

**Accessibility and the choice of network investments in the
London Underground**

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Abstract

In 1863, the Metropolitan Railway of what came to be known as the London Underground successfully opened as the world's first subway. Its high ridership spawned interest in additional links. Entrepreneurs secured funding and then proposed new lines to Parliament for approval, though only a portion were actually approved. While putative rail barons may have conducted some economic analysis, the final decision lay with Parliament, which did not have available modern transportation economic or geographic analysis tools. How good were the decisions that Parliament made in approving Underground Lines? This paper explores the role accessibility played on the decision to approve or reject proposed early London Tube Schemes.

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Chapter 1

Introduction

The advent of modern steam railways occurred in 1825 with the opening of the Stockton and Darlington Railway in England. By 1836, the London and Greenwich Railway found itself the first line to reach the capital. To preserve the cohesion of the City of London, which would be lost were every intercity line to enter the regional core at grade or in a trench, the 1846 Royal Commission on Railway Termini established a moratorium on intercity railway lines entering the City of London and areas immediately west (See Figure 1.1).

Yet Londoners demanded a solution for the street congestion, and concern arose that businesses would locate elsewhere. A commission was established to examine alternatives, out of which came a charter for the North Metropolitan Railway (later renamed the Metropolitan Railway) in 1853. Of equal concern was moving goods into London. With a moratorium established people sought to move freight underground. The lines created by the Metropolitan Railway were used to move freight. Though today it may seem like the sole purpose was to move passengers, quite the opposite was true in the mid 1800s. Because underground transport was sought for multiple reasons,

Traveling Underground provided a dedicated right of way, allowing people to traverse London more quickly than at grade. When the Metropolitan Railway of what became the London Underground opened for service in 1863, its intent was to increase the ease of connections between key intercity termini across the northern edge of developed London. It also made it much easier for people making intracity trips to travel across London, at a time of large population growth.

The period leading up to the opening of the Metropolitan Railway was dominated by inter-city rail growth. In 1829 only 82 km of track had been laid in the UK. This figure would grow to 24,800 km by 1871 [9].

The Metropolitan Railway opened to immediate success. Over 40,000 trips were taken on the first day (10 January 1863). At the beginning, trips ran every 15 minutes from 08.00-20.00, and every 20 minutes from 06.00-08.00 and 20.00-24.00. The travel time from Paddington to Farringdon was 18 minutes, almost the same as today.

In the early years of the Metropolitan Railway, many thought the enormous levels of ridership were too good to be true, and dubbed it “curiosity traffic” [9]. Future years would prove the opposite however, and ridership would grow further beyond the expectations of optimists.

The overwhelming success of the Metropolitan Railway begat many other proposals, some of them constructed, others confined to the archives [4]. Over the first 50 years of the London Underground there were over 100 proposals that failed due to a lack of funding, insufficient plans, or Parliamentary rejection.

Accessibility has been demonstrated to be a significant factor affecting travel demand and land use [11, 21, 24, 34, 31, 18, 17, 38, 19, 26]. This study explores the relationship between accessibility and network investment. While funding is a project cornerstone, the decision to construct a line is influenced by many factors.

This study tests whether accessibility (the ease of reaching destinations) [42, 19, 23, 48, 25, 40, 37, 36, 22, 20, 46, 29, 5, 11, 13, 38, 34, 31, 27, 21, 39, 54, 53] explains network growth (which lines are built) [33, 50, 12, 55, 30, 7, 6, 51].

The networks used in this study are the first few decades of the London Underground. As such, the change or proposed change in each network is limited, often a change in one link or line on the Underground network. It has been hypothesized that the proposals with the greatest accessibility impact for the lowest cost will be chosen for construction.

Geurs and Wee [15] have defined four basic measures that accessibility analyses can cover. The four bases are: 1) location, 2) people, 3) infrastructure, and 4) utility. This study focuses on the former two.

This paper starts by describing the data and networks used. The process for merging the networks is then described. Assumptions regarding travel speeds are stated. Locational accessibility methods are shown, calculating the accessibility for every network

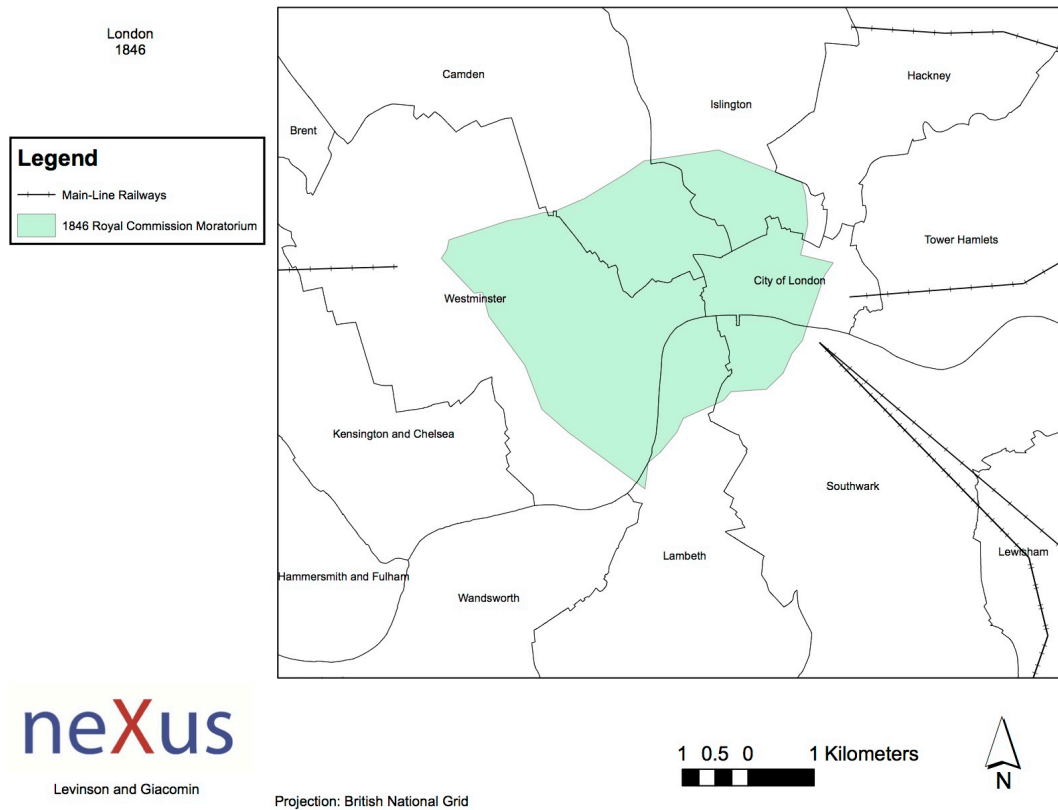


Figure 1.1: Royal Commission Limits of 1846

from every 200 m x 200 m block in London. The accessibility calculations are weighted by population, and person-weighted accessibility (PWA) is used to compare proposals. An estimated cost per km from 1885 removes bias from the quotes given to Parliament. Inflation over the first 50 years of the London Underground remained around 0% and is therefore omitted from analysis. The accessibility results explain the decisions made to construct new lines on the network.

Chapter 2

Background

Accessibility was first defined by Hansen in 1959 [19]. This study focuses on two forms, locational accessibility and person-weighted accessibility. Locational accessibility calculates reachable destinations from a location. Person-weighted accessibility weights the accessibility of many locations based on the population of each. The primary benefit of person-weighted accessibility is that it provides analysis in one number, allowing for inter-network and intra-network comparison. Locational accessibility provides a cartographical benefit. A map displaying locational accessibility information can help identify areas in need of more transit, or any mode of transportation.

2.1 Locational Accessibility

Measuring accessibility of non-motorized modes is a topic of little research. Iacono et al. examine walking and biking accessibility for various destination types [22] in part of the Minneapolis metro. Other studies are also very focused in their study area [52, 2]. This study uses walking accessibility as a base level for transport.

Accessibility can be measured retroactively. This study measures accessibility in London in the 19th century with a focus on the modes of walking and underground rail service.

Locational accessibility bears particular relevance to planning. Maps of accessibility impacts allow central planners to effectively understand the impact of transit development. As such information was not available in 19th century London, the effectiveness

of central planning in London, had it existed, is of much debate. Odlyzko notes that central planning at the time may have actually decreased the efficiency of the rail network in Britain [43].

2.2 Person-Weighted Accessibility

While locational accessibility provides a cartographical benefit, its use is limited in quantitative analysis. With limited funds planning agencies must decide between an array of options. Such a decision may be to add a stop along a route, or at the end of a route. Calculating person-weighted accessibility allows for comparison when the options affect different populations. Once cost information is included on the two proposals, the more cost-effective option can be chosen. Throughout history this has not always been done, but people have the ability to estimate and to an extent this is sufficient.

In 19th century London, it was not possible to calculate person-weighted accessibility, but planners and decision-makers made less systematic estimates of expected values.

Chapter 3

Data

3.1 Population Data

Census data has been collected in the UK since 1801, and much of it was digitized by the Vision of Britain project. However as geographic boundaries continuously changed, the lowest administrative district at which a consistent digital population set has been made publicly available from 1801 to the present is at the level of borough (London is divided into 33 boroughs) [[Greater London Council and Office for National Statistics](#)]. Great Britain Historical GIS Project (which releases data to the public via the Vision of Britain website) recoded UK Censuses conducted prior to the establishment of current boundaries to give totals for current districts. The population dataset comprises 6 decennial censuses (1861-1911) for 33 areas.

3.2 Network Data

While the focus of this analysis is on the incremental accessibility offered by proposed Underground railway lines, those lines exist in a context of a network where people may walk or take existing rail lines to their destinations. In other research, straight-line or a network distance have been used to model walking. Because network distances are longer than Euclidean distances (but not uniformly so), this research uses a pedestrian network to represent travel costs between origins and destinations, between origins and stations, and between stations and destinations. To our knowledge, no complete

digitized pedestrian network exists for 19th century London, but most of the links that existed then are present today. Certainly more links are present today, but areas then without links were also areas without much population at the time, minimizing the bias that assumption of the street network as background would produce. An Open Street Map network file for modern day London was used as the background pedestrian network [49]. The file was used throughout every study year and network. The speed on this pedestrian network was assumed to be $5km \cdot h^{-1}$.

For every study year, the existing Underground railway network was included as well as any lines currently under construction. Including lines under construction is important because it helps identify what proposers would have known about the future of the network, and would guide investment decisions. A time penalty of two minutes was used to represent a transfer between the walking network and the London Underground network. The transfer could only occur at London Underground stations. The speed on the Underground network was assumed to be $12km \cdot h^{-1}$.

Inter-city and other surface railway data was included for the year of each study [8, 10]. Like the London Underground, surface railway data for the study year was included in the network. A time penalty of two minutes was used to represent a transfer between the walking network and the surface rail network. Transfers could only occur at surface rail stations. The same time penalty was used for transfers between the Underground network and the walking network. The speed on the rail network was assumed to be $12km \cdot h^{-1}$.

3.3 Proposed Lines

For every proposed line, details were taken from the book *London's Lost Tube Schemes* [4] and digitized based on available information. In many cases straight lines were drawn between stations. Since the lines were never built, the accuracy of the spatial representation is lower than that of London Underground lines today. These are detailed in the Appendix.

For each year with proposals, a base network is analyzed that included an example walking network (2012 London road network), surface rail lines that existed in the study year, and existing and under construction Underground lines. Lines under construction

are included because proposers of additions to the network would have knowledge of current plans, and likely made decisions based upon that information. The proposals are then compared in analysis. Some proposals resulted in slight changes to the network, perhaps an extension to an existing line. Others established entirely new routes, sometimes making significant changes to the network especially early on.

Chapter 4

Methodology

An accessibility analysis is conducted for every base year, starting with 1862, the year before the first line. In 1862, the network only includes the walking network and existing surface rail network. For each subsequent base year, the additional and/or proposed London Underground links would be added as well as any new surface lines.

4.1 Block Population

This study assumes that the population is distributed homogeneously within each borough, as no more detailed analysis can be made with available data. To measure accessibility, blocks are generated in 200 m x 200 m squares. The block is assigned the population density of the borough in which the centroid fell. If the centroid of a block fell outside of London, it was omitted from analysis. The remaining blocks numbered 39,858.

The centroids are then snapped to the network. Occasionally points would snap to an isolated part of the network. In this case, the isolated part of the network would be re-snapped to the nearest part of the larger network. Specifically, the points are snapped to the walking network only. It is not logical to snap them to any other mode as it is not logical to begin or end a trip at subway or rail stations. The same blocks were used to measure accessibility for every change (or proposed change) in the network.

$$P_i = \frac{k_i}{k_b} P_b \tag{4.1}$$

where k_B = the area of borough b ,

k_i is the area of block i .

P_b is the population of borough b .

From these P_i is obtained, the population within block i .

4.2 Locational Accessibility

The performance measure of accessibility is proposed as a factor explaining which proposed Tube Schemes were most likely to be approved by Parliament. A cumulative opportunities accessibility is used, measuring the number of people that can be reached from a point within 30 minutes travel time by walking, national rail, or Underground line.

In measuring accessibility for each block centroid, an OD cost matrix is created for every network. For the other block centroids that can be reached, their populations are summed providing the cumulative opportunities for that block centroid. These values are represented in Figure 5.10.

$$A_{i,T} = \sum_{j=1}^J P_j f(C_{ij}) \quad (4.2)$$

where $A_{i,T}$ = cumulative opportunities from a block centroid (i) to every other block centroid j reachable in time T ,

C_{ij} = generalized (real) time or cost from block i to block j ,

$f(C_{ij}) = 1$ if $C_{ij} < T$ and 0 otherwise.

In this study, a value of $T = 30min$ was used unless otherwise noted.

4.3 Person-Weighted Accessibility

Equation 4.3 calculates network-wide person-weighted accessibility. This measure increases with population at the origin and the population of destinations that can be reached within 30 minutes from each origin. It allows for comparison between proposed lines, implemented lines, as well as comparison across years.

For the population of each sample point (that represents a block), the population density was used to identify the weight assigned to each point.

$$A_{pw,T} = \sum_{i=1}^I A_{i,T} P_i \quad (4.3)$$

where A_i is the opportunities of block i , and P_i is the population within block i (see Equation 4.1).

4.4 Costs

The task of estimating the cost of a project is complex. Furthermore there is pressure to underestimate costs as the primary goal is to win a project. Once construction has begun, it becomes near impossible to switch companies at which point providing additional funding is easier than switching contractors. These issues were in-play in 19th century London. Flyvbjerg et al. ask the question of cost overrun in public works projects [14]. They find that the time period between the decision to build and the beginning of construction is particularly influential in cost escalation. The longer construction is postponed, the greater the costs escalate. Unfortunately the data for London in the 1800s is incredibly sparse and varies in form. As such a cost estimate from the time is used. Many variables for the time exist and are quantified in Flyvbjerg's work. Land values changed dramatically over the first decades of London Underground construction. These underground lines were the first of their kind in the world, adding to uncertainty about construction costs.

The cost model in Equation 4.4 is based on the estimate given in the era [1] that a typical double-track line cost £208,000 per mile (£174,000 per km).

$$C_{ij} = £174,000 * L \quad (4.4)$$

where L = length of the proposed line in km.

Over the period from 1863 to 1910, inflation fluctuated but the overall inflation was around 0% [45]. As such, inflation data was omitted from the cost model.

Figure 4.1 shows how the estimated costs compare to the proposed costs of unbuilt lines. As the model cost is based on an estimate from the time, it is likely that the

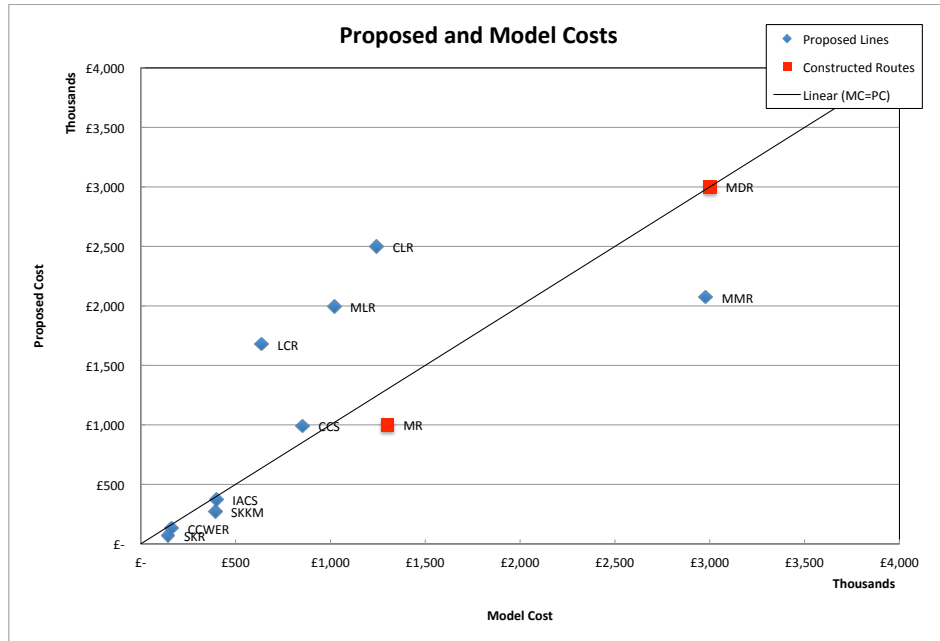


Figure 4.1: Proposed Cost versus Model Cost (£174,000/km)

estimate was relatively close to actual values. Figure 4.1 concurs.

Chapter 5

Results

5.1 Person-Weighted Accessibility

Table 5.1 shows that the most cost-effective choice for additions to the Underground was almost always chosen over the period 1860-1890. This shows cost efficiency based on a model of expected costs, not on the proposed costs that would have been submitted to Parliament at the time. From the table it is clear that the strongest indicator for success (construction) of a proposed addition to the London Underground is the percentage increase in PWA the project offers per pound spent. It has much less to do with the cost of the project in isolation. With almost no variation, the threshold requirements for Parliament to approve an addition to the network was around 20,000 additional opportunities per pound (£). Inflation remained constant over the study period with minor fluctuations allowing easy comparison.

5.1.1 Metropolitan Railway: Ridership and Revenue

The Metropolitan Railway opened to ridership levels much higher than expected. Demand forecasting has always been prone to error. Many late twentieth century urban rail projects in the US overestimated ridership, and as a result, many metropolitan planning agencies may have made different decisions were they to have accurately estimated actual ridership levels [47]. Generally ranges are better than single point estimates, though forecasting has usually produced and published the latter.

Table 5.1: Proposals and Implementations to the London Underground by $\Delta\text{PWA}/\text{£}$

Year	Name	Built	PWA	% ΔPWA	Length	Model Cost	$\Delta\text{PWA}/\text{£}$
1885	Population Incr.		10.40	7.30%	0.00	£0	inf
1864	MR Extension	1868	5.12	2.13%	1.98	£255,648	41,803
1872	District	1874	7.21	0.76%	1.10	£142,299	38,057
1885	London Central		9.77	1.11%	3.05	£393,811	27,362
1856	Metropolitan	1863	5.01	6.09%	5.50	£1,300,000	22,124
1885	KCCC & WS		9.78	1.22%	4.28	£553,300	21,336
1881	Mid-Metro Railway		9.73	4.09%	17.12	£2,213,019	17,264
1872	Mid-London Railway		7.28	1.77%	5.86	£757,646	16,717
1864	London Central Rwy		5.06	0.91%	3.66	£472,780	9,654
1885	MARC & CS		9.73	0.67%	5.23	£675,954	9,643
1885	CC & ER		9.69	0.29%	2.38	£307,049	9,270
1885	Islington & City		9.69	0.25%	2.29	£296,489	8,011
1885	SK & K & MAS		9.15	0.29%	2.26	£291,578	7,855
1881	E. London & Others	1884	9.73	4.01%	37.34	£4,826,437	7,762
1872	So. Kensington Rwy		7.16	0.08%	0.83	£106,844	5,096
1885	Clapham & City		9.68	0.17%	4.90	£633,303	2,593
1864	OS & CR		5.02	0.17%	3.80	£491,392	1,733
1881	Charing Cross & WE		9.35	0.01%	0.94	£121,555	1,104
1861	Pre-Underground		4.72		0.00	£0	

Notes: PWA x 10^{11}

Length in km

Bold indicates built proposal

Abbreviations:

OS & CR – Oxford Street & City Railway,

KCCC & WS – King’s Cross, Charing Cross & Waterloo Subway,

CC & ER – Charing Cross & Euston Railway,

MARC & CS – Marble Arch, Regent Circus & City Subway,

SK & K & MAS – South Kensington & Knightsbridge & Marble Arch Subway.

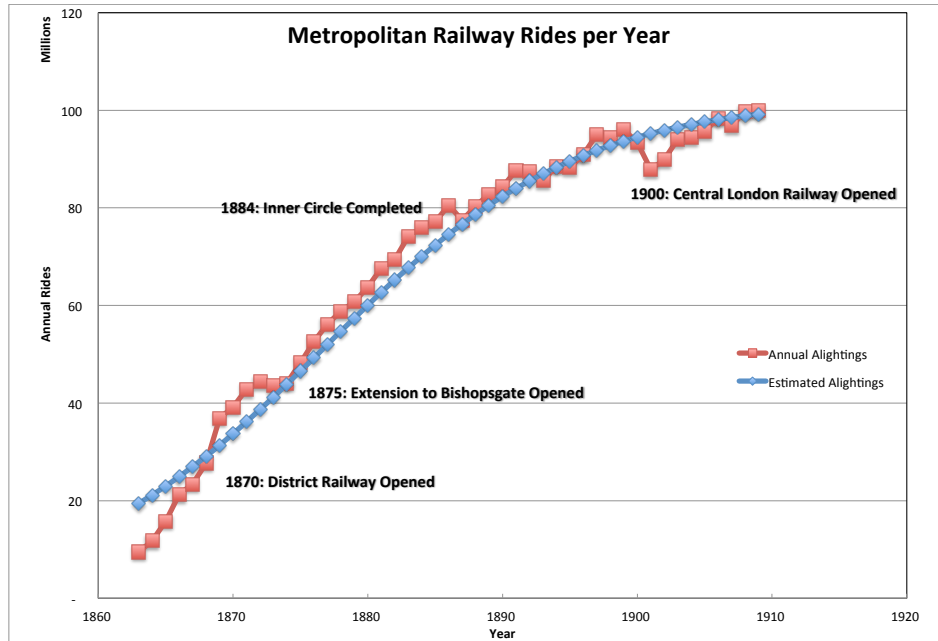


Figure 5.1: S-Curve of Metropolitan Railway Annual Ridership

The Metropolitan Railway would operate until 1933, at which point it was amalgamated. Data on annual ridership and revenue is reported through 1909. Figure 5.1 shows an S-Curve approximation of the maturation of the Metropolitan Railway in ridership. The actual ridership each year has some fluctuation. Perhaps most notably, a remarkable increase in ridership occurs in the years following the opening of the District line. Completion of the inner circle does not seem to bear as great an impact on Metropolitan Railway ridership. From Figure 5.1 it is clear that in 1909 the Metropolitan Railway was near maturity (about 100 million annual rides). Less than 15 years later the Metropolitan Railway company was consolidated into an integrated and publicly owned London Transport.

We posit Person-Weighted Accessibility is important because it explains ridership

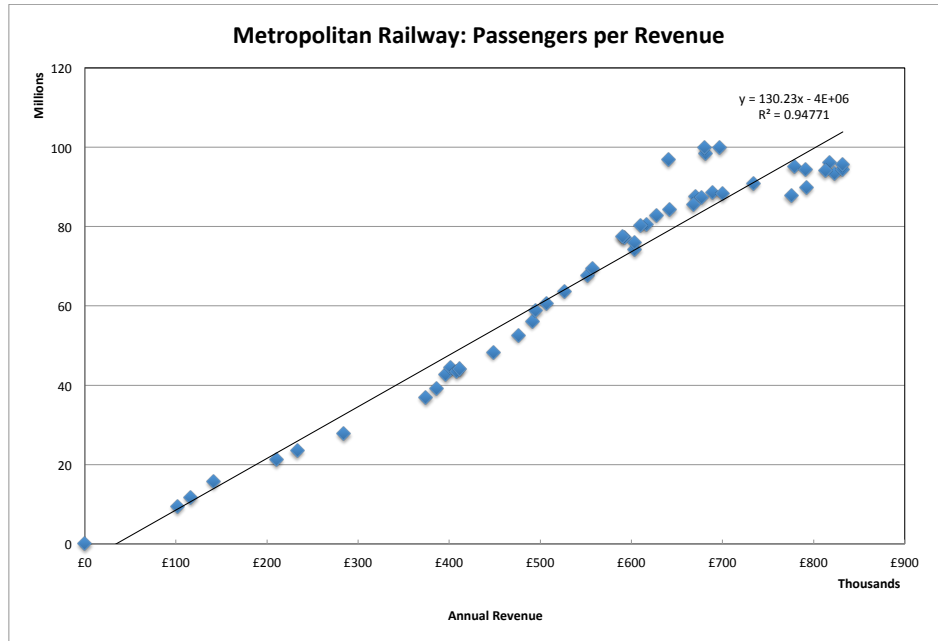


Figure 5.2: Annual Passengers v. Annual Revenue, Metropolitan Railway

and revenue. Figure 5.2 shows annual passengers over annual revenue for the Metropolitan Railway company. Figure 5.3 shows annual PWA over annual ridership. Figure 5.4 shows the change in annual PWA over the change in annual ridership. Change was calculated over study years. Figure 5.5 shows annual PWA over annual revenue. Figure 5.6 shows the change in PWA over the annual change in revenue.

5.2 Locational Accessibility

Figure 5.7 shows the accessibility in central London just before the Metropolitan Railway opened (early 1863). surface lines are shown, many of which lead near London but not too deep within the city. Figure 5.7 shows the potential demand for rail in the inner

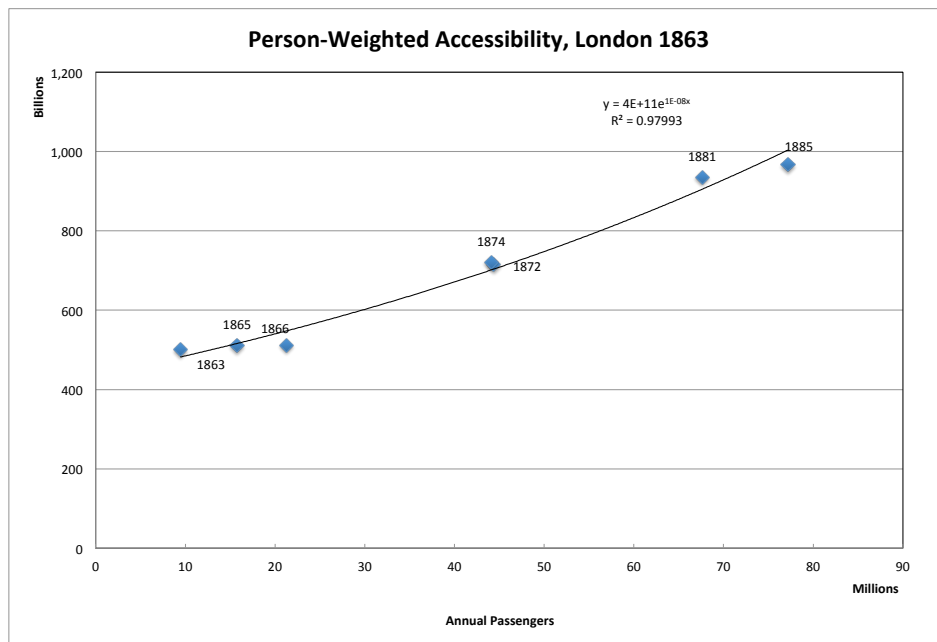


Figure 5.3: Person-Weighted Accessibility v. Annual Passengers, Metropolitan Railway

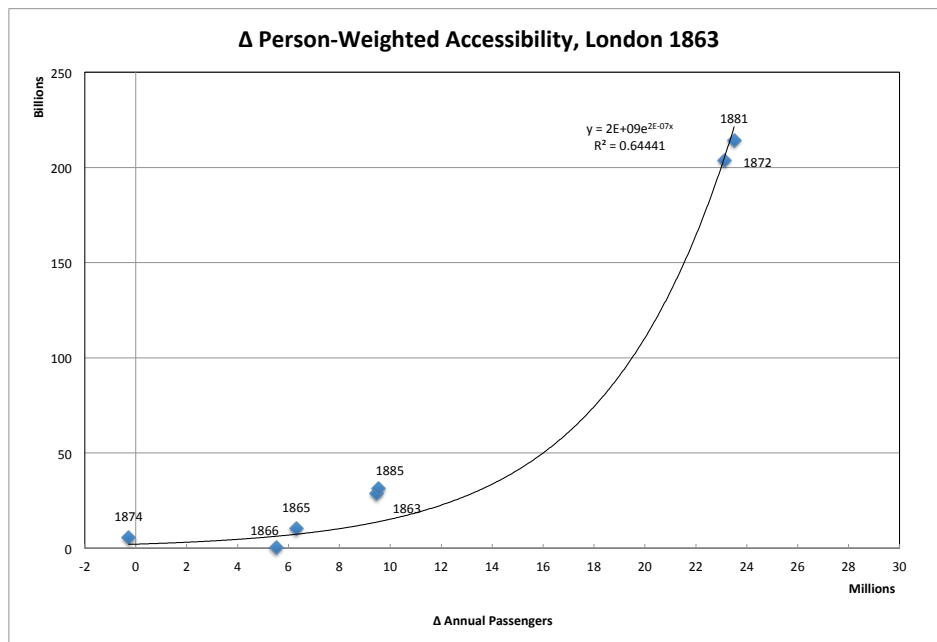


Figure 5.4: Δ PWA v. Δ Annual Passengers, Metropolitan Railway

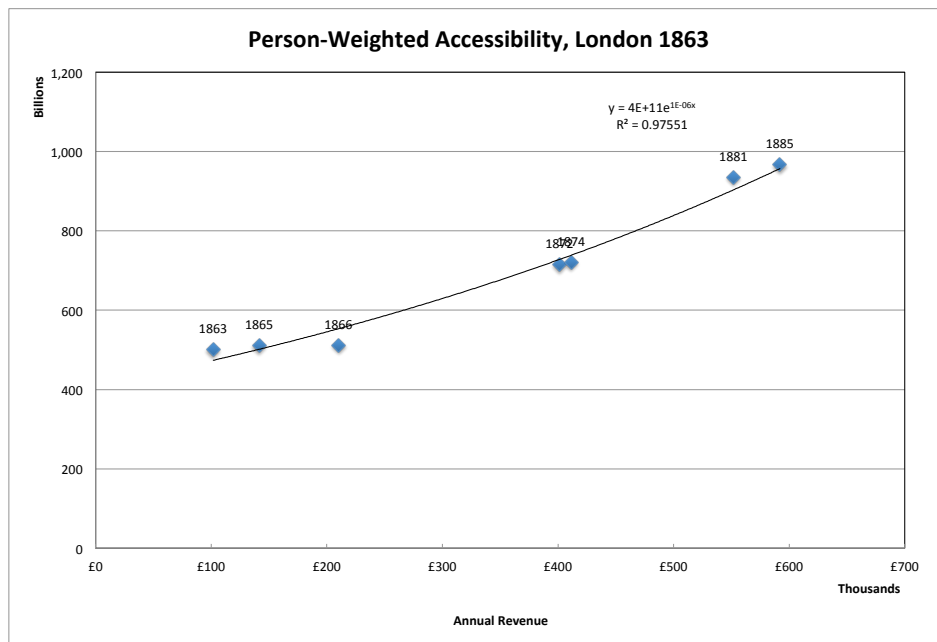


Figure 5.5: PWA v. Annual Revenue, Metropolitan Railway



Figure 5.6: Δ PWA v. Δ Annual Revenue, Metropolitan Railway

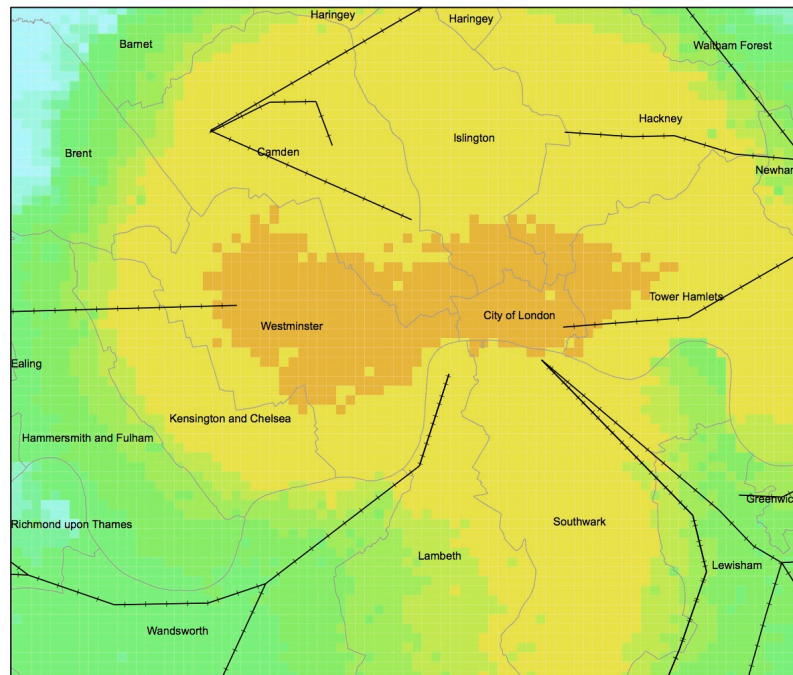
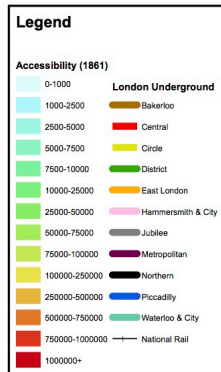
city, before any lines opened Underground.

Over the next decade, transport would drastically change in London (see Figure 5.8). Though these were not the lines in operation at the time, in all of these figures modern Tube map coloring is used to help identify relations of the early stages to the modern Underground network.

Figure 5.9 shows an inner circle that clearly indicates higher levels of accessibility around circle stations. As expected, the greatest accessibility is found along the northern half of what is now the inner circle. This was where the Underground began in 1863 with connections to the northern suburbs, particularly at the center of the original Metropolitan Railway. In the lower left of Figure 5.9 accessibility along what is now part of the District line is clear around stations as it travels out of the city.

In comparison with Figure 5.9, there are only minor changes with 1891 (Figure 5.10), with the most noticeable ones in the northern areas of Southwark. Part of the current Northern line is added, and the northern part of Lambeth also sees an increase in accessibility. The measurements are made with the populations of their time which changed between 1881 and 1891.

Accessibility 1861



Data Source:

Underground Network: Sanders, E. (2006) and Rose, D. (2000)

Projection: British National Grid



Figure 5.7: London Accessibility in 1861

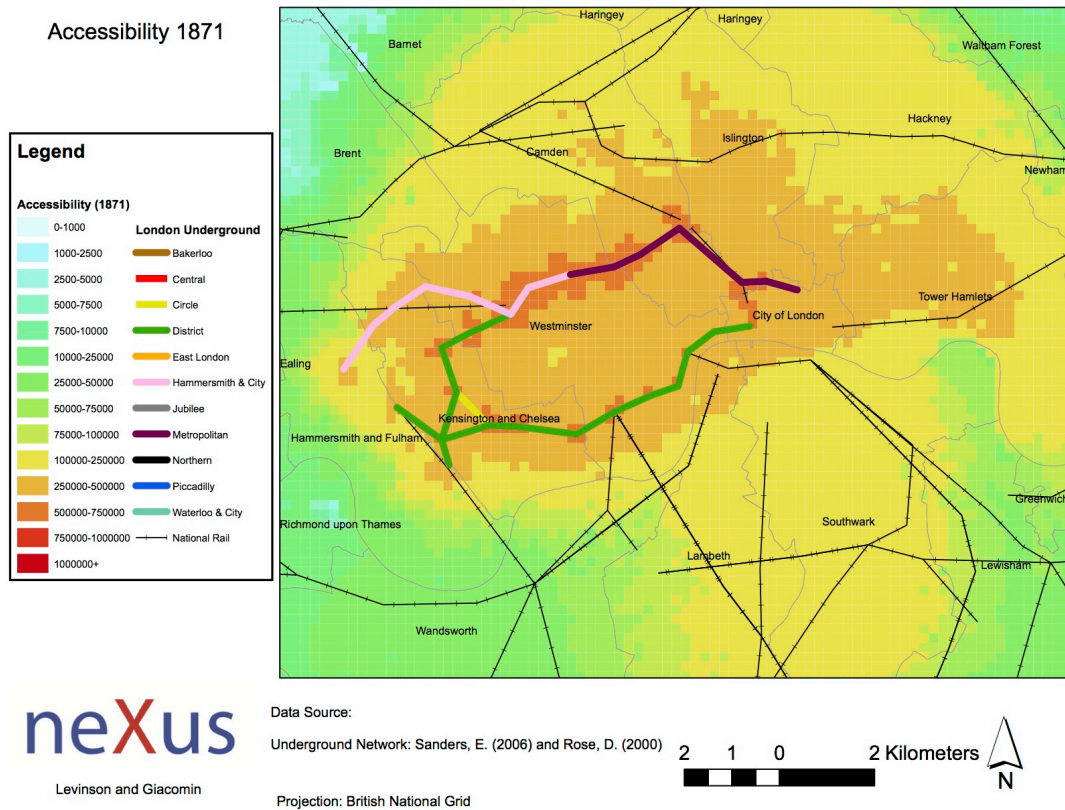


Figure 5.8: London Accessibility in 1871

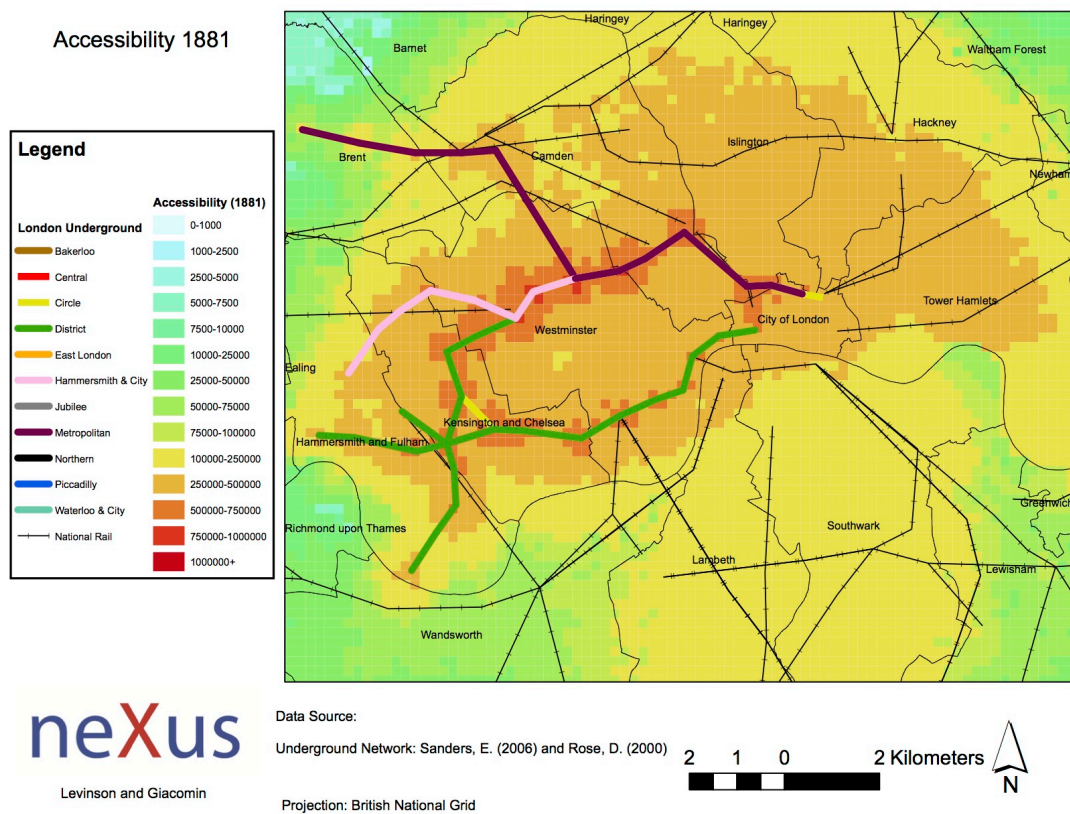


Figure 5.9: London Accessibility in 1881

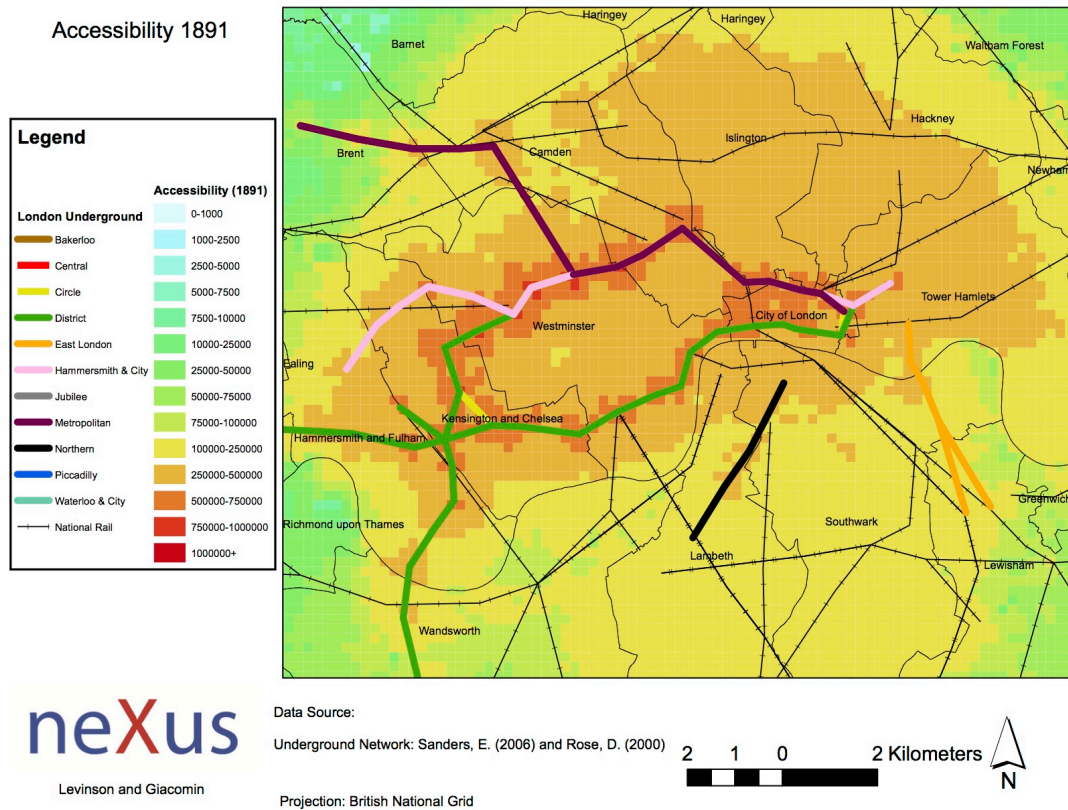


Figure 5.10: London Accessibility in 1891

5.3 Historical GTFS Comparison

The analysis above does not consider transit schedules in calculating accessibility, and thus assumes when individuals arrive at stations (or transfer points), a transit vehicle will be immediately waiting for them. However transit services are scheduled, so this likely overestimates the accessibility gain due to transit investments. This section uses a transit-based accessibility analysis to estimate the size of the error. Though it is more accurate, a disadvantage of this method is the higher data and computational burden. Many historical networks have missing data, and creation of GTFS data is unfeasible. Comparing the two methods (without and with schedules) allows transit agencies to compare the accessibility impact of a network’s ideal capacity (zero-wait) compared with actual or expected conditions.

For the original Metropolitan Railway line in 1863, a General Transit Feed Specification (GTFS) database was created [3]. The line ran at headways of 15 and 20 minutes depending on the time of day. The Open Trip Planner (OTP) analyst was used to calculate the accessibility for every minute during the morning peak [41].

Table 5.2 compares the person-weighted accessibility from this study with the methods used in Open Trip Planner Analyst for calculating accessibility. In the OTP Analyst, accessibility is calculated for every 200 m block in London. This data was then weighted by the population of each block to determine a person-weighted accessibility for every minute. Figure 5.11 shows an overlay of 20-minute and 15-minute headways on the Metropolitan Railway. The peak accessibility for the 20-minute headway (which occurred during the intervals 06.00-08.00, 20.00-24.00) is slightly higher than the lowest accessibility during the 15-minute headway (occurring 08.00-20.00). The time axis begins at 0:00 to identify when service of that type begins.

5.3.1 Walking Speed Sensitivity

The speed of pedestrian walking plays an influential role in the results of this study. As is consistent with previous literature, a walking speed of 5 kilometers per hour is used throughout. In a network with walking as the sole mode of transport, one expects the reachable area to approximate a circle. If destinations are homogeneous in an area, then the accessibility as a function of walking speed should increase according to Equation

5.1. Table 5.3 shows the accessibility results for London in 1863 with the Metropolitan Railway running at a 60-second headway.

Table 5.2: Open Trip Planner Analyst Comparison (1863)

Headway	PWA
20-min Peak	4.1495*10 ¹¹
15-min Peak	4.1630*10 ¹¹
1-min Peak	5.0097*10 ¹¹
No Transit - Open Trip Planner	4.0844*10 ¹¹
No Transit - 0-min Headway	4.7221*10 ¹¹

Table 5.3: Walking Speed Sensitivity (1863)

Speed	PWA
2.5 kph	1.0672*10 ¹¹
5 kph	4.3300*10 ¹¹
7.5 kph	9.1837*10 ¹¹

5.3.2 Time Threshold Sensitivity

Using a 30 minute threshold for commutes will include a majority of commutes actually experienced today. Data for commute times is unavailable for 19th century London. However there is a lot of evidence for travel time budget hypothesis [28, 35, 32], which would support using a 30 minute threshold. As such it is important to understand how the time threshold impacts person-weighted accessibility. Table 5.4 shows person-weighted accessibility for the existing 1872 network in London at a few different time thresholds.

$$A = \pi * s^2 \tag{5.1}$$

where s = walking speed.

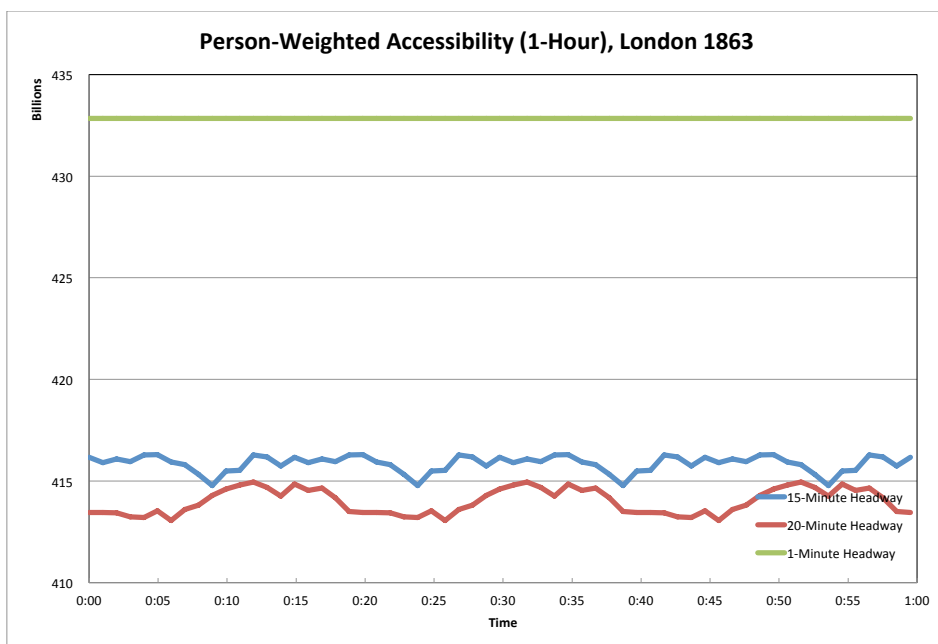


Figure 5.11: Metropolitan Railway PWA by Headway

Table 5.4: Time Threshold Sensitivity (1872)

Speed	PWA
20 minute	2.8327×10^{11}
25 minute	4.7207×10^{11}
30 minute	7.1544×10^{11}

Chapter 6

Conclusion

As the London Underground was the world's first subway, it provides a basis for network growth in transit networks. Today in many urban areas, transit is a way of life. The networks that exist influence travel behavior and destination choice. Businesses locate based on proximity to their clients and employees. Transit networks like the London Underground increase said proximity.

Such analysis as described in Section 4 was not possible in the 1800s. Simply put, Figures 5.7-5.10 could not have been generated, and the numbers behind them could not have been calculated. Odlyzko notes that the inclusion of gravity models could have made the British rail network much more efficient, and this could have lessened huge economic losses in Britain [44]. Had gravity models been considered in British railway mania of the 19th century, a greater focus may have been placed on local travel, namely travel within London. This could have greatly changed the development of what is now the London Underground.

Measuring accessibility at every location provides important qualitative maps to aide in understanding of the accessibility impact to an area. To do this, a more comprehensive measurement must be used. For this reason, the measure of person-weighted accessibility was used in analysis.

Often, the most cost-efficient increase in PWA to the Underground was chosen. This is pleasing to see, indicating that PWA may indicate the most desirable (or most frequently chosen) addition to a transit network. As the surface network changed over time, it influenced the accessibility impact of the Underground.

It is important to understand the cost of each project. In order to compare small additions to bigger projects, cost-efficiency can be measured. With the case of many proposals never seeing construction, it is possible that the quoted costs of the projects were wrong. Many may have been underquoted to increase the chance of Parliamentary approval. This would agree with some projects that were actually built, as it was common for projects to require additional funding during construction or simply stop construction short of the intended project goal.

For proposals that were never implemented, a cost estimate per kilometer is used to estimate the likely cost of the proposal were it constructed.

Another variable in analysis arises from how the cost of the projects actually built took place. In 1868, for instance, the Metropolitan District Railway ran out of funds and halted construction. Because of this, the proposed cost essentially equaled the actual cost, however the proposed distance of the line was longer than the actual distance. As many variables exist in cost estimation, the estimate from 1885 was used.

At the time, many aspiring London investors wanted to be first-movers in this newly discovered industry of Underground transportation. This is evidenced by the large number of proposals brought before Parliament for consideration. Funding was often a factor that silenced many proposers. Had the measures of PWA and accessibility been around in the 1800s, discussion regarding proposals for additional metro links could have been far more quantitative. Their proposals are discussed in the appendix.

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Chapter 7

Appendix

The proposals considered in this study are those diagrammed in London's Lost Tube Schemes over the first few decades of London's Underground system. There were more proposals than just those in the book. The proposals that were included in the book were primarily that it was a tube railway tunneled at depth. This could include tunneled railways with cut and cover stations. Most of these fell along an east-west axis along Oxford Street or a north-south axis between Euston and Charing Cross. Such proposals are detailed in the following subsections.

7.1 The Metropolitan Railway

The plan for the Metropolitan Railway was originally approved in 1855. In the following years, funding would be secured and construction began in 1860. Upon completion, the total cost was £1,300,000, exceeding original expectations. Yet the line opened to great success, and many more proposals would be considered in subsequent years.

7.2 Proposals of 1864

The year following the opening of the Metropolitan Railway saw considerable interest in Underground lines. A few received serious consideration, including the London Central Railway and the Oxford Street and City Railway. The London Central Railway was to run a line from roughly Charing Cross up to King's Cross via Goodge Street,

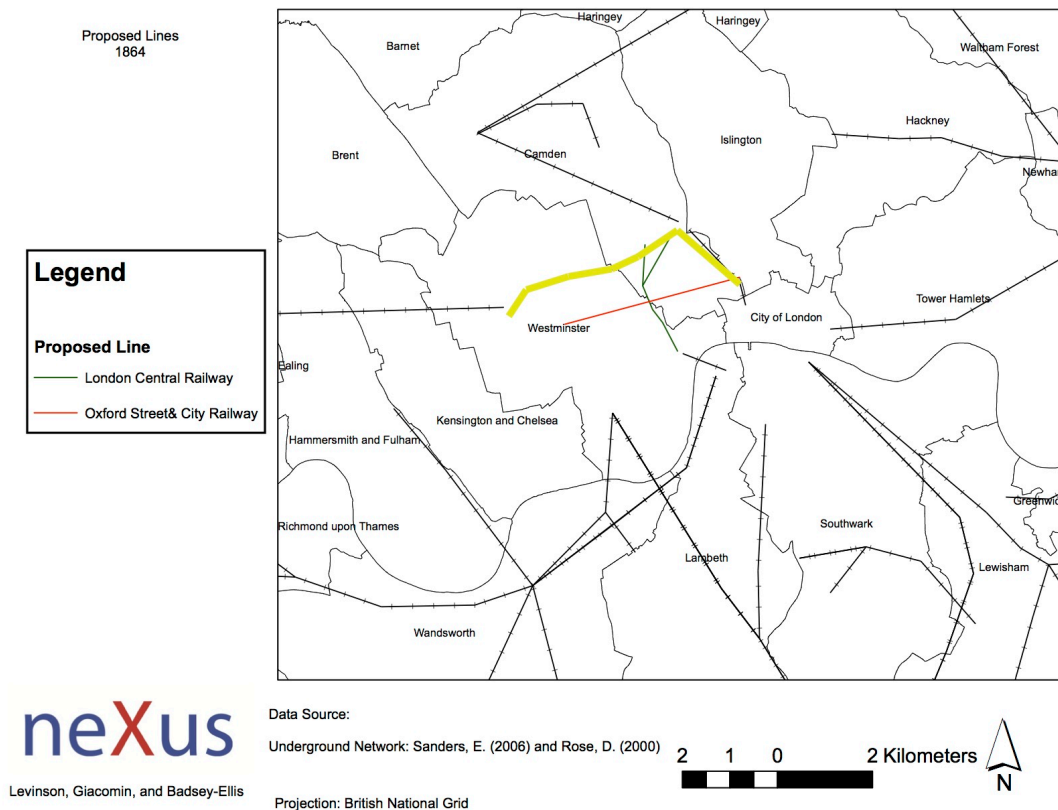


Figure 7.1: Proposed Lines of 1864

with another end point at Euston. The Oxford Street and City Railway was to run a line from approximately present-day Marble Arch to Farringdon. Both proposals failed, and ultimately an extension of the inner circle would be built. Specifically the lower west portions from Paddington around to Westminster. An extension east of the Metropolitan Railway was also made. The proposals of 1864 are shown in Figure 7.1.

7.3 Proposals of 1872

Only a few proposals made it to a point of serious consideration. The proposals of 1872 are shown in Figure 7.2. Among those that failed were the Mid-London Railway and the South Kensington Railway. The South Kensington Railway was only a minor

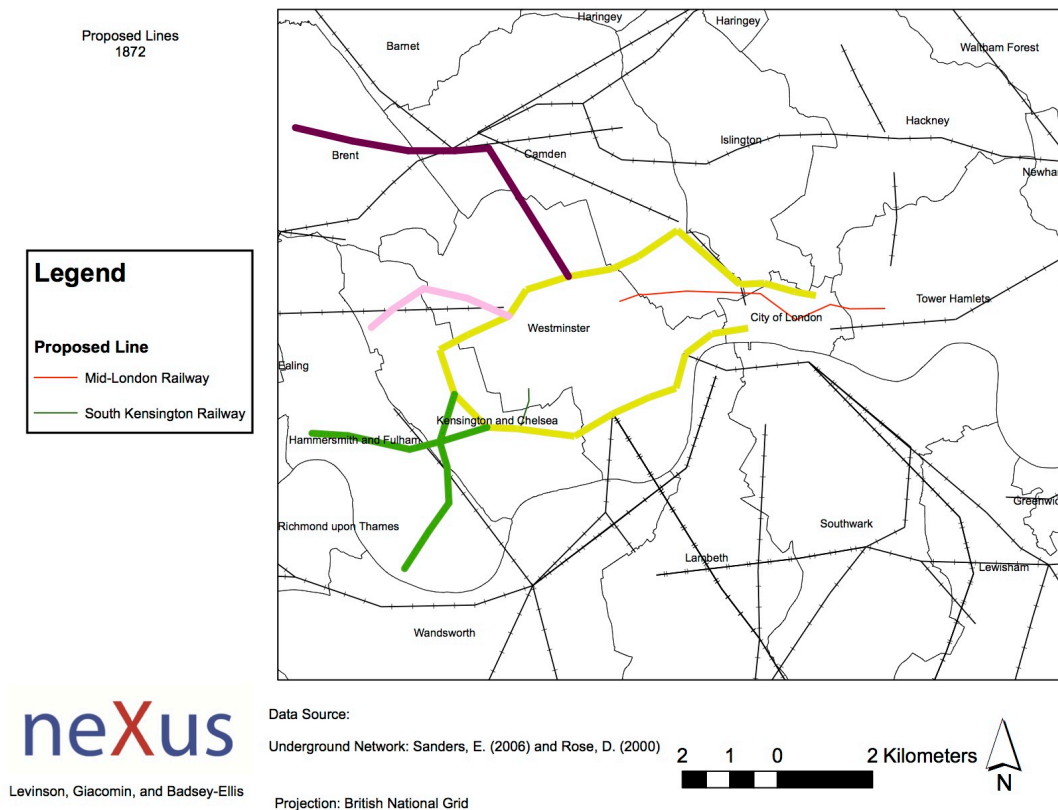


Figure 7.2: Proposed Lines of 1872

addition, adding a few stations north of South Kensington. The Mid-London Railway was a larger line to be operated east of Aldgate East over to just north of Oxford Circus with many stops along the way. Portions of this line would ultimately be picked up in later stages. At the time, only a few extensions to the network would be made.

7.4 Proposals of 1881

In almost every year with digitized proposals, the most cost-effective proposal at increasing person-weighted accessibility was chosen. The only exception was in 1881. The year 1881 was also abnormal in the sense that many lines were constructed in the subsequent years, and likely were all parts of separate proposals. Another important point is

that the East London Line (one of the larger additions) was a multi-purpose line. The East London Line carried freight and was built to surface line standards. It is possible that this additional objective decreased the accessibility impact of the additions from 1881. In other words, the “implementation” of 1881 was not as simple as that of other years. Additionally, the only digitized proposal that had a more cost-effective increase in accessibility was the Mid-Metropolitan Railway, which consisted of three lines. It was more like a set of proposals all under one name. One of the lines started at Shepherd’s Bush in the west and ended by Aldgate in the east. The second was a simple connection between Westminster and Paddington with stops along the way. The third was a short radial line from Marble Arch to South Kensington. In either case, this most cost-effective increase proposed in the form of the “Mid-Metropolitan Railway” was not as good as any of the other implementations before it’s time. In fact, the only analyzed implementation after it’s time had an increase in efficiency merely as a result of population increase. The decades following the introduction of the Metropolitan Railway were booming for Underground rail in London, and with many additions occurring in short time it can be difficult to quantify the benefit of individual projects. The proposals of 1881 are shown in Figure 7.3.

7.5 Proposals of 1885

Many proposals were digitized in 1885, more than any other study year. None were chosen. As a result of sheer population increase, person-weighted accessibility increased in London by 7.3%. Figure 7.4 shows the proposals of 1885.

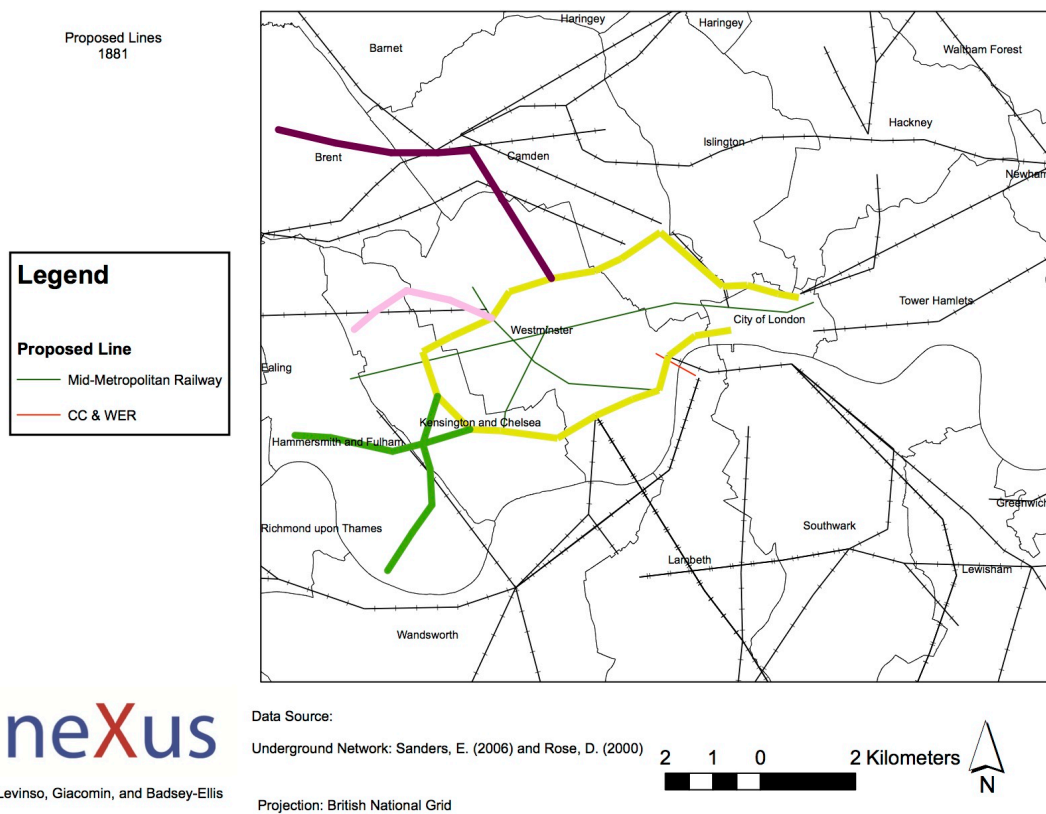


Figure 7.3: Proposed Lines of 1881

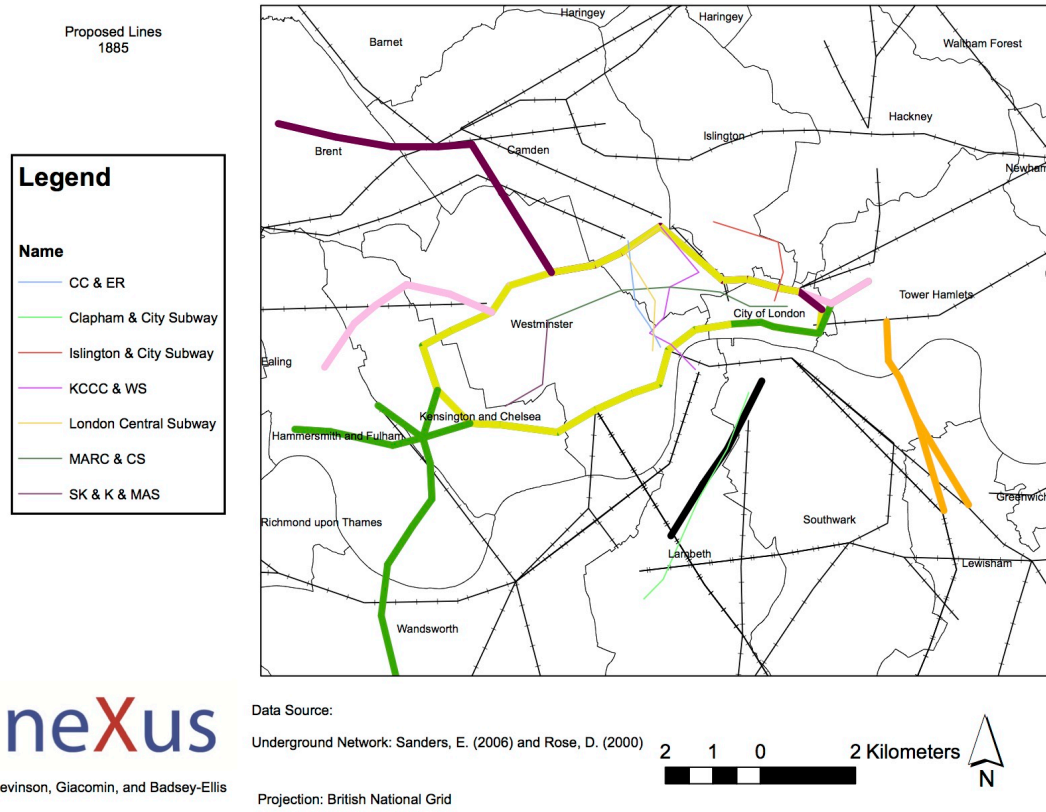


Figure 7.4: Proposed Lines of 1885