

## Long-term supportable development programs for railway systems

### Programas de desarrollo sostenible a largo plazo de los sistemas ferroviarios

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#### Abstract

Supportable programs were embodied in 17 Supportable Development Goals and approved in the 2030 agenda of the United Nations Organization, to avoid environmental degradation and establish a more prosperous world, with peace and justice in the eradication of poverty. The objective of this research was to characterize the different stages of supportable programs for railway systems in the long term, considering the useful life of the railway infrastructure and the dependence on subsidies. However, the long-term supportable programs of rail systems supported by subsidies have the possibility of reaching a stage of maturity at the same time as the economic explosion of the environment, on the other hand, the long-term supportable programs of rail systems that do not have subsidies are intended for inoperability and lack of reinvestment. A mixed methodological analysis was carried out to identify the subsidy parameters used by the supportable development programs in railway systems in their different stages of the project. Sources of formal and informal scientific, technical, and empirical information were the basis for identifying the strategic sources of subsidies that generate stability and quality of service.

**Supportable development, useful life of the railway, long-term project**

#### Resumen

Los programas de sostenibilidad fueron plasmados en 17 Objetivos de Desarrollo Sostenible y aprobados en la agenda 2030 de la Organización de las Naciones Unidas, con el fin de evitar la degradación ambiental y establecer un mundo más próspero, con paz y justicia en la erradicación de la pobreza. El objetivo de esta investigación fue caracterizar las diferentes etapas de programas de sostenibilidad de sistemas ferroviarios a largo plazo considerando la vida útil de la infraestructura ferroviaria y la dependencia de los subsidios. Sin embargo, Los programas de sostenibilidad a largo plazo de sistemas ferroviarios apoyados por subsidios tienen posibilidad de alcanzar una etapa de madurez a la par de la explosión económica del entorno, por otro lado, los programas sostenibles a largo plazo de sistemas ferroviarios que no cuentan con subsidios están destinados a la inoperatividad y a la falta de reinversión. Un análisis metodológico mixto fue llevado a cabo para identificar los parámetros de subsidio que emplean los programas de desarrollo sostenible en sistemas férreos en sus diferentes etapas del proyecto. Fuentes de información científica, técnica y empírica, formal e informal fueron la base para identificar las fuentes estratégicas de subsidios que generan estabilidad y calidad del servicio.

**Desarrollo sostenible, vida útil férrea, proyecto a largo plazo**

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## Introduction

The world demand for transport is growing logarithmically in the transfer of passengers and cargo, due to social and economic progress, however, this will generate a demand for energy and greater atmospheric polluting emissions in the next century. The railway has the potential to solve to a great extent the problems that growth in urban environments entails. High-speed rail is an alternative to short-distance air travel, and freight rail can complement other modes of transportation by providing efficient mobility (Railway-News, 2023).

Transportation annually consumes around 50% of world oil production, generating approximately 25% of the planet's polluting emissions. Therefore, the implementation of a rail transport in its different energy modalities in trajectories typical of this transport reduces the time of transfers and pollutants, making it an efficient means of transport. Currently, railway systems move around 10% of passengers and goods globally with an energy demand of around 2% of world oil production (Five years into the 2030 Agenda: Time to give a big push to railway transport, s.f.)

Currently, 800 million people in the world are mobilized by rail-electric transport, while a couple of decades ago there were around 320 million people. The railway sector is the system that has the greatest affinity for electrification due to its infrastructure conditions and that will hardly be matched by the automotive, aeronautical, and maritime sectors in the coming decades. Passenger rail systems present 90% greater electrification than freight systems (A Supportable and green rail system, s. f.).

The regions with the greatest activity for high-speed electric trains are Europe, Japan, and Russia, while Latin America depends on hybrid systems or fossil fuels in low-speed rail systems of less than 250 km/h on short, medium, and long distances. Conventional railways represent about 90% of world passenger movements, first India with 39%, China 27%, Japan 11%, and the European Union 9% (Sustainability - UIC - International union of railways, 2023).

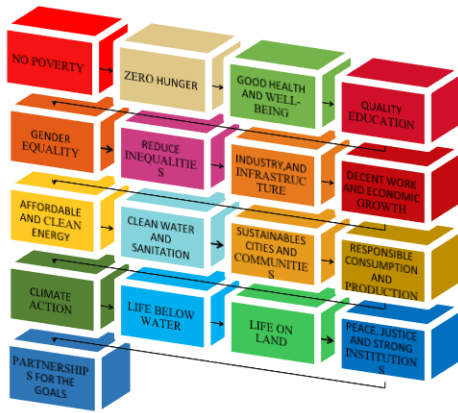
The aims of this research were to characterize the different stages of sustainability programs for railway systems in the long term, considering the useful life of the railway infrastructure and the dependence on subsidies. However, long-term sustainability programs for rail systems supported by subsidies have the possibility of reaching a stage of maturity along with the economic explosion of the environment, on the other hand, long-term Supportable programs for rail systems that do not count with subsidies are destined to inoperability and lack of reinvestment.

The identification of strategic sources of subsidies used by Supportable development programs in railway systems in their different stages of the project, it is essential to know them to generate stability and quality of service in the long term. The sustainability programs of transcendent projects of the Nations must comply with the 17 Supportable Development Goals approved in the 2030 agenda of the United Nations Organization.

## What is the difference between supportability and sustainability?

Supportable development is ecologically bearable, economically viable and socially equitable. Supportable is what can be maintained for a long time without depleting resources. Satisfy the needs of present generations without compromising the possibilities of those of the future to meet their own needs and aspirations, without consuming their resources indiscriminately sustainable development explains the reasons for defending with reasons the preservation, protect and conserve current natural resources and futures (Supportable Development, s. f. and Sustainability, s. f.).

A better way of understanding sustainability is the 17 Supportable Development Goals approved in the 2030 agenda of the United Nations, see figure 1. These goals are interrelated. a global vision elimination of poverty, inequality, quality education, avoiding environmental degradation, a more prosperous world, with peace and justice, in an environment of equity and globality, they seek the development and equitable well-being of people, taking care of the environment (Five years into the 2030 Agenda: Time to give a big push to railway transport, s.f.).



**Figure 1** Supportable Development Goals approved in the 2030 agenda; United Nations Organization (Five years into the 2030 Agenda: Time to give a big push to railway transport, s. f.)

### **Promising means of mobility railway projects; Supportable with long-term subsidies.**

The classification of the railway systems is, high-speed trains and metros (which travel long distances operating at a speed greater than 250 km/h), Metrorail (urban services of high frequency and capacity, separated from traffic, underground or elevated), and light trains or trams (lower speed capacity and at street level). High-speed rail, an alternative to aviation, and Metrorail offer a solution to congested and polluted cities.

Freight rail activity in exclusive freight trains is concentrated in China, the United States with a quarter and Russia a fifth of global freight activity. Minerals, agricultural products account for most of the railway activity (Bai & Weng, 2023).

The future of the railway is promising as a green transport means that can meet the demands of exclusive transport and presents great advantages over competing means of transport, however a disadvantage that it will have to face in the coming years will be the high costs of infrastructure and operation required until it becomes a self-sustaining medium.

Population growth in developing and emerging economies in cities is growing exponentially and will require high demand for more efficient, faster, and cleaner transportation, but the need for speed and flexibility tends to favor car ownership and air travel.

However, the railway systems have their field of action together with the other means of transport and none will displace another, they will only present an expansion in the coming years, each one in its field with greater performance according to volumes, masses, and speed of transfer. The railway industry requires strategic investments and Supportable development plans that trigger the subsidy economy of the system and improve commercial competitiveness and technological innovation. (Feng et al., 2023)

The scenario of a future railway system shows growth of around 42% with 4% energy consumption in the next three decades. The advantages of the railway industry over all means of transport are to have a confined lane (which is only used by this means of transport), which generates a second advantage: reduction of transfer times, which implies two more advantages, reduction of energy consumption and generation of pollutants. On the other hand, its disadvantages are compared to other means of transport, it is the railway infrastructure, involvement of other developing sectors such as the generation of electricity to supply the system, long distances, topographic elevations, lack of flexibility of the railway infrastructure, among others.

The railway systems industry in the next three decades will experience a stage of radical changes from oil-based energy systems to hybrid systems and from hybrid systems to electric, until the energy sector in electricity generation can detonate its expansion for the supply of different electric means of transport. The sources of electricity generation at present obey, to generation plants by petroleum-derived energies such as (generation plants based on Diesel motor systems, combined cycle and mineral coal), alternative energy sources in the generation of electricity ( hydroelectric, wind, geothermal, solar panels, photovoltaic systems, among others) and the generation of electricity through nuclear power plants, which in a controlled manner represent green energy sources (Zhu et al., 2022).

The stages of evolution of railway systems in the next three decades will not only be limited to energy systems, but they will also experience radical changes in the implementation of railway systems in technology parameters and high speeds (greater than 250 km/h) for trajectories. long enough to interconnect remote cities. Some countries like India do not have high-speed trains, however their mobility is carried out mostly through low-speed trains, due to this, a next stage of evolution proposed for India and countries with similarities is to celebrate a collaboration agreement. with powers such as Japan for the implementation of high-speed trains with state-of-the-art technologies.

In 2050, it is expected that rail activity will move 15 billion passengers worldwide in urban areas with large populations and this exponential growth in population areas ensures the high demand for rail systems, which is a very important factor for subsidies of the system are reduced and reach a Supportable operation in a Sustainable environment (X. Chen et al., 2023).

### **Economic, social, and environmental sustainability in rail transport**

In order to contribute to the design of models applicable to rail transport systems; The United States has developed the National System of Intermodal Transport, economically efficient, environmentally rational that competes in the energy-efficient global economy, on the other hand the European Commission Supportable Urban Mobility Plan, improves accessibility and social inclusion based on income, social status , quality of life, urban environment, improvement of road safety, public health by reducing factors that impact health caused by the chain of effects of environmental pollutants, help the health sector in the transfer of medicines and greenhouse gas emissions, economic viability, environmental quality. (Wang et al., 2023)

The affordability, accessibility of services and social factors of nodal transport companies in a competitive market with a short-term horizon, raised in government programs, do not tend to expel highway operators, they become trunk nodal means of the main rail transportation system.

The government tends to integrate different modes of transport in a Supportable way, encourage and impose economic challenges and key policies of mobility, accessibility, road safety, traffic and better quality of life, increase in the market share of rail transport, cleaner ports between others. (Zhou et al., 2023)

The dimensions of sustainability, such as expanding knowledge, interactions, implementation, and adaptation of railway project models, simultaneously improve economic, social, and environmental sustainability in transport. Governments pursue sustainability objectives based on previous actions of railway systems with greater experience of transport systems of leading countries with documented strategies of this technology such as implementation of taxes, subsidies, transport study based on market data, fuel tax policies. Fiscal policy could shift 0.8 percent from road transport to rail, causing a reduction in road transport gallons of total fuel consumption per year while tax policy could increase rail. Governments that follow these policies applied to mobility grant as part of their budgets a percentage of subsidies per year to intermodal transport, however, the government aims to gradually reduce subsidies as the maturity and sustainability of the independent mobility.

### **At some point, can the government become independent from the payment of subsidies without affecting the sustainability of rail transport?**

Energy efficiency, environmental factors, side effects. Programs that require initial investment, trucks that increase fuel consumption, lower transportation prices, absorb greater demand. rebound effects competition intermodal transport. optimal government policies. Sensitivity analysis, levels of strategic, tactical, and operational planning do not allow the independence of government subsidies to the means of transport because it is a demanding factor initially, of great absorption in its operation, maintenance and continuous modernization, in addition to the fact that the Transport prices generate a chain of price controls that balance the economy.

Urban railway systems require large amounts of financing that sometimes exceed 80%, which indicates a disconcerting amount in a business plan where economic profitability of the project is required. A railway system presents a project that generates ecological contributions, demographic mobility, savings in transfer times, but this does not mean that in the economic part it can walk in perfect synchrony with these factors and even less so in the initial stages of the project.

A railway system requires large investments for its construction, maintenance, operation, capital equipment renovations, expansion, renovations, and system upgrades among others, so organizations may have difficulties obtaining funds affecting the income of the urban railway in the long run. term. The railway system must have plans and programs from the beginning attached to international regulations and strategies attached to their sustainability.

Government subsidy through taxes, issuance of bonds, stimulation of income from fees, income from property rentals (stores in stations, advertising spaces, loan dependency, subsidies, direct subsidies or cross subsidies, among others, avoid borrowing to finance regular operations, direct grants are used to “fill” any shortfalls in revenue and cover operating costs from tax revenue, less than amount to maintain good condition, include concessional rate support, El Service level is generally measured through train or car-km.

### **Evaluation of plans and programs of railway systems**

The health of a railway system can present a downward spiral, due to the decrease in the number of users and cargo services that reduce the finances generated by the system as a railway company, coupled with this, restricted government financing causes impacts on the system. negatives that sharpened the downward spiral. Given these operating conditions, the quality of service and infrastructure deteriorate, presenting a logarithmic drop behavior of the railway system.

The plans and programs of a railway system must propose both quantitative and qualitative mixed scenarios, based on the performance of railway systems in the region and, in the event that it does not exist, because it represents an innovation system in the region to be implemented, it must be based on results and rail system strategies in different regions of the world that offer higher amounts of similarity. The conjectures of international organizations generated from the conclusions of groups of experts and scientists in the field of railway systems will be essential for making mixed decisions that will strengthen the health of the railway system.

Socioeconomic, political, geographical aspects, use and interpretation of qualitative data from the last decade will strengthen the strategies to be followed in the plans and programs of railway systems that can cover plans of up to 100 years with a vision of supportability and sustainability of the same.

The strategies of the railway systems must establish qualitative objectives of sustainability based on political and government changes in the long term, where the management of projects of a nation involved in an upward spiral at the international level can respond to the paradigms of mobility based on growth in accordance with the geopolitical strengths of the region, since a radical change in uses, customs, and activities in the region by geographic location would undermine the objectives of the plans and programs of the railway system and its sustainability. The irresponsibility of ignoring the variables involved in the development of a railway system can undermine the capital financing that will provide the sustainability of the system in the coming decades and in the process of maintaining the balance of project financing, many strategies could be tried, without However, previous studies put full payment for the service by the user as the primary strategy, which causes the system to be abandoned and displaced by preferences for other means of transport, putting it on the verge of bankruptcy until it becomes inoperable (Wei et al. ., 2022).

### Supportability sensitivity

The lack of an index system for the selection of sites in the decision making to solve scenarios with more objectives and goals based on a comparative sensitivity analysis. The selection of sites for the occupation of the railway environment for the creation of infrastructure that allows the Sustainable development of the railway system can be very varied, from power generation plants to service sales centers. In the case of a photovoltaic plant, it has quantitative and qualitative factors, however, experts are more concerned with sustainability than with profit, which in the long term will generate a more solid transportation network.

The rapid population growth coupled with the expansion of the railway system by 2035, demands a greater number of electrical energy sources that will lead to an increase in greenhouse gas emissions. To mitigate this impact, the electrical energy consumed by the electric or hybrid railway systems will be generated by diverse and varied energy sources (ranging from those that use petroleum derivatives, alternative and nuclear energies) whose infrastructures have different requirements that depend on various factors such as sources of transformation, size of the plant, required environmental conditions, dangerousness of the system for an urban environment. All these qualitative and quantitative variables generate a modeling that, based on criteria priority, contributes to model theory decision-making on possible solutions and their feasibility based on sensitivity analysis, placing qualitative criteria above profitability. the systems. Large cities and their tendency in decision-making are more concerned with making sensible decisions for sustainable development with robustness that allows the sustainability of the railway system in the long term than promising short-term solutions whose sustainability does not transcend, because experiences in the railway industry could lead the system to parameters of inoperability due to lack of sustainability. Uncertainty based on mixed information models (quantitative and qualitative) is a challenge for humanity because it cannot be dealt with effectively, the assumption of independence of the decision criteria does not fit reality and the problems do not it can be resolved in scenarios with more changing goals according to interests with future priority (Yin et al., 2022).

The financing of urban passenger trains has become a concern for the economy of a country, due to the problems that influence the fluctuation of passengers, financing, and sustainability of the system in the long term. The sustainability of a railway system is affected by the vulnerability of inflationary effects, political interference, consumer prices that lead to the reduction of income in real terms. To maintain high-quality operations of the railway systems in their construction stages, continuous maintenance and renovations of capital goods, taxes and cross-subsidies are required to improve direct subsidies, which are guaranteed by legislation, reducing their instability in budget allocation. the time established by decree of the project, thus not influencing the changes of government, however the budget assigned to the mobility system in its different modalities can be modified by the governments, because it does not represent a priority factor of a country such as the health, hunger among others.

Previous studies record that all the train systems in the world have presented the requirement of subsidies to be able to operate. The importance of the operability of the urban railway systems seek to generate a point of reference and balance in the costs of private transport and factors that regulate the economy of a country. On the other hand, passenger rail systems do not report large profits in their different stages and require subsidies to maintain it as a quality transportation system (Xuto et al., 2022).

The investment required in its different stages of a railway system is very large and its sustainability is based on long-term subsidies, hence a project of this nature at an international level represents a commitment to an investment policy in favor of the improvements in sustainable development conditions, but not exactly a profitable project in the short, medium, and long term. In the case of a policy system of austerity and limitation of subsidies, marginalization and distortion of public funds, the non-existence of programs for the allocation of lost funds, together with a demographic use limited by geopolitical factors, will cause a downward spiral until its inoperability of the rail system.

The investigation of railway system model approaches will be limited to the practical parameters of the system, however, the experiences of multiple railway systems carried out by multidisciplinary expert teams are the ideal development base for its implementation for the first time in a country with deprivation from experience.

Revenue stream, constant subsidy (public finance, politics, and heterogeneous sources), general sales tax, additional tax rate, employment tax, subsidies (come from government loans or tax revenue), cross-subsidies (tariffs, depending on the price), congestion charge, vehicle fuel taxes, commercial income, funds from a specific source, provide the railway system with sustainability, but without being guaranteed by legislation, they can stop being generated, favoring instability (SUPPORTABLE Development, 2018).

### Prices per service of the rail transport system

In the first world countries, wages generally increase faster than consumer prices, growth is less than inflation (wages). This influences an annual adjustment of the rates of the railway systems that increase the price index per trip, generating increases in the income of the railway system that can be used in improvements. If the railway system is geolocated in a country where the price of the trip regulates other economic factors and the increase in salary is nil or minimal for decades inclusive, it represents a factor against the acquisition of economic income to the railway system that they will have to be corrected by a greater injection of subsidies into the system in order to achieve sustainability.

Equity in transportation (refers to justice concerns including economic redistribution to address social inequality) is framed in fare affordability with real-world implementation, subsidies can be useful to help address serious equity issues, particularly during economic crises. However, a tax adjustment may need to be spread over time for capital investments, as the beneficiaries are those who use the system in the future.

The surrounding population must feel that the railway system is part of the growth of its environment that will bring progress with a responsibility to take care of the system's assets, because if this does not happen, the system components are blocked, looted, and maintaining the assets represents a challenge. For the administration of the railway system impacting on the subsidies that will have to be allocated to enable the system.

### Methodology

This research used a mixed type of methodology. Quantitative techniques were used to analyze statistics that determined the dependency of the subsidies that the railway systems require for their stability and quality of service throughout the useful life of the project, until reaching their independence and profitability in the long term. On the other hand, qualitative techniques were analyzed to estimate as a predictive means the decision-making that will influence the sustainability of the railway system. The objective of this research was to characterize the different stages of sustainability programs for railway systems in the long term, considering the useful life of the railway infrastructure and the dependence on subsidies. The mixed analysis determines control variables such as sources of subsidies, economy, social equality, and ecology in responsible decision-making for long-term Supportable systems. Projects with infrastructure renovation requirements to reach maturity in total dependence on subsidies must have a broad vision aligned with the 17 Supportable Development Goals so that project profitability can be achieved through synchronized growth, conservation, and modernization of the environment. and demography responsibly.

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## Conclusions

The sustainability of a railway project is limited to the continuity of the subsidies in its different stages of the project. The railway infrastructure, similar to all machines, is subject to wear and tear, so the long-term project with a scheduled time of around 100 years should not only cover the initial costs of the infrastructure, maintenance, operating expenses, innovation, etc. It should also be considered that the railway system has a useful life and within the scheduled period at least two to three total substitutions will be made depending on the timely maintenance. Railway systems with high rates of wear have a greater possibility of failure that can directly impact the loss of human lives due to accidents. Investments in railway systems are large investments for a developed country, but they will be even more so for underdeveloped countries whose finances are limited, so a long-term trust is the means of acquisition that in some cases becomes public debt. For the railway systems to reach a stage of maturity and profitability, they must comply with adequate and responsible planning according to the demographics accompanied by several stages with subsidies that strengthen the railway system for its next stage of substitution that makes it the preference of the users as a means of quality mobility, otherwise the railway system will enter an economic crisis until total bankruptcy.

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