

TRAMWAY PROJECT ANALYSIS IN EUROPE: OPTIMISATION OF THE NEW TRAMWAY IN BARCELONA

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1. INTRODUCTION

A critical component in people movement is the travel time used going and coming between home surroundings and other activities. Since the Second World War, in 1945, two new metro systems are put into service every year somewhere in the world, in addition to the tramways and light rail transit systems constructed to improve the public transport supply.

Currently, and in spite of the huge investments the urban guided transportation systems represent, a big number of cities are incorporating metros, light metros and tramways into their transport networks.

One of these is the new tramway in Barcelona, which is composed of three lines meeting in a communal stretch along Avinguda Diagonal. This stretch can be described as running segregated from the road, its route being crossed by some major streets that have congestion problems at certain times of the day, and by the existence of some single track sections in two of the three lines.

2. OBJECTIVES

The main objective of this research is to elaborate a list of benchmarks in order to assess the feasibility of a certain project once knowing the information provided by the promoter, through an evaluation of the various economical, financial, social and environmental parameters that must be considered to implement an urban transport project.

To make this work, it is necessary to analyse projects already financed, in order to establish acceptable ranges of values and comparative ratios of the relevant variables of projects, and afterwards to locate the situation of a new project in relation to those considered acceptable in the past.

Once those ranges of values and the comparative ratios have been established, it will be possible to classify the economic and operational performance of a new project. In summary, the objective is to elaborate a Decision Support System (DSS) to show the status of these indicators, in relation to metros and light rail transit projects. This DSS, therefore, represents a tool conceived with

the idea of determining both analytically and graphically, the acceptability of a certain project for its financing.

Another objective of this dissertation is to study in particular the case of the new tramway in Barcelona to discover the determining factors of the commercial speed, as well as to find a way to maximize it, optimising its commercial potential.

Following this line of thinking, this work studies the speed of the Barcelona tramway in different cases, starting with the most favourable scenario down to the worst.

3. URBAN TRANSPORT PROJECTS FINANCING

The financing of public transport operations are based, in general, on a combination of: the fares collected; other commercial revenues (advertising, property rentals, etc.); specific compensation for concessionary fares and social obligations; as well as any further remuneration required from the public authority to enable the required levels of service to be achieved.

In general, the financing of the operation of Public Transport cannot be fully covered by the revenue from fares. The amount of public transport expenditure covered by fares might differ greatly from one situation to another. The same applies to the content of the expenditure that is charged to the operation companies, depending whether or not the operator owns the infrastructure, the treatment of depreciation, the allocation of financing costs, whether charges are applied for the use of such assets as bus stations. As a result there are wide differences in the requirements for and shape of public funding.

The fact that outside financial support is required to fill the gap between income from passenger fares and costs of operation does not in itself mean that a company is inefficient or non-viable. It only reflects the fact that fares and service levels are set with specific policy objectives in mind. Governments, local authorities and other bodies, including the private sector, thus make finance available to public transport for economic, social, transport and environmental reasons.

Discussing the present problem of traffic in cities as an imbalance between the mobility -in terms of Vehicles / KM- and the necessary infrastructure -Tracks / KM-, in other words, demand versus supply, would be enough to get to a solution resorting to an increase of supply up to the limits set by the demand.

Nevertheless, experience reveals the existence of a latent demand of motorized mobility that abolishes in short or medium term the advantages of a greater supply of road infrastructures. This proven fact, along with the physical impossibility to continue constructing new roadways and parking in certain urban zones has led to investigators and people in charge of the transport to look for other possibilities and other means to solve this problem:

- An optimisation of the existing infrastructures that includes all the necessary measures of traffic engineering and the management of the demand, as much as the level of use of the infrastructure as of the vehicles - increase of the occupation index -.
- Once the first solution is completed, move toward an improvement of collective transports in the cities.

Actually competitively and European cohesion vertebrate in two big exigencies: It is necessary to meet the growing mobility demand, especially in the countries that will become EU members, and conservation of the environment makes it necessary to establish limits to the uncontrolled proliferation of new infrastructures and raises the price investment cost.

4. TRAMWAY PROJECT ANALYSIS IN EUROPE

The criteria used to evaluate Urban Transport Projects are based on the *Relevance, Efficiency, and Sustainability* present in every project. Beginning with these criteria it is appropriate to estimate the financial and economic rates of return, as well as economical and operational benefits, investment, operation and maintenance costs, demand and supply of each project.

Every project has its own characteristics that differentiates it from the others, but it has common characteristics as well, that allows establishing the differences between a viable project and one which is not.

For the aims of this research an analysis of single variables and a combinatory analysis of variables seems to be the right approach for developing a "UTP's analysis document".

The single variable analysis allows establishing the ranges of permissibility of values that can have a variable in a certain project compare to others similar. As the combinatory analysis will allow us to determine which are the variables highlighting the project's relevancy.

4.1 Relevant indicators

The feasibility¹ of a new project is given by some parameters that, once assessed, result in relevant indicators of the project's economical, financial, social and operational characteristics, which can be compared with those of others previously financed (i.e. considered satisfactory). As a result of the analysis carried out during this research, these parameters are:

- The Supply (production, capacity)

- The Demand (expected)
- The Investment Costs
- The Operation and Maintenance Costs
- Social Benefits and Time Savings
- Economical and Financial Indicators

In addition to these parameters, the determination of several Comparative Ratios that somehow measure the performance of each project, play an important role in the global appraisal, and thus the final acceptance of the project for its financing.

The Comparative Ratios that were considered relevant to the aims of this work are the following:

- $R_u = \text{Demand/Capacity}$
- $R_p = \text{Benefits/Demand}$
- Investment/Benefits
- Demand/Investment
- $R_u/\text{O\&M Costs}$
- Passenger Profit = $R_p - \text{Average Revenue}$

4.2 Results

Using the existing database of projects financed by the EIB in the last decade, a set of Ranges of variation was obtained for each variable. The main utility of these ranges is to compare projects of the same kind to determine the viability of the new one respect those others already financed and evaluated. Table 1 summarizes the results obtained of the analysis of single variables of projects:

Ranges of Values

Variables	Unit	Tramways and LRT		Metros	
		Minimum	Maximum	Minimum	Maximum
Demand	M Pax/Year	10	26	30	100
Train/Car Capacity*	Pax/(Train/Car)	205	360	160	225
Peak Hour Capacity	Pax/Hour/Dir	2,300	3,850	13,000	26,000
Project Unitary cost	M EUR/Km	9.0	21.0	32.0	80.0
RS Unitary Cost*	M EUR/(Train/Car)	1.5	2.4	1.0	1.9
RS Place Cost	EUR/Place	6,300	8,500	6,000	8,600
O&M Costs*	EUR/(Train/Car)-Km	3.5	5.7	1.7	2.8
Cover Ratio	%	40	78	41	79
Avg. Revenue	EUR/Pax-Journey	0.35	0.77	0.30	0.70
ERR	%	3.6	8.8	3.9	8.1
Time Savings vs. Car	Minutes/Journey	5	11	7	17
Time Savings vs. Bus	Minutes/Journey	7	15	7	17

* In these variables the unit "Train" is used for Tramways and LRT and "Car" for Metro Projects.

Table 1. Ranges of values.

As well as these Ranges obtained from the analysis; some graphics of regression lines (with bandwidths that make it possible to locate the project with respect others previously accepted) and clusters of points (surrounded by a geometrical figure) were the result of the analysis of the combined variables (Comparative Ratios). These Graphics were included as a part of the Decision Support System (Figure 1).

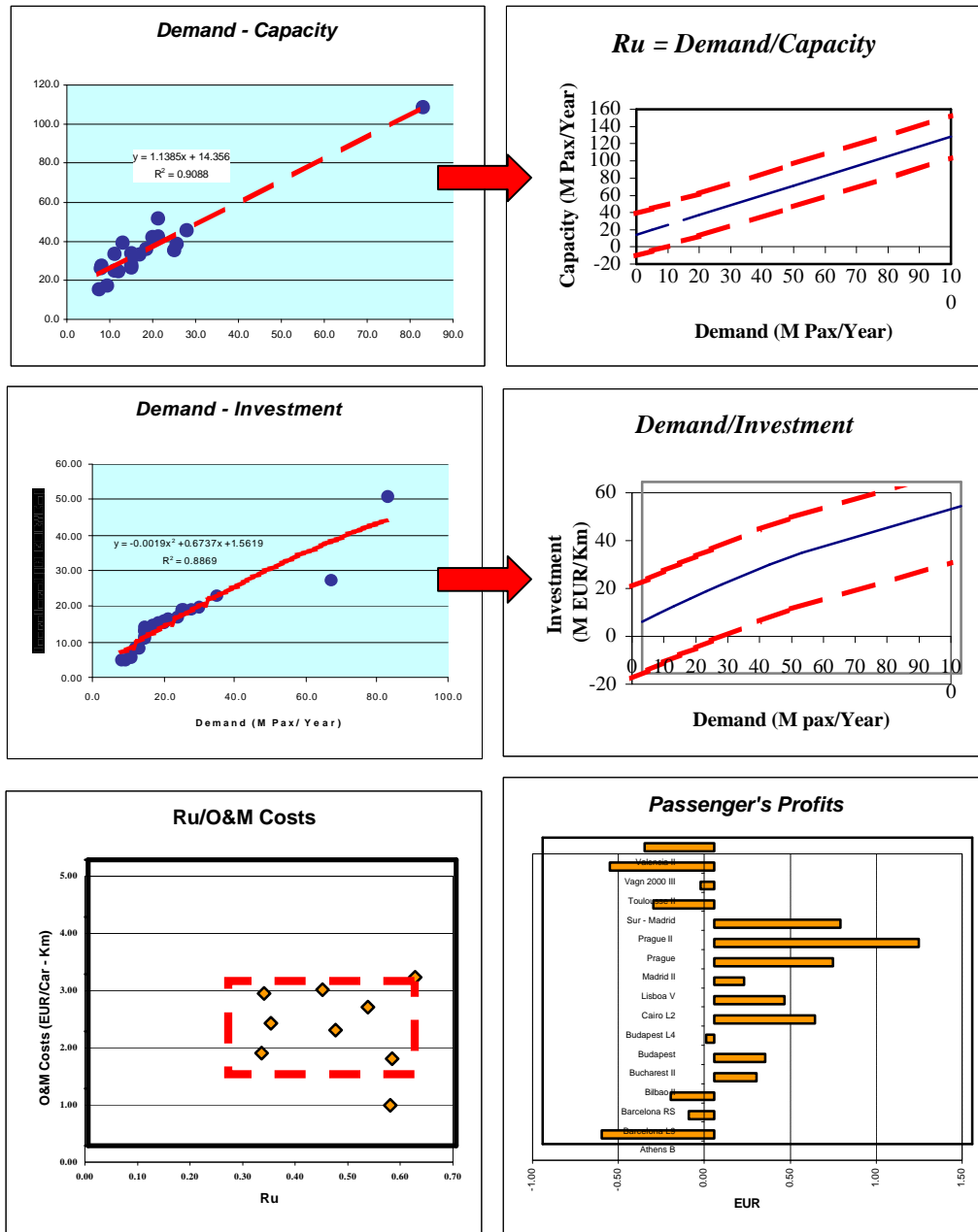


Figure 1. Results of the analysis.

4.3 Conclusions

In addition to the numeric values and graphical results, some other considerations were determined as well. Sometimes, values do not reflect all

the specific characteristics of a certain project and, therefore the following conclusions were obtained:

Variable	Commentaries
Demand	As an example, the demand for a LRT project is not suppose to be the same in Seville as in Bursa due to the huge difference in the population density of these two cities. In spite of setting a range value to classify projects with similar characteristics, the properties of each city evaluated have to be taken in consideration.
Project Cost	The cost of a project varies according the geographical zone where it would be constructed. The explanation to this affirmation is clear, the GDP per capita is greater in countries of the west of Europe than the one in the East. Projects in countries of Eastern Europe and in countries such as Turkey, Egypt and Tunisia are less expensive, approximately 1/5 for Metro Project and 1/4 for Tramways and LRT, than projects in Western Europe according to the results revealed by the analysis.
Rolling Stock	As the Rolling Stock are built by multinationals companies, its cost is the same everywhere; therefore, the unitary cost of a Tram unit or a Metro wagon would be similar in Barcelona and in Bucharest, whenever the characteristics of both Rolling Stock would be similar.
O&M Costs	The Cost of Operation and Maintenance varies depending on the Administrator politics and the country in which the projects operates; Some Administrations consider in their O&M Costs the Rolling Stock Renewals that must be made from time to time (according to the technical life of the equipment), others do not. The country's GDP per capita affects the manual labour costs of Operation & Maintenance, and therefore a difference between costs in countries would not represent a surprise.
Cover Ratio, and Economical & Financial Indicators	The administration and the supply of the service take an important place in the difference found in these parameters. The results revealed that whenever elevated cover ratios appeared in the projects it was because a lack of supply with respect the demand, in some cases not even being able to satisfy the estimated demand, or an insufficient maintenance of the project's equipment and infrastructure, causing fictitious "Robust" Economic Rate of Return. On the other hand, a very low Cover Ratio is the result of poor productivity in terms of production cost or extremely low fares set by the administrator of the project.

Fares	Fares are greatly affected by the GDP per capita of each country, and the difference between fares of cities is well marked; the media of Average Revenue per passenger per journey in Western Europe countries is almost four times the Average Revenue per passenger per journey in countries of Eastern Europe, Turkey, Egypt, and Tunisia. GDP per capita affects the 85% of the cost of a transport ticket, and most of the times the 15% remaining is left to the Administrator consideration.
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Table 2. Conclusions.

The final result of all of these analyses was the ***Decision Support System***, which is a tool conceived to determine analytically and graphically the acceptability of a certain project for its financing.

5. THE NEW TRAMWAY IN BARCELONA

Tramway's revival as an efficient and modern means of transport brings up some operation aspects to optimise its operation and obtain the best service for the users.

In general, a tramway's commercial speed in most of the cities is around 20 km/h, except for some particular cases because of the route design or the road traffic. Compared to other means of transport, a tramway's commercial speed is higher than the bus commercial speed and lower than the metro's commercial speed; however, for short distances, a tramway is quicker than metro owing to its good accessibility.

The new Tramway in Barcelona (better known as Trambaix) runs through seven municipalities from the Barcelona surroundings. The new tramway is made up of three lines (10 km each one) which meet in a common stretch.

5.1 Commercial speed

Following this line of thinking, this work studied the speed of the Barcelona tramway in different cases, starting with the most favourable scenario (which means at the time of the day when there wouldn't be any kind of incident that could cause problems to its operation) down to the worst case scenario when the tram is submitted to continuous obstructions along its way (at the peak hour).

A simulation gave the space-time diagrams and the different commercial speed in the different cases (Table 3).

	T1	T2	T3
OFF-PEAK HOUR	24,06	23,99	24,20
PEAK HOUR	22,82	22,78	23,03
Congestion at the end of the way.	21,36	19,06	23,03
Congestion in the middle.	17,74	16,56	18,50
Congestion at the beginning of the way.	15,24	15,24	16,34

Table 3. Commercial speed.

5.2 Intersections

Another object of study in this work was the intersection at Avinguda Diagonal and Carrer Numancia; a very critical point in the tramway route because of its high saturation level at peak hours, which could negatively affect the commercial speed of the Trambaix.

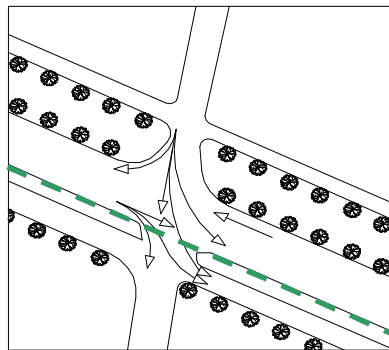


Figure 2. Intersection studied.

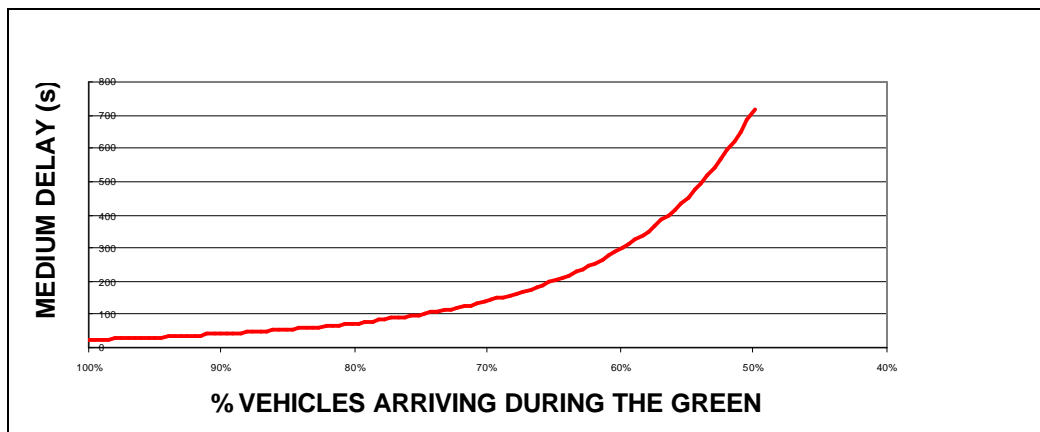


Figure 3. Delay produced for not existing traffic lights coordination in the intersection.

5.3 Single track effects

The next step was to study how the single track influences the commercial speed, because the lines T2 and T3 have some stretches of single track. Even beginning with a good operational plan, if several problems appear during the

tram's course, it is possible that two vehicles will meet at the entry of a single track section so that one has to stop, producing certain delays which will considerably reduce the commercial speed.

With the simulation, the results obtained are a delay around 2,14 minutes in T2 (T2 has 1,23 km of single track) and 4,16 minutes in T3 (it has 2,81 km of single track).

5.4 Conclusions

Finally, the results obtained in each part of this work are analysed, and they will be the basis for developing a simple but efficient support system to help plan tramway lines in relation to the commercial speed required, and to optimise the potential of existing ones.

The new tramway in Barcelona is an absolutely competitive mean of transport, with a commercial speed between 24 and 15 km/h.

Congestion is the most determinant element in commercial speed, reducing it between 5% and 30%.

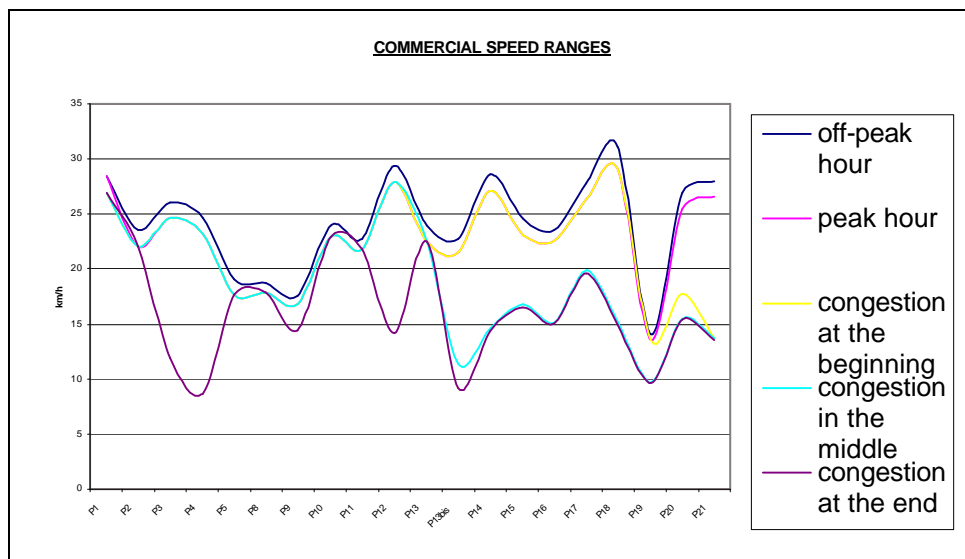


Figure 4. Commercial speed in line T3 in the different cases.

Peak hour reduces commercial speed around 5%, so a good traffic plan is fundamental for the good tramway operation. So the traffic lights coordination is a basic element to achieve the tramway competitiveness.

After peak hour, the most decisive element in commercial speed is single track. If a tramway has to stop to wait for another one in the single track stretch, then delays rise for the rest of the vehicles, with commercial speed reductions of 12%.

The final conclusion is that to optimise tramway operation are fundamental good planning and correct traffic management.

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