

Energy, Innovation and Transport: the Electrification of Trams in Spain, 1896-1935¹

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Abstract

The electrification of trams has been one of the most significant changes in urban transport. It led to price reductions, increased speed, better regularity, comfort and convenience and the popularisation of this means of transport. Its introduction required a new business model, characterised by massive investment, modern management and the use of more sophisticated technology.

The Spanish case shows a certain delay in this process along with the importance of the foreign capital (from Belgium and backed by German electro mechanic multinationals), the little intensity of the backward looking effects, because the technological dependency, and the conquest of mobility as the main forward looking effect.

Keywords: electricity, urban transport, tramways

The electrification of trams has been one of the most significant changes in urban transport. It led to price reductions, increased speed, better regularity, comfort and convenience and the popularisation of this means of transport. Its introduction required a new business model, characterised by massive investment, modern management and the use of more sophisticated technology. In peripheral countries (where these factors were not very abundant), electrification led to the entry of powerful foreign business groups. These were mostly Belgians, often backed by German electro mechanic multinationals, interested in new openings for their products. Their strategy was very clear. Firstly, they initiated the unification and homogenisation of networks. Then they carried out electrification. Once the basic network was set up, they pulled back out of the Spanish market, pressured by the nationalist surroundings of the twenties.

The aim of this paper is to study this process in Spain. In this sense, we will firstly look at the electrification of trams, both from a chronological and geographical point of view. Then we will analyse the change of the business model which facilitated the change from traction. Finally, we will evaluate the forward looking and backward looking effects of the electrification of urban transport.

The process of tram electrification²

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The first trams (which used animal traction) circulated in New York in 1832, but were not popular in Europe, including Spain, until 1870³. The American leadership was motivated by larger and faster urbanisation, the more extensive character of this and maybe also by its greater predisposition to technical advances. Applying steam to trams clashed with the social opposition derived from its contaminating character in urban surroundings, (especially in Europe), so its use was restricted to suburban lines (McKay, 1988).

The history of electric traction, initially applied to trams and later to the railway, is usually divided into three periods: 1835-1881 was the phase of trials then 1881-1895 was the phase of resolving the problems of urban and suburban traction and subsequently those of interurban traction. Finally, from 1895, the adopted solutions were perfected (Cayón et al, 1998: 85).

The application of electricity to urban transport required a series of trials during the 1880s, until the version based on overhead contact wires triumphed. As hoped, the pioneers and leaders in the electrification of trams were Germany and especially the United States, powers which also led the Second Technical Revolution, of which electricity was one of its main components⁴.

The legislative impulse to the electrification of trams in Spain was set by the Law of 14/8/1895, which authorised the substitution of the traction system. It can be said that there was a symbiotic relationship between public policies, (particularly at local level) and tramway development⁵. The historical financial weakness of the Spanish state meant there was a preference for legislative means (which were far cheaper) over investment in promoting economic development. This also happened in public services like trams. Central government influenced the evolution of this sector, establishing the general regulatory frame in which the business activity had to be developed. In a broader sense, other aspects of its policies, such as commercial aspects (taxes on set input), monetary (type of exchange), fiscal (taxes on companies), social (labour costs), energy (availability and costs of electricity) or external (attitude towards foreign investment) have conditioned tramway firms, especially in certain situations. On the other hand, as this is an urban activity, the role played by local administration was by no means insignificant, due to the detailed regulation of the service established in the concession, including tariffs and administrative authorisation for its expansion⁶. Nevertheless, tram companies have not been passive but rather have tried (and succeeded on many occasions) to influence government decisions which affected them. For this, they used newspapers, contracted prestigious lawyers, accessed diplomatic representatives (in the case of foreign companies) and, above all, integrated prominent politicians to their Boards of Directors, both locally and nationally⁷.

By the end of the 19th century, more than 80 European cities (some of which were in more delayed places than Spain such as Eastern Europe) had already electrified their urban transport (Alayo and Manubens, 2007: 348). In the case of Spain, the first city to electrify its tram was Bilbao, in 1896, the work of a Belgian- German company. At that time, Spanish delay was relatively important as compared to the most of

² A historical review on electricity in Spain in Cayón (2001).

³ See Tarr and Mcshane (2008) for information on the horse as urban technology.

⁴ Until 1882, Germany had the advantage (Siemens) (McKay, 1988: 10).

⁵ About the complex relationships among engineers, managers and politicians, see Hannah (1982).

⁶ Due to the chronic budget deficit of local public funds in Spain, no direct or indirect financial backing of loans was given to tramway companies like in the US.

⁷ For example Santiago Alba, a former President of the Spanish government.

Western European countries (**Table 1**) and much more so with relation to the United States where the electrification of trams was far faster than in Europe⁸. The Spanish tram network was still very small, eminently urban and basically used animals. The electrification of lines was almost non-existent, both as regards absolute values and the percentage in the network. On the other hand, other countries of a size similar to Spain, including some far smaller countries like Belgium, enjoyed a far more extensive tram network. In some cases like Italy, Belgium, Switzerland or France, suburban trams which used steam predominated⁹. The leading country of electrification of lines, both as regards kilometres and total percentage was Germany. Surprisingly, Britain used more animal traction than even Spain.

Table 1. Length, in kms, of tramlines, according to the type of traction in Europe in 1895¹⁰

	Animal traction	Steam	Electric	Total	Animal traction	Steam	Electric
Country	Kms	Kms	Kms	Kms	%	%	%
Italy	248	2,478	40	2,766	9.0	89.6	1.5
Germany	927	233	491	1,651	56.1	14.1	29.7
France	566	798	130	1,495	37.9	53.4	8.7
Great Britain	935 ¹¹	200	68	1,202	77.8	16.6	5.6
Belgium	119	1,056	26	1,200	9.9	87.9	2.1
Spain	200	47	14	261	76.5	17.9	5.6
Switzerland	26	224	32	282	9.1	79.4	11.4

Source: Gerard, 1897: 297-299.

There are significant differences in the diffusion of tramway technologies in Spain. In the case of animal traction, the Spanish chronological lag was notable, almost four decades. Its technological matrix was Anglo-Saxon, with an American patent and English and Belgian implementation. British companies took centre stage as regards business and financing and implanted the first lines at the start of 1870 in large cities like Madrid and Barcelona. The electrification of networks presented a minor temporal lag, (15 years), a usual phenomenon in the Second Industrial Revolution and which is linked to the acceleration of technological change and its diffusion which accompanied this first globalisation of economies¹². In this case, the technology came from the United States and, especially Germany. The latter also developed the traction motors and associated electrical equipment, whilst its Belgian associates dealt with the chassis and rails. Companies which carried out the electrification of networks were usually Belgians, but with a strong presence of electro-technical German capital (AEG and Siemens). The origin of the material is motivated by the comparative advantages of the

⁸ In 1893, 60% of the 12,000 miles of the tram network were electrified; ten years later, 98% of its 30,000 miles (McKay, 1988: 11).

⁹ For financial and technical reasons, French industrialists and technicians took some time to opt for electricity as compared to the traditional system of steam (Larroque, 1994: 1136).

¹⁰ A year of variation of statistics depending on countries. It distinguishes between the length of lines and tracks, the latter being larger. The first is adopted. The source seems to underestimate the length of the electric tramway network, at least in some countries such as Belgium, Italy or Great Britain. For instance, the *Revista de Obras Públicas*, 1900, I: 218, offers data for 1894-1899 which differs partially, also including electric railways. Moreover, according to the *Annuario Statistico d'Italia*, in 1898 its mechanical network was 3,106 kms long, 169 kms of which were electrified.

¹¹ Taking into account, in this case, the big difference between the length of lines and tracks, I adopted the semiaddition of both.

¹² On this aspect, see Derry and Williams (1960), and Dossi, Giannetti and Toninelli (eds.) (1992).

different countries in international commerce and helps one understand the dynamics of tram electrification.

Spain formed part of peripheral Europe (Mediterranean, Nordic and Eastern), which introduced and later electrified its tram networks to a large extent with the support of foreign capital (initially British and Belgian-German in the last phase of electrification).

In the mid thirties, the process of laying the basic networks and their electrification was completed in Europe (**Table 2**). The most developed countries had fundamentally produced the electrification of an already developed network at the end of the 19th century, whereas in countries which were a little behind like Spain, in the first third of the 20th century, there was a parallel process of growth of networks and their progressive electrification. In this way, there was a significant reduction of previous distances, although not total elimination, due to the persistence of differences in the levels of urbanisation and income. At this time, the trolleybus started to expand itself in Europe, especially in Great Britain,¹³ whilst in Spain the first line, in Bilbao, did not function until 1940.

Table 2. Length, in kms, of electric tramlines in Europe, 1/1/1934

Country	kms
Italy	2,884 ¹⁴
Germany	1,990
France	1,370
Great Britain	1,354
Spain	1,122
Switzerland	583
Belgium	349

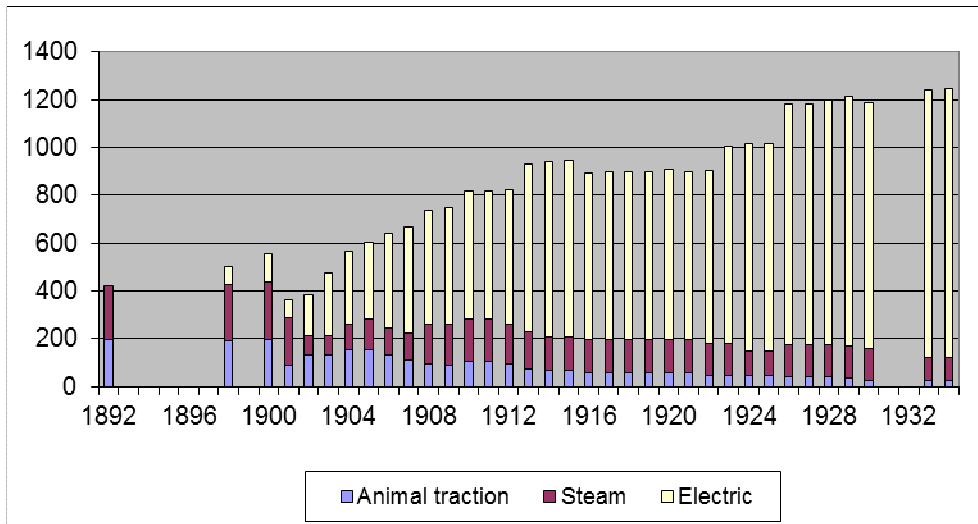
Source: *Anuario de ferrocarriles y tranvías*, 1935: XXXIX.

During the first years, at the end of the 19th century and the start of the 20th century, electrification advanced slowly, due to the technological limitations of electrical production (thermal generation) which made it more expensive (graphs 1 and 2). The process accelerated in the decade previous to the First World War, coinciding with the second phase of Spanish electrification. The hydroelectric generation and technical advances in long distance transport allowed a substantial cost reduction and the consequent spread and diversification of its uses. The difficulties of the Great War and later crises put a halt to the growth of the network and the process of the substitution of animal traction and steam for electrical traction. Nevertheless, this dynamic was reintroduced in the mid twenties, coinciding with an expansive phase of the economy, urbanisation and business concentration. In this way, on the eve of the Spanish Civil War, the double process of expansion of the tram network and its electrification can be considered as practically concluded.

**Graph 1. Running Tramlines, depending on their type of traction in kms,
1892-1934**

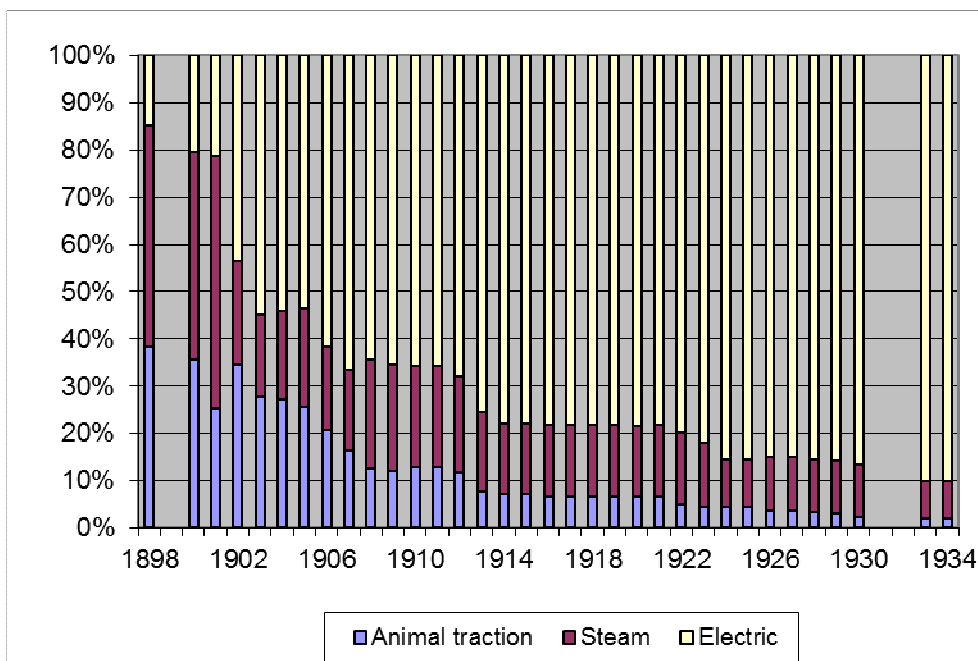
¹³ In 1935, there were 586 kms in exploitation, as compared to 71 in Italy and 27 in Germany (*Ferrocarriles y Tranvías*, November 1940: 342-344).

¹⁴ We replaced, for having little credibility, the data source (332 kms) by the *Anuario Statístico d'Italia*, which points at 1,730 km electrified suburban lines and 1,154 in urban areas. In general, data in the *Anuario de ferrocarriles y tranvías* appears undervalued, as they are well below those given by McKay (1976: 82) for 1913.



Source: 1892: *Memorias de Obras Públicas*, 1892; 1898-1900: Ministerio de Fomento. Dirección General de Obras Públicas, *Estadística de las obras públicas de España*, 1898-1900. Madrid, Minuesa; 1901-1930: Ceballos¹⁵, 1932: 381; 1931-1934: *Anuario Estadístico de España*, 1931-1934.

Graph 2. Running Tramlines, depending on their type of traction, in percentages, 1898-1934



Source: 1898-1900: Ministerio de Fomento. Dirección General de Obras Públicas, *Estadística de las obras públicas de España*, 1898-1900. Madrid, Minuesa; 1901-1930: Ceballos, 1932: 381; 1931-1934: *Anuario Estadístico de España*, 1931-1934

Once we have seen the temporal sequence of electrification, we should analyse its special coverage in the Spanish territory (**Table 3**), to discover in this way its diffusion guidelines. The start of electrification took place in the largest and most

¹⁵ One must take this author's data with precaution as he does not quote his sources and his data does not coincide with the existing data for previous years of other quoted sources. In this sense, the graphs reflect trends rather than totally reliable data.

dynamic cities (Bilbao, Madrid and Barcelona), whose strong expectations of growth of demand made them more attractive for the powerful international investor groups who took the lead in these actions.¹⁶ These very cities had also been the pioneers in the introduction of the tram led by animal traction. In the three cities, electrification was carried out by Belgian-German capital, dominated by SOFINA. The business strategy was quite similar, especially in the cases of Madrid and Barcelona (Martínez, 2002 and 2006). In both major cities there were initially various small tram companies of generally indigenous capital but there were also some foreign ones, mainly British. Consequently, there was a plethora of lines, of different widths, without a coherent global design and with different management systems. This complex structure, with its intrinsic characteristics of animal traction and high tariffs led to a reduction in demand and negative results in operation.

The tendency for a natural monopoly and to take advantage of the economies of scale stimulated, in a quite rapid sequence, unification, homogenisation and electrification of networks. The process was undertaken by powerful Belgian/German business groups, a result of the merge of financial interests of these countries, of the metallurgical industry and Belgian mechanical construction, and, above all, of the German electro mechanical multinational AEG. The electrification of networks of the large cities was carried out quite quickly, having been completed at the start of the 20th century. Without this, it was not possible to carry out efficient and profitable management.

Electrification of average sized cities took place in the decade before the First World War, linked to the increase in the number of tram businesses during that period (see graph 3). Foreign capital investment was low as the market was less attractive. Local financial groups¹⁷ were now more prone to invest, due to previous experience in the large cities, the lower need for capital and the euphoria on higher returns.

The War and post War crisis meant a sudden halt to this investment, which was reintroduced at the start of the twenties, partly in small cities which profited from the advantages of latecomers to directly create new technology. In this sense, one must note the acceleration of the technological change, seen in the progressive reduction of the interval between the introduction of the tram of animal traction and the electric tram. In this final phase, the initiative came almost exclusively from local capital in relation to the nationalist situation of the moment and the small markets involved. In any case, and in an even clearer manner than in other more indispensable public works services (such as water or electricity), there is a minimum threshold of population, (modulated by its density) which allows the electric tram to be profitable. This figure tends to go down over time (as the service extends) and is around 30,000 inhabitants. Nevertheless, this is a necessary but insufficient condition, as seen in the fact that some Spanish cities which had a population higher than this did not manage to get the electric tram.

Table 3. Geographical spread of electric tramway

City	The year the tram started	The year the electric tram started	Interval, in years, between the start of the tram and the electric tram
Madrid	1871	1898	27
Barcelona	1872	1899	27

¹⁶ For foreign investment in Spain, see Broder (1981), Costa (1981), Tortella (2000) and Loscertales (2005).

¹⁷ The Escoriaza group and the banks Urquijo and Pastor are some of the most important ones.

Santander	1875	1908	33
Bilbao	1876	1896	20
Valencia	1876	1912	36
Valladolid	1882	1910	28
Zaragoza	1885	1902	17
San Sebastián	1887	1897	10
Sevilla	1887	1900	13
Gijón	1890	1909	19
Las Palmas	1890	1910	20
Palma de Mallorca	1891	1916	25
Alicante	1893	1924	31
Oviedo	1895	1922	27
A Coruña	1903	1913	10
Granada	1904	1904	0
Murcia	1906	1906	0
Vigo	1914	1914	0
Avilés	1921	1921	0
Ferrol	1924	1924	0
Pontevedra	1924	1924	0

Source: local monographies.

The most extensive networks were situated, as one would hope, in the larger cities such as Barcelona, Madrid and Bilbao. In percentage terms, electrification had advanced more in 1910 in these cities and in some medium-sized cities. On the contrary, small cities and most medium-sized cities had little electrification of their networks at that time. Two decades later, the panorama had changed radically. Most cities with public transport had already electrified their networks, although some small or less prosperous cities kept animal traction in smaller networks.

Table 4. Distribution of the provincial network trams, 1910 and 1930

Province	Total network, in mts	% electrified	Total network, in mts	% electrified
	1910	1910	1930	1930
Alicante	52,243	0.0	30,500	85.2
Badajoz	1,802	0.0	2,719	0.0
Baleares	16,112	0.0	11,000	0.0
Barcelona	164,831	65.4	109,430	100.0
Cádiz	31,285	98.7	25,380	78.8
Canarias	28,063	100.0	17,208	0.0
Castellón	30,900	0.0	40,766	0.0
Coruña	5,843	0.0	24,260	100.0
Gerona	33,375	0.0		
Granada	13,553	82.4	123,381	98.1
Guipúzcoa	19,073	72.5	58,888	100.0
Jaén	41,781	100.0	17,860	100.0
Madrid	109,467	66.1	187,241	79.7

Málaga	16,220	100.0	21,651	100.0
Murcia	36,761	72.7	68,113	73.6
Oviedo	37,478	23.7	73,993	69.8
Pontevedra	7,230	0.0	85,460	100.0
Santander	25,623	66.9	23,849	100.0
Sevilla	25,859	100.0	45,000	100.0
Tarragona	3,554	0.0	3,554	0.0
Valencia	75,567	54.9	106,039	94.7
Valladolid	51,461	0.0	11,000	100.0
Vizcaya	106,169	81.9	125,493	100.0
Zaragoza	15,639	100.0	30,000	100.0
Totales	949,889	57.4	1,242,785	86.2

Source: Ministerio de Fomento. Dirección General de Obras Públicas, *Estadística de las obras públicas de España*, 1910. Madrid, Minuesa, 1910: 340-341; *Anuario Estadístico de España*, 1930: 495.

The change of the business model

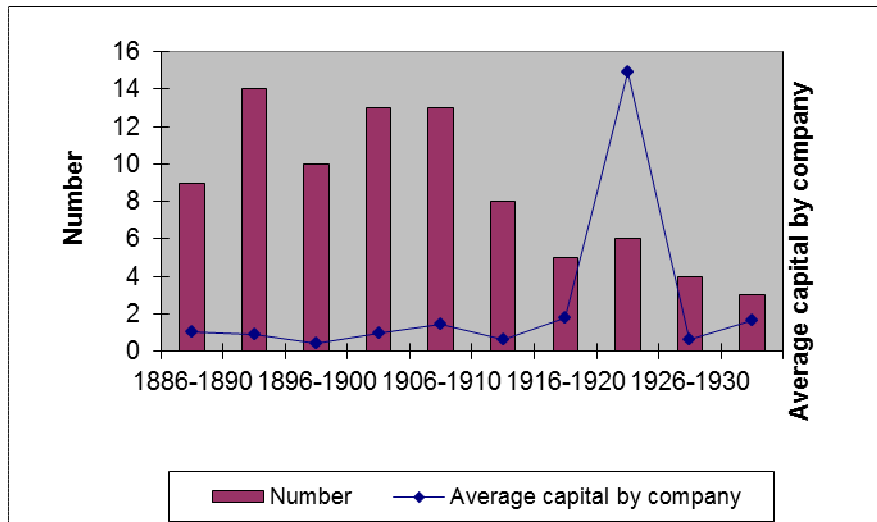
Electrification of networks demanded significant investment on the part of tramway companies and this led to their expansion. These firms were amongst the largest ones in the country.¹⁸ This is especially true in medium-sized and small cities, in which utilities businesses often represented the first and main example of a large modern company.

The creation of tramway companies had its defining moment from 1890-1910, as the entrepreneurial fever was waning (**Graph 3**). Nevertheless, the evolution of business size, expressed as the average capital in the set up, presented an almost opposing profile. Until 1902, the trend was low, and new companies with animal traction were created in average-sized cities. From 1903-1924, with the exception of the pause caused by the Great War, companies' capital increased¹⁹, and firms were created which started the electrification of their lines, for those which had high financial resources. These resources did not come solely from their own funds, via the actions of the founders or through increased capital but increasingly from distant funds via debentures issues in the capital markets (local market in the case of small and medium-sized companies and international in the case of the large foreign companies). This tendency to use more debentures than shares was due to the increasing needs of capital, the wish to externalise risks and the expansion of the financial markets.

Graph 3. Creation of tram companies, 1886-1935, five-yearly measures

¹⁸ In 1917, three tram companies (one in Madrid and two in Barcelona) figured amongst the 50 largest Spanish companies. Nevertheless, the progressive growth of other sectors of the Spanish economy and its growing investment reduced this to one single company in 1930 (Carreras and Tafunell, 2005: 788-789).

¹⁹ The sharp rise in average capital between 1916-1920 was due to the influence of the large firm Sociedad Madrileña de Tranvías, set up in 1920 with 75 million pts.



Source: *Anuario de la Dirección General de los Registros y del Notariado*, 1886-1909 and 1911-1959.²⁰ Capital in millions of pts.

Whereas small companies of animal traction could originally satisfy their (reduced) needs with their own resources and self-financing, the greater financial demands of electrification and the network expansion obliged them to accept a radical rethinking of the companies' financial strategies. These had to be increasingly backed by banking institutions, both to solve treasury problems and, above all, to ensure long term financing. This banking support was shown not so much in the direct package of resources but in the placing of securities (shares and debentures between its clients), which tended to expand local capital markets, mainly in medium-sized cities. In other cases, especially in large towns, they were electro-mechanical companies (mainly German) which either directly or frequently through electro-tramway holdings or banking institutions, provided the financial resources²¹. The significant investment effort occasionally made the financial balance of companies difficult, especially in small cities and when the results obtained did not respond to the expectations generated. This lag occurred mainly in suburban lines, threatened by the competition of buses and lorries. (Martínez (dir.), 2006).

Electrification meant there would be a significant change in companies' assets, with a higher weight of fixed capital assets as opposed to working capital. Rolling stock valuation increased due to the higher cost of engines.

The change did not affect purely the size and business financing, but also the actual management of companies. Electrification demanded a thorough reorganisation of companies, in order to optimise resources (both human and material) which were now more technical and expensive. All this led to the application of the new managerial model based on separating property and management, with growing professionalism of the latter and greater weight put on technicians²². The companies' management passed into the hands of experts who came from the field of engineering, reflecting the

²⁰ This source presents some limitations, highlighted by Carreras and Tafunell (2005: 710).

²¹ In France, the 1880 Law prevented tramway companies from giving out debentures of a higher amount than their capital. This led electro-mechanical groups to participate although these tended to part with their share packages after the Great War (Larroque, 1994: 1138).

²² This managerial style was more French or Belgian than American. In fact, it is not possible to use Chandler's model of management for American railways in European tram companies. See the special issue of *Business History Review*, summer 2008, vol. 82 issue 2 for information on Chandler's achievements and his critics.

importance given to this factor. In fact, in many small and medium-sized companies, it was the utility companies, which introduced these new methods in the local business surroundings, acting not only as technological disseminators but as management models²³. The diffusion of management practices occurred through several mechanisms: mainly mediating influence of investment banks and interlocking Boards of Directors²⁴, and to a lesser extent through a community of technological practitioners²⁵. It's unclear where the explanatory forces lie, because the technology and the business model probably operated dialectically and developed each other.

The car-km costs reduced with electrification, although so did income, due to the initial lower occupation of wagons, to larger distances and to the fact the tickets were now cheaper. However, despite the fact that the unitary margin of exploitation reduced, global benefits increased as did the volume of business. Despite the initial beneficial effect of electrification, income became stagnant in absolute terms from the third decade and even declined by km of line mainly due to the implementation of buses, especially on distant lines (Graph 4). Buses were more appealing than trams, as they were faster, more autonomous, versatile, less vulnerable and demanded less initial investment²⁶. Nevertheless, the difficulty to obtain fuel during the Civil War and long Post War period delayed the substitution of technological model. In any case, the monographs available (Martínez (dir.), 2006) suggest that electrification lead to a favourable qualitative jump as regards profitability, which remained positive during the twenties and was only slightly impacted by the Great Depression²⁷.

This article will *not* focus on the substitution of electric trams by buses. Nevertheless, one must point out that it was a slow process which lasted through the second third of the 20th century, with the trolleybus as transition technology. As the process was frequently initiated by the actual tramway companies themselves²⁸, this resulted, on the whole, in a new smaller and more dynamic business model and management²⁹.

Graph 4. Income of tram companies, 1901-1930

²³ Chandler (1977) has pointed out, in the case of North America, how the managerial revolution began in railway companies, later extending to other industrial sectors.

²⁴ This practice was quite common, especially in foreign companies.

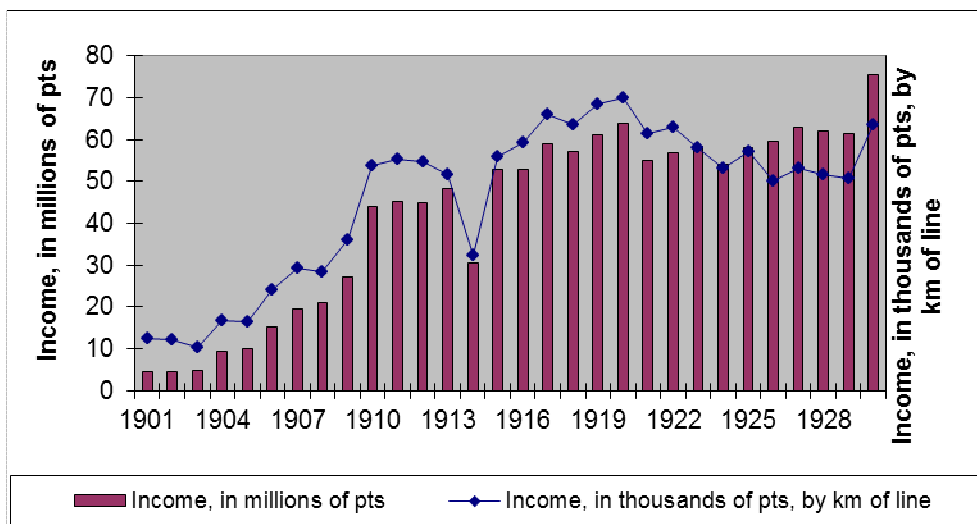
²⁵ On the diffusion of managerial practices, see Chandler (1977, 1990), Hannah (1976).

²⁶ On a more generic approach, the beginning of the competition between railroad and road transport, see Hernández Marco (2002).

²⁷ In other countries such as France, the behaviour was less favourable as the operating ratio of the period between the wars went back to the levels of the period of animal traction, 85% (Larroque, 1994: 1140). In Britain and American urban railways, electrification meant an initial deterioration of the operating ratio, although figures were more favourable, 55%-70% (Reilly, 1989: 24-26).

²⁸ For instance, Tranvías de Zaragoza set up Autobuses Urbanos de Zaragoza in 1934.

²⁹ See, for instance, what happened in A Coruña (Martínez, 2006).



Source: Ceballos, 1932: 381.

The impact of electrification

When we talk of the (economic) impact of a means of transport, we usually distinguish between its impacts on sectors which supply resources (backward-looking effects) and its incidence via the improvement of mobility (forward-looking effects). This focus is usually reductionist, as it does not evaluate social or environmental aspects which are more difficult to evaluate quantitatively. This type of exercise has generally been carried out for railways³⁰. Here we will apply it in the case of the electrification of trams.

The backward-looking limited effects: technological dependency

The main input and supplies provided to tramway companies in their process of network electrification were capital, electricity, fixed assets, rolling stock and technological developments.

The investment for electrification of tramway networks was logically far higher than that needed for the main lines of animal traction, due to the price rise it needed and, above all, the new fixed capital (rails, electricity distribution system) and the higher costs due to the larger size and sophistication of rolling stock. In relative terms, investment in urban transport was a modest 5.9% of the total investment in infrastructures from 1890-1935, overtaking that of telecommunications³¹. Its investment was much lower than that of the railway during the critical phase of its construction, 64.7% from 1845-1890 (Herranz, 2008: 35). In this sense, the diversion of capital for electrification was not a hindrance to other sectors for various reasons. Firstly, for its reduced quantity in terms of percentage of GDP and secondly, as it was produced at a time when Spanish industrialisation was already set up and the financial markets were more developed. Finally, most of the required capital (increased capital and distribution of debentures) came from abroad: Belgium³² (with German³³ backing) for shares and

³⁰ For the Spanish case: Comín et al (1998): 101-148 and a current revision done by Herranz (2008: 131-176).

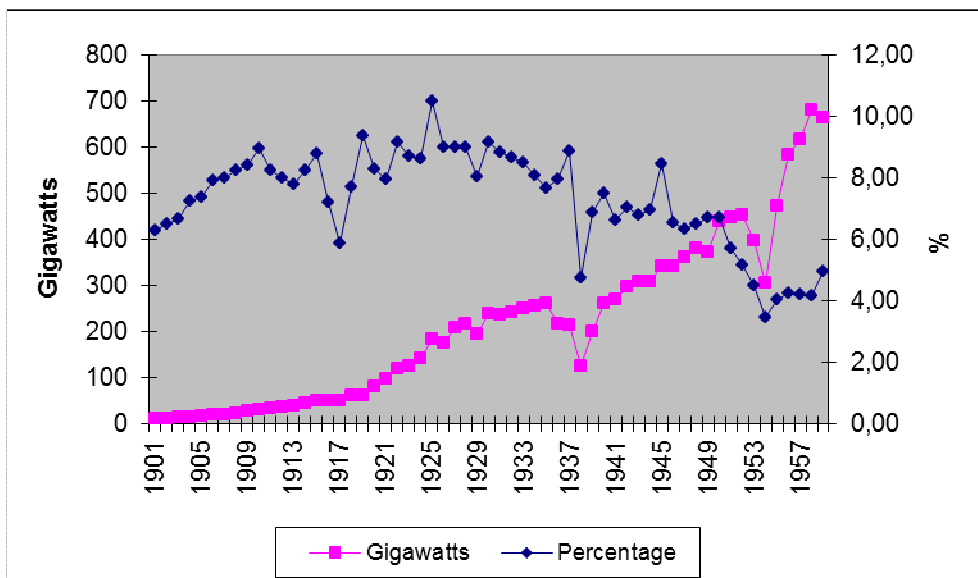
³¹ It reached its greatest participation (11.7%) from 1916-1925.

³² Some of the most important shareholders, according to the *Recueil Financier*, were the families Allard, Empain, Fichet, Fris, Grumiaux, Hammelrath, Ithier, Jacobs, Jansenn, Lagasse de Locht, Lambeau, Passelecq, Philips, Ranscelot, Thys and Urban.

the markets of Brussels and Paris for debentures³⁴. Nevertheless, in small and medium-sized cities, the local capital took on a more dominant role – due to lower foreign interest in its market. This stimulated the local capital market and led to modernisation of its financial system. However, in these types of cities, it was often difficult to attract capital due to the local investors’ reticence when faced with an activity perceived as high risk when compared to the traditional and safer investments of real estate and state securities.

Electrification of transport meant a growing source of demand for electricity companies (**Graph 5**). Electric consumption, in absolute terms, grew at a continuous rate (although moderately) until the First World War, due to the limitation of the network and the high price of energy obtained via thermal means. The War led to a halt in demand due to the stagnation of electrification for financial reasons and the importation of material. The twenties signified the Golden Age of electric consumption in traction, due to the strong growth of the electrified tram network, the setting up of the underground systems in Madrid (1919) and Barcelona (1924) and the development of rail electrification (basically narrow gauge). The Depression led to stagnation of this process, due to the fall in demand, compounded by the Civil War and the destruction of infrastructure and rolling stock. Recovery was slow during the forties, due to the electrical restrictions of the time and coincided with the gradual substitution of trams by trolley buses. The most spectacular growth would take place in the second half of the fifties but led now by wide track railways, and a dismantling plan was undertaken from 1956 for narrow gauge railways (Olaizola, 2005: 839-840).

Graph 5. Consumption of electricity for traction in Spain, in gigawatts and percentage on the total³⁵, 1901-1959



Source: *Anuario Estadístico de España*, 1901-1959.

In relative terms, the contribution of traction to electrical consumption was modest as it practically never went over 10%³⁶. Nevertheless, for electric companies,

³³ In the case of Germany, a significant person is Dannie Heineman, Director of AEG, and who is on the Tramway Board in Barcelona.

³⁴ On the role of multinational enterprises and international finance on the global electrification, see Hausman, Hertner and Wilkins (2008).

³⁵ Includes railways, losses and self consumption.

especially in cities with little electrified industry, the demand from trams, with public lighting, made up a relatively significant part of its business³⁷, which was especially relevant during the first years, when private consumption was still scarce. Tram companies represented a safety net for volume and stability with regards to fluctuations and uncertainty of private demand. This interest by electrical companies to boost this segment of demand explains its presence – direct or via holdings or connected banks -, in the shareholdings of tram companies, especially those in the phase of moving from animal traction to electrical. In fact, it could be said that the electrification of trams was (to a large extent) motivated by the electromechanical multinationals' search for new markets in a similar way to what would happen decades later with the car industry and oil companies.

Traction increased continuously during the first decade of the 20th century, coinciding with the first phase of tram electrification. The second decade was a backward step which suggests that the difficulties of Great War affected it more than industry. The twenties was the era of greater importance and stability. The crisis of the thirties meant a progressive fall which continued during the forties and, especially, fifties. The performance of traction is logically linked to the behaviour of the others components of consumption. Lighting fell from almost its initial 70% to 13% in the Post War and stayed around this figure later on. The fastest and most spectacular growth occurred in engines which moved from 11% in 1907 to 59% in 1929, fluctuating around this figure from then onwards. In turn, losses and self consumption tended to increase gradually especially from 1933, and were 20%-25% of the total.

Electrification demanded a very high volume of investment, in absolute terms and in kilometres of lines when compared to the era of animal traction. The rails needed were heavier and more expensive. Finally, the overhead cable and electrical sub stations had to be installed. All this new infrastructure generated a significant source of demand which was essentially met through previous imports from Germany and Belgium, and through companies connected to electro-tramway holdings of these countries (*Unternehmensgeschäft*), following guidelines in line with competition law. In this sense, a large number of rails, wagons and chassis came from Belgium whilst the Germans provided practically all of the electrical installations. The geographical origin of the suppliers of the fixed and rolling stock for Spanish trams is particularly interesting for the analysis of possible connections between the tramway companies and the manufacturers of these materials.

Electricity was one of the main innovations of the Second Technological Revolution. Its flexibility, versatility and economy meant a significant improvement as compared to previous energy sources. The first experiments in the field of transport developed in trams, due to their clear superiority compared to animal traction and to steam in an urban environment (McKay, 1976). Spain, like other countries in Europe, remained a straggler in technological innovation, especially in leading sectors such as

³⁶ The invoiced consumption would be somewhat higher, not including losses and self consumption. Nevertheless, in terms of income, the percentage would be less as the average price of kwh per traction was less than per strength and overall, than for lighting (0.08 pts, 0.11 pts and 0.60 pts in 1935, respectively, Bartolomé (2007: 18).

³⁷ In 1929, the final electrical commercial consumption in traction was 9.9% of the total in Spain, only overtaken in Mediterranean and Northern Europe by Portugal and, probably Greece, which showed its negative correlation with electrical intensification and the level of industrial development (Bartolomé, 2007: 18). In neighbouring Portugal, the percentage of electrical consumption in traction varied considerably from some cities to others, with a positive correlation to its size, at around 15%-25% of the total from 1930-1945 and representing 2-5 times more than public illumination (Cardoso de Matos et al., 2004: 392).

the electrical sector. This delay was seen in the reduced number of patents registered by nationals: 35.2% in electrical material between 1882-1935, with a Technological Developing Advantage of 0.7 (Sáiz, 2006: 62).

In the case of electrical traction, the patents registered for the Spanish in 1883-1935 only signified 11.5% of individuals and 3.6% of companies. In the former, the Americans predominated, with a third in total, followed by the Italians, French, British and Germans with 8%-14%. Amongst companies, the concentration was larger, dominated by the French -especially Thomson Houston de la Méditerranée³⁸-, with half, followed by the Swiss with a quarter (Brown Boveri) and the Germans (Siemens) with 12% (Cayón et al, 1998: 96-99). The French company was a branch of a homonymous North American group and used to channel the patents of General Electric. In turn, the Swiss electrical sector maintained strict links with German multinationals³⁹.

From this, one can gather that the technological innovation spread in Spain came overwhelmingly from the two leading countries: the USA and Germany. One can see a certain specialisation in companies / countries. The French North Americans dominated the general improvement of the engine, transmission and suspension, governing systems (electric traction), the third rail and the underground channel. In turn, the Swiss and Germans controlled locomotives and electric motor units, apparatus of power points and, above all, the overhead power cables.

These managed to hold the most relevant patents which they ended up imposing. Most electric transport patents refer to traction (58%), as opposed to 42% of alimentation systems. Among the first, those linked to wire apparatus dominated (22%).

With regard to alimentation systems, most patents referred to the underground channel (52,6%), as opposed to the overhead power cables (43%) and the third rail (4.4%), although it was the overhead power cable which ended up being imposed in Spain, like in the rest of the world (Cayón et al, 1998: 99; McKay, 1976). We do not know the chronological evolution of the type of patent registered, but it is highly likely that, like in other countries, the basic patents of traction and alimentation until 1914 and those linked to travellers' safety and comfort during the period between the Wars took precedence⁴⁰.

From 1897-1901, the highest number of patents was registered, coinciding with the boom of tram patents in general and companies being set up. Until 1920, most inventions were related to trams, whilst the relative saturation of this market and plans to electrify the railways from this date stimulated the market towards railways. The period between the Wars was the Golden Age for electric trams, making it a mature sector, as the level of technological innovation reduced, increasing the barriers for the greater needs of businesses⁴¹. Indeed, most of the material (both fixed and rolling stock) was acquired and installed in the fifteen years before the start of the Great War. Progressive obsolescence of this material occurred between the Wars⁴². On the other

³⁸ For Thomson-Houston's strategies for the electrification of urban transport, see Froelicher, 1991. Rail electrification in France was due to American technology, even if it became progressively independent during the period between the wars, a step in which French technology had a notable influence on Spain (Bouneau, 1993).

³⁹ On the international strategies of the electromechanical companies of these two countries, see Broder (1982), Hertner (1986) and Segreto (1994).

⁴⁰ This was what happened in France for example (Larroque, 1994: 1143).

⁴¹ In France, the curve of registration of urban transport patents also declined progressively from 1904, the decline of the twenties and thirties being especially notorious (Larroque, 1994: 1143).

⁴² A similar process occurred in France, including the countless repairs of material in the companies' own workshops. By contrast, American firms commissioned 17,500 new trams between 1921-1939 (Larroque, 1994: 1145-1146).

hand, each urban tram network used to belong to a different company as the process of business concentration in the sector had been limited generally to the range of each city. For this, there was a lack of standardisation of materials, partly eased by limiting their origin to certain manufacturers, most of which were foreign⁴³.

The lack of renewed material worsened in Spain case during the Civil War and Post War, due to the difficulty of importing the necessary technology, forcing companies to overexploit material and resort to their own workshops to reinstall parts from previously discarded rolling stock. All this led to a situation which culminated in the disappearance of trams from Spanish cities in the sixties, preceded by the trolley bus (in the 40s and 50s) as an alternative means of transit between electrical technology and the internal combustion engine⁴⁴.

On the other hand, the spread of electricity advanced slowly, especially with regard to the railway, due to problems of demand, a high initial cost and a tendency for an oligopsony. The electrification of transport took place mainly in trams, secondly in narrow gauge railways (in the Basque country above all) and, to a far lesser extent, wide track⁴⁵.

All this explains the minimal development of electro-mechanics in Spain and the strong dependency of importation, especially before the First World War⁴⁶. This came mainly from the USA, Switzerland and, especially, Germany⁴⁷. In fact, Spain limited itself in most cases to the fabrication of less sophisticated components such as rails⁴⁸, railcar casing, trailers and overhead cables. In any case, the impact of electrification of trams in the Spanish metal and mechanical construction industry was higher than that of half a century previously with railways, due to the move from a free trade policy (just for the railway materials) to a protectionist one and to the incipient development of Spanish industry⁴⁹. The main Spanish manufacturers of rolling tram (and rail) stock were the companies Talleres Carde and Escoriaza, and Compañía Auxiliar de Ferrocarriles (CAF), the first being acquired by CAF in 1947. Escoriaza moved from public works contractors to builders of rolling stock and from here to promoters of tramway companies (Zaragoza, Granada, Cádiz, San Sebastián, etc) and narrow track railways, setting a clear example of the trend already mentioned and the vertical integration between tramway companies and material suppliers. It is important to stress their early and continuous relationships with French and Belgian entrepreneurs and financiers, namely Thomson-Houston, a manufacturer of tram engines. They also maintained close collaboration with the Urquijo group, CAF's main shareholder and

⁴³ In contrast, the two main Spanish rail companies (Norte and MZA) went from owning 55% of the total number of wide track locomotives in 1877 to 74% in 1914 (Comín et al, 1998: 103).

⁴⁴ Faced with the major expansion of the trolleybus in Anglo-Saxon countries from the end of the twenties; in other countries such as France, its development was much less. (Larroque, 1994: 1148).

⁴⁵ In the mid-thirties, there were 1,122 kms of electrified tramlines, as compared with 787 narrow gauge and 400 wide track (Anuario Estadístico de España, 1934 and Olaizola, 2005: 835).

⁴⁶ In 1913, domestic production was slightly over a third of electrical material consumption in Spain. The increase of protectionism favoured a certain process of substitution of imports so that in 1925, Spanish production fulfilled almost 40% of its consumption (Tena, 1988: 362). Customs barriers stimulated the introduction in Spain of electromechanical multinationals, especially German ones. (Loscerales, 2005).

⁴⁷ Germany's market share in the Spanish market reached its highest in 1910, with 70%. It maintained this supremacy despite being affected by the Great War and the rise of the USA, during the interwar period, with 18% in 1926 and 28% in 1935 (Tena, 1988: 353).

⁴⁸ The importation of rails fell from 63% of consumption in 1891-1902 to 26% in 1902-1914 (Comín et al, 1998: 114).

⁴⁹ To our knowledge, there are no specific studies on the manufacturing of tramway material in Spain. Most recent literature on the mechanical construction industry does not analyse this subsector (Pascual & Fernández (eds.), 2007).

also strongly compromised in electrical, railway and tramway businesses. (Puig y Torres, 2008). The narrow market and the irregularity of demand for rolling stock for railways and trams meant that in Spain auxiliary railway companies were unable to develop a strategy of specialisation. This forced the Escoriaza group to diversify from the '20s: bus bodywork, mining wagons, locksmith's material, material for the Army, real estate promotion etc (Núñez, 2000) and also CAF from the '30s: spanning farming machinery, bus and tram bodywork, the construction of railcars as well as the manufacture of foundry material⁵⁰.

This tendency to “Hispanicise” the material was reinforced from the twenties with the acquisition of foreign tramway companies by Spanish financial groups led by the Urquijo Bank, in the increasingly nationalist framework of the era (**Table 5**). This impulse towards the mechanical industry strengthened with state help given to the rail companies, which also moved into Spanish hands during these years.

Table 5. Rolling stock of Madrid's tram network

Acquiring Company	Material	Number	Year	Supplying Company
Madrid Street Tramway	trailer	106	1871	
Madrid Street Tramway	railcar	55	1898	Monasterios (Madrid), Carde y Escoriaza (Zaragoza). Engines Thomson Houston
Madrileña de Tracción	railcar	50	1901	Engines Schuckert.
Madrileña de Tracción	trailer	25	1901	
Madrileña de Urbanización	locomotive	17	1901	Krauss, Koppel
Madrileña de Urbanización	trailer	34	1906	
Madrileña de Urbanización	railcar	31	1908	Carde y Escoriaza. Engines Thomson Houston
SGTEE	railcar	182	1900	25 Belgian engines, 100 Westinghouse and 57 Thomson Houston
SGTEE	trailer	28	1901	
SGTEE	railcar	80	1908	Franco-Belga de la Croyere. Engines Charleroi
SGTEE	trailer	27	1908	Franco-Belga de la Croyere
SGTEE	trailer	82	1914	Franco-Belga de la Croyere
SMT	railcar	50	1922	Lladró Cunat (Almacera-Valencia). Engines Charleroi
SMT	railcar	50	1925	Carde y Escoriaza (15), Lladró Cunat (25) and CAF (10). Engines Charleroi
SMT	railcar	3	1930	CAF. Engines Westinghouse and Charleroi
SMT	railcar	65	1932	CAF. Engines General Electric
SMT	trailer	50	1943	CAF and Electromecánica de Córdoba
SMT	railcar	160	1946	Fiat (110) in collaboration with CAF, Montajes Móviles y Construcciones. Engines General Electric
SMT	railcar	125	1947	Auxiliar de Transporte, Los Certales and Material y Construcciones. Recycled engines Charleroi and General Electric

Source: López Bustos, 1986: 182-245.

The forward-looking effects: the conquest of mobility

Mobility is a polysemic term born in the 1920s with the works of Sorokin and the Chicago School. This school conceived mobility, alongside the process of

⁵⁰ <http://www.euskomedia.org/aunamendi/31782>

urbanisation, as a factor of social disorganisation, breaking equilibrium. At the dawn of World War II, the field of mobility was already divided between sociological research, which defined it principally as a change of position, role or status, and transport science which regarded it as flows of movement in space (Kaufmann, 2009; Gallez and Kaufmann).

Traditionally, historiography has analysed this theme preferentially from the point of view of the *offer*, (like the history of transport), subdivided into different sectorial fields: land, sea and air. Recently however, a new vision has opened up, focused on the study of the *demand*, i.e. a history of mobility (Floneau and Guigueno, 2009). This methodological reorientation is in relation to the importance attributed to the phenomenon of mobility in modern societies (*mobility turn*) and the need to overcome the impenetrable behaviour which prevents interdisciplinary dialogue. The debate which arises presents a new paradigm, which is still underway. This new paradigm is characterised by its interdisciplinary and transnational focus. This historiographic trend is seen for example in the shift (as a main object of research), from the railway to the road, from collective transport to individual transport, from an economic to a cultural focus, from the long-term to the period after the Second World War and from the British area to that of continental Europe (Mom, 2009; Mom, Divall and Lyth, 2009).

Traditional public transport using animal traction had serious limitations for satisfying urban populations' demand for mobility e.g. low capacity, reduced speed, rigidity and hygiene problems all of which resulted in higher fares. This limited its use to the enjoyment of the Upper Classes. As compared to steam, the advantage of electricity was its lower environmental impact, its low cost and possibility of travelling over rough terrain. Electrification allowed these restrictions to be overcome, bringing about a real revolution of urban transport, facilitating what one could call "the conquest of mobility". This would form part of a larger process of modernisation of Spanish society and, especially of its cities (urbanism, public services), which developed during the first third of the 20th century (Cardesín and Mirás, 2008).

Electrical traction allowed the speed and frequency of trams to increase, although its dependency on the source of supply made it more vulnerable as usually occurs with more sophisticated technology. The carriages could now be larger, hold more people and were more comfortable. The high cost of the new fixed and mobile rolling stock encouraged a more intensive use to recoup costs more quickly: from here, there was an increase in kms travelled by railcars and lines. These could now extend to the suburbs, including on uneven surfaces and slopes. The advantages of electricity were especially evident for intense traffic and for long distances, particularly on uneven territories, providing that the concession was long enough to allow the redemption and repayment of the high investment needed⁵¹. Large companies which were involved in the unification and electrification of networks aimed to secure greater line concessions. On the whole, they achieved this, prolonging concessions until after the Civil War.

The increase of the scale of operations allowed cost reduction, and clients' fares then reduced. This led to a gradual increase both in the number of users and the annual average number of journeys. It progressively became a more popular means of transport⁵², used increasingly for daily work journeys, not simply weekly or yearly. Nevertheless, this increased mobility depended on the size of the population in the

⁵¹ *Congreso internacional de ferrocarriles, tranvías y electricidad celebrado en París en 1900. Memorias de los ingenieros de caminos, canales y puertos*. Madrid, 1901: 273-279.

⁵² In 1910 in European cities, transport signified 2.5%-4.5% of the salary of a qualified worker (Capuzzo, 2000: 630-631).

centre and on the substitution of the combined artisanal model (working / residential space) by the industrial model whereby working and living took place in separate spaces (Capuzzo, 2000: 631-632). The nature of the available sources does not let us provide greater detail on the users of the Spanish tramways, their attitudes toward tramway construction and electrification (and the disruptions that that process entailed), and the degree to which the construction of new tramways and the electrification of existing tramways altered patterns of mobility. Nevertheless, it is generally admitted in literature that the electrification of trams led to an extensive and intensive increase of their use.

Social construction of technology (SCOT) is a theory which argues that technological choices are shaped by social groups' interests⁵³. It is not enough, according to SCOT, to explain a technology's success by saying that it is "the best" -- researchers must look at how the criteria of being "the best" is defined and what groups and stakeholders participate in defining it. The most basic relevant groups are the *users* and the *producers* of the technology, but sometimes also politicians and journalists. Some of its core concepts are The *Principle of Symmetry*, the *Interpretative Flexibility*, the *Design Flexibility* and the *Closure Mechanisms*. The symmetry principle, adopted from the Strong Programme of Sociology, holds that all arguments (social, cultural, political, economic, as well as technical) that social actors put forward for the acceptance/rejection of any technology are to be treated equally. Interpretative Flexibility means that each technological artefact has different meanings for various groups and these alternative interpretations generate different problems to be solved. On the other hand, Design Flexibility holds that there are multiple ways of constructing technologies, reflecting the interpretations of certain relevant groups. Over time, as technologies are developed, the interpretative and design flexibility collapse through closure mechanisms, but closure is not permanent. New social groups may form and reintroduce interpretative flexibility, causing a new round of debate or conflict about a technology⁵⁴. The SCOT's approach can help us to better understand how the electrification of tramways took place in Spain and how the different social groups (various kinds of users, tramways companies, electromechanical multinationals, politicians at different administration levels and urban technicians) shaped its development.

From an aesthetic point of view, the visual impact of overhead cables in urban centres sometimes made their installation difficult due to the reticence on the part of municipal employees and public opinion⁵⁵. Nevertheless, opposition was less than in other European countries, probably due to the delay of the process in Spain or perhaps to the urban cultural context of Southern Europe versus Northern Europe, more concerned in the last case to preserve historical heritage, as we can still see nowadays. In Europe, there was clear preference for the overhead cable as opposed to other technical alternatives such as the underground cable or third rail.

Another very important aspect of the electrification of transport, (through the development of urban networks of transport that it brought about), was its impact on urban structures and on the location of economic activities, above all commercial, for

⁵³ Bijker, Hughes, and Pinch (eds.) (1987); a critical vision of SCOT in Winner (1993).

⁵⁴ For instance, the recent debate about the reintroduction of tramways in Spain due to the new ecological sensitivity.

⁵⁵ This criterion had greater weight in European cities than in the USA. In the first, 72% of alimentation systems used overhead contact in 1893, a percentage which increased to 83% in 1899 (McKay, 1988: 12-13; 1976: 76). In the French case, the problem was resolved by installing overhead wire in the outskirts and subterranean cable in the city centre (Larroque, 1994: 1137). On the other hand, British construction and maintenance techniques of the heavy rails which then demanded electric traction were superior to those of North America (Semsel, 2001: 51).

which visibility and accessibility were key (Mirás 2005). This theme has not yet been wholly explored, although it has been discussed by several authors (Monclús and Oyón, 1996; Oyón, 1999). The tram acted as a vector of urban growth, reinforcing a structure of radial character which linked the centre to the periphery, initially the Borghese districts of the Ensanche⁵⁶ (Widened districts) but later also to popular districts. As compared to the simple and reduced initial networks (animal traction) which would link the city centre with the railway station and the Borghese Ensanche, electrified networks were denser, more complex and longer, favouring the slow homogenisation of urban space and growth towards peripheral and suburban areas, establishing the basis for the future Underground system. The creation of urban space and added value through transport was seen, for example, in the promotion of specific lines⁵⁷, building companies by tram companies⁵⁸ or in the participation of shared Directors or even famous town planners on the Board of both types of companies⁵⁹.

Spain followed, despite a small lag behind more developed countries. The increase in the number of travellers basically took place during the second decade of the 20th century, coinciding with the extension of networks and their electrification⁶⁰. This was also seen in the strong increase in the number of travellers per line. However, while the number of users continued to grow during the twenties, albeit at a less intense rhythm, the number of travellers per line tended to fall. This suggests that in this stage, the growth was extensive, based on the expansion of networks, but that the new peripheral lines were less attractive as regards volumes of transported travellers, coming up against the growing competition of other means of transport such as the Underground in large cities and the bus in suburban lines⁶¹.

Graph 6. Travellers transported by tram, 1901-1930

⁵⁶ *Ensanche* means "widening" in Spanish and is used to name the development areas of Spanish cities around the end of the 19th century.

⁵⁷ For instance, in some cities (A Coruña, Vigo – mainly in the suburbs) the Board of Directors insisted on building and maintaining unprofitable, financially problematic service lines, probably because they owned land in those villages.

⁵⁸ The Escoriaza group, the owner of tramway companies in Zaragoza and Granada, created various real estate companies in these cities.

⁵⁹ This is the case, for example, of the *Compañía de Tranvías de La Coruña* and *Compañía Coruñesa de Urbanización*, which shared several Directors, or the urbanite Arturo Soria and his *Compañía Madrileña de Urbanización*, which promoted tram lines in Madrid.

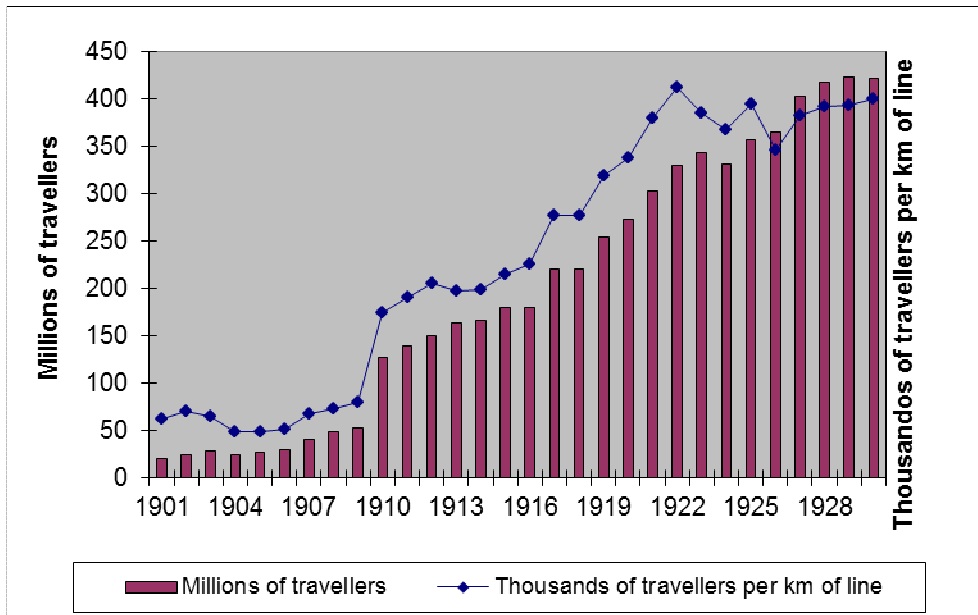
⁶⁰ The great increase in the number of travellers because of the electrification of trams was somewhat common in cities. For various large European cities, it fluctuated between 40-80% in the first five-year period, Capuzzo (2003: 28).

⁶¹ The problems derived from the recession of the '30s, the Civil War and the autarky, postponed the substitution of trams by buses in Spain, also delaying the decline of public transport. See Martínez (2006) for a concrete example.

In Central Europe, unlike Paris and especially London, the role of buses in suburbanisation was lower and occurred later, Capuzzo (2003).

For the impact on the different transport technology in work displacement, see, Pooley, Turnbull and Adams (2006).

On the decline of urban public transport in the USA and Germany, see Yago (1984).



Source: Ceballos, 1932: 381.

Conclusions

The electrification of Spanish trams basically took place in the decade before the First World War. The process developed slightly behind Western Europe although the lag was less than with the implementation of animal traction. The process was concluded by 1930. The electrification of trams and the expansion of the networks were shaped by institutional regulations, at national and local level, as in other European countries.

Electrification started in the large cities, later spreading to medium-sized cities. In small cities, networks were “born” already electrified. The process was led, especially in the large towns, by Belgian/ German companies which were interested in selling electro-mechanic material.

The greater sophistication and cost of the new technology led to the appearance of a new business model, based on the professionalism of management and on a larger size and more financial resources.

Its effect on the electrical industry and the Spanish mechanical construction was reduced due to the dependency on imports. Only the small local markets, electrical distributors and unsophisticated segments of the industry of capital assets were favoured, during the phase of the initial electrification of networks and during the “Hispanicising” of the tram sector in the twenties (in the case of the mechanical industry).

The inherent advantages of the new system, (capacity, speed, regularity, comfort and reduction of unit costs) allowed the popularisation of urban transport. However, the appearance of new competitors (Underground and bus) started to captivate clients and slowly erode companies’ income from the twenties. Nevertheless, the Depression of the thirties, the Civil War and the long Post War delayed (until the sixties) the change of transport model from electricity to the internal combustion engine.

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