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Private Financing or Not, That is the Question: Lessons from the Light Rail Systems in Spain

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Abstract The objective of this paper is to analyze if there is any difference between the light rail systems in Spain according to whether they have been carried out through public financing or private financing (totally or partially). The importance of this study lies in the fact that, for decades, the public–private partnership has been proposed as an alternative to public financing of public transport projects in order to obtain additional financial resources, reduce the public deficit, and increase efficiency. However, there are hardly any detailed studies describing how these initiatives have turned out. Therefore, the present study analyzes if there is any difference in the main variables explaining the performance of light rail projects in Spain depending on their source of funding can be found. For this, the relationship between variables related to design, operation and costs of the projects, and the percentage of private financing were statistically analyzed. As the most relevant conclusion, we underline the fact that the investment per passenger increases when financing is completely private. This would indicate that the most cost-effective lines, from a social standpoint, were financed totally or partially by the public administrations, whereas the least beneficial ones for society were assigned to private enterprises. This finding provides an advance in the knowledge of the consequences of private participation in the financing of public transport projects, indicating, moreover, that the biggest beneficiaries of this type of projects might be the construction companies and the politicians involved.

Keywords Light rail · Private funding · Public funding · Public–private partnership · Spain · Public transport · Transport financing

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1 Introduction

Light rail (LR) systems in 13 Spanish cities (Valencia, Alicante, Madrid, Barcelona, Parla, Sevilla, Vitoria, Bilbao, Murcia, Tenerife, Zaragoza, Jaén, and Vélez-Málaga) are analyzed in order to study the possible influence of private financing on the main variables explaining the performance of such projects in Spain. In some cases, these LR systems involved high costs of implementation and operation far beyond the resources of the respective financing entities (public administration and/or private enterprise). Moreover, they are generally operating at a much lower level of demand than the intended capacity [1]. Therefore, there is clearly a need to study the reasons behind the success or failure of this novel means of transport. Granted, such an analysis is very complex and should be approached from diverse perspectives. The present contribution focuses on the influence of private financing in these projects to shed some preliminary light on this complex issue.

2 State of the Matter

Nowadays, a main reason for using private funding to finance infrastructures that were traditionally publicly funded is the strict deficit policy put in place by the European Economic and Monetary Union [2, 3]. In this context, a mechanism met with enthusiasm was the public–private partnership (PPP)—the participation of private enterprises in financing, building, and/or operating transport infrastructures of public interest. Cullingworth [4] found private financing to be particularly beneficial when public expenditure is unlikely or impossible to obtain, as long as resources are intelligently allotted.

This is a subject matter that should have stirred up considerable debate. Glaister [5] states that, despite progress in using the PPP model, involvement on the part of the private sector has occasionally led to a waste of resources. In other words, privately funded projects might incur higher costs. It is therefore logical that part of the risk be borne by the private participation. Addressing the public–private partnership (PPP) of the London Underground, Shaoul et al. [6] explain it was not viable in economic terms and holds that such projects entail too much risk and not enough cash for the private sector. Also in a British context, Panayiotou and Medda [7] studied means of attracting private investment for infrastructures despite the potential risks, concluding that a regulatory framework is essential to attract private resources. Further criticism of the PPP alludes to a lack of proper assessment a priori of the costs of private financing [8]; Hodge and Greve [9] and Shaoul et al. [6] note that PPP does not really represent new funding opportunities, since in the end, taxpayers and users pay the bill. Church [10] describes a practical case (London Docklands LR) where private financing implied neglecting the needs of citizens in order to attend to other more profitable matters.

Weihe [11] looks at the synergy between public and private partners in PPP projects, concluding that in most cases benefits are smaller than expected, mainly due to a lack of collaboration. A more quantitative approach (based on Value for Money) is applied to a selection of PPP projects by Hodge and Greve [9]; while the results vary between success and failure, the authors acknowledge a lack of scientific rigor in studies surrounding these projects.

In Spain, the participation of private enterprise in the financing, construction, and exploitation of urban and metropolitan railways extended rapidly after the concession of the LR in Barcelona, in the year 2003. Over half of the LR systems developed since then have relied on the build–operate–transfer procedure. Sastre [12] compares the development of the LR in Spain undertaken by private management and financing through concessions, as opposed to public financing and management, pointing out the pros and cons of each system, and how determinant the setting or environs may be. The franchisee consortia for this type of project generally comprise construction companies, transportation operators, financial institutions, rolling stock manufacturers, and/or engineering consultants [13].

3 Light Rail Transit Systems in Spain

The present study focuses on 11 Spanish cities, as the LR systems of Jaén and Vélez-Málaga are not functional at present, due to low demand and a lack of funding.

3.1 Madrid

Madrid has three LR lines (ML1, ML2, and ML3). ML1 is a stand-alone line that runs between the metro stations of Pinar de Chamartín and Las Tablas. It provides service to the new neighborhoods of Sanchinarro and Las Tablas, whose development has greatly benefited from the development of this means of transport [14]. This line spans 5.4 km and features 3.62 km of cut and cover tunnel. The construction of new neighborhoods near the line can be considered "low intensity" development; the fact that several plots are still empty has contributed to the low demand for this line.

The concession for works, financing, and exploitation of ML1 was awarded to the bid submitted by Metros Ligeros de Madrid S.A., whose shareholders were Metro de Madrid, the infrastructure management company Globalvia, and the transportation company Alsa. The required investment was 277 M€ [15], which is equivalent to a unit cost of more than 51 M€/km. This is an extremely high price tag, largely owing to the proportion of the line built underground. A good part of this additional cost could have been avoided, given that the area was still under development, and the LR could have easily been integrated into the surface infrastructure.

ML2 runs along the outskirts of Madrid from the subway station of Colonia Jardín (common station with ML3) to the commuter station of Aravaca, passing through the town of Pozuelo de Alarcón. It provides service to office buildings, shopping malls, and university campuses. Except for its two end stations, ML2 covers a sparsely populated area with no chance of being urbanized. Its demand is rather low: 3.7 million passengers in 2011 [16]. The investment was 283 M€ [15], which amounts to roughly 32 M€/km. This elevated cost can be attributed to the many underpasses and overpasses built to avoid road level crossings. Many of them could have been avoided by changing the layout to have some level crossings with traffic light priority for the LR.

ML3 runs from the metro station of Colonia Jardín to Boadilla del Monte. Its length is 13.7 km, just 1.4 km of them underground. This interurban radial line provides service to leisure areas, office buildings, and university facilities. Like ML2, ML3 runs through sparsely populated areas, with the exception of both ends. The investment was 286 M€ [15], approximately equivalent to a unit cost of 20 M€/km. This is an extremely high cost for a line that runs on surface, due to the same reason mentioned for ML2.

The concession for the construction and operation of ML2 and ML3 was awarded to Metro Ligero Oeste S.A., whose shareholders were the construction and infrastructure management companies OHL and Comsa, and the investment group Ahorro Corporación [17].

3.2 Parla

Parla is a dormitory town located just south of Madrid. The City Council of Parla contributed 33% of the investment, essentially through the application of a tax for the new urban district of Parla Este, built around the new line. The remaining investment was previously provided by the franchisee, also responsible for the design, construction, and operation of the line. The awarded company was Tranvía de Parla S.A.; their shareholding pertains to Globalvia, the rail transport company Detren, and the bank Caja Castilla La Mancha [17]. Although a portion of this line runs through the center of Parla, it mostly runs along the outskirts of town, providing service to some industrial areas and the neighborhood of Parla Este, a district with numerous unbuilt plots.

3.3 Barcelona

Barcelona has two independent LR networks: Trambaix and Trambesós. Each comprises three lines running through densely populated areas, with high demand. Tramvia Metropolitá S.A. was the concession holder for Trambaix; their responsibilities were drafting the project and undertaking the civil works and the exploitation of the lines. Tramvia Metropolitá S.A. is a consortium formed by the company of railway rolling stock Alstom, the construction and infrastructure management companies FCC, Comsa and Acciona, the transport operators Veolia, Moventis, FCC and Detren, the financial institutions Banco de Sabadell and Société Fenérale (6%), and the public transportation operators FGC and TMB [18]. The concession holder for Trambesós was Tranvía Metropolitá del Besós S.A., whose shareholding is the same as Tramvia Metropolitá S.A. [18, 19].

3.4 Bilbao

This LR was promoted and funded by the public company Bilbao Ría 2000, the Autonomous Government of País Vasco, and the City Council of Bilbao. In addition to helping improve public transport, a main objective of the project was the urban regeneration of the zone (previously an industrial area) while boosting the image of Bilbao and its new Guggenheim Museum.

3.5 Tenerife

The LR network of Tenerife has two connected lines. Both traverse heavily populated zones and provide service to hospitals, museums, university centers, and interchange stations. The company in charge of contracting and directing the works was Metropolitano de Tenerife. This joint enterprise is owned by Tenemetro, which is integrated by the construction sector, transportation operators, and engineering consultancy companies, as well as the bank CajaCanarias and the public administration Cabildo Insular de Tenerife [20, 21]. Tenemetro is likewise responsible for the operation of the tram over a 50-year concession. The high unit cost of Line 1 (almost 22 M€/km) is due mostly to the complicated topography of the area.

3.6 Zaragoza

The LR line of Zaragoza links very populated areas: the historic city center and the two main nodes of urban sprawl. The construction and operation of the line were awarded by concession to a mixed society called Traza, integrated by the City Council of Zaragoza plus a set of civil engineering companies, rolling stock companies, transportation operators, and banks: FCC, Acciona, CAF, Tuzsa, Ibercaja, and Concessia [22].

3.7 Vitoria

The only LR line in Vitoria connects the neighborhoods far from the city center with the downtown area. Investment came from the Autonomous Government of País Vasco, the Provincial Council of Alava, the City Council of Vitoria, and the public railway company Eusko Trenbideak–Ferrocarriles Vascos S.A. [23].

3.8 Murcia

The limited demand of the LR of Murcia can be attributed to the fact that it traverses low-density areas, such as university schools, industrial areas, and sparsely populated areas with neighborhoods of single family homes. The investment was provided by the franchisee (Tranvía de

Murcia) in exchange for an exploitation lasting 40 years [24]. The shareholding of the franchisee pertains to the construction companies FCC and Comsa [25].

3.9 Valencia

The Valencia LR network consists of Line 4, which connects areas of high demand—the university campus and Playa de la Malvarrosa—to the underground network, and Line 6, which circumvents Valencia. The LR in Valencia was built directly by the Generalitat Valenciana, using public funds. The public railway company Ferrocarrils de la Generalitat Valenciana (FGV) operates it [16].

3.10 Alicante

Most of the LR networks in Alicante (5 lines) come from the transformation of a former narrow-gauge railway. It is a tram train that connects Alicante with towns bordering on the metropolitan area [26]. It was funded and built directly by the Regional Government [16]. The agency responsible for its exploitation is FGV.

3.11 Sevilla

The LR in Sevilla is limited to one short line from the historic city center to San Bernardo, where commuter and metropolitan bus stations are located. It supports a high demand, as it runs through the most emblematic streets of Sevilla, where it circulates at a very low speed so that tourists can use it to see the area quietly and comfortably. Funding came from the City Council of Sevilla and the Autonomous Government of Andalucía. Its operation depends on Tussam, the municipal transportation company [16]. The fact that it runs entirely on surface through historic areas implied important works for the redevelopment of the traversed streets, which explains its high cost.

Table 1 offers a summary of the main variables and data for these LR systems.

4 Methodology

Before proceeding, it should be stressed that the variable *percentage of private financing* adopts just five different values (Table 1). In view of the data, these five values could be grouped as three: no private financing (near 0%), partial (around 67%), or total private financing (100%). For this reason, a classic approach such as regression of the data (or other statistical models) may not result effective. A more appropriate option would be to group the variable of private investment into two or three groups and evaluate the differences among them, for each of the remaining variables. After trying different data groupings, the one proving most adequate in terms of statistical efficiency was distinguishing the LR systems totally or partially financed by the public administrations (Group 1: Parla, Bilbao, Tenerife, Zaragoza, Vitoria, Valencia, and Alicante) and those whose financing was totally private (Group 2: Madrid, Barcelona, and Murcia).

5 Data Analysis

5.1 Descriptive Analysis

According to Table 2, the mean is higher (taking as the value of reference 10%) in the group of totally private financing for the variables *total investment*, *percentage of underground length*, *unitary investment, operation costs, operation costs per kilometer*, *investment per passenger*, and *fare*. Contrariwise, there are lower mean values in the group of totally private financing for the variables *annual demand* and *maximum capacity*.

A look at the box plots (Fig. 1) reveals that some variables take on values situated in a higher range in one group than in the other. The extreme cases (e.g., the third quartile of Group 1 being equal to or lesser than the first quartile of Group 2) are *percentage of length underground*, *operation costs*, *investment per passenger,* and *fare*. In contrast, for variables such as *annual demand* and *maximum capacity*, the opposite occurs: the first quartile of Group 1 is far superior to the first quartile of Group 2.

5.2 Data Heterogeneity Treatment

The pursued objective of explaining the differences between types of financing could be affected by other relationships involving the data. Since all of the variables are numerical, it is easy to visualize the magnitude of these relationships with a correlation matrix (Fig. 2). To avoid bias, only certain informative variables are considered. More precisely, *operation costs* and *total investment* are left out because they are absolute values and can lead to misinterpretations; they have to be contextualized, in this case divided by *length*.

There are certain strong relationships that should be taken into account: investment per kilometer is highly correlated with the percentage of underground sections, operation cost per kilometer is negatively correlated with network length, and minimum frequency appears to be negatively correlated with investment per kilometer and demand.

To confirm these findings, a Kendall Tau test was performed on all the variables in Fig. 3. This is a means of rejecting the null hypothesis of independence between

Table 1 Principal characteristics of Spain's LR systems

	MADRID ML1	MADRID ML2	MADRID ML3	PARLA	BARCELONA TRAMBAIX	BARCELONA TRAMBESOS	BIL-BAO	TENE-RIFE	ZARA-GOZA	VITO-RIA	MUR-CIA	VALE-NCIA	ALICA-NTE	SEVI-LLA
Total investment (M€)	277.28	283.83	286.02	139.95	364.51	332.23	51.59	358.35	436.66	104.77	262.72	364.43	–	58.38
Public investment (M€)	0	0	0	46.18	0	0	51.59	346.63	141.92	104.77	0	364.43	–	58.38
Private investment (M€)	277.28	283.83	286.02	93.77	364.51	332.23	0	11.72	294.75	0	262.72	0	0	0
Private funding (%)	100	100	100	67	100	100	0	3.27	67.5	0	100	0	0	0
Length (km)	5.4	8.7	13.7	8.2	15.1	14.1	5.57	15.9	12.8	8.2	18	20	51.34	2.2
Underground (%)	67	31.5	10.4	0	0	11	0	0	0	0	0	0	3.3	0
Unit investment (M€/km)	51.35	32.62	20.88	17.07	24.14	23.56	9.26	22.54	34.11	12.78	14,6	18.22	–	26.54
Operation cost (M€/year)	–	8	9.8	6	13.7	12.5	–	9	9.5	8.1	11	–	–	–
Annual demand (M passengers)	4.9	3.7	3.7	5	16.1	8.05	3	13.96	11.5	7.4	3	9.5	5.4	4.8
Daily demand ('000 s passengers)	13.42	10.14	10.14	13.7	44.11	22.05	8.22	38.25	31.51	20.27	8.22	23.84	14.79	13.15
Maximum capacity (passenger/hour in each direction)	2448	2040	2040	1754	2640	1650	1152	2412	2472	2440	1116	2400	3780	2040
Investment per passenger (M€/annual demand)	56.59	76.71	77.30	27.99	22.64	41.27	17.20	25.67	37.97	14.16	87.57	41.89	–	12.16
Minimum frequency (min)	5	6	6	7	5	8	10	5	5	6	10	5	10	6
Fare (€)	1.5	1.5	1.5	1.3	2	2	1.4	1.35	1.25	1.25	1.35	1.4	1.25	1.4

M million, – data not available. [15–42]

Table 2 Descriptive statistics

	Total investment (M €)	Underground (%)	Unit investment (M €/km)	Operation Cost (M €)	Op. Cost per km (M €/km)	Annual demand (M pass.)	Maximum capacity (Pass.)	Investment per passenger (€/pass.)	Minimum frequency (min.)	Fare (€)
Group										
G1										
Group size	7	8	7	4	4	8	8	7	8	8
Mean	216.3	0.4	20.1	8.2	0.8	7.6	2306.3	25.3	6.8	1.3
Median	139.9	0	18.2	8.6	0.7	6.4	2406.0	25.7	6	1.3
Minimum	51.6	0	9.3	6	0.6	3	1152	12.2	5	1.3
Maximum	436.7	3.3	34.1	9.5	1.0	14.0	3780	41.9	10	1.4
SD	163.8	1.2	8.4	1.5	0.2	3.8	750.8	11.6	2.1	0.1
G2										
Group size	6	6	6	5	5	6	6	6	6	6
Mean	301.1	20.0	27.9	11	0.8	6.6	1989	60.3	6.7	1.6
Median	284.9	10.7	23.9	11	0.9	4.3	2040	66.7	6	1.5
Minimum	262.7	0	14.6	8	0.6	3	1116	22.6	5	1.4
Maximum	364.5	67	51.4	13.7	0.9	16.1	2640	87.6	10	2
SD	38.9	25.7	12.9	2.2	0.1	5.0	550.8	24.9	2.0	0.3
$\mu 2 > \mu 1$ (%)	39.2	4744.4	38.8	35.0	17.1	− 13.1	− 13.8	138.6	− 1.2	23.9

variables using a nonparametric test based on the number of concordant and discordant pairs. As shown in Fig. 3, there are statistically significant relationships between:

- Demand and maximum capacity
- Demand and maximum capacity, and minimum frequency
- Operation cost per kilometer and network length
- Investment per kilometer and minimum frequency
- Investment per kilometer and maximum capacity.

Having discovered some important relationships, additional considerations must be taken into account at this point to determine all of them. Several variables take few different values, namely, percentage of underground sections (six), minimum frequency (five), and fare (six). Furthermore, because most of the six values for percentage of underground sections are zero (nine times), it would be better to discretize it in two classes (partially or totally on surface) to discern the real implications of these variables on the others. The same process was applied to minimum frequency, dividing it into high frequency (5 and 6 min, which represent 9 out of 14 instances) and low frequency (7–10 min). Fare values are more uniformly distributed (maximum of three times for a single value to appear), so they were not discretized.

The Kruskal–Wallis test was applied to all the variables under this grouping of discrete variables in order to reject the null hypothesis of both groups following the same distribution. Resulting *p* values are given in Table 3.

As shown in Table 3, significant differences in the value distribution by groups can be found for investment per passenger (grouped by percentage of underground sections), while marginally significant differences were found for investment per kilometer and for maximum capacity (grouped by minimum frequency).

In sum, all these relationships should be taken into account when performing further analysis, described below.

5.3 Non-parametric Contrasts

The usual statistical inference tests, such as ANOVA or linear regression, which might be ideal for the objective of this study, require strong assumptions on normality and homoscedasticity. Unfortunately, such assumptions cannot be made in this case; the amount of data is too small and normality and homoscedasticity tests would be insufficient, making further tests ineffective. Nonparametric contrasts may be used as a substitute to determine whether there are statistically significant differences between the group distributions. The decision to apply these contrasts to all the variables was based on the fact that, although some do not appear to have evidence against the normality of the data, it cannot be known for certain if such small sample sizes provide normality. Therefore, the Wilcoxon–Mann–Whitney nonparametric test was applied. The end intention is to determine whether the distributions are equal, or rather, the numbers are more likely to be larger in fully privately financed networks. Thus, the hypotheses of the test are:

H_0: G_1 and G_2 are equally distributed

H_1: G_2 is stochastically greater than G_1.

Bearing in mind the results shown in Table 4, the final conclusion is that the hypothesis of equality of distributions at the 95% confidence level is rejected for the variables *percentage of line underground*, *investment per passenger,* and *fare* (in the latter case, the confidence interval is 99%). It can be said that the investment per passenger, the percentage of underground network, and the fare are greater when the financing is totally private.

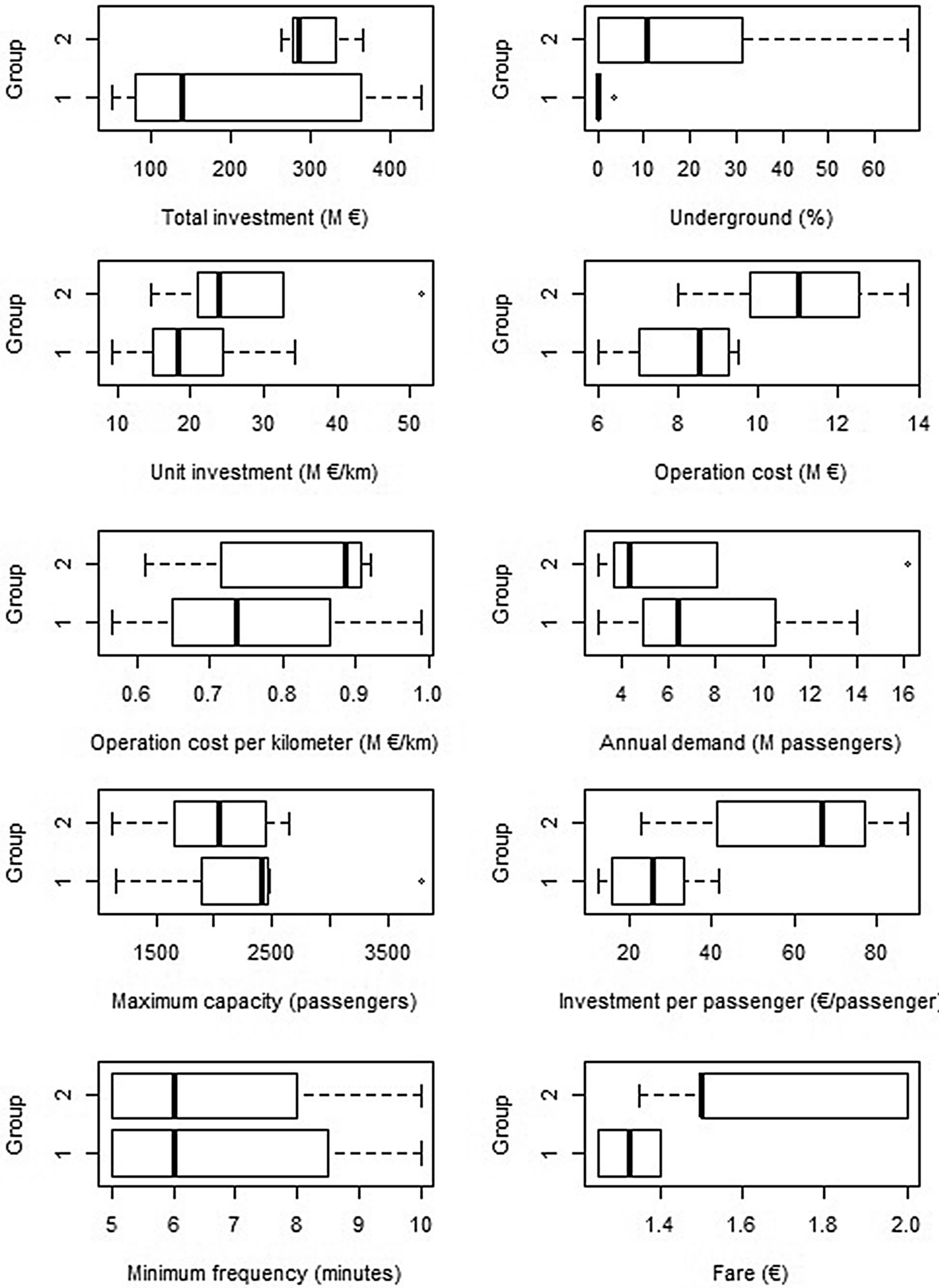
The focus now is on *percentage of line underground* results, as this variable suffers the problem of few unique values (described in Sect. 5.2). Using the same partition (partially and totally on ground), cross-tabulation was made with the private financing partition. The results are given in Table 5.

Table 5 shows evidence of differences in underground percentage according to the financing type. A Fisher exact test of independence was performed to contrast the hypothesis of the Odds Ratio being no greater than 1, meaning that the probability of a light rail network having an underground section is not increased when financing is totally private. The *p* value of the test was 0.06294, so this hypothesis can be rejected with a confidence level of 93.7%.

6 Analysis of Results

6.1 Total Investment

According to the descriptive analysis (Table 2), the mean total investment is greater when the financing is totally private. This could be interpreted as an indication that public administrations resort to private funding for more expensive LR projects. Theoretically, this kind of funding is a solution when public administrations do not have sufficient budgetary resources for the construction and commissioning of a project necessary for society. Assuming equal efficiency between public administration and private enterprise, such projects prove more expensive than when faced by the public administration alone, as the private companies involved in the financing obviously reap industrial benefits.


Group
1
2
100 200 300 400
Total investment (M €)
0 10 20 30 40 50 60
Underground (%)
10 20 30 40 50
Unit investment (M €/km)
6 8 10 12 14
Operation cost (M €)
0.6 0.7 0.8 0.9 1.0
Operation cost per kilometer (M €/km)
4 6 8 10 12 14 16
Annual demand (M passengers)
1500 2500 3500
Maximum capacity (passengers)
20 40 60 80
Investment per passenger (€/passenger)
5 6 7 8 9 10
Minimum frequency (minutes)
1.4 1.6 1.8 2.0
Fare (€)

◀**Fig. 1** Box plots by variables, according to financing group

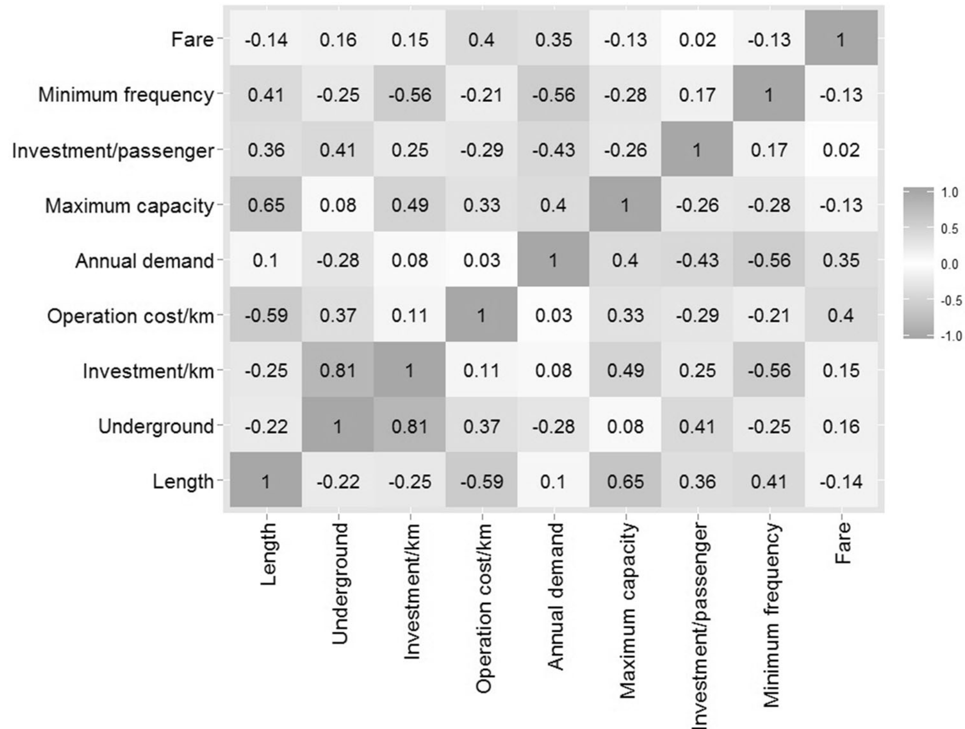


Fig. 2 Heat map of correlations between nontype of financing variables

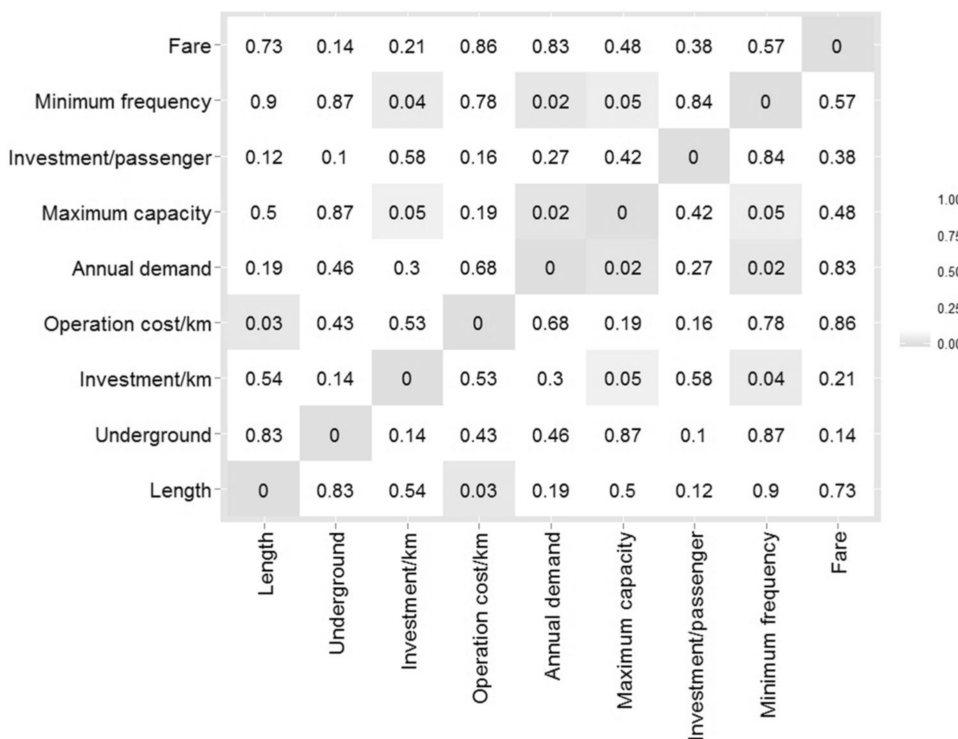


Fig. 3 Kendall's Tau test *p* values for each pair of variables

Table 3 Kruskal–Wallis test *p* values for differences between groups in each variable

Length	Underground	Investment/km	Operation cost	Operation cost per kilometer
Kruskal–Wallis test *p* value grouping by percentage of underground sections				
0.841	0.000	0.123	0.796	0.606
Annual demand	Max. Capacity	Invest/pass.	Min. Frequency	Fare
0.385	0.738	0.045	0.533	0.136
Kruskal–Wallis test *p* values grouping by minimum frequency				
0.504	0.938	0.064	0.796	0.439
Annual demand	Max. Capacity	Invest./pass.	Min. Frequency	Fare
0.204	0.071	0.758	0.002	0.542

6.2 Length of Line Underground

While LR is considered ideal for surface circulation because of its accessibility and optimal urban integration, some of the lines studied were built partially underground, meaning decreased accessibility and soaring costs. Here, a comparison of means and the box plot analysis (Fig. 1) shows that the percentage of underground length is greater in those projects financed completely with private capital. Moreover, the nonparametric contrasts reveal differences according to whether the funding is totally private or not. This leads one to surmise that LR systems financed and built with private capital tend to overuse the underground option, which heightens the cost. That extra cost is recovered by means of the subvention that the public administration grants for the construction or exploitation of such lines, as the firms funding the project are usually also the ones commissioned for subsequently operating the system [14].

6.3 Unit Investment

According to the descriptive analysis, the mean of the *unit investment cost* is greater when funding is totally private. It may be that more expensive projects—for instance, those having a greater underground length, as demonstrated in 5.3—are preferentially financed with private capital, or else the LR systems funded with private capital end up being more expensive due to the industrial gain that private agents must derive from their investment.

Table 4 Non-parametric test of equality of distributions

Variable	Wilcoxon–Mann–Whitney test *p* value
Total investment	0.267
Underground (%)	0.015
Unit investment	0.147
Operation cost	0.056
Operation cost per km	0.452
Annual demand	0.801
Maximum capacity	0.756
Investment per passenger	0.011
Minimum frequency	0.527
Fare	0.002

6.4 Operation Cost

The comparison of means (Table 2) and the box plots (Fig. 1) indicate that operation costs tend to be higher in those LR systems that are totally funded through private initiatives. This may be, at least in part, because the underground length is greater in the LRs financed totally with private capital. Underground systems involve additional costs: moving stairs, illumination, ventilation, control of access, security/vigilance, tunnel maintenance, etc.

6.5 Annual Demand

The descriptive analysis (Table 2) shows that the annual demand is greater in the LRs whose funding is totally or partially from the public administrations. This means that public financing is tied to the projects most necessary for society, whereas the projects financed solely with private capital have led to the construction of LRs under less demand by society.

6.6 Maximum Capacity

The comparison of means (Table 2) and the box plots (Fig. 1) show that the LRs involving public funding usually have a greater maximum capacity. It may be that the systems financed entirely with private capital and operated by private companies try to restrict supply in order to lower costs and therefore increase benefits.

6.7 Investment per Passenger

Both the correlation coefficient (Fig. 2) and the descriptive statistics (Table 2), as well as all the contrasts (Sect. 5.3), come to show that the investment per passenger is greater

Table 5 Contingency table of underground and on surface networks and their financing type

	Partly or totally public financing	Totally private financing
Totally on ground	7	2
With a certain % underground	1	4

when the financing is totally private. This indicates that the most beneficial projects from a social standpoint were undertaken totally or partly with public capital, whereas the socially less beneficial projects tend to rely on private capital. Also, the contrasts reveal that projects with a greater investment per passenger have a higher percentage of line underground, which builds a three-way relationship between factors. The interpretation could be that investment per passenger is higher when financing is fully private because of the higher amount of underground sections those projects present.

6.8 Fare

The correlation coefficient (Fig. 2), the comparison of means (Table 2) and the box plot analysis (Fig. 1) all show that the fare is more expensive when the projects were totally funded with private capital. Moreover, the non-parametric contrast (Sect. 5.3) corroborates that there is a difference depending on whether the funding was totally private or not. Accordingly, the concession for exploitation of LR lines to private firms generally gives rise to higher fares. This might be explained by the fact that the private concessionary firms (the same ones that financed the project) need to obtain an industrial benefit and also because of the greater facility to obtain subsidies when public administrations are involved in the financing and exploitation of the system.

7 Conclusions

This study looked into the possible influence exerted by the presence of private funding on the main variables explaining the results of LR projects in Spain. Despite the great simplification of approaching this matter through a single variable, there is statistical evidence that the source of funding may have an impact on such projects. Specifically, this influence is detected in the following variables: *total investment*, *unit investment*, *operation cost*, *operation cost per km*, *annual demand*, *maximum capacity*, and in a statistically significant way in *proportion of length underground*, *fare,* and *investment per passenger*.

In view of the results, it is noteworthy that the investment per passenger increases when financing is completely private. This would indicate that the most cost-effective lines, from a social standpoint, were financed totally or partially by the public administrations, whereas the least beneficial ones for society were assigned to private enterprises. It should be underlined that the annual demand in the vast majority of light rail systems in neighboring countries such as France [43] is much higher than in Spain. Clearly, the advantages of LR as a transportation system do not justify its implementation when demand is low, given the high investment required. Nevertheless, high costs and low demand are traits common to many LR systems in Spain [1]. Their promotion was justified by unreliable (or even nonexistent) viability studies—e.g., overestimating demand, layout through scarcely populated areas—in conjunction with very costly projects—unnecessary underground sections, excessive crossings at different levels, etc. At the root of such projects, there may lay political impulses and opaque intentions, with certain sectors or parties benefiting from the introduction of a modern means of transport in their city. Here is where the vast influence of Spain´s major banks and construction companies upon the public administration would come into play: strategic alliances may appear between public powers and private enterprise, launching very costly projects, for the benefit of both, at the expense of the taxpayer. It has to be noticed that these kinds of projects usually include the urbanization of new areas, the redevelopment of existing ones and the improvement in a city's image, reasons that usually play an important role in the development of LR systems [3, 13, 14].

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Compliance with Ethical Standards

Conflict of interest None of the authors have any conflict of interest in the manuscript.

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