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Creation of a regional and urban railway network system in Mauritius



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Mots-clés

Étude de choix du système de transport, Monorail, Bilans socio-économiques, Infrastructures, Île Maurice.

Keywords

Alternative systems review, Monorail, Social and economic statements, Infrastructures, Mauritius Island

Introduction

The Republic of Mauritius is a middle-income country with an open and diversified economy. Despite its size, limited natural resources and its geographical isolation, it is fully integrated in the global economy. It is characterized in particular by a high density population (628 inhabitants per km^2) with 1.262 million inhabitants for an area of 2,040 km^2.

The government has announced an ambitious program in order to access to an emerging country status by 2025, through sustainable and fairly distributed growth.

For that purpose, the country has launched the national program called "Vision 2030", which provides the conditions for the completion of this transition. The support of the main financiers of the country's modernization programs (the African Development Bank [ADB], the French Development Agency [AFD]) is consistent with this internal dynamic.

In order to achieve this, there has to be solutions to resolve the absence of modern infrastructure and sized to the country's growing needs for transport. Indeed, the private sector in Mauritius considers "inadequate infrastructure", especially in the transport field, to be the third most important obstacle to business in the country.

The development of quality public transport solutions is at the heart of the current reforms undertaken by the government. A road decongestion plan has been initiated as early as 2014 and the construction of transport infrastructures to provide mass transit function is on the way: the construction of a light metro project called "Metro Express" Should start by the 10th March 2017.

It is in that context that it has been proposed to identify what type of railway and urban network could be the most relevant to fulfill its inhabitants' needs, while achieving the country's prospects.

Firstly, this study will assess the state of the country in its current context, both in terms of its demography and evolution, as well as its economic, political and institutional situation. In order to complement the general contextual analysis, the existing modes of transport as well as the population flows will be examined.

Secondly, we will reflect on the stakes to be met by the means of transport in situ as well as the constraints and risks related to it, in order to understand the reasons for choosing the appropriate transport system.

A technical proposal of the chosen transport system is then proposed. It includes the constituent parts of the track, power supply, rolling stock, system design, layout, operation and maintenance.

Finally, the conditions for the actual implementation of the project is specified, particularly in terms of organization (role of the different participants, project planning, implementation planning) and financial planning.

1. Current state of Mauritius

1.1. Demographics

The population of Mauritius is distributed unevenly in the territory: a dense axis emerges in the northwest of the island, along which the future Metro-Express would be built. According to the Demographic Report, made in 2015 by the National Institute of Statistics of Mauritius, the population of the island has already reached its peak at 1.26 million residents. The projections over 20 years are rather stable (1.16 million in 2035).

1.2. The economic activity

Since the beginning of the decade, Mauritius has experienced quite a low growth due to a problematic international environment and decrease in local trades (sugar, textile, tourism).

Agricultural and industrial shares are shrinking and one of the main areas of development for the country is to refocus on the tertiary sector with banks, new technologies and services, which already employ over 63% of the active population. However, the country offers investors a stable political and economic environment, a strong judicial system, a stable financial sector and a skilled and dynamic workforce.

1.3. Geography - Environment

The island is made of diverse geographical components: the mountain "Le Pouce" the mountain range "Long Mountain" as well as plateau. The island is the target of tropical meteorological phenomena such as torrential rain (more than 100 mm of rain in 12 hours) and cyclones (winds of ≥ 120 km/h). These phenomena impose certain restrictions in terms of civil engineering and the application of specific operating rules.



Figure 1: Map of Mauritius Island - Source: Eric Gaba, CC BY.

In terms of geology, topology and seismic activity, Mauritius is located in the Mascarene archipelago, which includes La Réunion and Rodrigues. It is the result of submarine volcanic eruptions that occurred some eight million years ago. However, no volcanic activity has been recorded for more than 100 000 years.

The island is surrounded by mountain ranges, whose height varies from 300 meters to 800 meters above sea level. The terrain rises from the coastal plains to a central plateau that reaches a height of 670 meters. The highest peak, Piton de la Petite Rivière Noire at 828 meters, is located in the south-west. Streams and rivers dot the island; many of which were created by the flow of lava.

There are also environmental concerns. Within the Mascareignes ecoregion, several species of fauna and flora, some of which are endemic to Mauritius, are threatened and listed in the IUCN and WWF Red List.

The island is increasingly considering its ecological heritage because it is an asset for foreign tourism. It is progressively strengthening its regulations on land use and wetlands. An ecological study will be necessary to ensure compliance with the various regulations and to minimize or even offset the ecological impact of the project both during the work phase and after exploitation.

1.4. Transportation offer

The main means of transport are road transports (buses and passenger cars) In Mauritius, the road transport field is primarily responsible for greenhouse gas (GHG) emissions. It is a major threat to the natural environment, which is of exceptional quality and must be protected.

Two freeways run along the island: one crosses the island diagonally, from the airport in the south-east, crossing the center of the island and the capital (Port Louis) to reach the north at Grand Baie. The other, finished in 2013, makes it possible to circumvent the traffic congestion of the capital. It crosses Ebène, Terre Rouge, Pamplemousse and finally reaches the first freeway leading to the north.

The bus network in Mauritius seems rather efficient, making sure to serve the territories from the capital, Port Louis. However, the fleet is aging: buses are uncomfortable and most are not air-conditioned.

There is growing traffic congestion, together with an increase in ownership of private vehicles: between December 2014 and December 2015, a net increase of 21 092 vehicles (4.5 %) was registered by the National Transport Authority. The saturation of road transport networks and traffic accidents cost the economy almost 1.2 % and 1.6 % of GDP respectively. The Mauritian government in place after the December 2014 elections launched a road decongestion program for nearly 13 billion rupees.

There is an informal maritime cabotage network, but it is very difficult to estimate this traffic and the potential market share to be targeted. This share will therefore be

ignored in this study to avoid any approximation. In addition, the island is served by the Sir Seewoosagur-Ramgoolam International Airport, located in Plaine Magnien in the Southeast of the island, hub of the national airline Air Mauritius. There is no internal air transport to the island.

Finally, a light metro project called "Metro Express" was the subject of a feasibility study in 2012-2013 by the Singapore Cooperation Enterprise (SCE). Construction is scheduled to begin on March 10th 2017 for commissioning in 2021.
The project in a few figures:

- connecting Curepipe to Port-Louis (26 km) in 32 min of travel time;
- 20 stations and 5 urban transport terminals;
- 25 to 28 daily trips;
- cost: "economically, financially and technically viable project" for 24.8 billion Rupees;
- operating Cost: 820 million Rupees,
- traffic: 163 800 passengers per day for in 2018 - 178 200 passengers per day in 2038.

1.5. Political context

Mauritius' good performance in terms of good governance and political stability has given it a head start over other African countries. Since independence in 1968, elections held in the country have been free and fair. Non-bipartisan, political life is characterized by alliances between different political parties, which have an impact on the sustainability of programs and hence on the coherence of the implementation of national projects.
The objective of the Mauritian government's program, presented by its Prime Minister on 22 August in his "Vision 2030", aims to further develop the country's infrastructure, in particular transport, in order to improve the delivery of public services and the competitiveness of the economy so as to attract private sector investment pushing Mauritius from the status of middle-income countries to that of a developed country.

2. Monorail system: an adequate solution for Mauritius

2.1. Expectations

There are major transportation issues in Mauritius during commuting hours when thousands of vehicles are driven between Port-Louis and Curepipe (and in less significative number from Grand Baie to Port-Louis).

The main objectives of a new transportation solution are:

- to reduce traffic congestion by providing a rapid and inexpensive alternative;
- to improve quality of life by reducing traffic noise, pollution and accidents;
- to boost the economy.

2.2. Solution

Several solutions have been studied: BRT (Bus Rapid Transit), Tramway, Light Rail Transit (both underground and elevated), Monorail and Mass Rail Transit.

- Bus Rapid Transit (BRT) or Tramway would not meet the demand and probably cause more congestion as it would reduce the roads' capacity and take priority at crossroads.
- Mass Rail Transit is obviously over dimensioned for the needs of the island.
- Underground Light Rail Transit has an elevated cost and the high risk of major inundation cannot be balanced by the advantages of underground infrastructure (mostly its invisibility and the reduced need of expropriation).
- Monorail and elevated LRT are quite similar and seem to be the best solutions in terms of price, capacity and city integration. In that way, Monorail infrastructure is less massive and less expensive so we recommend this option.

2.3. Service description

A layout plan has been determined by placing stations in high density areas and activities areas in a way that infrastructure construction is compatible with existing city layout.

Using population, labor and transportation statistics from Mauritius[1], the traffic was evaluated to 6 000 pphpd during pick hours. As the demographic and economic growths are low, the line capacity will be of 6 600 pphpd to anticipate a moderate increase of demand. A further increase would be possible by improving frequency thus investing in new rolling stock.

As demand is lower on the northern part of the island (from Le Hochet to Grand Baie), this section will be built during a second phase, after the commissioning of Curepipe - Le Hochet section.

When fully operational, the monorail will automatically run with 2 services, one from Curepipe to Le Hochet and one from Curepipe to Grand Baie. The safety of

1. All statistical data is available from the website of Statistics Mauritius department of Mauritian government.
Republic of Mauritius. *Statistics Mauritius - Home* [en ligne]. Disponible sur http://statsmauritius.govmu.org/English/Pages/default.aspx (consulté le 16 février 2018).

passengers will be ensured by an onboard attendant, who will oversee the trip and be in charge of evacuation if needed.



Figure 2: The line on the map - Source: Eric Gaba, CCY BY.

2.4. Line characteristics

	Curepipe – Le Hochet	Le Hochet – Grand Baie
Line length	28 km	13 km
Number of stations	16	3
Capacity	6 600 pphpd	3 300 pphpd
Frequency	3 min	6 min
Infrastructure and rolling stock cost	36 GRs	14 GRs
Operational cost	637 MRs	957 MRs
Ticket price	30 Rs	
Maintenance	30 000 m² depot between Le Hochet and Tombeau River	

2.5. Stations

The organisation in station must be done in such a way that the security and the comfort of passengers are guaranteed: provide handicapped access, safety exits and sufficient passage for the flow of travelers in and outside the stations.

The configuration of the bays on this project is two parallels platforms. This allows to maintain the ease in orientation (direction) as well as a better handling of the crowd.

2.6. Evacuation

Evacuation will be done by transferring passengers to another vehicle whenever possible. When the viaduct is accessible by road, an alternate way will be road evacuation. A walkway will be built to reach those areas when no roads are available nearby (on bridges for example).

2.7. Impacts

The traffic in peak hours in Port Louis could be reduced by 30 % by the monorail line. Viability of the line will be ensured by ticketing, advertising spaces and resale of power generated by photovoltaic surfaces.

3 Feasibility study

3.1. Civil Engineering Works

For this system, the choice of beams used has been the "straddle-beam large" type. This choice has been done from the standards recognised by experts worldwide. Specification applicable to this project:

Items	Specifications
Monorail Type	Straddle-beam
Train width	3 m 30
Minimum turning radius	Main lines R- 60 mStation R- 0 mDepot R- 50 m 30 m
Minimum distance between two consecutive curves maximum gradient	Main lines 60 ‰Stations 0 ‰
Vertical alignment	Radius minimum 1000 m
Axial distance	3.7 m minimum
Bay length	70 m
Axle load	11 tons. Maximum load on a beam 66 tons
Beam weight	55 tons for 22 m long beam
Switches	Flexible switches up to 5 ways
Pier/column	single and double piers

The reinforced concrete beam chosen as a standard in the project is the PC-Girder with a length of 22 m. The steel beam will be used when longer span is needed to cross obstacles such as roads or natural formation. The length will vary between 22 m and 60 m. Furthermore, in the case of a span even wider, a monorail bridge that will be able to carry the system will be built.

The types of structures that can be used for column/pier on the monorail are single and double column/pier. The height of the piers must be able to provide safe passage for road vehicles underneath, with a minimum height of 5 m and the appropriate width.

Two types of foundations have been considered: two to four piles with small diameter cast on site with pile caps; one pile with big diameter and no pile cap.

The construction challenges are:

- use of efficient construction methods while maintaining the quality standards;
- planning and organizing all the construction site to respect delays and the continuity of traffic flow;
- construction and organization of plants to manufacture prestressed concrete beams;
- implementation of management plans for road traffic accommodation;
- moving of underground services or implementation of design changes;
- maintaining safety condition both on site and off site during the construction phase.

3.2. Rolling stock

The rolling stock will consist in 39 m long trains for 330 passengers. They will be straddle type monorails, fully automated, with rubber tyred bogies. The maximum speed expected is 80 km/h with acceleration and deceleration of 1.1 m/s^2 and a 550 kW energy requirement.

Considering two services: Curepipe-Le Hochet (28 km) every 3 min and one train out of two will continue to Grand Baie (total: 41 km). The number of trainsets in line is 31, so the total need including maintenance and back-up is 36 trainsets.

Figure 3: Monorail Bombardier in Sao Paolo.

Source: Governo de São Paulo – Guilherme Lara Campos / A2 Fotografia, licence CC BY;



3.3. Power supply

A report from Statistics Mauritius in 2015 about the energy indicated that the power supply generated is about 714 MW in the country with a maximum peak demand of 460 MW (+3 % compared to 2014). The power supply energy comes mainly from fossil (oil, coal) as well as 17 % produced from sugarcane and 5 % of renewable energy.

With a fleet of 36 trains of 550 kW in use, without tractioning all at once, the power supply needed will be of 9 MW in peak hours of consumption. Considering the length of line and the meshing of the electrification network, it will be advantageous to define from the first phase a supply of 1500 Vdc which is a standard in the railway system. The number of sub-station will be less than with a 750 Vdc supply solution thus reducing the losses. It has been planned to install 6 substations of 3 MW that will be installed in the stations and the depot.

To guarantee flexibility in operation and maintenance, the system will require a separate supply for the main lines in order to guarantee the constant power supply needed. The supply will be done from 2 catenaries (feeder and return) fixed on both side of the bearing beam.

In order to reduce the effect of the project on the environmental and to lessen the power supply demand, it has been planned to install solar panels on the shade structure of stations and depot.

Solar panels have a good output on energy considering the climate in Mauritius island. On a good sunny day, the panels can generate 4450 $Wh/m^2.d$. With a minimum daylight duration of 7 hours on the island with an efficiency of 0.18 for the known production of a solar panel, it with would be possible to have a steady production of 801 Wh of electricity per square meter installed per day. Per station, the output can be estimated at 340 kWh per day for a 40 x 15 m (424 m^2) installed.

The whole solar panels could supply all fixed installations (stations, depot) and an average of 9 % of the energy required for traction of trains, considering typical characteristics of the rolling stock (acceleration, regenerative braking …) that lead to a consumption of 4 kWh/km.

3.4. Schedule of Implementation

The project will be executed in two phases:
Phase 1: construction of the section between Le Hochet and Curepipe.
Phase 2: the extension from Grand Baie to Le Hochet

Activities	Years							
	1	2	3	4	5	6	7	8
Project studies (All phases)								
Financing searches (phase 1)								
Preliminary design and tendering process (phase 1)								
Awards and negotiations (phase 1)								
Detailed Design (phase 1)								
Construction (phase 1)								
Commissioning (phase 1)								

4. Implementation

4.1. Possible Funding Agreements

In addition to its funding capabilities, the government could request:

- the contribution of a line of credit from India, a privileged historical economic partner of Mauritius;
- financial assistance from foreign institutions such as the EIB or the IBRD;
- on the local level, assistance from commercial banks, if it succeeds in convincing them of the financial viability of the project;
- the introduction of a tax on oil products. The current taxation is not excessive but the import costs increase the prices too much compared to the purchasing power of the Mauritians. A little more than 10 % of the price per litre is already used for the development of Mauritius and the decongestion of roads. A slight increase could even be considered if an exemption is made in favour of public transport;
- the use of urban tolls and / or the generalization of paying car parks, but the cost of setting up can be quite high;
- financing projects through public-private partnerships (PPP), as it is strongly supported by international institutions. Among the advantages of this solution: rapid completion, limited investment budgets and financing mainly by banks with limited recourse to shareholders and industrials;

4.2. Project management and governance

Given their complexity, PPPs require a clear legal and institutional setting and accessibility to regulation for ensuring legal and judicial security for investors.

A project team will be set up within the Ministry of Public Infrastructure, the "Monorail Project Management 2025", composed of international experts, contractors and local experts in all areas necessary to carry out the project and in particular in a legal, financial and technical sense. It will manage and coordinate the entire project until it is commissioned, with the assistance of project management (AMO).
In particular, the Monorail 2025 Project Management will work with:

- beforehand, with the services of the Ministry of Finance and Economic Development for the preparation of the public-private partnership contract;
- the Environmental Assessment Division of the Ministry of the Environment and Sustainable Development to assess the environmental impacts of the project beforehand and ensure the implementation of measures to reduce the negative environmental impacts of the project;
- in the works phase, the technical services of the Ministry of Public Infrastructure and Land Transport;
- during the operation, the National Transport Authority (NTA), which is part of the Land Transport Division and which could eventually become the country's Transport Authority.

The Monorail Project Management 2025 will define and coordinate with the help from its AMO and the expertise of international sponsors:

- the economic, legal and technical conditions of the project through the drafting of the PPP contract;
- the smooth running of the tender process and the competitive dialogue with the candidates;
- trade policy;
- the construction of the viaduct adapted to the monorail system;
- the acquisition of the trainsets from the selected builder;
- the construction of a depot and maintenance workshop near Le Hochet for the maintenance of trains;
- the construction of stations;
- commissioning;
- the support on the exploitation part for a period of four months after the commissioning.

4.3. Identification and appropriation of the legal control

The project team will have to prepare the conditions for the assessment and award of the public-private partnership contract, together with the services of the Ministry of Finance and Economic Development.

Training to strengthen the skills of officials in the Ministry of Finance could be useful. Since the beginning of 2012, nearly 300 executives throughout the African continent have been trained through the "PPP Course" set up by the African Legal Support Facility, AFD (through its corporate university, CEFEB) and Expertise France.

Moreover, due to the absence of a local company capable of doing it, the contract could also provide for the operation for a period of 5 years at the end of which a call for tender would be reissued by the newly created Transport Organizing Authority (see below).

4.4. Organizing authority

The National Transport Authority (NTA), attached to the Ministry of Public Infrastructure and Land Transport, has as its main responsibility: motor vehicle registration and licensing, regulation and control of road transport. Its current missions include:

Provide the strategic framework for the delivery of transit services and plan for the future needs of the country.

Regulate and control the movement of goods and passengers to ensure that the public is provided with adequate, safe, affordable and reliable transportation services.

Review legislation, streamline procedures and undertake capacity building to improve efficiency and service delivery to our clients.

The NTA could gradually recruit additional FTEs and through training, develop a genuine role as Transport Organizing Authority.

The objective would be to extend its current skills, limited to the road field, to entrust them with the management of transport services throughout Mauritius so as to ensure the consistency in the structuring of the road network and transport within the territory.

To this end, the financing of a partnership with an existing AOT (STIF, SYTRAL) via FEXTE (Fonds d'Expertise Technique et d'Exchanges d'Experiences), an AFD tool, is recommended.

Conclusion

The analysis carried out during this study leads to the consideration of the automated monorail solution as a technically feasible system adapted to the needs of the Mauritian population.

However, since it is an atypical transport solution, the country, which is not currently equipped with a rail network, may not agree to the implementation of an undeveloped system throughout the world.

The automation of the system can also be questioned on the social level. It appears as a factor for less job creation. However, its integration at the start of the project could start early the reflection upon it, even before the realization of the project, avoiding the risk of a later social conflict.

The implementation of a consultation procedure beforehand, carried out by the Monorail 2025 project management, around associations of local residents and elected representatives concerned by its layout, would offer the opportunity for an important public debate in order to understand the expectations of future users of the latter and to ease its acceptance.

One of the essential conditions for the project's success is the clarification of its governance and the allocation of sufficient human and technical resources to carry out all the tasks assigned to the client. Training and partnership arrangements with international experts or organisations with experience in PPP contracts, project management and construction of transport systems will be essential.

Finally, the realization of this project will be correlated with its capacity to federate all the political parties and not to make it an issue for partisan struggle. Indeed, through alliances, the development of projects in the country are made and dismantled at high rate, just like this project of collective transport whose first reflections go back to more than twenty years.

Nevertheless, the construction of this system with futuristic aesthetics would be a real opportunity to develop a transport infrastructure essential to the country and attract foreign investors as well as make the country rise to the emerging country status. It is, therefore, coherent with the "Vision 2030" roadmap implemented by the Government of Mauritius.

It also gives an answer to the proven need to reduce road traffic congestion: localised along the Port-Louis-Curepipe axis, it causes increasing traffic problems and the government must find a lasting solution.

Due to its innovative technology, particularly its low energy consumption and its silence, the monorail solution finally presents the notable advantages of a sustainable system.