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Creation of a tramway line for the city of Qom in the Republic of Iran



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Mots-clés

Étude de choix du système de transport • Tramway •
Dimensionnement fonctionnel des stations • Exploitation • Qom (Iran)

Keywords

*Alternative systems review • Tramway •
Station functional sizing • Operation • Qom (Iran)*

Introduction

The agreement signed on July 14th 2015 is a historical event for Iran, allowing the country to join the international community after the end of penalties. Iran is indeed a promising country with a potential market of 80 million people and a well educated middle-class. President Rohani has even stated that the government's priority is the country's economic recovery. The program unlocking Iranian assets and reopening borders for international trade should thus encourage foreign direct investment, increasing trade and stimulating growth. Sanctions relief increase public expectations of economic improvement and international commitment.

The transport field has been neglected for years, in favor of industrial fields such as oil and gas, metals and minerals. The city of Qom has been particularly suffering from alarming problems of pollution, congestion and high road accidents, whereas public transport field is still very limited. Monorail and metro projects have already been launched, but they are still under construction.

Our project starts with a diagnosis at a national scale to describe geographic, environmental, institutional, economic and sociodemographic aspects. Then, we focus on specifics of the city of Qom in order to better understand the local expectations.

After making an assessment of transportation modes in Qom, we will analyze the mobility in the city to decide if we need to develop a third urban transport system. This will lead us to identify two main corridors in the city, carriers of flows, allowing us to draw a horizontal alignment for this public transportation line. Afterwards, a study of the transport demand on this axis will help us choose the relevant means of transport.

A proposal for a complete tramway system will be given, including a technical feasibility study for Infrastructure and Rolling Stock structural subsystems and an operational feasibility study for Operations and Maintenance functional subsystems. Finally, an economic feasibility study will be submitted, taking into account cost and revenue aspects to assess the socioeconomic and financial profitability of such a project.

Lastly we will propose project funding options and conditions necessary to support the launch of the project with regard to redirecting transport policy, in order to make it financially viable.

1. Environmental and Demographic diagnoses

1.1. Geography

Qom is the capital of the province bearing the same name. It is the 8th most populated city of Iran and covers 127 km². The city is located 150 km to the south of Teheran, but stands out by being at the crossroads of both railways and highways that link the south part of Iran with its capital Teheran. The city is on a plateau surrounded by a mountainous area on one side. On the other side, there is a plain stretching to the Nawak Great Salt Lake in the East.

1.2. Seismic risk

Iran is located between two major seismic areas: the Arabic plate collides with the Eurasian plate. These tectonic mechanisms imply several faults, the main ones are located in the north and south of Iran and there are many frequent seismic activities. Qom province is in the central area and is classified as an average seismic zone.

1.3. Population growth and density

The latest census of the population recorded 1,074,036 inhabitants in the city of Qom six years ago. The population annual growth is about 2.4 % since 1996, so we estimate the current population to be about 1.23 million inhabitants.

The Qom province is highly urbanized (nearly 95 %), because the majority of the province population lives in the city of Qom. It is the 6th most densely populated city of Iran (9,600 inhabitants per km² on average), with also the 6th highest population growth, fueled by both demographic growth and rural exodus. Education level is relatively high, but unemployment rate reaches 9.2 % in general. Qom population reflects today's Iranian population: young, educated, urbanized and suffering high unemployment.

2. Transportation diagnosis

2.1. Transportation organization

The transport field is a field highly funded by the state in Iran. The policy for the development of transport infrastructure is defined and implemented by the Ministry of Roads and Transport.

There are several umbrella companies having their own master plans: Port & Shipping Organization (PSO), Civil Aviation Organization (CAO), Iranian Airports Holding Company (IAC), Iran Railway Company (RAI) and Road Maintenance & Transportation

Organization (RMTO). The Urban Planning and Architecture Department supervises the urban development and landuse planning. The organization of transportation at the provincial level is carried out by municipalities. The office of circulation and public transport reports directly to the mayor.

Qom Urban Railway Organization was established in 2008 to manage the city's public transport projects. It plays the role of a local transport authority. The objectives of Qom Urban Railway Organization are based on a sustainable and cost effective urban development in terms of air quality, green energy and noise reduction.

2.2. Transportation in Qom

Currently, the public transportation relies mainly on buses, collective taxis and private cars. Qom city is changing its strategy to develop mass transit system with the launching of a metro and a monorail.

The metro project is currently under construction. The length of the line is 14 km. It has 14 stations, with a connecting station to the monorail. The commercial speed is forecast at 35 km/h with a maximum at 80 km/h. The whole line would run underground. The monorail is also under construction. The first part of the line would be 8 km long and build above ground. In a second phase, the complete line would be 25 km long with 17 stations.

These two projects are supervised by the Qom Urban Railway Organization. This study is focused on the opportunity of implementing an additional transportation system in Qom.

2.3. Road accident, congestion and pollution

Like all major Iranian cities, Qom has traffic congestion, pollution and road accidents. Iran suffers from a very high road accident rate. This rate is decreasing since 2007 but still remains very high: it reached around 16 600 deaths in 2015.

Most of cars in Iran are obsolete and were manufactured according to standards that do not comply with the latest environmental guidelines. A yearly increase ratio of 15 % of cars' fleet is observed since the last decade: the situation is becoming alarming. Moreover, since the country does not have many public transportation means, congestion problems are recurring and paralyze traffic. Air pollution is a significant environmental problem in Iran, mainly in urban areas. All these factors are the main reasons behind the urgent need of development of public transportation in Iran.

3. Economic Diagnosis

3.1. Qom's activities

Qom's activities are mainly focused on the following areas:

- Pilgrimage tourism brings some 20 million national and foreign tourists per year, or an average of 55,000 per day. It is the main activity of the city, and it provides many jobs.
- Since the country was until recently closed in on itself, the State remains the main employer of the country, and many administrative offices are located in the city of Qom.
- Services generally represent a significant part of the economic landscape (banks in particular).
- The carpet industry, although in decline since 1970, is still active with a production of Persian carpets turned to export to the whole world.
- Automotive, construction and small industry can also be mentioned, despite their current difficulties.
- The city reopened a large shopping mall in the city center.

Important sites of heavy industrial production are present in the city of Qom's outskirts, but have no impact on the transport system under study because of their distance from the city center and the reduced number of workers.

3.2. Holy city of Qom

The holy city of Qom is the second largest Shiite education center in the world after Najaf in Iraq. The institution responsible for teaching principles of Shia Islam in Qom is known as Hawzah Elmieh. More than 70,000 Iranian and foreign students in theology live in Qom. Theology schools are under the protection of Hawzah Elmieh and are equipped with highly advanced technological resources.

Qom has two pilgrimage sites: the mausoleum of Fatimah Ma'sumeh, sister of the eighth Imam, and Jamkaran located outside the city. Other famous sites are the eight universities, the libraries and many mosques such as the Friday Mosque, the Atiq Mosque, the A'zam Mosque and the Qom Grand Mosque. Peaks of pilgrims flows are observed during the months of Ramadan and Moharram, the month of mourning of the Shiites, and during famous religious festivals such as the birth and martyrdom of Imam Ali, Achoura, the day of the martyr of Hussein, and the Iranian New Year (21st of March). Qom's municipality published in a report that flows of pilgrimage to Jamkaran in 2013 reached 10 938 291 passenger cars.

3.3. Qom's main attractions

The city's points of interest are the main types of facilities such as: train station, city hall, hospital, university, religious centers, touristic monuments (monuments, museums, etc.), stadium and residential areas.

Peripheral population growth and increase of density in the city center are major trends. With many transport projects and other construction projects in the outskirts, the city has launched a policy of modernization and development.

4. Transportation system study

4.1. Advised alignment of main features

Many factors have been taken into account to determine the most suitable alignment for the project:

- the metro and monorail projects currently under construction;
- the existing transportation means (buses, collective taxis, ...);
- the density of the city neighborhoods;
- the main centers of interest and the location of the main areas of employment.

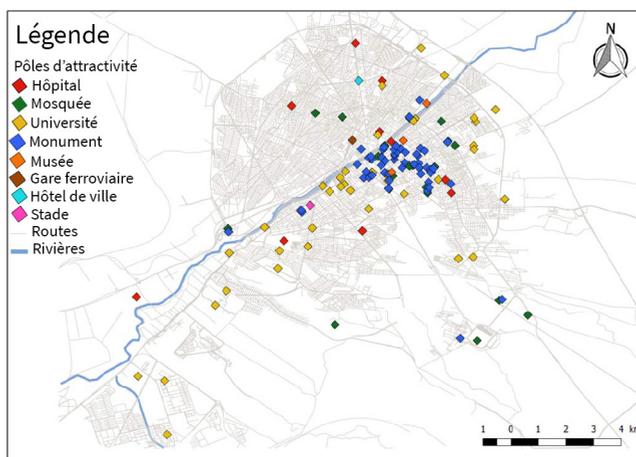


Figure 1: Tramway route.

Our analysis leads us to consider two alignments with distinct and complementary goals. The ring alignment improves transportation service in currently unserved highly dense areas and will provide a strong network effect with the coming metro and monorail lines. The radial alignment gathers two sections of the two main existing bus lines

of the city and provides a service to the south west part of the city under development, without requiring massive property expropriation.

Multi criteria analysis showed that the radial alignment should be made in priority mainly because of the expected traffic growth and the employment areas it will service (see map at the very end of this summary to see it on a bigger scale). The ring alignment should not be discarded though, and could be built after the radial alignment has been done.

4.2. Traffic demand analysis

Given the lack of data such as origindestination matrix, a semi qualitative approach has been adopted to estimate transport demand along the alignment, instead of the four steps classical method.

The highest load is expected in the center of city where the transportation system will replace existing highly loaded bus lines and provide an alternative to congested car traffic. Bus traffic in the central area, currently estimated to 2,400 pphpd on peak hours, is expected to fully transfer to the new transportation system. For road traffic, estimated to 8,280 pphpd on peak hours, 20 % is expected to transfer to the new transportation system. Based on these hypotheses, this new line is expected to attract 4,015 pphpd on peak hours on the most loaded section when the line will be brought into operation.

On a daily basis, the number of trips is estimated to be 9 times the highest pphpd at peak hours, i.e. 36,131 passengers per day. The traffic growth is expected to follow the population annual growth of 2%.

4.3. Choice of transportation system

The estimated passenger load at peak hour (4,015 pphpd) at the opening of the line is within the theoretical capacity range of Light Rail (metro), tramway and BRT. As said previously, Qom is currently building a metro line and monorail line, with problems delaying the opening. An additional metro line will add investment and operation costs, which would be difficult to bear for such a city, without addressing a real need.

A BRT (biarticulated bus) could provide the required capacity at the opening of the line, if operated at a very short headway (2 min or less). Such a solution does not provide any capacity margin to match the transportation need in the future. But a 43 m steel wheel tramway appears to be the most appropriate choice. Its capacity allows to face the transportation demand at the opening of the line with a reasonable headway. This headway can be reduced down to three minutes to match the transportation need growth for the coming decades.

4.4. Rolling Stock Sizing

The rolling stock fleet of the line designed in this study is calculated by the ratio of the complete round trip over the minimum headway, increased by an operational reserve and a maintenance reserve.

It is calculated for the launch date and each time the minimal headway has to be decreased to meet the capacity needed. The fleet for each period is shown in the table below:

Dimensioning of the fleet	Launch date	9 years later	20 years later
Round trip	132.3 min		
Minimum operating headway	5 min	4 min	3 min
Tramway in operation at peak hours	27 trains	34 trains	45 trains
10 % maintenance reserve	3 trains	4 trains	5 trains
Operational reserve	1 train	1 train	1 train
Total Rolling stock	31 trains	39 trains	51 trains

5. Feasibility Study

5.1. Rolling Stock's features

Based on ridership estimations and line characteristics, the most suited rolling stock appears to be a 43 m long tramway such as Alstom Citadis 402. Similar rolling stock may be provided by several suppliers. Tramway capacity is at 395 passengers. At the opening of the line, headway will be of five minutes during peak hours; this operation scheme will meet the traffic demand.

This rolling stock has a lowfloor structure, 350 mm higher than the rail level, which avoids a step between the platform and the train; it improves boarding and unloading time during the stop in the stations. It maximizes the passenger's exchange, and provides easy access for disabled people.

To respect Iranian customs, the tramways are equipped with compartment dedicated to women and children. The train interior and exterior design is adaptable to the city and has to participate to the urban renewal of Qom. The main power supply is overhead line catenary fed with 750 V DC. In the historical center of Qom, catenary free system may be considered to reduce the aesthetical impact. Several solutions are available, such as Alstom APS technology, battery, or super capacitors. The integration of the complete system (rolling stock and the infrastructure) allows an urban renewal which is a bonus for Qom development.

5.2. The infrastructure's characteristics

The track is embedded into concrete for a street running operation; it is composed of two grooved rails fixed on bibloc sleeper. The track gauge is of 1,435 mm, and there is no ballast track on the main line. Ballast may be considered in the depot to reduce costs.

The length of the line is of 21.05 km with a double track, and the track platform is between 5.85 m and 6.40 m. The minimum curve radius is 25 m, but the target is to keep the curve radius above this value to have a better commercial speed and improve passenger comfort.

Each 2.5 km, a junction or a crossover (track 1, track 2) allows vehicle turn-back: in case of an incident, the faulty section is isolated from the healthy section of the line, where pinched loop operation is preserved. Line operation is supervised by the Centralized Traffic Control.

The 37 stations are equipped with two platforms each, and they are only installed in track straight alignment to avoid a gap between the tram and the platform. The maximum gap between the platform's edges is limited to 35 mm to allow disabled people and people in wheelchairs to access to the tram.

The maintenance workshop and stabling is located to the north of the line, all trains are in a secured area to prevent deterioration. All preventive and corrective maintenance will be performed in this center. Track and Signaling equipment fit with the urban environment. But at the beginning of operation, the future operator has to raise public awareness about the risk of collision between the tram and cars or pedestrians.

5.3. Civils Works and structures

Considering that the soil in Qom has a good bearing capacity, surveys should be carried out in more detail to develop geotechnical studies. Civil works are limited to the construction of one bridge crossing Qom Rood River and to inevitable earthworks caused by some variations of altitude in the southern part of the city.

Due to urban insertion constraints that required avoiding residential areas, the viaduct crosses obliquely the river. Regarding the type of bridge, we chose a two beam mixed steel and concrete bridge 200 m long, having 6 spans. Central spans are 40 m long whereas end spans are 20 m long. Specific constraints on central piles in the river bed should be taken into account.

The horizontal force generated by an earthquake must be considered in the calculations for the structures. Adequate seismic design techniques should be applied.

The line has been divided into seven sections according to level variations based on the vertical alignment. We identified for each section, length, minimum and maximum altitudes as well as extreme slopes.

When the section has a flat topography and the slope is less than 7 %, no earthwork activity is necessary. We identified two cases where we could avoid building a bridge by lowering the peaks of the hilltops, making the level difference acceptable, and thus the slope. Earthmoving operations are indeed much less expensive than the construction of a bridge structure.

In the first case, the peak was lowered by 6 m, in the second, by 1 m. In addition, few earthworks in terms of excavation and backfilling at specific areas were deemed necessary even though they remained limited. The excavated soil volumes of the mountain will be used for the backfilling as it is a good material.

5.4. Operations

The fundamental goal for a tramway network is to meet the transport demand in the best conditions of safety, regularity, comfort, speed and cost.

Types of Operations:

- Normal Operation: Line operation is performed in accordance to the time table, which defines the headway for the different times of the day. The layout of the shunting zone has to be designed to provide some margin between the minimum headway and the time required for turn back.
- Headway variation during the day requires the operator to inject and withdraw trams from the line to the stabling. If required, trams withdrawn from operation are sent to a planned maintenance or a washing machine, according to a predefined schedule.
- Degraded Operation: small problems shall be managed as far as possible by the tram's drivers with the support and guidance of the regulator located in the OCC. For major operation incidents, the operator in OCC deals with the situation in accordance to emergency procedures. He provides information to the passengers and directs them if necessary to alternative transportation means. In order to limit the consequences of the incident on the commercial service, he follows the degraded operating procedures. Degraded operation procedure includes for instance the implementation of short turn back in order to maintain service on healthy section of the line, on both sides of the faulty section where operation is stopped. Another degraded operation procedure is to empty a faulty train from its passengers to withdraw it from service.

The detailed definition of the organization may vary from one operator to another, but the following functions are compulsory:

- the line will be overseen by a line manager;
- the OCC, staffed with several regulators and a regulator-in-chief, in charge of traffic supervision, the traction power, information to travelers and staff, the tracking of the facilities anomalies, the management of drivers during their service;
- the person in charge of preparing the timetable: to meet the transportation demand as accurately as possible, by taking into account seasons, specific events and feedback from the previous years of operation;
- safety and procedure: analysis and investigation after incident, update of procedures when required, training of staff regarding safety and procedure;
- fare control: roaming ticket inspector and their supervisor;
- drivers: it is by far the most abundant kind of staff. Their number has to be determined by calculating the actual driving time and has to include some margin to cope with absenteeism. The organization of driving shifts is crucial to ensure a smooth operation of the line.

The actual operation set up will depend on the level of integration with the other transportation system of Qom such as the upcoming metro and monorail. Some of the functions listed above may be merged with their equivalent in the metro and monorail operation organization to improve the availability and efficiency of the staff, and to obtain the best balance between quality of service and operation cost.

5.5. Rolling Stock Maintenance

The Rolling Stock Maintenance Facility will be located to the north end of the line. Two main activities will be managed: tramway maintenance and tramway stabling.

The maintenance will be carried out in a covered hall allowing preventive and curative interventions on the trainsets. The hall houses several workshops (oil, hydrocarbons and solvents, electricity, batteries, mechanics, brake test...) and is composed of 3 level tracks and 2 tracks on pit, equipped with footbridges allowing access to the roofs of the trainsets. These tracks are 50 m long to accommodate one train at a time.

5.6. Infrastructure maintenance

Visual, audible and vibration abnormalities will be reported to the CTC by drivers, maintenance staff or local residents. For the maintenance of the track, signaling and low currents equipment, a railroad truck will be used.

5.7. Maintenance Teams

The tramway's maintenance teams are not designed to work in the maintenance centers of the Monorail and Metro. When the maintenance of urban transport in Qom will become be fully developed, this question can be studied again. The sizing of the maintenance crews is done according to the planned maintenance load for the tramway.

5.8. Planning

The project planning is divided into the following main phases:

- olanning, investigation, and concept design: to determine the main project objectives and costs, collect entry data (topographic, geotechnical, utility network);
- procurement: preparation of bidding document, bid analysis, negotiations and contract award;
- construction;
- testing and delivering.

The duration of the phases may vary significantly due to local context (process for political decision, number of public agencies involved in the decision ...), but the overall duration from the start of the studies to the beginning of revenue service is estimated to six years. Special attention shall be paid to rolling stock procurement and delivery, since production rate is limited by the manufacturer capacity. Utility diversion should also be planned ahead to avoid project delay.

5.9. Financing

Financing of transportation project has been difficult in Iran for the past years, leading to delayed projects, such as Teheran's metro. Under international sanctions, Iran had very few options for financing and had to make deals with the Chinese government, that provided both financing and proven technical solutions from its industry. The sanction relief allows now Iran to seek new ways to fund its projects.

The project could be eligible for partial financing by the BIRD since it would address some of the primary issues identified by the World Bank in its 2005 report (pollution, road safety...). But this financing would likely come with some requirements regarding project management but also transport pricing policy. Such requirements could be rejected by the government as they would be likely seen as unpopular measures. Alternative lenders such as the Islamic Bank of Development may also be considered.

Another alternative is to seek for private international financing alongside the bid for the transportation system. Industrial bidders would be required to partner with banks to provide a financing offer in addition to their technical offer. In this strategy, competition between suppliers is preserved and technical requirements have to be met. Given the huge Iranian oil resources, this financing strategy may also be adapted to include some way to use oil as a collateral or a part of the back payment.

Conclusion

The study of the Iranian market and the diagnosis of the territory have shown that environmental and mobility issues are at the heart of the challenges that the country will face in the coming years. Major railway investment projects have been launched at national level, and locally in Qom the mutation of transport modes and their organization is underway: metro and monorail lines are under construction and supervised by Qom Urban Railway Organization.

To support the economic development of the city and meet current and future transportation needs, two corridors have emerged: a ring alignment in the heart of the city and a radial alignment connecting the north to the periphery in the southwest. A multicriteria analysis revealed that the radial route is the priority need with most promising perspectives in terms of traffic growth.

The analysis of the current demand on this axis shows that there is a market for a third urban transport system within the city of Qom, especially as the growth of the population will create a bigger need for transport.

The estimated passenger load at peak hour (4015 pphpd) at the opening of the line constitutes a key input in the modal choice. The tramway appears to be the most adapted mode to the stakes of the city and its constraints. One of the intrinsic qualities of the tramway is that it is able to respond to changing demand under realistic investment and operating conditions.

The technical feasibility of such a project doesn't have any problem: the rolling stock and its requirements already exist on the market; technical solutions recommended for infrastructures and fixed installations are conventional; civils works, structures and land acquisitions are under control; and feasibility in terms of operation and maintenance is verified. Moreover, the study of a long-term schedule shows that the duration of studies and construction before commercial startup will be spread over nearly six years. Finally, an economic feasibility study has been conducted to assess the socioeconomic and financial profitability of such a project. According to our set of hypothesis in our basic scenario, the socioeconomic net present value reaches €41,459,899 over 40 years, with an economic rate of return of 6.93 %, above the discount rate of 6 %, proving that the project is economically viable.

Our study tends to show that this third urban transport system within Qom is a realistic solution. However, this result must be modified by the limitations of the present study. Indeed, the main prerequisites for launching such a project are firstly to carry out a fine modelling of traffic because this input data takes decisions on the modal choice, the dimensioning of the transport supply and therefore the necessary investment.

In addition, the NPV and rate of return estimations are based on a set of hypotheses, that have to be clarified and refined to verify the economic relevance of this project. Moreover, financing solutions are broadly dependent on the stability of Iran's international relations with the rest of the world. The risks and threats of this type of project will have to be assessed.

These aspects should not, however, make us forget that the Iranian market has a potential of 80 million inhabitants. Active participation in the stability of the country, central and strategic anchor in the Middle East, as well as the possibility for France to resume strong economic and political contact with Iran are strong issues that will attract the attention of investors and political authorities. The promotion of French skills in terms of transport industry and engineering is also an asset for a country in a full comeback and eager for infrastructure investments, economic recovery and job creation.

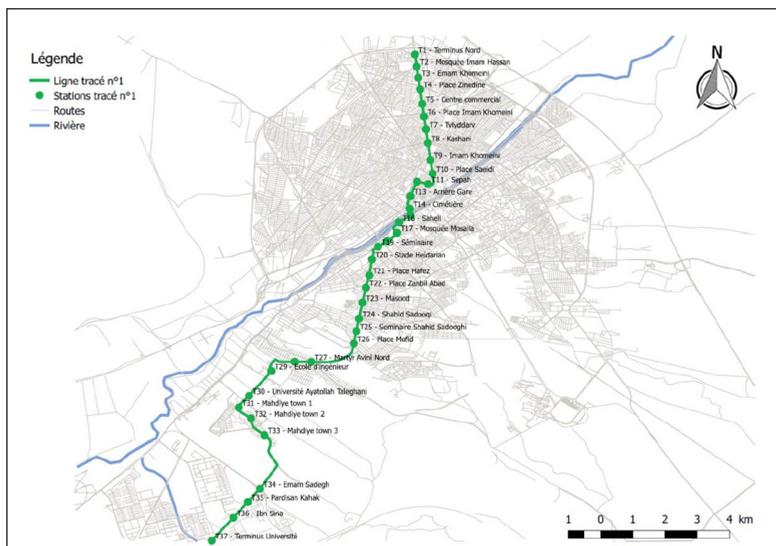


Figure 2: Tramway route