EVOLUTION OF URBAN TRANSPORT SYSTEMS AND FUTURE TENDENCIES – A LITERATURE REVIEW

EVOLUÇÃO DOS SISTEMAS DE TRANSPORTES URBANOS E TENDÊNCIAS FUTURAS – UMA REVISÃO DA LITERATURA

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ABSTRACT:
Transportation is an important sector that has significant economic, social and environmental impacts. Public transportation plays an important role on traffic operation, regarding benefits for the environmental and human health. Thus, this sector has been receiving a considerable attention by the science and industry in the last decades. However, innovations and implementation costs are considered expensive. Therefore, the purpose of this paper is an overview based on the development of the bicycles and automobiles plus Bus Rapid Transit systems, Light Rail Transit and Rapid Rail Transit (Metro). In this way, innovations in transportation, such as the sharing of cars, as well as autonomous vehicles were analyzed. In order to try to reduce harmful emissions affecting health, global warming and life quality, concern for urban mobility has become an interesting issue for large cities. Furthermore, the flow of vehicles, mainly in large cities, has enhanced the demand for mass transit, as less impact as possible to the environment and for a more efficient public transport. Therefore, the construction of train lines and Bus Rapid Transit systems has shown recently a considerable increase, mainly in cities and towns in development. Thus, the results indicate that these modes of public transport are fast, efficient and with low emission of pollutants. What reduces traffic on the streets and travel times, increases real estate speculation near the stations and, conveniently, the quality of services. The bibliographic review shows that bicycles still are the most economic transportation mode, which also favors the human and environmental health. Automobiles, which are considered the villain, have received many investments from different companies. This modal is becoming more efficient and technological, in terms of autonomous driving, car sharing and electric propulsion.
KEYWORDS: Rapid Rail Transit; Bus Rapid Transit; Light Rail Transit; Bicycles; Automobiles; Sustainable Transportation.

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RESUMO:
O transporte é um setor importante que tem impactos econômicos, sociais e ambientais significativos. O transporte público desempenha um papel importante na operação do tráfego, em termos de benefícios ambiental e saúde humana. Assim, este setor vem recebendo considerável atenção da ciência e da indústria nas últimas décadas. No entanto, inovações e custos de implementação são considerados caros. Portanto, o objetivo deste trabalho é uma visão geral baseada no desenvolvimento de bicicletas e automóveis, além de metrô, *Bus Rapid Transit* e *Light Rail Transit*. Desta forma, inovações no transporte, como o compartilhamento de carros, bem como veículos autônomos foram analisados. A fim de tentar reduzir as emissões nocivas que afetam a saúde, o aquecimento global e a qualidade de vida, a preocupação com a mobilidade urbana tornou-se uma questão interessante para as grandes cidades. Além disso, o fluxo de veículos, principalmente nas grandes cidades, aumentou a demanda por transporte coletivo, reduzindo o impacto ao meio ambiente e proporcionando um transporte público mais eficiente. Portanto, a construção de linhas de trem e *Bus Rapid Transit* mostrou recentemente um aumento considerável, principalmente em cidades e vilas em desenvolvimento. Assim, os resultados indicam que esses modos de transporte público são rápidos, eficientes e com baixa emissão de poluentes. O que reduz o trânsito nas ruas e tempos de viagem, aumenta a especulação imobiliária perto das estações e, conveniente, a qualidade dos serviços. A revisão bibliográfica mostra que as bicicletas ainda são o meio de transporte mais econômico, o que também favorece a saúde humana e ambiental. Automóveis, que são considerados os vilões, receberam muitos investimentos de diferentes empresas. Este modal está se tornando mais eficiente e tecnológico, em termos de condução autônoma, compartilhamento de carros e propulsão elétrica.
PALAVRAS-CHAVE: Metrô; *Bus Rapid Transit; Light Rail Transit;* Bicicletas; Automóveis; Transporte Sustentável.

01 – INTRODUCTION

The rapid growth of urban and suburban areas of contemporary cities, especially in developing countries, has resulted in a series of social, economic and environmental impacts that challenge producers and city planners (SAURIM, 2005).

The Brundtland Report defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Moreover, the current patterns of urban mobility, marked by a growing individual motorization, have high social, economic and environmental costs (BARCZAK; DUARTE, 2012). In this context, urban mobility should have deserved attention, in order to contribute to the development of cities and people and to reduce future problems for the environment. This is why it is important to focus in new ways to encourage public transport, in order to reduce the number of cars transiting in the city. In relation with the progressive economy, activity experienced has led to an increase in traffic congestion resulting from a boost in the purchasing power that enabled the population to acquire their own cars and switch to individual transportation modes (SILVA et al., 2012). However, current congestion

conditions and the environmental impacts of motor vehicle emissions are grounds for changes in thinking and values in the transportation sector.

In analogy to the use of the automobile and the investment in collective transport, there must be a change in culture in order to make a success in the use of alternative transports such as the bicycle, improving life quality. The bicycle is the mode of transportation that provides the lowest primary energy consumption and should be the right mode for short-distance urban travel. Its benefits are numerous and contemplate both the urban community and the users.

Furthermore, this article presents the temporal evolution of automobiles from the arising of the first models, to the current hybrid, electric vehicles and conventional vehicle. It briefly presents the operation of the current vehicles, with their main technological deficiencies and advantages. Thinking about the future of mobility, the automotive technologies that will be offered in the market and the ones that are already on the streets in some countries are briefly described.

In relation to public transportation, the Bus Rapid Transit system has become very popular in large cities due the low implementation costs, by the very short period to implementation compared to other transport systems and, also, for the offers almost the same advantages as metro, for example. The BRT reduces travel times by using exclusive lanes for the buses in order to avoid daily transit. This is only one of the BRT main characteristics.

In the social and demographic context in cities, the public transport systems are considered the key elements for urban mobility. In order to solve the actual problems of public transportation in cities trams were created and currently, the use of Light Rail Transit (LRT) is being considered as a solution for public transport problems in large cities. The first trams were horse-drawn and appeared in New York, these vehicles were moved through tracks. In 1873, in San Francisco, United States, was introduced the first tram with mechanical traction and this is a transport model which is still in development in present days. In many cities, metro systems appear as the optimal solution to achieve a sustainable mobility for the growing urban population (XUE et al., 2015).

Rapid Rail Transit (RRT) or Metro has a reputation of “green transport” due the rapid, efficient, low pollution, convenient and comfortable services and becomes one of the effective methods to alleviate problems in urban development (IEDA, 2010). This system can also provide many benefits including fast, regular, safe and comfortable services (VIGNE, 1996). Other benefits include ‘reduced traffic congestion’, ‘increased property values’ and ‘stimulated urban development’ (MACKETT; EDWARDS, 1998). Nowadays, outbreaks of large-scale urban haze and smog have raised increasing concern about the relationship between air quality and human health (JAIN; CULLINANE; CULLINANE, 2008), and although, the metro increases the public’s travel convenience, air quality has also become a concern regarding the potential impact on health (JAIN; CULLINANE; CULLINANE, 2008).

There is a lack of research comparing different public transport systems in the literature. Thus, the main purpose of this paper is to compare different human transport and future trends.

02 – BICYCLES: TRENDS

According to Turner (2013), technological developments, especially with the addition of the range of integrated products to the Internet, are the great driver of a brilliant urban mobility, where public transport operators will be able to make services optimal through continuous analysis of service performance. More than that, urban planners will have an integral vision of the city's movements, thus accompanying their work which is now based on insufficient data or that do not fit 100 percent with reality. Following the same thinking of Campos (2015), that the use of technologies has been favoring public transportation systems around the world and that in Brazil, where there are more cell phones than people, is a reality that can not be ignored.

2.1– Shared Bicycles

In 1966, the public was granted the first program of shared bicycles, also known as public or community. This way was designed by Luud Schimmelpennink and took place in Amsterdam (ESCOLA DA BICICLETA, 2015). From then on, the system of shared bicycles was directed to different sides, from gratuity to the safest and technologically advanced system, but without losing the essence of the concept: to stimulate bicycle use in order to reduce the use of motorized transportation (ITDP, 2014).

At present, on average, more than 400 cities in the world have shared systems and this number grows annually, as well as the success of large systems helps promote the feasibility of cycling as modal (ESCOLA DA BICICLETA, 2015).

According to Shaheen, Guzman and Zhang (2010) unlike a bicycle rental model that is generally situated where there is high tourist demand, it has a limited number or only place for pick up and return of bicycles, snake per hour of use and has As an attendant, shared bicycle systems have a precept: Individuals use bicycles, in which they do not have to worry about the costs and responsibilities of having a bike of their own. Bicycles are accessible for use for short periods in stations, in order to provide for the daily commuting needs of the population.

The reasons why cities choose to implement shared bicycle systems are the most different possible, some of them increasing bicycleurban use, such reducing congestion, noise and visual pollution, as well as increasing the supply of transportation Non-motorized vehicles integrating with public transport modes available in the cities, bring improvement in the quality of life. Its benefits, therefore, are identified at the most varied levels (ITDP, 2014).

There are some limitations to the implementation of bicycle sharing systems, such as: (i) excessive use or idleness; (Ii) losses; (Iii) theft; (Iv) vandalism; (V) relocation; (Vi) economic unfeasibility; And (vii) economic and technological exclusion. But each city interprets in its own way the concept of sharing bicycles, overcoming barriers and identifying the experiences of other cities in context. Density,

topography, climate, infrastructure and culture transform from one city to another, and should be considered in the planning of these systems (FISHMAN, 2015).

2.2 – Electric Bicycles

The idea of building an electric motor bike was born in the second half of the 19th century, and in 1895 the first patent for Ogden Bolton Jr was abandoned in the United States of America, though it was a rustic model with a 10 V battery and An engine that spent 100 A (ESCOLA DA BICICLETA, 2015).

Some of the aspects that have led to the inclusion of cycling in favor of the coherent use of energy in the transport sector, there is still a possibility of using hybrid bicycles, which despite the disadvantage of higher costs can inspire cyclists who wish to have greater autonomy in the movement.

The use of hybrid electric vehicles helps in the effectiveness to increase the energy efficiency in the transport sector and to reduce the emission of atmospheric pollutants and the noise in the urban centers. They are motor vehicles that use at least one motor driven by electricity for their traction. It is especially distinguished by high energy efficiency and low or zero emission levels of pollutants and noise (NUNES, 2008).

2.3 – Hybrid Bicycles Using Human Propulsion with Electric from Fuel Cell

The bicycles are not coincident with those that store electrical energy in batteries, by the use of a cell or a fuel cell for this function. Fuel cells are devices that convert the chemical energy of a reducer, almost always hydrogen, with the aid of an oxidant, but oxygen, directly into electrical energy without the need for passage through the heat cycle (RIBEIRO, 2001).

Hydrogen fuel cells are guides to a change in the energy model, which is increasingly advocated: the use of renewable and non-polluting energy as a substitute for fossil fuels (oil, gas). Fuel cells thus provide a highly efficient technological potential for the new energy generationdevelopment.

03 – AUTOMOBILES: TRENDS

Both the environmental concern and the fuels availability affect, greatly, fuel trends for transport vehicles (SALVI; SUBRAMANIAN.; PANWAR, 2013). The development of new energy for vehicles has now attracted the attention of many countries and vehicle companies worldwide (SHI et al., 2016). In this way, many actions are being put in practice to use EVs, PHEVs and more discretely the FCV. Worldwide, some countries already stand out with a considerable market share of EVs and PHEVs, with Norway standing out with 22.4% in 2015, according to Fig. 1. This result is mainlydue to subsidies, tax benefits and available infrastructure Countries.

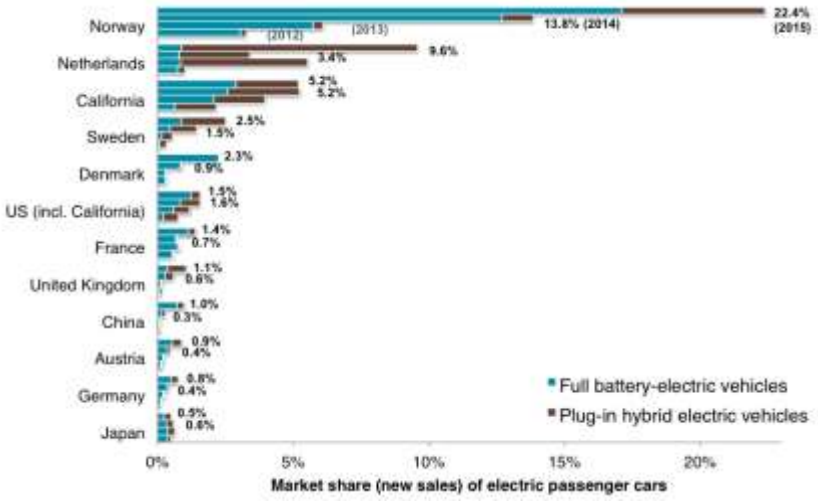

Fig. 1. Businessof sharedelectric passenger cars. Source: The International Council on Clean Transportation (ICCT).

Some countries have gone even further, announcing that in the future they will ban sales ICEVs. Norway intends to ban the use of vehicles powered by gasoline, compressed natural gas or diesel by 2025 (BARBOSA, 2016). Another country that also intends to ban the use of fossil fuels in the future is Germany, in the year 2030 (AUTO ESPORTE, 2016). Like these countries, other nations should take similar actions in a near future

Another technology that will bring considerable benefits is the self-driving cars. Most carmakers today already have designs in this direction. Among the main advantages that this technology promises is the reduction of urban traffic stress, mobility for those who do not drive, increased efficiency and reduction of emissions

and especially the reduction of traffic accidents (LITMAN, 2014). Azmat, Schuhmayer and Kummer (2016) sought to clarify and highlight the importance of autonomous vehicles in daily life and also consulted expert opinions on the subject. The results showed that the vast majority of experts think that "the future has begun," and autonomous vehicles are not just science fiction.

04 – BUS RAPID TRANSIT (BRT): TRENDS

A BRT system has been very popular in the last decades around the world because of its advantages in terms of short travel times and reduction of emissions, and low costs of operation and maintenance. In order to reduce road congestion, which affects a great number of large cities, it is essential to considerate the adoption of exclusive lanes, which separates public transport from the rest of the vehicles. This is one of the main vantages of a BRT system. The BRT system has adopted many elements from LRT and Metro to provide a rail-like service: high speed, large capacity and high reliability (DENG; NELSON, 2011).

> Bus rapid transit systems emerge from the need of a more efficient and cleaner transport. Therefore, it was decided to create a system that could take advantage of a transport guided by rails, of the usage of exclusive lanes, and besides, having the qualities of a conventional bus, of flexibility in maneuvering and low cost of operation (Vargas et al., 2012).

According to Dos Reais et al (2010), this operational system is based on the elimination of any type of interference on the roads, for example trucks, motorcycles or any other vehicles, which are out of the system. In order to be considered a BRT, the transport system has to attend some specific requirements. The installation of an exclusive lane for buses has a key role in ensuring the functioning of the system. With no interference in their route, frequency, speed and punctuality of public transport can be controlled. In addition to exclusivity, it is necessary that buses have priority at traffic lights and at intersections. Another main characteristic of a BRT system is the use of advanced electronic ticketing systems in order to reduce boarding times. Hidalgo and Munoz (2014) comment that information technology applications for centralized control, such as automatic vehicle location, online and personal data appliance routing

and schedule information are some technological advances used normally in this type of transportation system.

Table 1. Technical Aspects of Bus Rapid Transit Vehicles. Source: Arias et al. (2007).

Aspect	**Operational Characteristic**
Vehicle type	Articulated vehicles
Fare Collection	Off-board
Lanes	Exclusive Lanes
Passenger capacity	~160(single car consist)
Average Speed	23-39 km/h
Emissions	Euro III standard technology
Technology	ITS (Inteligent Transportation System)

Weinstock et al. (2011) argument that there are three main reasons why many cities have made the decision to invest in BRT systems which are: 1) compared to other transport systems, the implementation time of a BRT system are far shorter, 2) the capital and operating costs tend to be considerably lower than those for rail-based alternatives, and 3) it is easier to establish a full network using bus-based mass transit.

Vehicles used in BRT systems around the world use as propulsion conventional diesel, compressed natural gas (CNG), liquefied natural gas (LNG) and hybrid drives. There exist prototype technologies based on fully electric batteries and hydrogen fuel cells.

> Diesel is still the most used, low cost and efficient engine in public transport, but has raised concern due to its large emissions and increasing fuel cost. As a result, there has been extensive research and development by vehicle manufacturers to comply with increasingly strict emissions standards and improve efficiency. (HIDALGO; MUNOZ, 2014, p. 202)

Battery electric buses and fuel cell buses are the most promising bus technologies for the future urban transport e-mobility in terms of operational parameters, cost, environmental effects as well as long term national energy strategies (SLAVIK, 2014). One of the main purposes of implementing battery electric and electric fuel cell buses is to reduce emissions to the environment. In China, Shenzhen city is targeting 1,000 fully electric buses (EARLEY; KANG.; GREEN-WEISKEL, 2011). According to Slavik (2014) the traction batteries mostly use lithium-ion technologies nowadays, however, the effective range of this buses is still about 130-150 km. Chung, Elgqvist and Santhanagopalan (2015) comment that China, Japan, Korea control the

majority of automotive lithium-ion battery production (LIB), comprising 79% of total automotive LIB production. China is a country facing a problem of population growth, then, this is forcing them to invest in alternative energy systems in order to keep up with the energy demand. The strong requirements to reduce greenhouse gas emissions and achieve energy efficiency improvements are constant targets of studies and researches in the automotive sector, especially in China (MASIERO et al, 2016). The major producer of electric buses is the Chinese company, Build Your Dreams (BYD), they supplied the city of Shenzhen with buses which can fully charge in less than 5 hours.

Electric buses support the transition process towards a more sustainable public transport (ROGGE; WOLLNY; SAUER, 2015). There are to main types of fully electric buses, the ones where the battery is charged directly in the bus and another one where the empty batteries are exchanged for batteries fully charged, this eliminates charging idle times, making the system more efficient for the users. The main difference between them is the supply of electricity as explained by Rogge, Wollny and Sauer (2015). A major requirement for a public electric transportation system such as quick battery recharging to ensure continuous service was nicely answered with an in-route battery exchange system (JEONGYONG; INHO; WOONGCHUL, 2015). Normally electric buses do not let the battery discharge more than a 30% in order to extend the battery's life and it takes less than 10 minutes approximately to partially recharge in stations for the newest models.

Fuel cell electric buses are not as developed as fully electric systems. In order to bring fuel cell engines into a series production, still needs much research and development as well as the hydrogen infrastructure high initial investment, Slavik (2014) explains. Between the zero-emission bus options, hydrogen fuel cell buses are the most comparable in operation to conventional buses, with high driving performance and route flexibility, refueling at stations and depots, infrastructure is the major obstacle to overcome (WING, 2013).

In Fig. 3 is shown that a fully electric and a fuel cell electric vehicle are much more sustainable than the rest of the energy sources, this is the main reason why most of the developed countries are investing in the technology development.

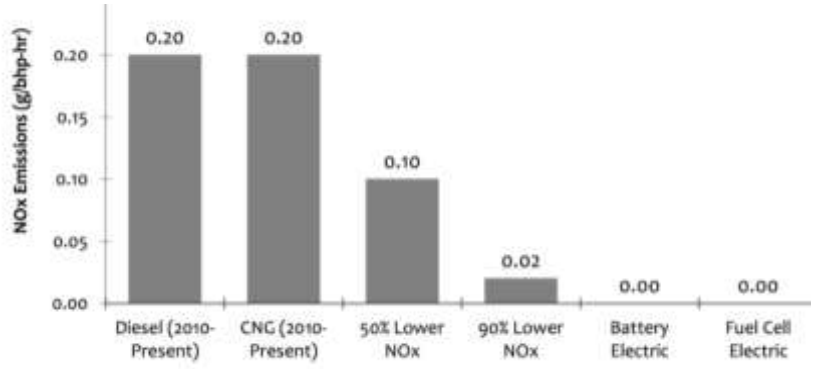

Fig. 2: Engine Certification Standards for NOx Emissions. Source: Adapted from Carmichael, Dastoum and Christensen, (2015);

05 – LIGHT RAIL TRANSPORT SYSTEM (LRT): TRENDS

LRTs without a driver are a trend the advantages of this extend far beyond the economy of wages. When computers instead of people are controlling trains, they are able to run more closely, increasing network utilization by up to 30%, experts say. When trains without a driver may seem like a novelty, they have a track record across the globe. One of the most successful systems, according to Mr. Herritty, is Docklands Light Railway in East London, which has no drivers since 1968 (BARDSLEY, 2009).

The Citadis model, which since November 2015 has already circulated on the streets of Dubai, looks more like a modern train than a tram. The city in the United Arab Emirates was the first in the world to have a LRT 100% catenary free, ie, without the overhead power cables to power the vehicles (SOUZA, 2015).

Climate change and emissions, which occur due to burning and fossil fuels, can not forget the exchange of fuels, as alternative sources of energy there is hydrogen, decarbonized coal, winds (wind energy), sun (solar energy) , Biomass (biofuels), Earth's own heat (geothermal energy), besides the most tested and accepted, which are nuclear energy and hydroelectric power(GIDDENS, 2009).

About from the point of view of cost, Giddens (2009) points out which all these sources of energy will be more expensive than fossil fuels, even the need to refine the technology.

The manufacturer French of trains Alstom has signed a letter of intent with the district of Calw in south-west Germany for the planned use of new trains powered

by hydrogen fuel cells on the scenic Hermann Hesse railway line, which aims to improve access to the Black Forest (ALSTOM, 2015).Vehicles equipped with hydrogen fuel cells began circulating on March 5, being the first light rail line in the Chinese city with 8.8 km. The services are operated by a fleet of seven for City 15T LRVs, which were built by the CRRC Qingdao Sifang under license from Skoda Transportation (VILLANI, 2016).

06 – RAIL RAPID TRANSPORT (METRO): TRENDS

Despite numerous electrification projects in several countries(ALSTOM, 2016a), a significant part of Europe's rail network will remain non-electrified in the long term. Thus, the application of renewable energy technologies tends to be more used to ensure the expansion or use of the Metro. However, in many countries, the number of diesel trains in circulation is still high – more than 4,000 cars in Germany, for instance (ALSTOM, 2016a). Contradicting these numbers, the European train builder Alstom presented its first zero-emission train at the InnoTrans 2016, in Berlin. The zero-emissions Coradia iLint regional train replaces the diesel power plant with hydrogen PEM fuel cells, while offering the same level of performance (ALSTOM, 2016b). Furthermore, Alstom one of the first railway manufacturers in the world to develop a passenger train based on hydrogen fuel cell technology, as the Letters of Intent that Alstom signed in 2014 with the German states of Lower Saxony, North Rhine-Westphalia (NRW), Baden-Württemberg, and the Public Transportation Authorities (ALSTOM, 2016b). The Coradia iLint trains will have a performance comparable to the latest generation of Coradia Lint diesel multiple units, i.e. a maximum speed of 140 km/h (87 mph) with similar acceleration and braking performance, and a comparable passenger capacity(ALSTOM, 2016b)with 300 passenger and can travel up to 497 miles(FINGAS, 2016).

In well-to-wheel analysisof electric and hydrogen light rail realized by (WASHING; PULUGURTHA, 2015), the inefficiencies of the hydrogen train's power plant and hydrogen production process are apparent in the hydrogen train's well-to-wheel efficiency value of 16.6–19.6%. The electric train, due to improved pathway

efficiencies, uses substantially less feedstock energy with a well-to-wheel efficiency value of 25.3 (WASHING; PULUGURTHA, 2015).However, this efficiency analysis should be considered for each region depending on the energy source.

07 – FINAL REMARKS

Since the diverse mode of transport existing nowadays in cities then is possible to considerate this study of extreme importance, considering the sustainable development of these urban transport systems is essential. For this, particularities of each mode of transport must be observed, such as historic evolution, main characteristics, energy sources, as well as the main impacts produced, mainly emissions (greenhouse gases and particulate matter). The public transport trends are based on the use of renewable energy sources, and in innovations in the use of transport like car-sharing, as well as autonomous vehicles.

These alternatives have becoming more clean that motorized transportation, despite the advantages, causes significant negative environmental impacts and, at the present moment in which we are experiencing a shortage of fossil fuel energy sources, there are few alternatives to overcome this type of problem. The study showed that transport by bicycle is a viable alternative of mobility in urban traffic, because it is an economic mode of transportation, which favors health and does not bring negative impacts to the environment. This type of transport can reach much larger numbers of users, if there are investments in infrastructure and safety, because for short distances, the bicycle is a viable alternative.

Based on the literature review, the BRT systems seem the best solution for the most traffic problems in large cities. The costs of implementation is relatively low as well as the number of advantages that this mode offers, which is suitable in order to try to reduce the number of cars circulating in urban zones. The main disadvantage of this modal is that currently BRT vehicles use diesel as energy source, but there are already developments in battery electric and fuel cell buses which reduces the emissions to the environment.

In this study, the Light Rail Transit (LRT) are electric vehicles that operate on metal rails along the tracks of cars and people, which is a light vehicle and have low cost of implementation, if compared with the urban trains. In other hand, this is considered an old vehicle, but different countries are investing in its development. Among the main tendencies is that they have no driver and the use of hydrogen cells as fuel.

Studies have specifically investigated the health hazards caused by the metro environment and the damage to human health caused by air pollution in the metro system; the results suggest that the risk is much more severe than that in public residential buildings. Air pollution is a severe problem in major urban areas due to the increasing number of vehicles, reduced road capacity and few investments in public transportation, especially in developing countries.

The metro building and train lines have increased in recent decades in developed cities and towns. This is a popular mode of transport in the modern world which requires features as quickly, efficiently generating little damage to the environment and helping to reduce transit in cities. Nevertheless, the negative influence of the metro construction refers to the expensive costs, its noise, dust, and the impact on nearby life quality of the residents, including daily shopping times, the water suspension, electricity and gas.

This article presents the future of mobility, briefly described in terms of the automotive technologies that are observed on the streets and that are already on the market in some countries.

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