BLOTTMATTHEWS 2016/17 COMPETITION: AIRPORT TO AIRPORT (A2A)

Competition Submission from Therfield School, Leatherhead

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Overall Description

Our proposed solution is to use maglev trains as the method of transportation. The reason we have chosen this method is that it provides the high speeds necessary to complete the transits in the required time. These trains are efficient and reliable, and are a current and tested method for long distance and high speed transportation.

We have decided to use London City Airport as the main central hub which each train would pass through. Each airport will have a service that stops at London City, or continues to any of the other airports, for example a service from London Luton can either stop at London City, or keep going via one of three routes to London Gatwick, London Heathrow, or London Stansted. While this may increase transit time than say going directly from London Luton to London Stansted directly, we have chosen this method as it allows us to cut down on tunnel and track construction costs significantly, thus decreasing the cost of the ticket to the passenger. This method will also still allow us to transport passengers within the required 20 minutes, even taking into account the slightly longer route.

Planning and Environment

Urban Tunnelling

A majority of the tunnelling will be deeper than 55 metres to avoid interference with most of the London underground tunnels and any other underground tunnelling networks; however the exact location and depth of existing tunnels will need to be mapped. At this depth most of the geology will be formed from London Clay[1]. However, tunnelling from Gatwick and under the Thames will pass through chalk (figure 1). Earth pressure balance Tunnel Boring Machines (TBMs) will be used to dig through the London clay and mix-shield machines through the chalk layers not only near Gatwick but under the Thames as well[2]. Soil pressure will need to be maintained as the tunnel is being dug. Earth pressure balance TBMs are able to reduce the risk of subsidence for underground tunnelling[3].

Ground borne noise is unlikely to exceed Significant Adverse Effect level and therefore will not be a problem during the urban tunnelling. If there are any noise complaints, acoustic construction sheds could be used over machines in addition to restricting work to daytime only hours to avoid inconvenience but this would increase the completion time.[4]

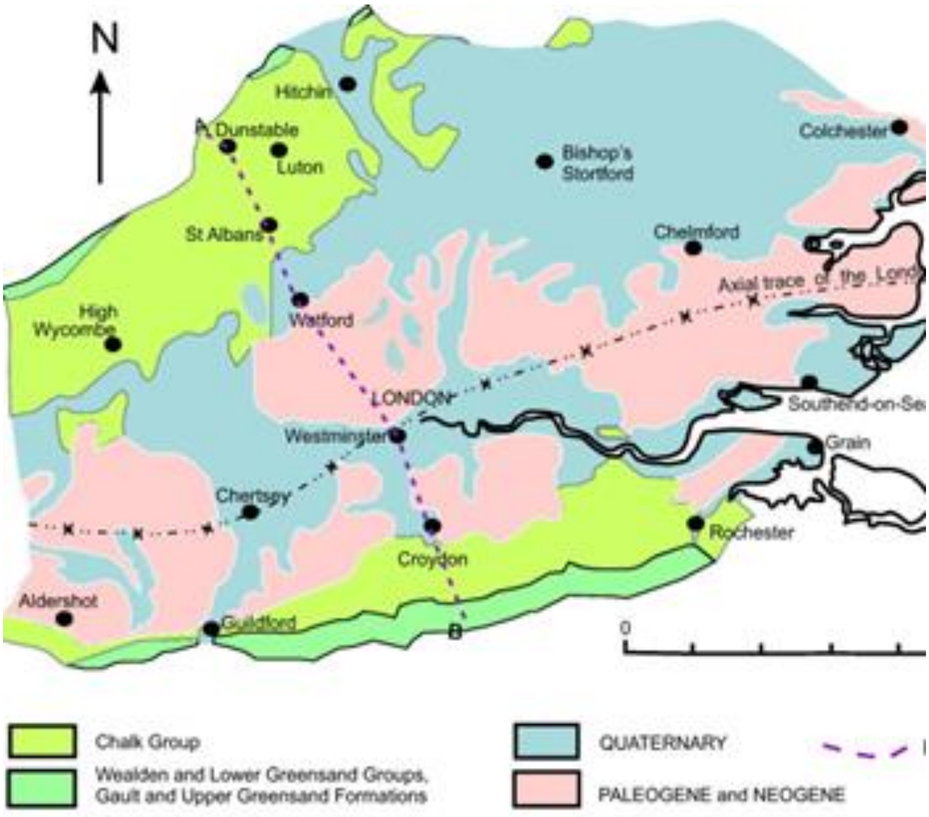


Figure 1 [1]

Passenger Transfer

Generally high speed rail and maglev transport systems carry between 50 and 100 passengers per carriage. The Shang Hai Transrapid Maglev transport system has between five and ten carriages per vehicle and around 400 seats on each train. In total this means it can hold, at maximum capacity around 1000 passengers. Our Maglev transport system would have similar capacities to this. An average train would carry 100 to 120 passengers per carriage with less seating space and more provision of grab rails for standing passengers. In this way passenger numbers can be increased in future with some trains having only minimal seating for priority passengers (expectant mothers, elderly or disabled passengers and those carrying infants). On average seven to eight carriages would be used for each train however at peak times this would increase to 10. Overall this would mean at peak times with 120 passengers per carriage and 10 carriages, 1200 people would be transported per vehicle.

Figure 2 [6]

The number of carriages assigned to each airport would, initially, be proportional to the average number of passengers traveling through that airport each day. However within the first year of the system surveys will be carried out detailing the number of maglev passengers travelling to each airport and their initial starting location on the transport system. In this way the number of carriages needed can be refined and the system made more efficient.

Figure 3 [7]

Passenger Pick Up

Initially passenger pick up points for the Maglev train will be located only at airports and no hub pickup points would be used. Passengers will be able to travel to their destination from their closest airport. We chose this because airports already have readily available parking, hotels and facilities therefore removing the need to build new facilities. By only having passenger pick up points at airports we avoid unnecessary tunnels and trains therefore making the system more efficient and less costly. With good underground connections, airports provide an alternative mode of transport if there are any delays or cancellations to the maglev trains thereby avoiding people being stranded without adequate transport facilities in case of emergency.

Figure 4 [8]

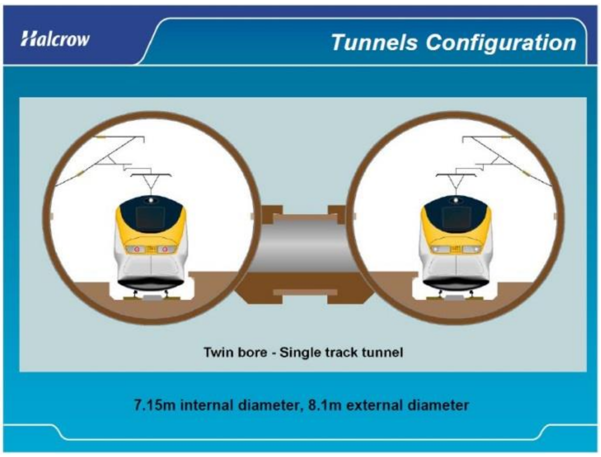
In the future, taking into consideration the most popular passenger journeys, pick up points may need to be extended as the maglev trains become more popular. This may cause issues as smaller airports may not be able to handle increased passenger numbers passing through, this could be surveyed and improved on in the first year. There is the possibility of hub points in other major cities such as Birmingham and Manchester that could directly link people to London airports however this would only be possible once the customer demand for the maglev system was proved. This might cause a decrease in use of other less environmentally friendly transport systems such as HS2.

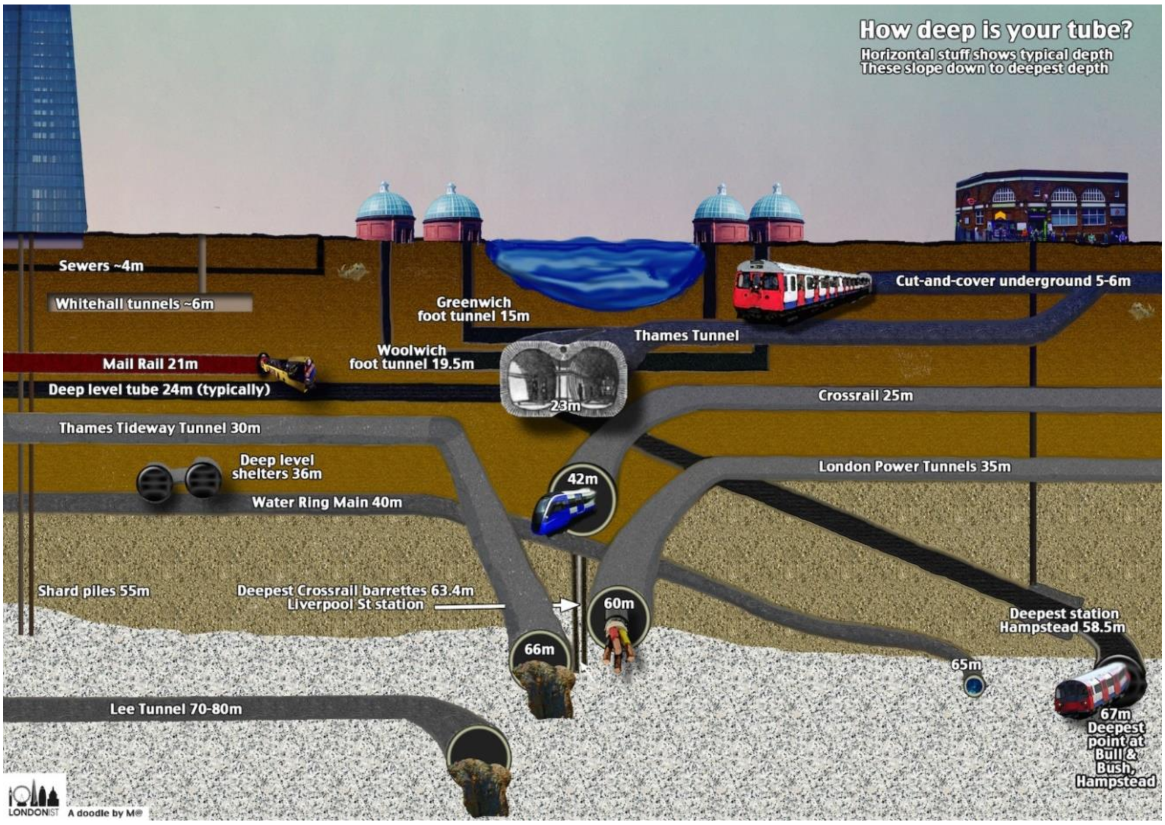
Civil Engineering

Tunnelling

To start things off I would like to address the largest piece of construction this project involves. Our proposal involves 176 kilometres of twin bore tunnels, Meaning that 352 kilometres of tunnel needs to be excavated in total.

We chose to use twin bore tunnelling for a number of reasons: Firstly it reduces the amount of shafts need to lower equipment and remove waste, reducing the surface level disruption caused by the tunnelling which, in the centre of London, is extremely beneficial. Secondly, by having two single track tunnels it makes the completed system safer to maintain and, in the event of an emergency, evacuate the passengers as the opposite track can continue to run with no risk to the personnel in the stopped train's tunnel.





Source: http://londonist.com/2015/10/how-deep-does-london-go

For this project we have decided to tunnel at 55 meters below ground level whilst inside the city limits, this avoids most of the already congested underground network beneath London and give the shortest possible route between stations. Tunnelling for extended distances at this depth is more costly than at shallower depths but with speeds as high as those achieved by maglev trains we felt the tunnel should be as constant as possible to keep stress on the very expensive system, as well as travelling times, to a minimum.

This excavation requires the use of 8 separate tunnel boring machines working 24 hours a day, with 3 8 hour working shifts of 'tunnel gangs'. With this rate of work we estimate that this project will take 6 years to complete, including the construction of stations in each airport, tunnelling, installation of the maglev rail and computer systems as well as any inevitable delays that come hand in hand with projects this size.

Waste management

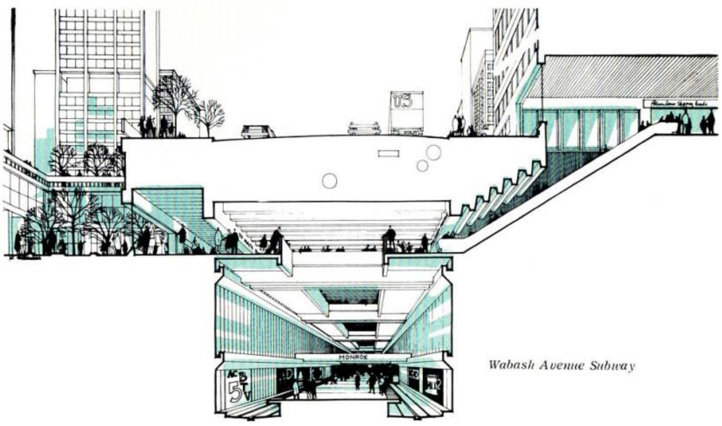
The second largest task after digging the tunnels is removing the waste earth and rock from the site and disposing of it. We hope to take a similar route to Crossrail and recycle over 90% of the excavated material for use in wildlife and land fill restoration projects as well as selling it for use as hard-core in construction projects, but before any spoil can be used it has to have its chemical composition tested by a third party company such as ESG to ensure it is safe for purpose.

The easiest way to remove the spoil from the tunnels being dug by earth pressure balance machines is by lorry, driving it to either its destination or to a rail yard for long distance journeys. The same method of transport will be used for the bentonite spoil generated by slurry shield machines but it must first have the mining slurry filtered out for re-use and the left over clay/waste deposit compressed and dried before it can be moved.

Station and platform construction

The stations take on a tiered design with the platforms for each rail line being buried at about close to half the depth of the line its self (raised platforms aiding acceleration and deceleration). While the rest of the station, circumstances permitting, will be above ground (this includes ticket counters, kiosks etc.). However, if space is at a premium then the entire station can be built underground.

The stations and platforms can be constructed at the same time as the tunnelling is taking place due to the millimetre accuracy of the TBM, so unless major problems are encountered with their construction they should not impact the estimated completion date.



This is a potential design for a station, But they will obviously vary depending on the space available at each airport.

Boring equipment

As mentioned earlier we will be using two different designs of tunnel boring machines, earth pressure balance & slurry shield machines. The EPB TBM's will be used for tunnelling under stable ground made up of clay and hard rock that supports most of London while the SS TBM's will be used for excavating unstable or water logged earth like that found under the Thames. These machines both cost similar amounts, which has been incorporated into the total cost of the tunnelling and of the final budget.

Safety regulation

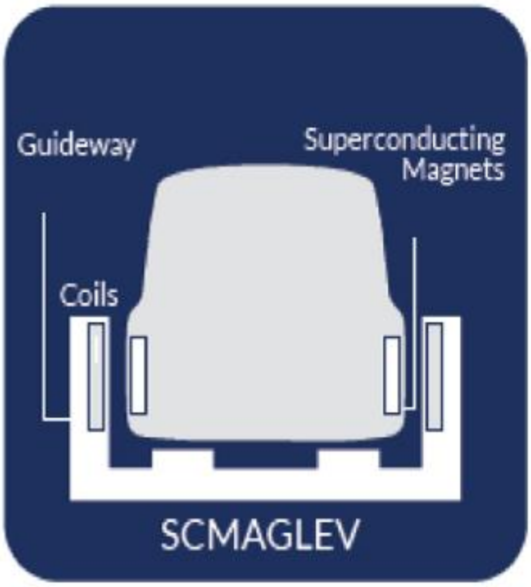
Throughout this projects duration a number of things must be monitored and regulated to avoid damages to the surrounding buildings ant land. Any buildings/ infrastructure above the tunnel system will be monitored for signs of disruption and/or ground movement while the surrounding area will be monitored for seismic activity and pollutants that could be harmful to life.

Contingency

Although every measure will be taken to drive these tunnels without affecting the surface infrastructure, it is likely that some unforeseen local ground condition will cause a problem that requires a break in construction and section of rework. We have therefore anticipated an extra duration of 10% of the quickest time to complete the project. A sum of money has also been set aside for repair/stabilisation work to any location that settles as a result of the tunnelling work.

Mechanical & Electrical Engineering

Underground maglev train using superconductor-based electrodynamic levitation, null flux loops to provide added stability, and regenerative braking to recover much of the energy used to accelerate the train.



Our solution relies on the principle of Electrodynamic suspension(EDS), a form of magnetic levitation that uses where conductors are exposed to changing magnetic fields, inducing eddy currents that form repulsive magnetic fields, holding the train in place above the rails. This solution was chosen as an EDS system is the only effective method of achieving the a top speed of over 150 m/s, required to travel the 87 km distance between Stansted Airport and Gatwick Airport without incurring the added cost of a direct link, or subjecting passengers to unreasonable levels of acceleration.

EDS is superior to Electromagnetic suspension at the high speeds used, as it automatically corrects the course of the train, as Electromagnetic force is inversely proportional to the square of the distance, meaning even a small change in position results in a large resultant force to re-centre the train. This effect can be augmented through the use of null flux loops, which are figure-of-eight shaped meaning a current only flows when the train is off centre, producing additional repulsion to correct the course of the train. The primary problem with EDS systems is that below speeds of about 30 km/h the repulsive force generated is not sufficient to support the weight of the train, requiring the use of some form of landing gear to support the train while it is travelling slowly.

Power consumption:

The vehicle dynamics equation is:

$$M(1+\varphi)\frac{dv}{dt} = F_{\frac{T}{b}} - F_D - F_G$$

For our purposes this can be simplified to:

$$M\frac{dv}{dt} = F_T - F_D$$

$$F_D = F_A + F_M$$

$$F_A = 2.2v^2(0.265N + 0.3) \times 10^{-1}$$

$$F_M = N(0.05 \times v^{0.5} + 0.008 \times v^{0.7}) \times 10^3$$

Where N is the number of carriages

Using this equation (for full speed) gives:

F_A=8,043N

F_M=4,396N

F_T=12,439N so P=Fv=1,865,907W

However peak power consumption will be just below top speed, while the train is still accelerating (while this magnitude of power consumption will be very brief the cables will need to be built to withstand it) giving:

F_T=5,712,439N

P=P=856,865,850W

Reliability

The mag-lev train requires less maintenance than conventional mechanical railways, this is due to the small amount of contact points between the carriage and the track. In a conventional railway system, much of the maintenance required is a result of friction between the track and the carriages. Our initial investment includes four extra carriages, which, in the event of carriage maintenance, will be used in the place of the carriage that requires maintenance. During events for which there will large number of passengers, these extra carriages can be used along with the existing carriages. This would allow us to add 720 extra passengers (with luggage) every hour, this system also allows us to add more carriages to particular routes which are being heavily used.

Costs/Timing

The goal of the ticket price was to make it so that the project could be paid back within 20 years of opening. The overall cost the project included the price of the track construction, the price of the trains, the price of the train stations as well as continued staffing and maintenance of the project.

An estimate based on the pricing of previously built tunnels got us to a price of £60 million pounds per km. The overall cost of the tracks are calculated using price estimates based on current projects. The price of £100 million per km times by the overall distance multiplied by two as we need two tunnels, brought the overall track price to £30 billion. We then made an estimate of the train station construction costs of £100 million as there were very few sources to follow. This brought total prices up to £30.1 billion. Trains estimate are based on the price of the Transrapid train prices at £15 million per carriage. At 8 carriages per train and 12 trains in total, the overall price of the trains is £1.44 billion. Running costs are also to be considered. At about 8p per kilometre per passenger and a maximum journey length of 90 km the price of the running cost per passenger is £7.20. This will be added on add the end. The total price is therefore £31.54 billion.

To calculate the necessary tickets price to pay back within the time we must look at traffic per day and the time in which it must be paid back. Using the average passengers per hour given to us in the challenge briefing we can work at the average total passengers per day which some from the sum of the averages per hour multiplied by 24. This is 222,000 passengers per day. Then taking the total amount of days in 20 years, which is 7,365 and multiplying this by 222,000 gives us the total amount of passengers to use the service in the time given. The total comes to 1.635 billion passengers. Now, we can get the total ticket price as: (total cost/total passengers) + running cost per ticket. This gets us a price of £26.50 per ticket.

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