogen powered buses have zero emissions.

EMT (Empresa Municipal de Transportes de Madrid) is the public company that operates all the public buses in Madrid, having a fleet of around 2000 units. The strategic plan of EMT for 2017-2020 has the goal of replacing all their diesel buses for eco-friendly buses by the end of 2020 (Empresa Municipal de Transportes de Madrid, 2017). This eco-friendly or green fleet consist of the low emissions or zero emissions buses, which are powered by Compressed Natural Gas (CNG), hybrid and electric buses. EMT currently has around 1000 diesel, 940 CNG, 40 hybrid and 20 electric buses.

By the end of 2020, EMT will have acquired close to 80 new electric buses and 940 new CNG buses, achieving a full green fleet. The present study aims to be the seed of the future strategic plan of the company, on its way to the 0 emissions fleet. Therefore, the three main goals of it are

Strategic analysis of the company (internal and external), focusing in the fleet, infrastructure, human resources and everything related with the electrification.

Benchmarking of the situation of the public transport in other cities and their plans and strategies.

Creation of a model that can guide and support other Transport Companies and City Councils of the world to decide which transport fleet is the best to implement in their cities depending on their necessities and resources.

The rest of the paper is organized as follows. Next section presents the methodology used, while section 3 presents the results obtained in the Strategic Analysis and Benchmarking, which includes the strategic lines that the company should implement. In section 4, the Decision Tree is presented, and finally, in the last section, conclusions, limitations and avenues for further research are gathered.

2 Methodology

The methods used for the strategical analysis of the company were the model of the competitive forces (Michael E. Porter, 1998) and the PESTEL Analysis (Political, Economic, Social, Technological, Ecological and Legal Factors) for the external part and Analysis of the significant documents, interviews with the stakeholders and visits to the different sections of the company for the internal part of the analysis. With these factors, a SWOT matrix (Strengths, Opportunities, Weaknesses and Threats) was created and used to decide the Strategic lines of Attack, Defence, Reorientation and Survival.

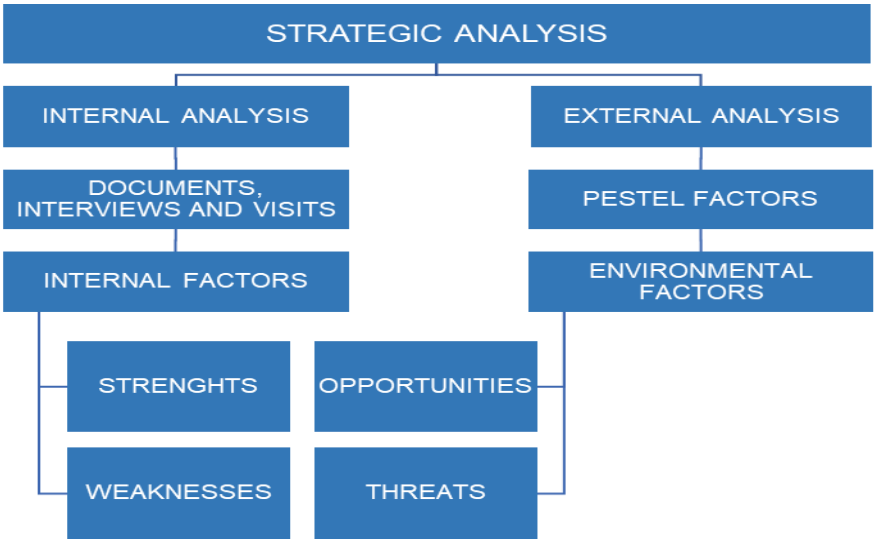

Fig. 1 Methodology used for the Strategic Analysis

The method used for the Benchmarking was first to define the goal that was wanted to be achieved. After, select the 25 cities with the criteria of similarities with Madrid or innovation in the transport. Next, choose the parameters to search and analyse all the available documentation related with the topic of each company and find correlations. Finally, decide what could be implemented in Madrid.

Fig. 2 Methodology used for the Benchmarking

Last, a decision tree has been crafted, in order to allow for replicability of the strategic decisions.

3 Strategic Analysis and Benchmarking

The result of the Strategic Analysis was a SWOT matrix that describes the most important internal and external factors of the company, focusing in the electric transition.

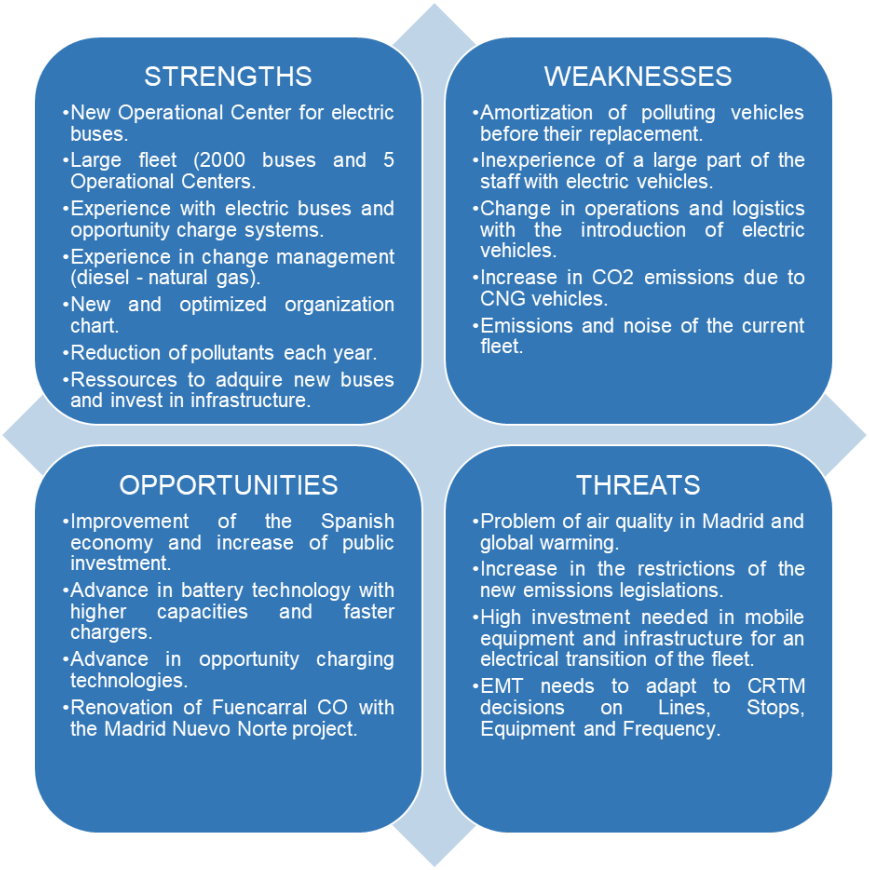

Fig. 3 SWOT Analysis of the EMT

With the SWOT analysis, 4 strategic lines have been defined: Attack (Take advantage of the Opportunities with the Strengths), Defence (Face the Threats with the Strengths), Reorientation (Correct Weaknesses with the Opportunities) and Survival (Face the Threats that affect the Weaknesses).

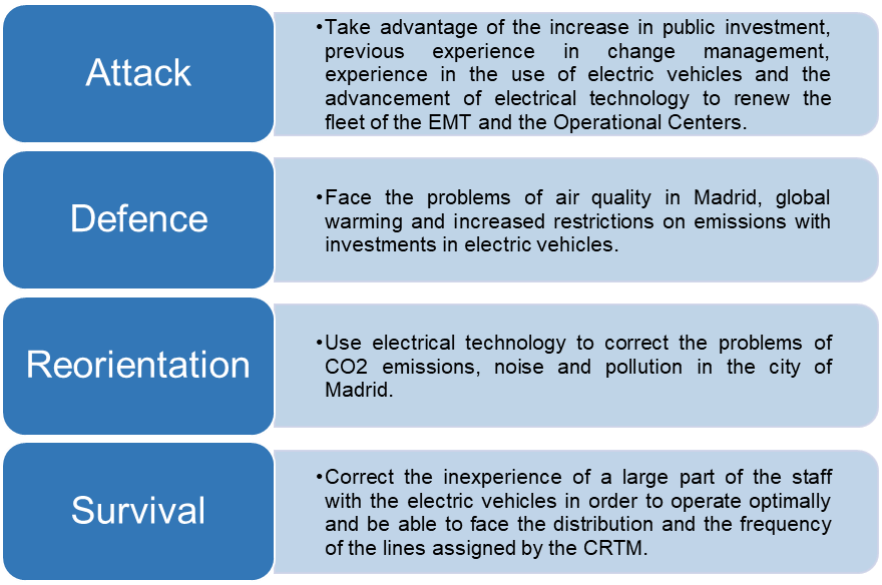

Fig. 4 Strategic Lines of the EMT

The goal of the Benchmarking was to analyze the situation of the public transport in other cities of the world and their plans for the future and strategies to achieve them.

25 cities have been selected for this analysis, choosing with the criteria of similarities with Madrid (population, pollution, economy, fleet…) or innovation in the transport (special buses, new systems, alternative management solutions…).

A heat matrix has been created, showing graphically the different fleets that each city is using nowadays (diesel, gas, hybrid, electric and hydrogen). Another heat matrix has also been created to represent the opportunity electric chargers of each city (trolleybuses, magnetic induction and pantograph).

Most of the companies have the highest percent of their fleet formed by diesel vehicles, because it has been the traditional fuel used by buses. But it exists a general tendency to electrify the fleets in the most relevant cities of the world to fight against the air quality problems.

Many actions and implementations in the public transport field have been found in this analysis, also similarities and correlations between cities. With this information, combined with the strategic analysis of the EMT, the Decision Tree was made.

4 Decision Tree

The decision tree is a model that can guide and support other Transport Companies and City Councils of the world to decide which transport fleet is the best to implement in their cities depending on their necessities and resources.

The parameters that this model combines are buses, infrastructure, emissions and costs and investments.

In this model, it has been considered that the objective of the cities is to obtain the least polluting fleet within the economic possibilities of the city and trying to reuse the existing infrastructure. Also, that the priority of the cities is the reduction of NO_X and of the particles before CO_2. With options of emissions and investments of the same order of magnitude, preference is given to the option with the simplest logistics.

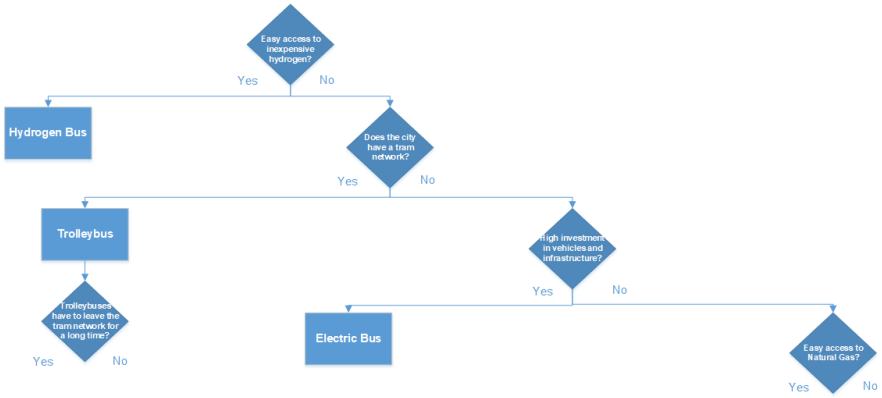

Fig. 5 Beginning of the Decision tree for the best fleet for the city

In this model, hydrogen buses have been considered as the best option, since the logistics of their use is similar to diesel and natural gas buses, and hydrogen vehicles do not have any type of emissions. The problem of hydrogen is its difficult access for most cities, so the first question is if the city has the possibility of easy access to hydrogen at low cost.

The second-best option is the trolleybuses, since they can work in electric mode for long periods of time, since they obtain electricity directly from the network that can charge their battery to operate when they need to travel in places without tram infrastructure. In the cases in which they must circulate during very long periods of time outside the electric line, they should be hybrids, preferably of CNG. The main problem with trolleybuses is their infrastructure, since it goes through the surface of all or a large part of the line and has a very high cost and visual impact. For this reason, the second question is if the city already has the trams infrastructure, because, if not, it is not a good alternative.

Electric vehicles are the best option after hydrogen vehicles and trolleybuses, as they do not have emissions. For its proper functioning, a large investment must be made in the recharging infrastructure and buses so that they have long duration batteries. For this reason, the question is asked whether a high investment in vehicles and infrastructure can be made.

The next question, within the electric buses, is whether the necessary time of operation before returning to the Operational Centre to recharge is very long. If this time is longer than the duration of the batteries, opportunity charging systems are required in addition to the charge in the Operational Centre.

Within systems of opportunity charge there are Magnetic Induction and Pantograph. Magnetic Induction systems require a higher investment, but the infrastructure is more protected and generates less visual impact.

Inside the Pantographs, there are the exterior ones, placed in the tower that charge the bus or pantographs placed in the bus that are connected to the charging tower. Those placed in the tower have a higher infrastructure cost, while those placed in buses have a higher cost of the vehicle.

The same happens in the Operational Centres, where Pantographs or Plug Chargers can be placed, depending on the charging time that the bus needs before starting the service.

If it is not possible to invest in electric buses, the solution to reduce local emissions is Compressed Natural Gas buses. If the city can also have electric chargers, the best option is the GNC Plug-in Hybrid buses.

If it is possible to invest in CNG vehicles, but not in electrical infrastructure, the least polluting vehicles are the GNC Non-Pluggable Hybrid vehicles, although they cost more than CNG vehicles.

If the city cannot invest in CNG vehicles, but in electric chargers, the best option would be the Hybrid Diesel Plug-in buses, because of their possibility of operating in electric mode recharging their batteries.

If the city cannot make any type of investment in infrastructure, the best option is the Hybrid Diesel Non-Plug buses, since they have less consumption and emissions.

5 Conclusions

The result of the analysis supports the proposal of switching to a 100% electric fleet at EMT. However, the large investments and change costs required call for a gradual implementation. To this end, new Operational Centers need to be built. Alternatively, adaptation of the existing ones and, in some cases, implementing opportunity charging structures, such as pantographs and magnetic induction chargers on the bus lines, will be needed. The employees of the company should

be trained to work with this new electrical technology, especially the mechanics, since electric engines and batteries are completely different to diesel and natural gas engines.

A decision tree that can guide and support other Transport Companies and City Councils of the world to decide which transport fleet is the best to implement in their cities depending on their necessities and resources has been created.

This study is the detonator of a process that will re-shape the emission of pollutants within the city of Madrid. Insights for the development of a new strategic plan have been given, which conclude with the need of creating a 0 emissions fleet for the company in the near future. This will influence private users, which will move to this type of mobility as well.

To this end, attention should be paid to the three key points to focus in the implementation of the electric buses, namely the fleet, the infrastructure and the human resources. They should be perfectly coordinated during all the transition to ensure a proper change.

Investing in sustainable mobility is investing in the future, improving health and life quality of the citizens, and building a better city and a better world for future generations.

6 References

World Health Organization (WHO). 2005. “Air quality guidelines - global update 2005”.

Empresa Municipal de Transportes de Madrid (EMT). 2017. “Plan Estratégico CERCA 2017-2020”

Ayuntamiento de Madrid. 2017. “Plan de Calidad de aire de la ciudad de Madrid y Cambio Climático”.

Michael E. Porter. 1998. “Competitive Advantage: Creating and Sustaining Superior Performance”