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The Eighth Wonder of the World: How might access for vehicles have prevented the economic failure of the Thames Tunnel 1843-1865?

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Introduction

Marc Brunel's Thames Tunnel was the world's first subaqueous tunnel and spurred an innovation revolution. Built between Rotherhithe and Wapping in the East of London, the 1,300 feet tunnel ran beneath the river bed and connected the shores which the River Thames cut in two and provided a transport link that was desperately needed in this area, given the high level of trade which occurred in the nearby docks. It was not the first attempt at constructing an underwater tunnel in London- Ralph Dodd, Robert Vaszie and the notable engineer Richard Trevithick had all previously tried and failed[1]- and Brunel's success in doing so was hailed an engineering triumph. Yet this triumph did not come without serious delay; floods and financial issues caused construction of the tunnel, which Brunel estimated would take between two and three years to complete,[2] to take eighteen years in total.

The Thames Tunnel was labelled the "Eighth Wonder of the World" by contemporaries and has been hailed as the first great innovation in modern day tunnelling. The tunnel's most important innovation was Brunel's shield. The shield- 38 feet wide by 22.5 feet high, containing 36 cells in twelve frames over three levels3- became the prototype for all future shield construction. Adaptations by Peter Barlow and James Greathead have been credited with the birth of London Underground, the world's first underground railway, and thus London's greatest source of public transport.4 More recently, elements of Brunel's shield were present on the digging shields used during the construction of the Channel Tunnel. It is evident that the Thames Tunnel had a significant impact in terms of innovation.

However, in terms of the short run effects of the Thames Tunnel and the original aims that the Thames Tunnel Company and Brunel set out to achieve, the tunnel was a financial and conceptual failure. Between the years 1843 and 1865 the tunnel operated as a pedestrian transport service, became a great source of tourism, but fundamentally failed to make profit.[5] Consequentially it was sold to the East London Railway Company in 1865 for £200,000, just twenty two years after its completion.[6] The tunnel proved to be more prosperous as part of the railway system and is still a part of London Underground today.

[1] West, *Innovation and the Rise of the Tunnelling Industry*, pp.104-105.
[2] Brunel, *A New Plan of Tunnelling, calculated for opening a Roadway under the Thames*, p.3.
[3] Thames Tunnel Company, *An explanation of the works of the Tunnel under the Thames from Rotherhithe to Wapping*, pp.12-13.
[4] Day, *The Story of London Underground*, pp.29/40.
[5] Lampe, *The Tunnel*, p.212.
[6] Pike, *"The Greatest Wonder of the World"*, p.360.

One of the main reasons believed to have caused this failure between 1843 and 1865 was the inability to provide access for vehicles, part of the original plan devised by the Company. Whilst a roadway to enable vehicular transport was constructed within the tunnel, the ramps to provide access for vehicles did not materialise due to lack of funds. It is believed that the level of vehicular traffic that would have passed through the tunnel on a daily basis would have been large owing to the high trading activity surrounding these areas and the need to transport goods between the North and South side of the river, intensified by limited communication links. This underwater crossing was highly desired by the businesses in the docks and many scholars of the Thames Tunnel, including Lampe in *The Tunnel* and Pike in *The Greatest Wonder of the World*, have stated that had the carriage ramps materialised the tunnel would have been a commercial success.

Although scholars have argued the tunnel would have been a commercial success had it provided access to vehicles, no attempts have been made to quantify this view. This is what this paper aims to achieve as a way of delving further in to the full extent of the carriage ramps' absence. It is hoped that the quantitative analysis used will facilitate a greater understanding of whether this viewpoint is valid.

This paper is structured in the following way: Section 1 outlines the hypothesis proposed and how I intend to determine whether it is valid; Section 2 outlines the historical context of the question; Section 3 outlines the historiographical context of the question; Section 4 outlines the methodology and data used; in Section 5 the quantitative findings are presented and analysed; in Section 6 a conclusion of the findings is drawn and Section 7 contains a bibliography of the primary and secondary sources used.

Section 2: Hypothesis

In this paper I propose one key hypothesis concerning the nature of carriage ramps and their impact on the Thames Tunnel, and intend to find a conclusion for this hypothesis using a counterfactual.

Hypothesis:

The building of the proposed carriage ramps which had been a part of the original plan for the Thames Tunnel would have created a positive cost saving for vehicular traffic, increasing the tunnel's usage thus revenue to a level which would have prevented the tunnel's subsequent financial failure.

I attempt to validate this hypothesis with the use of a counterfactual; I calculate the monetary and nonmonetary (time) costs to vehicles using the proposed Thames Tunnel and London Bridge, the next best alternative, to find a generalised cost for the transportation of goods between shores in the East. From this generalised cost, I find an estimate of the cost saving for the use of the Thames Tunnel as opposed to London Bridge. A positive cost saving indicates this new innovation would have lowered the overall cost of transportation, and thus travel via the tunnel is likely to have been large. This additional usage would have generated higher revenue for the Thames Tunnel Company, and if large enough would have prevented economic failure. Thus from the cost saving and recorded vehicle levels across London Bridge I provide an estimate of revenue and profit in terms of total construction cost, and from this infer whether prevention of financial failure is plausible.

I will outline my methodology and data more extensively in Section 4, but I would like to briefly note the possible flaws to my findings, but also how these flaws are justified in reaching a conclusion of the hypothesis.

Arguably, the most obvious flaw in this study is the use of a counterfactual. The plausibility of a counterfactual is always questionable given that it is contrary to fact, and any evidence gathered will purely be an estimate; thus, like the many social saving papers concerned with the economic importance of railways, these estimates will be very dependent on the assumptions which I make.[7] I therefore argue that in the case of my hypothesis, the actual numbers which are found are not of sole importance; they are more an indication as to what might have occurred rather than unadulterated fact. What I aim for this paper to achieve is a more refined understanding of something which is perceived to be conclusive.

Section 2: Historical Context

During the nineteenth century the metropolis was constantly transforming and became central to British trade. In the east, the docks were one of the most important industries on both sides of the shore, with copious amounts of trade occurring between the shores and the docks themselves given the specialisation and monopolisation of certain goods. In 1841, 646 steamers cleared 154,470 tons of foreign trade from London's docks, 40.4% of the total in England,[8] a clear representation of their scale and prominence. Trade flows were particularly important from the north side to the south,[9] and made a cheap and efficient source of transportation highly desirable. At the time of the construction of the Thames Tunnel there were two means of crossing the river in the East: London Bridge, accommodating vehicular and pedestrian traffic, and watermen/lightermen, providing a service to pedestrians (who, according to Flack, transported 3,700 passengers from Wapping across the river on a daily basis[10]) as well as a small amount of cargo.

[7] Leunig, *Social Savings*, p.792.
[8] Jackson, *The Ports*, p.233.
[9] Knight, *London,* vol.3.
[10] Flack, *Brunel's Tunnel and where it led*, p.2.

Congestion became a growing problem, owing to this lack in communication links. Vehicular traffic across London Bridge, according to Ball and Sunderland, was halted to walking pace.[11] This congestion caused delays and hence increased costs, affecting the circulation of the metropolis, something which was certain to intensify without the establishment of other transport avenues.

It is evident that, due to the rise in trade and population growth London experienced in the mid-nineteenth century, a new means of communication between the North and South of the river in the East was needed- with Brunel's tunnel the first to do this. His tunnelling innovation was of increased importance given the impracticality of building a bridge in this area due to the volume and size of ships passing through the docks.[12]

The tunnel encountered a number of major problems in construction, such as the array of unexpected costs not accounted for in original calculations. Brunel's financial estimates at the start of the project were naïve as he estimated the total cost at no more than £160,000, leaving £180,000 to be collected from private shareholders.[13] The extended time needed to complete the tunnel greatly increased costs. After the floods of 1827 and 1828, funds had dried up and construction would not have continued without the government loan of £246,000 in 1834,[14] which was further extended to £374,000 in 1837[15] in order for the tunnel's completion. It was these unanticipated costs and unexpected length of construction which made the construction of vehicle ramps, estimated to cost around £200,000, implausible.[16]

Given the lack of funds available to enable vehicular traffic between the years 1843 and 1865 the tunnel functioned primarily as a pedestrian tunnel. A year after opening on 5th March 1844 it was recorded that 2,038,477 people had passed through the tunnel[17]- as well as transporting commuters, the tunnel became a major site for tourism, highly unlikely in this part of the city. Yet despite this level of pedestrian traffic, the 1d toll which was paid for its use was not enough to pay the costs of running the tunnel as well as its shareholders; by 1865, when the tunnel had become a home for the criminals and prostitutes of the East End, selling the tunnel had become the only feasible option.

By 1869 the tunnel was in use again as part of the East London Railway and facilitated the movement of both commuters and goods between Rotherhithe and Wapping. The railways and underground network in London continued to expand throughout the nineteenth and twentieth centuries, bringing even greater change to the metropolis. Brunel's shield became the "prototype" of this deep level tunnelling.[18] By forming a circular shield as Brunel had envisaged in his patent of 1818, Barlow and Greathead were able to improve its mechanisms- producing faster, cleaner and less strenuous digging, forming a great deal of the London Underground which is still functioning

[11] Ball and Sunderland, *An Economic History of London; 1800-1914*, p.230.
[12] Lampe, p.215.
[13] Overman, *Sir Marc Brunel and the Tunnel*, p.34.
[14] Noble, *The Brunel's: Father and Son*, p.77.
[15] Wood, *The Thames Tunnel 1825-43*, p.138.
[16] Walford, *Old and New London*, vol 6.
[17] Lampe, p.206.
[18] Ibid, p.215.

today.[19] The Thames Tunnel is still in use daily between Rotherhithe and Wapping stations on London Overground and is the oldest part of the London Underground network.[20]

It is clear that a means of communication to transport goods between the docks of London was highly desired and given the limited modes of transport, access for vehicles through the tunnel is likely to have yielded positive outcomes to both vehicular traffic and the Thames Tunnel Company, and may have been great enough to have prevented the Tunnel's economic failure. Given its historical context I believe my hypothesis is relevant and that the application of a counterfactual to attempt to quantify the extent of the carriage ramps' absence is worthwhile.

Section 3: Historiographical Context

This historiography is broken down into two parts. Firstly, I assess the scholarship surrounding the Thames Tunnel and how I add to this knowledge. Secondly, I analyse the application of counterfactuals in railway analysis and the effectiveness of this form of study, and the application and adaptation of the technique in this paper.

Section 3.1: Literature on the Thames Tunnel

Whilst there was a wealth of information recorded by the Thames Tunnel Company, with many of these documents still in existence, much that was documented took place during the construction of the tunnel and few records survive from the period thereafter; making it difficult to estimate some of the costs and savings included in my counterfactual. In *The Origin, Progress & Completion of the Thames Tunnel and the advantages likely to accrue from it*, it is noted the expense of the Tunnel was much greater than expected with expenditure equalling £446,000, as opposed to the £160,000 estimated by Brunel.[21] In an earlier report, *The Origin, Progress & Present State of the Thames Tunnel,* the Company likened the use of the tunnel to a bridge; noted the net revenues of London's less congested, toll-operating bridges (£14,000 per annum for Waterloo Bridge and £8,500 per annum for Vauxhall Bridge) and acknowledged the expectation of similar revenues for the tunnel.[22] This report was written in 1827 and thus envisaged the tunnel's accommodation of vehicles. Although this report lacks certain information on these bridges, such as the price of tolls for vehicles in place and numerical data on traffic levels, which may have made their argument for similarities between the functioning of the bridges and the tunnel stronger, it is useful in the sense that it gives an understanding of how the tunnel would have operated had the carriage ramps come to being. An important primary source from the Thames Tunnel Company

[19] Harding, *Developments in Shield Tunnelling*, pp.17-18.
[20] Dwyer, *The Impacts of the railways in the East End 1835-2010*, p.69.
[21] Thames Tunnel Company, *The Origin, Progress & Completion of the Thames Tunnel and the advantages likely to accrue from it*, p.14.
[22] Thames Tunnel Company, *The Origin, Progress & Present State of the Thames Tunnel and the advantages likely to accrue from it*, pp. 23-25.

which I rely on in some of my calculations is *The letter addressed by the directors of the Thames Tunnel Company to the Commissioners for the Issue of Exchequer Bills for Carrying on Public Works, applying for a loan to complete the body of the tunnel*. This letter provides useful calculations performed by the company in terms of costs and expected costs, and also alludes to important data on traffic numbers across London Bridge, which I utilise when making my estimates. Greater analysis of this source is given in section 4.

Next I consider the scholars of the Thames Tunnel. Whilst the literature on the Thames Tunnel is quite limited, there are a few in-depth studies of Sir Marc and the Tunnel; with most commenting on the inability to provide access for vehicles. Whilst some, such as Bagust, simply note the inability to raise funds to make the "wheeled traffic approach" viable[23] others go further. Wolmar called the failure to build access for vehicles a "big mistake"[24] and Lampe stated that the tunnel was "a commercial failure as little was done with the carriage ramps".[25] Pike brings this view further stating that whilst the Company tried to encourage the "arcade identity" of the tunnel to attract necessary investment, this identity would have been needless had the carriage ramps materialised, establishing the importance that has been placed upon them. Work by Portman provides some crucial evidence from the Clerk of the Company, Joseph Chartier, such as his calculations of the cost of maintenance of the tunnel and his preliminary predictions of revenue,[26] which I discuss in greater detail in section 4 and adapt in my own estimates.

What these studies do not question is how, if an investor/investors/the Treasury had foreseen the necessity of and provided the funds for the carriage ramps, this would have changed the economic position of the tunnel. Some note that it would have increased revenue, but no one has yet attempted to see by how much. I believe a quantitative analysis of this expected revenue is worthwhile, and my estimates should add further support to this argument or call its credibility into question.

A conflicting point within the literature is the actual cost of the Thames Tunnel upon completion. It is essential to establish which of the different costs given is most reliable as this is central in my computation of profit as a percentage of total construction cost, and hence the ramps' importance. The Thames Tunnel Company stated the cost at £446,000,[27] Bagust as £454,810,[28] but the most common price given was £614,000 (broken down in terms of wages paid to staff, cost of land purchase, materials and so on). It is the latter estimate which I use. I believe there are limitations to the cost given by the Thames Tunnel Company as it was a premature estimate and it is also plausible to believe the Company may have announced a lower bound cost, enhanced by the continuing need to attract funding for the carriage ramps. Bagust, a great admirer of Brunel, also appears to have provided a lower bound estimate. He attempts to measure the income generated from tourism, and found income generated from admission and sales of books

[23] Bagust, *The Greatest Genius?*, p.99.
[24] Wolmar, *The Subterranean Railway*, p.100.
[25] Lampe, p.206.
[26] Portman, *The Thames Tunnel: A Business Venture*, pp.38-40.
[27] Thames Tunnel Company, *The Origin, Progress & Completion of the Thames Tunnel and the advantages likely to accrue from it*, p.14.
[28] Bagust, p. 96.

within the tunnel reached £468,250 by December 13th 1844. Given his total cost, this showed that in just twenty months the company was back in profit. This goes against all other literature concerning the Thames Tunnel and Bagust fails to give any reference from where his data was collected; making his calculations appear inconsistent, and thus unreliable. The breakdown of the costing which amounts to £614,000 appears to be far more comprehensive and reliable in terms of how the figures have been gathered and thus I consider it to be most accurate.

Section 3.2: The Literature of Railway Counterfactuals

There have been a number of counterfactuals concerning the impact of railways on the growth and development of given countries, with Robert Fogel devising the very first counterfactual as a means of estimating the economic impact of the American railroads in *Railroads and American Economic Growth*. From his counterfactual and those of Hawke (1970) and Leunig (2006) on the impact of British railways, I highlight the benefits and flaws of each of their approaches and discuss how I adapt and apply their methods to my own counterfactual.

Fogel was the first in any discipline to use a counterfactual and so his method is of great use to my study. I adapt Fogel's calculation of the "social savings" of the railroads to calculate the cost savings of the Thames Tunnel's carriage ramps. Fogel calculated the social saving of railroads as the "difference between the actual cost of shipping agricultural goods in a given year and the alternative cost of shipping exactly the same collection of goods between exactly the same points without railroads".[29] As well as calculating the cost saving of the use of railroads as opposed to canals, he also accounted for time saving and the comparable accessibility of railroads, a social saving totalling 4.7% of GNP for the year 1890. Unlike Fogel, my cost saving shall not account for the precise collections of goods, given that, as the goods transported in my counterfactual are likely to be of extremely similar weight, the importance of this measure is negligible. A crucial part of Fogel's study to my own calculations is the inclusion of time saving, with the greatest saving of the tunnel being time, given the four mile reduction in distance travelled.

There have been a number of criticisms of Fogel's estimates. It has been argued that his estimates are crude, given the amount of assumptions made,[30] which is something I am likely to encounter but something I hope is viewed as logical and justified given the nature of the study. McClelland provides a strong criticism of Fogel and his method. His criticism of Fogel's assumption that the marginal cost of the previous technology remains constant between old and new output levels[31] is something I consider in terms of issues such as congestion and the additional costs which must be added to account for this. McClelland also criticised the assumption that price is equal to marginal cost, and Fogel's failure to justify this assumption.[32] Despite the possible problems of this assumption, it may be justified by the limited data available on marginal cost, a justification I rely on for some on my own assumptions.

[29] Fogel, *Railroads and American Economic Growth*, p.208.
[30] Atack and Passell, *A New View of American History*, pp.450-451.
[31] McClelland, *Railroads, American Growth and the New Economic History*, p.115.
[32] Ibid, p.114.

Although Fogel's raw statistics have been criticised, what his results indicate- railroads were not indispensable from American economic growth- is the crucial importance of his study. Further studies have since taken place to extend his work and his view has become widely accepted by scholars. He argued that the main contribution of social savings studies has been to "provide a more detailed and somewhat more precise analysis of the nature of the [transport] revolution".[33] Leunig supports this point, stating that the wealth of the invention of social savings is in its ability to add "a value on an innovation" such as railways.[34] This is the desired aim of this paper- whilst the assumptions made may cause results to be crude, what is hoped is they can provide quantitative integrity and greater detail to a well-established viewpoint or present the possibility of rebuke, as well as a step for further research of this kind.

Hawke follows Fogel's social savings method in his study of the railways of England and Wales and their impact on economic growth. To support the belief that railways were cost-reducing and market widening, Hawke considered the costs and charges of rail versus other forms of transport, and found social saving for multiple years from the mid-to-end of the nineteenth century, calculating social savings of 0.7% in 1855, rising to 4.7% in 1890, possibly as high as 14.2%, as a percentage of national income.[35]

Gourvish provides a critic of Hawke's findings. Although he too believed railways brought "a marked improvement in the reliability of freight movement" he has noted that Hawke's estimates have been widely ignored in later studies on British railways owing to the range of flaws present.[36] Gourvish conducted his own estimates to indicate the "frail" and broad nature of Hawke's results for the year 1865. He found a "high" social saving of £147.3m and a low estimate of £17.1m compared to Hawke's finding of £42.5-76m.[37] He argued that Hawke used too slim a database and that his cost-benefit technique was more suited to an individual project than an entire industry over a number of years. I believe my study will too suffer from the use of a slim database, owing to a lack of available data and whilst it will clearly weaken my results I am limited to the sources available. However, as this paper does focus on an individual project, the subsequent drawbacks experienced by Hawke should reduce some limitations in my findings, and the cost-benefit technique is more applicable. Gourvish noted that "while Hawke has extended our understanding of the impact of railways, his social savings arithmetic is hard to use".[38] This is similar to the criticism of Fogel, but I must once again stress the worth of these studies, despite their numerical flaws, in their ability to increase understanding in a new form.

Leunig's recent study of the British railways extends the work of Hawke. He stresses the importance of the inclusion of a value of time saving in a social savings estimate, referencing Boyd and Walton's extension of Fogel's work, which proved that although canals were cheaper, passengers chose to travel by rail given its additional nonmonetary value.[39] Leunig calculates a value

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[33] Fogel, *Notes on the Social Savings Controversy*, p.48.
[34] Leunig, *Social Savings*, p.789.
[35] Hawke, *Railways and Economic Growth in England and Wales 1840-1870*, pp.88-89.
[36] Gourvish, *Railways and the British Economy*, p.9.
[37] Ibid, pp.36-37, 58-59.
[38] Gourvish, *Railways 1830-70*, p.82.
[39] Leunig, *Time is money*, p.639.

of the time saved from the average speed of transport, the number of hours saved and the value of one hour of time saved. By adjusting Hawke's figures and adding the value of time saved, he calculates a social saving of 2%, 5%, 10% and 14% of GDP for the years 1850, 1865, 1900 and 1912 respectively; with the value of time saving increasing and overtaking the value of money saving with time.[40] Leunig's study and representation of the value of time saved provides critical support to this paper, as the value of time saved is monumental to the belief that an ample amount of traffic would have been diverted from London Bridge towards the Thames Tunnel.

Section 4: Methodology and Data

The main method I use in my analysis of the hypothesis proposed is a counterfactual to determine the cost saving access for vehicles would have yielded on those transporting goods between the North and South side of the river in the East of London, and from this a prediction of the number of vehicles which would have chosen to travel along the Thames Tunnel. By determining the revenue of said vehicular traffic I infer whether the revenue and profit generated would have been large enough to prevent economic failure.

My cost saving calculation considers the cost of transporting a cart or wagon of goods from the entrance point of the tunnel at Wapping to the entrance point of the tunnel at Rotherhithe via the Thames Tunnel and London Bridge, combining both an estimate of the actual cost of travel and a cost measurement of time taken. A positive cost saving would indicate the tunnel was of economic benefit to these carts and wagons and would therefore have been a better choice of transportation. From this cost saving, I also determine an estimate of how many of the actual journeys made daily across London Bridge would have chosen the Thames Tunnel as an alternative means of travel, had it existed. From information on toll charges I estimate the average annual revenue which would have been raised from this vehicular travel. I add this revenue to the estimated average annual revenue raised from pedestrian travel and, after accounting for maintenance costs, derive an estimate of the average annual profit as a percentage of the total construction cost of the tunnel. I thus determine whether this would have been large enough to prevent economic failure.

As noted above, London Bridge was the main mode of transport for journeys across the river from the east of London at this point in history. Although it is clear many of the journeys accounted for would not have started their journey at the point I have chosen to measure from, the entrance of the tunnel at Wapping, I believe my decision to choose this point can be justified. Given the limited amount of data available on journeys made north to south of the river in the East other than that across London Bridge, the start point of the tunnel is a practical place to measure distance from, especially given its proximity to the docks. By making the assumption that the majority of the cart/wagon journeys made from the East would not have been private journeys, given the deprived character of the East and its lack of wealthy residence, one would assume that the majority of

[40] Ibid, p.669.

journeys made would be from the docks, for the transportation of goods. Some of these docks lay to the east of Wapping, some to the west; but none a great distance away. Once I determine the cost saving for vehicles from this point, I am able to determine whether it is more likely this saving would have encouraged the companies of the docks to use the tunnel instead of London Bridge given the shortening of distance and thus reduction in time taken; and using this and traffic data collected from London Bridge (discussed in greater detail later) I determine an estimate of the number of carts and wagons which would have used the tunnel.

It is likely that many of the journeys made to transport goods from the north to the south side of the river would not have ended at the entrance of the tunnel at Rotherhithe yet I once again feel I can justify this choice. Although goods may not have been transported directly to Rotherhithe it is likely that, at two miles in distance, those journeys travelling in an eastern direction from London Bridge would have travelled a similar length to the distance to Rotherhithe, if not further, making the distance used and thus the cost saving which I calculate plausible for the majority of journeys.

Although goods were also transported across the river via lightermen and other boats, I have chosen to not include this form of transportation in my cost saving given the very low level of goods which were transported in this way. I believe access to the Thames Tunnel would have had little or no effect on the amount of cargo which continued to be transported using these boats, causing it to have little or no impact on the revenue raised by vehicular travel, and therefore little or no impact on my hypothesis.

I determine the cost of travel for carts and wagons through the Thames Tunnel from the proposed toll charges. These charges were stated in the Thames Tunnel Act of June 1824 and show the maximum charge that could be placed on pedestrians, animals and vehicles according to Parliament.[41] It is unclear whether the actual toll charges for vehicular traffic would have been set at the maximum given in this Act, particularly as the only toll charge on which an actually price was set, foot passengers, was not set at its maximum. Whilst the highest toll charge for foot passengers allowed under this Act was 2d, the actual pedestrian toll was 1d, perhaps to generate greater traffic, especially given the implied lower wage of the working classes concentrated in this area. Nonetheless, I calculate the cost of vehicular travel through the Thames Tunnel at the maximum toll charge for both carts and wagons. Any other value chosen would have to be a rough estimate, something which may further complicate my results and cause more assumptions than necessary to be made. Furthermore, as vehicular traffic was assumed to be the company's main source of revenue, it is plausible the Company would have been inclined to charge the highest toll possible.

Determining the cost of travel via London Bridge is complicated. There was no actual charge for crossing London Bridge since tolls were abolished in 1782.[42] However, the cost that would apply to those travelling across London Bridge would be a cost of time lost in choosing this mode of transport as opposed to the tunnel. To a company operating in the dock, those most likely to use the tunnel, the cost they would incur would be wage-related. If an extra employee was hired to

[41] As given in Portman, p. 32.
[42] Pierce, *Old London Bridge*, p.270.

operate the cart or wagon, the cost of the time lost in choosing to travel across London Bridge as opposed to using the Thames Tunnel would be the extra wage that would have to be paid to this employee. If an employee who was already employed at the company operated the cart or wagon, the cost of the time lost would be the cost of the delay in completing the task which they would normally perform. As operating a cart or wagon would not have come without some sort of skill, I assume that the companies would have chosen the former. Therefore, I calculate the time loss of using London Bridge as opposed to the Thames Tunnel as the extra wage which would have to be paid to the cart or wagon operator.

To calculate this cost I calculate a wage for the vehicle operator and an expectation of the additional time it would take to cross London Bridge as opposed to the tunnel.

This wage is difficult to calculate, owing to a lack of recorded wage data for this particular industry at the time and a lack of published records still available, as well as the fact that a number of workers were employed casually. The data used to estimate this wage is from available evidence of the earnings of the dock workers. Although it is unlikely that these vehicle drivers would have earned the same wage as an average worker given the level of skill needed for this job, it is reasonable to assume that the companies paying the drivers would be the same as the companies paying the dock workers. Therefore it is plausible that these companies would have paid the drivers a similar hourly rate to the rate they paid their permanent and more highly skilled workers. Mankelow noted that in 1800 the docks paid 3s 6d a day to labourers, and thereafter the wage widely fluctuated.43 However he fails to note the source or sources from which he has gathered this information, affecting the usefulness of this statistic. Nonetheless, Pattison also stated that in 1802 the wage of a dock worker according to the West India Dock was 3s 6d a day or 5d for an hour, and whilst this was reduced slightly in 1822, permanent workers continued to be paid a higher wage.[44] It is well established that the wages at the docks fluctuated, making it difficult to distinguish earnings. However, from the assumptions stated, I would expect the vehicle driver to be paid hourly and at a higher wage than the usual dock worker. I therefore take the hourly wage of the driver at 7d. Although wages in the docks are said to have fluctuated from 1802 to the period I am studying, I assume that the hourly wage would be higher than 5d for a driver given the additional skill needed for this job and also accounting for the possibility of a natural rise in wage from 1802 and 1843-65, owing to inflation and increased living costs.

Calculating the exact time taken to travel from Wapping to Rotherhithe either by London Bridge or the tunnel is also difficult. Time taken to cross the tunnel is obviously an estimate, given that a crossing by a vehicle never took place. The length of the tunnel must be considered and also the time taken to descend at Wapping and ascend at Rotherhithe. The possibility of time delays along London Bridge owing to congestion must also be accounted for. It is evident that congestion was problematic and time consuming, as noted above, Ball and Sunderland considered the movement across London Bridge as close to walking pace and it has been said that crossing could take up to one hour. Therefore, when estimating the time taken to travel via London Bridge I consider the time taken to travel the total distance from Wapping to Rotherhithe minus the distance

[43] Mankelow, *The Port of London*, p.384.
[44] Pattison, *Nineteenth Century Dock Labour in the Port of London*, pp.264-265.

of the bridge itself, calculating this separately, in order to account for the additional time caused by congestion. I assume that although there may have been some congestion along the tunnel, it is unlikely to have been as significant, given the toll charge and its possible deterrence. The speed of horses must also be considered. This is estimated from the average speed given for a horse at walk- the most plausible assumption for the speed of a horse at this time given the quality of the road, the weight of the goods being transported, and the level of congestion- which is given at 6.4 kilometres per hour.[45] Although a cart would be operated by one horse and a wagon by two, given that a wagon is likely to have carried a heavier load of goods and the importance of congestion as a determinant of speed, I assume the speed of the cart and wagon was identical.

Clearly any time that I estimate for the distance will not be concrete. Time taken to travel would have varied on a daily basis, and it is clear that the time estimate I use in my cost saving calculation will not correspond to every day of every year throughout the period 1843 to 1865. Nonetheless, I believe this point is unavoidable and trust the speed and distances I am considering produce a realistic estimate given the data I have available and my own inference.

What must also be noted is the possibility that some carts or wagons would have paid the mileage duty in operation at the time. This mileage duty amounted to 1½d per mile in 1842, 1d in 1855 and ½d in 1862.[46] Given the four mile distance between Rotherhithe and Wapping when travelling across London Bridge, if applicable this would clearly have impacted on the decision to use the tunnel, particularly between 1843 and 1855. Nonetheless, as it is unclear whether or not this charge would have applied, I do not apply it to my own calculations, but consider its possible impact in my analysis.

The recorded data on the number of vehicles travelling across the river from London Bridge to the East is limited in that it only represents journeys made from North *to* South, not those travelling from South *to* North. This is clearly a serious drawback to my calculations. Nonetheless, from the data which I do have access to and from information concerning the nature of the docks in the South I make an inference of the number of journeys which would have been made from South to North. This is a lower bound estimate, in an attempt to avoid overestimating the impact of the revenue generated.

An important primary source I use in terms of data is the *Thames Tunnel's Directors letter to the Commissioners for the Issue of Exchequer Bills for Carrying on Public Works,* 1832. This document stated both the Company's expected cost of building the carriage ramps and the expected revenue the carriage ramps would bring.

The document gives a breakdown of the cost of building the carriage ramps, however, given hindsight it is clear this estimate was too low. In this letter the company has requested a loan of £248,000 for the completion of all work- including the cost of building the ramps in order for them to be ready at the opening of the tunnel (estimated at £102,000)- however despite eventually gaining a loan of £374,000, this was only enough to complete the foot passage. It is therefore appropriate to adapt the cost given in order to make my calculations more realistic. I do this by

[45] Harris, *Horse gaits, balance, and movement*
[46] Barker, *Urban Transport*, p.141.

considering the breakdown of the estimated costs for the completion of the ramps given in this document and other estimates of the cost, such as that by Walford in *Old and New London*. From this I calculate my own estimate for the cost of building the carriage ramps, adding this to the actual total construction cost.

In attempting to measure the revenue that would be gained from the use of the ramps, the document uses the maximum charge applied to carts and wagons as given in the Thames Tunnel Act, mentioned above. As this is the charge given by the Thames Tunnel Company itself, I feel their use of this charge reinforces my choice to use it also.

In their measurement of the expected revenue from the use of the ramps, this document also gives useful information on the daily traffic across London Bridge.[47] This data, collected by a number of persons stationed at London Bridge, is useful as it provides both the number of carts and wagons which travelled across the bridge in a southern direction, and the amount of carts and wagons from this number which then turned down Tooley Street in the direction of Rotherhithe. The drawback in this data is the date it was recorded-1829. Given that this was at least fourteen years before the opening of the tunnel, it is highly unlikely that the traffic still passing over London Bridge during the period of interest, and therefore the traffic turning down Tooley Street which may have chosen to use the tunnel, would have been the same. Given the rise in the population and the tonnage of goods traded at the docks one would expect this number to be categorically higher. Nonetheless, owing to a lack of later traffic data included in the London Bridge documentation held by the London Metropolitan Archives, as well as other sources, this is the data which I use and adapt in my own estimates. I increase the figures given by an appropriate percentage to account for the expected rise in vehicular transport levels. The limitations of this data and the assumptions that I make from it have some negative effects on my final results; however the assumptions made are as realistic as possible. What must again be stressed is the greater importance of what the numbers represent and the understanding that can be gained from them as opposed to applicable arithmetic.

In calculating the financial standpoint of the tunnel with functioning vehicular ramps, I account also for the revenue raised from pedestrian traffic, the annual maintenance costs and the total construction cost of the tunnel, including the additional cost of the carriage ramps. As noted in Section 3, I take the total cost of the Tunnel at £614,000 plus the additional cost of the carriage ramps, estimated at £204,000. A prediction of the average annual pedestrian revenue shall be taken from data recroded by the Company, as stated in Portman. This prediction is made owing to the lack of data on annual pedestrian revenue for the entire period in Company documentation.[48] The data in Portman stated that from 3rd December 1844 to the 2nd December 1845 the revenue raised from pedestrians was £4,968 15s 8d. As this was taken from the early period of the tunnel, I expect the average annual pedestrian revenue for the entire period to be slightly less than this figure, and so make adjustments to it in order to gather a more realistic result. The annual maintenance cost of running the tunnel as both a pedestrian and vehicular tunnel is taken from the

[47] Thames Tunnel Company, *Thames Tunnel: the letter addressed by the directors of the Thames Tunnel Company to the Commissioners for the Issue of Exchequer Bills for Carrying on Public Works, applying for a loan to complete the body of the tunnel*, p.26.
[48] Portman, p.365.

prediction made by Company clerk Joseph Charlier, accounting for costs such as general and safety maintenance. Given the previous predicted costs made by the company tended to be lower than the actual cost, I also adjust this cost in order to make it more realistic.

As can be seen from this section, there are a number of limitations to the methodology and data used in this paper. A lot of the data comes from primary sources found in secondary sources, or assumptions made from some form of relevant data, which is not ideal. However, this is unavoidable given the gaps in the data required for this study. I attempt to justify the assumptions made and comment on the impact they may have on the final result, something which I establish again in my analysis. Given the use of a counterfactual in this paper the need to make assumptions is inevitable, but in making these assumptions I acknowledge the need to produce the fairest results. Whilst the actual numbers produced may be disputed, they provide a quantitative understanding of the impact of the carriage ramps on the Thames Tunnel and add greater depth to my hypothesis, which until this point is largely believed to be conclusive, absent of quantitative application.

Section 5: Analysis

Section 5.1: Cost Saving

The maximum tolls to be charged by the Thames Tunnel Company to those using the tunnel as set by the Thames Tunnel Act of 1824 is shown in Table 1.

As noted in the table, I take the maximum charge given in this Act as the actual toll charge attached to the vehicles. I take type "1 horse more than 2 wheel carriages" as the toll charge attached to a cart and type "2 horse more than 2 wheel carriages" as the toll charge attached to a wagon. So the actual cost of using the Thames Tunnel in my calculations is for a cart 6d and for a wagon 1s. As noted, there was no vehicular toll charged for using London Bridge and so the actual cost for using this mode of transportation is zero.

To work out the cost of the time taken when using London Bridge to transport goods from north to south I estimate the total time taken when travelling across London Bridge multiplied by the wage paid to the driver in travelling this distance. I use the same calculation to work out the cost of the time taken in using the Thames Tunnel. This cost of time is added to the actual cost of using both modes of transport, forming the generalised cost. The cost saving is determined by the difference between the generalised cost of using London Bridge and the generalised cost of using the Thames Tunnel. A positive cost saving indicates that the cost of using the Thames Tunnel was the more economic choice.

I measure the time taken to travel using both modes of transport by estimating the distance between these points and multiplying this distance by the estimated speed of the vehicles. As stated in Section 4, I estimate this speed at 6.4 kilometres per hour. Table 2 shows the distances between

Wapping and Rotherhithe using either the Thames Tunnel or London Bridge, in feet and in kilometres:

These distances are given to three significant figures. I take the distance 0.396 kilometres as the distance between Wapping and Rotherhithe through the Thames Tunnel, determining the time taken to travel this distance using my speed in minutes. I do this by dividing the total number of minutes in an hour, 60, by the speed, 6.4, and then multiply this by the distance given in kilometres. I also add to this time the estimated time taken to descend and ascend the Tunnel, a total distance of 0.0456 kilometres. As this descent and ascent was likely to be a more difficult task than moving along the straight road of the tunnel, I infer that this part of the journey would have taken longer than my calculation would state, and so instead of using this calculation, I simply add an extra ten minutes to the time taken to account for this, as I predict it would have taken around this amount of time. With my calculation of the time taken to travel 0.396 kilometres equalling 3.7 minutes at a speed of 6.4 kilometres per hour, I calculate the total time taken as 14 minutes, or 0.23 hours to two decimal points. I also calculate the time taken to travel using London Bridge in two parts. I measure the time taken to travel across London Bridge separately as this was likely to be the longest part of the journey time wise, as traffic would have moved a lot slower than the speed I estimate for the rest of the journey given congestion. As it could take up to an hour to cross and with congestion likely to rise through the period, I estimate the average time taken as 45 minutes. To this time I add my time taken calculation for the rest of the journey, which after subtracting the distance of London Bridge, would be roughly 6.16 kilometres. With this distance equalling 57.75 minutes, I have taken the total time in minutes as 103, equal to 1.72 hours to two decimal points.

To determine the cost of the time taken, I multiple the time taken determined above in hours by the hourly wage of the driver. I assume this hourly wage was the same for both a cart and wagon driver at 7d. I take the cost to one decimal place.

My result for the cost saving of using the Thames Tunnel as a mode of transporting goods from the north of the River Thames to the south from Wapping to Rotherhithe as opposed to the use of London Bridge are presented in Table 3:

These results are both interesting and surprising. The cost saving for carts is positive and therefore the most economic form of transport for carts was to use the Thames Tunnel; however, the cost saving for wagons is negative and thus they should have continued to use London Bridge. The cost saving for carriages, at 4.4d, is larger than the cost loss for wagons (1.6d), suggesting the impact of the ramps in determining the use of either the tunnel or London Bridge would have been larger for carts than for wagons. It is likely that companies using carts to transport their goods would have been more highly persuaded to use the Thames Tunnel as opposed to London Bridge than companies using wagons would have been deterred from sending wagons through the tunnel and continuing to use the bridge.

The assumptions that are made and their impact on these results must be mentioned. Had the hourly wage of the driver been less than 7d, the total cost saving would have been less for carts and the cost loss for wagons would have been higher; clearly impacting on the attractiveness of the Tunnel. However, had it been higher than 7d, the cost saving for carts would have been even larger and it is possible that the cost loss for wagons may actually have become a cost saving. Had the ascent and descent of the Tunnel taken five minutes longer and the average journey across London Bridge taken ten minutes shorter, the cost saving for carts and wagons would have become 2.7d and -3.3d respectively. Although the signs of these cost savings are consistent with the results above, it is likely that the fall in the cost saving for carts and the rise in the cost loss for wagons would have had an impact of the decision to use the Thames Tunnel for both these types of vehicle. One must also note that had the mileage duty mentioned in section 4 been applicable to these carts and wagons, the favourable nature of the use of the Thames Tunnel would have increased dramatically, with the mileage duty large enough to create a positive cost saving for both carts and wagons.

I consider the results of my cost saving and the impact of the assumptions made when determining the impact that the cost saving would have had on the revenue of the vehicular traffic and therefore the financial position of the tunnel in the next section.

Section 5.2: Level of Transportation and Financial Impact

In the traffic report taken in 1829 it was stated that every day 3241 carts and 887 wagons passed over London Bridge in a southern direction, with 1700 carts and 480 wagons turning down Tooley Street towards Rotherhithe. The Thames Tunnel Company, in their estimate of the revenue raised from the carriageway, estimated that of these 1700 carts and 480 wagons, 850 carts and 240 wagons would have chosen to pass through the Thames Tunnel instead of using London Bridge.[49] This assumption was made on the basis that a large portion of these vehicles were used for trade and that companies in the London Dock and the East and West India Docks would prefer to use the Tunnel, whilst companies in St. Katherine's Dock would continue to use London Bridge. They assume that the former three docks would account for half of these vehicles, hence halving the number given in the 1829 traffic report.

Like the Thames Tunnel Company, I use and adapt the 1829 figures, however, I do this using the greater knowledge gained from my cost saving estimate. I feel the Company's estimates are quite pessimistic, and from the benefit of hindsight can infer that the level of traffic passing over London Bridge would have risen between 1829 and 1843-1865, including the implications of this assumption in my estimate. Given my cost saving, I believe it is highly likely that all docks to the east of Wapping- the London Dock and the East and West India Docks- would have chosen to use the tunnel given that the cost saving they would have made would have been similar to or higher than 4.4d. Given a saving of 4.4d, I also believe it is likely that some carts from St. Katherine's Dock, west of Wapping, would have used the Thames Tunnel as, at around 0.8 miles, the distance between St Katherine's Dock and the tunnel was shorter than the distance to London Bridge (1 mile), as well as

[49] Thames Tunnel Company, *Thames Tunnel: the letter addressed by the directors of the Thames Tunnel Company to the Commissioners for the Issue of Exchequer Bills for Carrying on Public Works, applying for a loan to complete the body of the tunne*l, p.25.

further deterrence given the additional time taken when using the bridge. Nonetheless one must assume that given the actual cost of the Thames Tunnel was 6d, with London Bridge costing zero, some companies would still have chosen the "free" option. Assuming that the average daily traffic of carts and wagons across London Bridge heading towards Tooley Street increased by 25 percent from 1829 to the average number passing 1843-1865, 2,125 carts and 600 wagons would have crossed the bridge daily, plausible given the rise in trade within the docks and the rise in consumer demand from increased population. Had access to the Thames Tunnel been available, I predict from my cost saving that around 80% of these carts and 10% of these wagons would have used the Thames Tunnel as their mode of transport, resulting in 1,700 carts and 60 wagons using the Tunnel daily. I have chosen 80% for carts as a number of companies may not have been aware of the cost saving, but the vast majority would due to the relatively large saving made. I have chosen 10% for wagons as although the cost saving from Wapping was negative, for some of the docks further east this saving may have been positive as at -1.1d, the loss is quite small. Clearly, the percentages here given are estimates and are undeniably limited. There is no evidence to determine the exact increase of daily traffic across London Bridge and the estimates of the percentage using the tunnel come from my cost saving which is itself an estimate. But I once again stress my determination to make these predictions realistic, which I believe I justify, and the greater importance of what the numbers should represent, not the numbers themselves.

As these figures only represent traffic moving through the tunnel from north to south, I also predict a figure of the traffic moving south to north. Given the operation of the Surrey and Commercial Docks on the south of the river, I increase my above figures by 30% to 2210 carts and 78 wagons. I have chosen 30% as evidence suggests that most transportation of goods from the Port of London moved north to south, yet it is clear a large number of goods brought into the city in the south would have been consumed in the north e.g. timber.

From my predictions, I estimate the daily passage through the Thames Tunnel and the average revenue raised annually, and the results are displayed in Table 4:

Assuming 300 working days in a year, the assumption made by the Company in their calculations,[50] the combined annual average revenue raised from carts and wagons is £17,745. I use this figure as my estimate for the average annual revenue of vehicular traffic through the Thames Tunnel.

It is important to note that carts and wagons were just two types of vehicles which were in operation at this time. Although these were possibly the two most common types, given that this figure is an estimate only for carts and wagons using the tunnel for the transportation of goods it is definitely possible that the actual revenue could have been higher than my prediction.

Using my figure for the average annual revenue of vehicular traffic I estimate the average annual profit generated by the Tunnel, and this profit as a percentage of the total cost. In generating the average annual revenue gained from pedestrian traffic, I reduce the figure for

[50] Thames Tunnel Company, *Thames Tunnel: the letter addressed by the directors of the Thames Tunnel Company to the Commissioners for the Issue of Exchequer Bills for Carrying on Public Works, applying for a loan to complete the body of the tunne*l, p.25.

revenue raised from pedestrian traffic December 1844 to December 1845 (£4,968 15s 8d) by 15 percent- given the reduction in pedestrian traffic towards the end of the tunnel's use in this form- which yields £4,223 to the nearest pound. I increase the predicted maintenance cost given by Charlier, from £3,000 to £4,000; both due to the Company's tendency to undervalue their own costs and evidence that the revenue raised by pedestrians was only just enough to cover these costs. Although the Company predicted the ramps would only cost £102,000, I believe this estimate it far too low and thus unrealistic. Walford estimated the actual cost of the ramps to be £200,000, so I double the figure produced by the tunnel to £204,000. The new total cost is thus £818,000. The average annual profit and this profit as a percentage of total construction cost are in Table 5:

As can be seen, it is possible that had carriage ramps been built, the average annual revenue under my assumptions and predictions would have risen from around £4,223 to around £21,968- a substantial increase. With revenue such as this, is it plausible to infer the tunnel would not have become a financial failure.

Yet it is important to note that the average annual profit as a percentage of total construction cost, given the increased total cost of the tunnel due to the ramps, was only 2.2%, not a particularly high return. Given this result does not account for inflation, it is also expected to be an upper bound estimate, further dampening its credibility. From this upper bound estimate, for my 22 year period the average return would still only have amounted to 48% of the total cost. Assuming this average annual profit remained constant, it would have taken 46 years for it to amount to a level above the total cost of the tunnel, clearly a long time.

However, as the tunnel remained a means of communication for pedestrians for 22 years with very little revenue, it is very likely had carriage ramps been built and followed a path similar to the one I have devised that the tunnel would have remained a pedestrian and vehicular tunnel throughout the period 1843-1865, and may have continued in this way until profit passed the total cost, and further. The continued use of the tunnel in this form may have been enhanced by the continuous growth of the docks and the increased usage expected from this. It is plausible that the capital investment in the form of ramps would have increased the intrinsic value of the tunnel, with the social gain generated from them clearly higher than without.

It therefore appears that from my quantitative analysis my hypothesis, that the building of the proposed carriage ramps which had been a part of the original plan for the Thames Tunnel would have created a positive cost saving for vehicular traffic, increasing profit to a level which would have prevented subsequent failure, is valid.

Section 6: Conclusion

The possibility of the prevention of the financial failure of the Thames Tunnel 1843 to 1865 is difficult to predict. It was the Thames Tunnel Company's intention to build carriage ramps to enable the use of vehicles through the tunnel, something which failed to materialise due to lacking funds. Consequently, the tunnel missed out on a potential major source of revenue and profit. Given the large amount of trade between the East of London at this time and the lack of alternative modes of transportation, it is highly likely that these ramps would have been in fruitful use. It has been widely suggested that had these carriage ramps materialised the financial failure of the tunnel and its subsequent sale to the East London Railway Company would not have occurred, yet no modern study has attempted to quantify this possibility. This is what this paper aimed to achieve.

By producing a counterfactual to estimate the cost saving for the use of the tunnel as opposed to using London Bridge, I have found that there was indeed a saving for carts and only a small loss for wagons. This indicates that a large level of vehicular traffic would have been created through the tunnel. From traffic data across London Bridge I made a prediction of the annual level of vehicular traffic through the tunnel, the revenue raised from this traffic and thus the overall revenue that these ramps would have created. From the average annual revenue generated, it is likely this huge increase in profit would have prevented the financial failure of the tunnel in the period 1843-1863, thus proving my hypothesis to be valid.

I have made a large number of assumptions and predictions when producing my quantitative data; however I believe I have given reason to justify them. I do not believe it is the actual figures themselves which are the most important part of my study, but what these figures inevitably represent and help to confirm in terms of the financial position of the Thames Tunnel- that it is indeed very likely that vehicular ramps would have prevented its financial failure.

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Table 1: Toll Charges for the Use of the Thames Tunnel

Type	Toll charge
Foot passengers	2d
6 horse more than 2 wheel carriages	2s 6d
3 & 4 horse more than 2 wheel carriages	2s 0d
2 horse more than 2 wheel carriages	1s 0d
1 horse more than 2 wheel carriages	6d
2 horse 2 wheel carriages	9d
1 horse 2 wheel carriages and taxed carts	6d
Horse drawn wagon and carts laden or unladen	4d
Wheelbarrows	2 ½d
Horses, mules and assess laden or unladen without cart	2d

Source: The Thames Tunnel Act (1824) in Portman (1998) p. 32

Table 2: Distances

Type	Distance in feet	Distance in km
Distance from Wapping to Rotherhithe through Thames Tunnel	1300	0.396
Distance of the descent to the Thames Tunnel	75	0.0228
Distance from Wapping to Rotherhithe using London Bridge	21120	6.44
Distance of London Bridge	928	0.283

Table 3: The Cost Saving of using the Thames Tunnel

Type	Actual cost of using Thames Tunnel	Cost of time of using Thames Tunnel	Generalised cost of using Thames Tunnel	Actual cost of using London Bridge	Cost of time loss of using London Bridge	Genearlised cost of using London Bridge	Cost saving of using Thames Tunnel
Cart	6d	1.6d	7.6d	0d	1s	1s	4.4d
Wagon	1s	1.6d	1s 1.6d	0d	1s	1s	1.6d

Table 4: Revenue raised from carriageways

Type	Number using the tunnel daily	Number using the tunnel annually	Average annual revenue
Cart	2210	663,000	£16,575
Wagon	78	23,400	£1,170
Total	2288	686,400	£17,745

Table 5: Revenue and Return of the Thames Tunnel

Average annual revenue generated from vehicular traffic	Average annual revenue generated from pedestrian traffic	Average annual maintenance costs	Average annual profit	Total construction cost of the Thames Tunnel	Average annual profit as a percentage of total construction cost
£17,745	£4,223	£4000	£17,968	£818,000	2.20%

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