International comparison of light rail operations with reference to urban population density patterns

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Abstract: The experience of urban light rail in Europe offers sharp contrasts. The German and French experience has placed light rail or tram at the centre of attempts to revitalise city centres using attractive modern forms of new public transport infrastructure. British experience has been based on a closer focus on value for money and tighter limits to subsidy, at both the infrastructure and operation stage.

With this policy contrast as a background, this paper reports on an international research project that used GIS techniques to map light rail routes and local population density patterns for a selection of case study cities. It addresses issues such as whether specific modern tram systems were handicapped by decisions over their routing together with the scale of international differences in local population densities and their impact on accessibility of the population to the light rail system. The project made use of local authority data from German, French, and British cities, plus analysis using MapInfo GIS software.

1. Introduction

This paper reports some findings from a research project 'Decisive Factors in the Success of Light Rail'. The project has been running since Autumn 2000 with funding support from English Partnerships, Transport for London, Rees Jeffreys Road Fund, The Institute for Logistics and Transport, and 3 other British local government transport authorities, Nexus (Tyne and Wear), Greater Manchester, and Hampshire County Council (Light Rail Transit). Further support has been discussed with the City of Dublin, and West Midlands Passenger Transport Authority (Centro).

2. The Research Project as a whole.

The project as a whole is still work in progress. The basic data set will consist of some 24 major cities with light rail drawn from 9 countries (Britain, Germany, Switzerland, Netherlands, France, Sweden, USA, Canada, Australia), and empirical analysis of the relative success or failure of their light rail systems. We will leave the full discussion of results for a future conference, since the data assembly process is still in course.

The wider policy relevance of the research is to try to distinguish between the effect of 'hard' and 'soft' measures that play a role in whether light rail plays a successful and growing part in the city's efforts to cope with its transport problem. By hard measures we refer to the physical provision of light rail service, quantified by average speed and frequency, and the details of population and employment densities along the routes. Soft measures would refer to marketing and price-related factors, together with complementary measures reflecting urban planning priorities, such as the length of pedestrianised and traffic-calmed streets. City centre car parking availability and price also plays a role.

Another important issue of course is how to find a simple and logical way to quantify the relative success of light rail. Currently, we have been experimenting with a combination of trips rates per capita on light rail and public transport as a whole, together with growth rates in these variables, converted into rankings.

In the British context, there has been something of a 'U-turn' on light rail in recent years. Having spent most of their first administration stressing the role of buses as a 'value for money' form of modern urban public transport, the pre-election period in

Spring 2001 saw the announcement by the Government of substantial funding for new light rail projects.

Following a statement in Autumn 2000 by the then Secretary of State for Environment, Transport and the Regions John Prescott that he had ‘changed his mind’ about the possible contribution of light rail in Britain. The 25 new light rail lines mentioned at that time included extensions to existing systems along with genuinely new systems. However March 2001 saw the approval of £871m. of Government funding for major new light rail projects in Leeds, Bristol, and South Hampshire (Portsmouth-Gosport-Fareham) (Tramways and Urban Transit, May 2001). It looks as if, having spent decades being brushed aside as poor value for money, light rail and modern tram now has a fair wind in Britain. The long process of ‘catching up with the French, the Germans and the Swiss’ can at least begin. Let us hope there is a long term commitment to these modern transport infrastructure policies.

3. Use of MapInfo GIS software to assess residential population densities along light rail routes.

One of the important questions in assessing the factors behind the success of light rail in cities such as Zurich, Basel, or Freiburg is whether light rail has benefited from a `compact’ high density urban form. This would imply that high passenger trips rates may partly reflect the ease with which people can access the light rail service. In contrast, one of the accusations against light rail projects that have emerged through the `urban regeneration process’ (such as in Sheffield, Greater Manchester, or Birmingham) has been that the routes have suffered from the depopulated nature of the areas they serve. Disappointing passenger numbers cannot be surprising if light rail routes and stops are not conveniently located for the potential users. The long run (and far from certain) development possibilities of vacant or derelict sites along routes may be an inadequate benefit flow for an expensively funded infrastructure project.

For the spatial detail at District, Ward, or the finest Enumeration District level in the UK Census, recent improvements in the Internet availability of Census data have led to digitised mapping of all the 1991 (and some earlier) Census results. This uses MapInfo GIS software, side by side with conventional data reproduction. For academic research users, this facility was made available through their university computing networks, administered by the University of Manchester MIMAS establishment (www.mimas.ac.uk and www.census.ac.uk/casweb). It constitutes an enormously valuable research resource, which will be further strengthened shortly by the addition of the 2001 Census results.

For this project, it meant that local ward or ED-level maps of British cities were immediately available in MapInfo form, and details of light rail routes and stops could easily be added as a separate MapInfo layer. (In practice, we had to order from the UK Office of National Statistics separate printings of Ordnance Survey maps with ward boundaries marked).

The Australian city (Melbourne) has a large and long-established tram system and also keeps its local city data in MapInfo form. For the other countries, local population and density data were available, but local area boundary maps had to be produced in MapInfo digitised form by research assistants. This was time-consuming work, but is now available as a useful research resource for the future.

Examples for various cities in the international sample of light rail systems, superimposed on shaded population density maps along and near the routes will be shown and discussed in the Zagreb presentation. However they are not in MSWord form and so cannot be included in the paper for the CD. They are known as `thematic maps' in MapInfo-speak.

4. Use of Buffer Zones.

One of the simplest methods to assess residential population density along a fixed route is to construct a `buffer zone' of given width either side of the line, or at given radius around each of the stops. The MapInfo software allows the estimation of the population which lies in such a buffer zone, by disaggregating the local ward populations in proportion to the area lying in the buffer zone, which the software measures itself.

We will focus later on zones around the specific stops; given that passengers can only get access through stops, this would be preferable. However, we were able to examine them in detail only for the British cities, for which the light rail systems were smaller and we had more detailed maps of stop locations. For the case study sample, we concentrate on buffer zones for the whole line network.

It was decided to construct first through GIS a 600 metre buffer zone, either side of the light rail routes for all of the project case study cities for which the maps were currently available. This was based on an assumption that 600m. was a reasonable `walking access distance' to a light rail public transport route (roughly equivalent to a 6 minute walk). Various countries have used various distances as the limit of reasonable pedestrian access, and 600 metres might be considered at the high end of the range. Hence, in addition we did the same exercise for a 300 metre buffer zone, either side of the line (that is 600m. in total width).

Table 1 summarises some results for 13 cities from 5 countries. The light rail system sizes vary widely, from 220 km. in Melbourne to 10 km. for the single line of Saarbrücken and 20 km. for the Midland Metro of Birmingham-Wolverhampton. (The latter has a number of much discussed extensions planned).

One would think that a high resident population within such a line buffer would be a useful precondition for a successful light rail network. However, there are many complex factors that affect urban population density, including those of urban economic, political, and urban historical form, superimposed and mixed. When the buffer zone populations were divided by the line lengths, we found that using the `600m. either side' buffer zone (1.2 km. total width) then the Croydon Tramlink came out with the highest population density in its buffer zone, followed by Bremen, with Göteborg having the lowest buffer zone density. Although Croydon is a suburban Borough of the biggest city in the case study sample, it is quite distant (some 15 km.) from central London.

It was also clear from examining the maps of the 600m buffer zones that in many cases there were overlaps of buffer zones, where people were within 600m of more than one line. In particular, very dense and complex light rail systems such as Zurich or Melbourne would have a low buffer zone population per km. of route because of these overlaps.

We therefore repeated the exercise for a 300m either side buffer zone, also shown in Table 1. Although the ranking remains pretty similar, Bremen now comes out as the highest buffer zone population density, with Leipzig the lowest. That is, Bremen jumps above Croydon once the impact of the `accessibility overlaps' is weakened by using narrower buffer zones.

Table 1. International Case Study Cities (Population residing in 0.6 km and 0.3 km line buffer zones per km line length)

City	**Total route length (km)**	**0.6 km line buffer popn.**	**0.6 km buffer Popn./ route km**	**0.3 km line buffer popn.**	**0.3 km Buffer Popn./ route km**
Birmingham (Midland Metro)	20.4	85,907	4,211	41,499	2,034
Croydon Tramlink	28	124,881	4,460	74,361	2,656
Tyne and Wear Metro	59.1	196,905	3,332	101,257	1,713
Manchester Metrolink	37	115,403	3,119	55,931	1,512
Bremen	63	280,829	4,458	186,425	2,959
Freiburg	24	92,117	3,838	55,184	2,299
Essen	73	313,257	4,291	196,269	2,689
Goteborg	137.5	240,086	1,746	167,867	1,221
Leipzig	155	305,416	1,970	179,310	1,157
Saarbrucken	10.3	36,381	3,532	17,157	1,666
Zurich	109	236,380	2,169	159,054	1,459
Melbourne	220	581,198	2,642	373,975	1,700
Hannover	98	352,101	3,593	212,466	2,168

Sources: Buffer zone populations, Census data;

Number of lines: Bushell, C. (1998) Jane's Urban Transport Systems (Coulsdon, Surrey; Jane's Information Group Ltd)

Leipzig in turn is fairly typical of a major traditional East German tram system, sustained as cheap and basic public transport for many years under the Communists (though becoming increasingly dilapidated before 1989). In many cities of the former Communist regimes, higher density social housing estates were built in the suburbs, served in most cases by tram (but not necessarily within 600m walking distance). The modernisation program carried through since German reunification has retained much of the network while renewing the vehicles and renovating the infrastructure.

Bremen is also noteworthy within the German urban planning context for having introduced at quite an early stage a series of measures (`traffic cells') to protect the city centre from motorised through traffic. This evidence confirms that the Bremen and Essen have high population density pattern adjacent to their light rail networks, a useful ingredient for a `compact city' planning strategy.

5. Comments on the Swiss, Rhine, and South German connections.

Our other work on the international case study, however, shows that it is a different set of cities that have led the way in Europe in terms of the intensity of use of public transport, and light rail in particular. Measured simply by the number of light rail passengers per capita or per route km of the light rail network, our international cross section showed that Zürich, Basel, and Freiburg were strikingly more successful. (Since there would be some argument over what population to use as the base for a `passengers per capita' index, here we give just light rail passengers per route km).

Table 2. Selected International Case Study Cities (Light rail passengers per route km., and annual light rail growth)

City	Light Rail passengers per route km (million)	Annual growth in Light Rail Passengers/Capita	Number of Years (mostly 1985-98)
Freiburg	1.88	4.45	14
Zürich	1.74	1.55	14
Basel	1.61	1.13	14
Hannover	1.02	0.72	14
Düsseldorf	0.89	1.63	14
Bremen	0.79	-0.09	14
Essen	0.61	1.71	14
Tyne and Wear Metro	0.59	-4.35	14
Melbourne	0.53	-0.97	14
Saarbrücken	0.49	19.75	1
Leipzig	0.47	-5.69	14
Manchester Metrolink	0.45	3.72	4
Göteborg	0.38	-0.24	17
Birmingham (Midland Metro)	0.32		
Croydon Tramlink			

Source: Bushell, C. (op cit) and Hass-Klau et al (2000)

It is clear that the light rail systems of the Swiss cities and Freiburg are `doing something right' in a very big way, relative to other German cities and the rest of the international sample. Their intensity of use is remarkable, and continues to be worth studying in detail in the extent to which successful marketing and cultural change in middle class attitudes to urban car use have been achieved. Table 1 above made it clear that their spectacular lead in light rail use is not simply explained by population density living adjacent to the lines. Indeed, Zürich has one of the lower buffer zone population densities of this set of study cities, although the role of central office employment and the true definition of `net' residential density was not possible. (In fact, we would have very much liked to study local employment densities within the same GIS format, but the data is not available.

In terms of annual growth in light rail passengers per capita (Table 2), the same three cities were also all impressive, Freiburg clearly leading the way but the Swiss cities achieving over 1% annual passenger growth too. In terms of best light rail practice, these cities clearly offer some lessons, especially to British and American cities introducing new light rail systems.

6. Further Remarks on British Light Rail Projects, and the Evidence from Stop Buffers.

Finally, we will comment further on the four leading British light rail systems, two of which (Croydon Tramlink and Midland Metro) are very new, and two systems are still to be opened. Nottingham Express Transit is planned to open in 2003, and South Hampshire has only recently received funding approval from the Government. It was one of the three major new urban light rail funding approvals, the others being Leeds and Bristol.

However, the proposed routes for Nottingham and South Hampshire (Portsmouth – Fareham) are already known in sufficient detail that we can calculate buffer zones around the lines or around each individual stop.

Table 3. British Light Rail systems: Buffer zone populations, route line length and number of stops; buffer zone population per route km and per stop.

LR System	0.6 km line buffer popn.	Total length (km)	0.6 km Buffer Popn./ route km (rank)	0.6 km stop buffer popn	Number of stops	0.6 km buffer popn. per stop
Midland Metro (B'ham-Wolv'ton)	85,907	20.4	4,211 (2)	62,963	23	2,738 (3)
Croydon Tramlink	124,881	28	4,460 (1)	110,884	38	2,918 (2)
Tyne and Wear Metro	196,905	59.1	3,332 (3)	138,353	46	3,008 (1)
Manchester Metrolink	115,403	37	3,119 (4)	80,167	36	2,227 (4)
South Hampshire Rapid Transit*	46,610	14	3,329	40,292	16	2,518
Nottingham Express Transit*	55,099	14	3,936	46,947	23	2,041

* Approved or under construction

We see from Table 3 that the residential population (from the 1991 Census) per km. of route using a 600metre line buffer has the four currently operating systems with the Croydon Tramlink having the highest density adjacent to the lines, and Manchester Metrolink the lowest. The latter therefore reflects a combination of the lower density of Greater Manchester relative to Outer London, together with the amount of vacant land or development sites adjacent to the Manchester lines.

An alternative measure of population access would be to estimate through GIS the resident population within a 600 metre buffer of each stop, and then divide by the number of stops. The stop buffer zones do of course partly overlap, depending on how many are located with less than 1.2 km. spacing from an adjacent stop. Using the stop buffer zones, we find that the Tyne and Wear Metro system (the longest of the British light rail systems, with the widest average spacing of stops) has the highest average residential density around stops, although it was 3rd of the 4 using the line buffer zones. One might conclude that the quickness and relative ease of specifying buffer zones around the lines should be interpreted with caution.

The two light rail systems under construction, Nottingham and Portsmouth-Fareham (South Hampshire) are quite different; although the projects approved or under construction are single lines of the same length, extensions are planned in the medium to long term. The Nottingham system is provided with more stops for its 14 km., and this makes its average buffer zone (600m.) population per stop lower, although the estimated population within 600m. of the line is higher. The Nottingham light rail project (N.E.T.) will therefore be similar to a high stop density, relatively low average speed service. This is essentially the character of the Swiss and Freiburg systems discussed above, and we noted how well they have performed there. The South Hampshire system is closer to the Midland Metro and Manchester Metrolink in terms of stop spacing, and shares some of the characteristics of a German S-Bahn or French RER. We will await with interest the first 5-10 years passenger numbers for the new British systems, where operating subsidy levels will be much lower than in other European countries.

7. Conclusions

The paper has provided some international comparative background on light rail urban transport systems, which have been increasingly enjoying a revival around the world in contributing to sustainable urban transport strategies. Comparing new with mature systems, and trying to disentangle the relative role of urban population density structure, compared to other factors that influence their relative success, is a challenging but important task. It also provides an important application of GIS (MapInfo) software, and uses the impressive on-line digitised map data output from the British Census. The investigation of the 2001 British Census, when available, will of course provide a major further research resource, which will add an extra dimension.

References

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