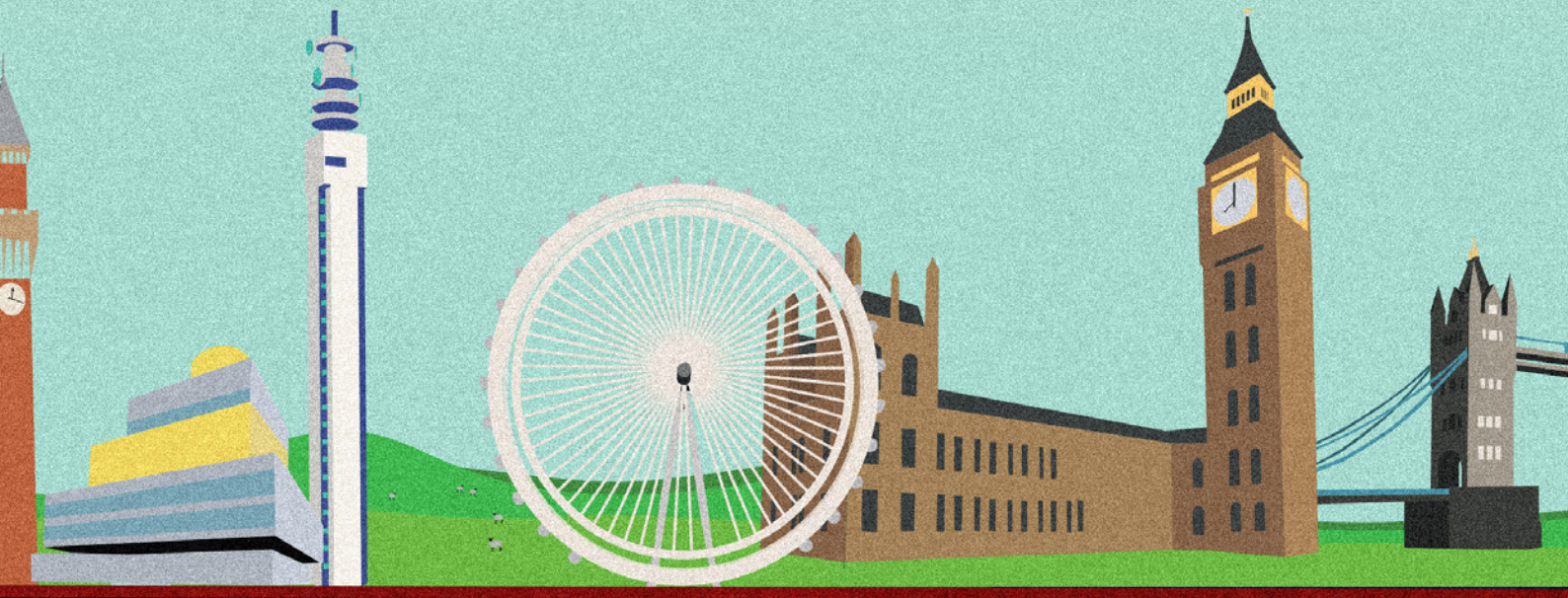
The UK Spine

A Regenerative Project for the United Kingdom




HYPED

- Executive Summary -

Historically, the United Kingdom has been at the forefront of technological progress in infrastructure: from the first steam railway between Manchester and Liverpool in 1829, the daily London to Edinburgh service on the "Flying Scotsman" from 1862 or the opening of the first underground railway in the world on the London Metropolitan line in 1863.

Hyperloop has the potential to address economic imbalances between different parts of Britain and drive growth across the entire country. Historically, step changes in transport connectivity have been pivotal in supporting growth and reducing inequalities. For instance, the British canal system of the 18th and 19th centuries played a vital role in the UK's Industrial Revolution. A new system allowing for movement of goods faster and more efficiently manner brought about significant social changes. Access to new trading opportunities spread wealth to communities in proximity to these routes and created growth in local economies.

Transport development has been a driving force of economic growth and social cohesion. However, in recent decades, the country has relied on a conventional rail network and an air system at capacity, provoking passenger distress and a loss of competitive advantage. The UK Spine, a Hyperloop route going through Edinburgh - Manchester - Birmingham - London seeks to add significant value to the three pillars of sustainability: economic, social and environmental. The revitalisation of the transport infrastructure with an investment in the UK Spine could be key in addressing all three pillars.

The United Kingdom is now characterized by stagnating productivity, deep inequalities between the North and South and a desire to shift to a cleaner economy, which the Industrial Strategy, the Northern Powerhouse and the forthcoming Emissions Reductions Plan seek to address. Many risks exist in the post-Brexit environment, including labour shortages, volatile exchange rates and subsequent higher import prices. However, the Government has pledged to tackle these through increased funding in innovative technological research and the development of new qualification requirements.

State Of Transport Infrastructure in the UK

An outdated transport network with a continuously growing demand

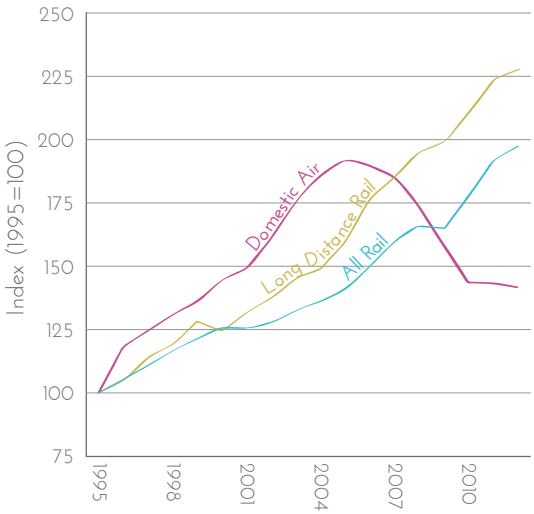
116%
increase in passenger-km travelled over last 20 years

1st
UK Rail has the fastest rate of passenger demand growth in Western Europe

200%
According to Network Rail, passenger traffic is likely to double again by 2040

Rail travel

Over the past 20 years demand for rail has exceeded governmental and industrial projections, growing faster than any transport mode in the UK. The trend is expected to continue because of deep-rooted structural trends such as population growth and a modal shift from road transport. Projects nearing completion, such as Crossrail, are focused on addressing capacity from under-investment in the past, meanwhile Hyperloop has a key role to play in catering for future demand.



During our public consultation, a number of stakeholders with whom we engaged expressed reservations as to whether the route was a duplication of, currently in delivery, High Speed 2 railway line (HS2). However, according to the Institution of Mechanical Engineers (iMechE) - despite recent substantial initiatives such as HS2, Crossrail and Northern Powerhouse Rail (NPR) - the UK will still struggle to meet passenger demand. In addition, a large part of the HS2 economic case is reliant on the transfer of passengers from the conventional rail network, allowing freight to be transported by rail rather than road. Hyperloop presents an opportunity to meet long-term demand and equip the UK with the tools to address capacity challenges due to arise over the next 30 years.

*Projects nearing completion - such as Crossrail - are **catching up** with under-investment in the past while **Hyperloop is about catering for future demand.***

Although Brexit may induce a slower economic growth rate, considerable investment is needed to re-

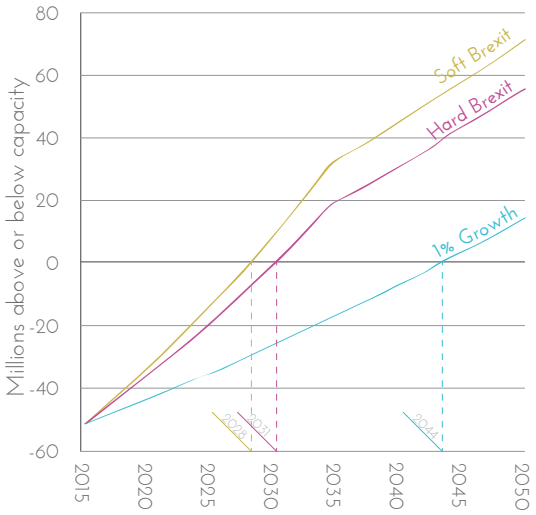
lieve the capacity pressure that already exists today. iMechE encourages further investment incentives, focusing on increasing capacity for nationwide passengers and accounting for both regional and city services simultaneously.

Air Travel

In the current geopolitical context, air demand forecasts are inherently uncertain. The Department of Transport (DfT) and International Air Transport Association (IATA) present multiple growth scenarios.

> *Heathrow Airport has been operating **at capacity** for the past 20 years and Gatwick is quickly approaching its own capacity.*

The expansion of Heathrow (with a third runway) is expected to partially address capacity issues that prevent the UK from competing with other European hubs. Important as it is for the future of the UK aviation industry, the third runway at Heathrow may not be enough to meet demand over the next 30 to 40 years.



London's airports are of strategic importance and attract the highest number of passengers; they therefore require a special focus. IATA forecasts a slower pace of growth in the first several years following Brexit. However, London's airports, inclusive of the new runway at Heathrow, will be at full capacity by 2050 even in the worst case scenario of 1% growth rates: capacity shortages at London's airports combined are forecast to attain at least 13.5 million passengers by 2050.

This is especially alarming as according to IATA post-Brexit growth rates will probably be higher than 1%, leading to an even earlier saturation point and even higher unmet demand over the next 30 years.

Additionally, it is noteworthy that so far, air demand has been growing at a faster pace than DfT forecasts, which may indicate that the expectations of market maturity may have been conservative.

13.5 million
passengers with unmet demand estimated by 2050, even with the third runway in place at Heathrow (hard Brexit case).

Overall, a closer examination of multiple forecasts and scenarios provides a compelling case for additional investments to increase capacity. Hyperloop could help to alleviate capacity constraints by serving domestic aviation routes, thereby relieving domestic pressures on airport demand. A shift from short-haul flights could also contribute to an environmental cleaner transport mix, which will be discussed further in the context of the UK Spine.

London vs. the rest: economic inequality across the UK

The United Kingdom—despite having one of the highest GDPs in the world—is marked by significant economic and social inequalities. These inequalities typically show a general North-South divide.

On average, impacts of globalisation have been of a net benefit to the UK. However, the relative benefits of globalisation vary significantly by region and city. This inequality in economic benefit has not only had an effect on social well-being, but has also led to distinct political instability and polarisation. The UK government has a duty to ensure that all areas of the UK can be economically competitive in a dynamic and globalising world. Hyperloop offers a prime opportunity to provide a unique, interconnected backbone to the UK economy— bridging the gap between the North and South regions of the country, and ultimately supporting economic and social collaboration.

Hyperloop presents a chance to bridge the North-South divide. The social inequalities in the North of England compared against London and the South-East mirrors the disparity of economic growth. Londoners are overall more qualified and have seen health benefits in terms of improved mental health and a lower suicide rate. By improving labour mobility, Hyperloop provides a path towards rectifying this issue, effectively unlocking the benefits of collaboration between the Northern agglomerations.

5th	24%	70%	30%
largest metropolitan economy in the world	*of UK graduates employed in London*	*GVA of London higher than UK average*	*of all UK taxes raised in London*

Because of the political and economic weight, a project of national significance cannot afford to ignore London in the process.

To reduce these inequalities, the UK Government acknowledges the need for development in its 'Northern Powerhouse' put forward in the 2010-15 and 2015-17 governmental terms. Its prime aim is to increase productivity and economic performance of key Northern cities, including Manchester, Liverpool, Leeds, Sheffield, Hull and Newcastle, shifting the country's economic focus away from London and the South East. Accessibility within and between Northern cities constitutes a large part of the proposal.

The Northern Powerhouse is a strong concept to promote the social and economic development in the North. However, choosing not to include London in a major infrastructure project runs the risk of not realizing the full potential of connectivity between UK cities.

The UK Spine route is designed to pass directly through the Northern Powerhouse aiming to increase the cooperation between cities with complementary skills.

Productivity

Challenges in the UK's international competitiveness are not solely exemplified by the gross inequalities that exist between London and the rest of the UK. Many of the UK's cities are falling behind other European cities in terms of productivity—nine out of ten of the UK's cities have a productivity below the EU average (Bessis 2016). As a result, the UK Government has made a central component of its Industrial Strategy to invest not just in London, but rather with the aim of increasing international competitivity in all regions of the country (Centre for Cities 2017).

9

out of 10 UK cities with a productivity below the EU average

The UK's Secondary Cities

Cities in the UK are characterized by deep inequalities, and the Government has committed to bridge the gap with investment in technology, innovation and infrastructure investments.

UK cities operate within similar sectors but exhibit a surprisingly low level of cooperation. Whilst London's main competitive industry lies in the **financial and banking sector**, the UK's secondary cities have varying sectors of economic advantage.

London

London is the capital city, and at the centre of the UK's economic, social and political activity. It is the most populous area of the United Kingdom, and is a leading global city, particularly in terms of its financial centre.

Population - 1.89 million
Metropolitan Population - 8.80 million
GVA - £ 334 bn

Edinburgh

The capital of Scotland. The economic output has grown faster than the other cities in our study, except Greater London, partly because it has seen an influx of population.

Population - 490,000
Metropolitan Population - 1.4 million
GVA - £ 24.1 bn

Manchester	Birmingham
United Kingdom's 2nd most populous metropolitan area. The Greater Manchester economy is growing at the highest rate in the UK outside of London.	*A major international commerce centre and a UK transport hub, with over half of the population under 30.*
Population - 520,200 *Metropolitan Population - 2.73 million* *GVA - £ 56 bn*	*Population - 1,101,360* *Metropolitan Population - 3.8 million* *GVA - £ 24.1 bn*

Liverpool, Manchester, Newcastle and Sheffield have historically been, and remain, **hubs for manufacturing and production**.

Growth in **digital and technological hubs** has been most prevalent in cities such as Glasgow, Edinburgh, Leeds and Belfast.

Edinburgh, Birmingham, Manchester and Leeds are also leading cities in the **Financial and Professional Services (F&PS)** sector.

*A lack of connectivity and collaboration is **inhibitive** to inclusive growth - Hyperloop could **unlock the benefits** of greater accessibility.*

The current lack of connectivity and collaboration is inhibitive to inclusive growth, and continues to foster economic inequality across the country; Northern cities reliant on goods-based exports are falling behind as a result of impacts of globalisation (Centre for Cities 2017). Hyperloop could unlock the benefits of greater accessibility between complementary cities.

Governmental Support for City Interconnectivity

To tackle inequalities across the UK, the Government has pledged to improve its structural dynamics in the Industrial Strategy. It presents the direction that the UK desires to pursue to meet its economic, social and environmental objectives in light of political hostility. The first three pillars of the Strategy are:

1 - Investing in science, research and innovation
2 - Developing skills
3 - Upgrading infrastructure

The strong need to increase international competitiveness renders the UK Government more receptive to innovative concepts such as Hyperloop. Respondents to our public consultation, including Edinburgh, Manchester and Glasgow City Councils, revealed a strong interest in the technology and pointed at a need for a disclosure regarding the cost and planned right of ways.

The UK Spine

Our proposal for a Hyperloop in the United Kingdom takes the form of a main line along the West coast, connecting the socio-economic hubs of Edinburgh, Manchester, Birmingham and London. Given the expectations of Hyperloop One's technology, we can expect to reduce the time taken to traverse the 400 miles between Edinburgh and London to under one hour, dramatically redefining today's work and leisure patterns.

Given that the average commute in the United Kingdom is 40 minutes, and 74 minutes in London, one could now live in Edinburgh, and work in London within the same budget of time, creating an inter-city commuting capacity. Considering the cities along the route, the main traffic generation source is tourism, with London and Edinburgh attracting approximately 17.4 million and 3.8 million tourists per year, respectively.

Overall, using data from ArcGIS, we found that approximately 6 million people live within a 30 minutes drive from a Hyperloop station, rising to 21.8 million within an hour drive. Given that the Hyperloop One design is inclusive of automated, on-demand vehicles, we expect the in-vehicle travel time to be optimized so as to extend the range twice.

Expanding under Hyperloop One's Autonomous Vision

Because of high population density, the United Kingdom represents an ideal case for the implementation of multiple portals. The UK Spine could be enriched with at least 8 additional portals along the preliminary Right of Way on the West Coast. These would include: **Brighton, Cambridge, Glasgow, Leicester, Liverpool, Milton Keynes, Oxford and Reading.** A case of specific interest is the triangle of Oxford, Milton Keynes and Cambridge. The study of this weakly-connected arc of territory has been undertaken by the National Infrastructure Commission and shows a strong need for inclusion on the rail network.

As the number of portals is increased, the population served increases. Now, a 30 minutes car drive reaches close to 12.3 million people in 30 minutes, rising to 36.6 million within 60 minutes, which is more than half of the UK's population.

Areas within 60min drive inc. 8 extra portals to be found on https://arcg.is/1j4qn

50%

The extended UK Spine reaches **over half of Britain's population**

53

flights per day in each direction between Edinburgh and London

Regarding the employment statistics of the population in proximity of the route, there are around 2.7m managers and senior officials, professional, associate professionals, admin/secretarial employees and skilled tradespeople within 30 minutes drive. This highlights the benefits of the route from a conservative standpoint, highlighting passenger potential for which the economic benefits from the line are likely to be greatest.

Extension of the route to Scotland is a vital component in increasing the overall economic reach and collaboration between UK cities. One potential risk to this extension may the case of a positive Scottish Independence Referendum result. However, there is significant political and economic evidence from all UK parties that this risk-level is low.

In their 2017 General Election manifesto, the Scottish National Party (SNP) committed to installing a high speed connection between Glasgow, Edinburgh and the North of England, as a component of any high speed rail network. Taking this into account, a Hyperloop following the UK Spine route has the potential to comply with the demand to build a stronger network between Scotland, the North of England and the rest of the UK. In an interview with BBC on the 2nd of June 2017 by Labour, Conservative and Liberal Democrat representatives in Scotland all agreed that after a referendum, maintaining a soft border is the only economically viable option. Consensus between all parties - especially the SNP party who have an independence referendum at the forefront of their manifesto - gives support to the fact that the case of Scottish Independence would not have a legal impact on Hyperloop connections between Scotland and the rest of the UK.

Displacement of Short-haul flights

Optimising Runway Capacity

Over the past 20 years, Heathrow has been operating at a critical 98% capacity. The magnitude of future capacity shortages in the South-East depends on the outcome of Brexit negotiations, but the most conservative forecasts point to 13.5 million passenger unserved by 2050. A Hyperloop system enables a modal shift from domestic flights by providing a compelling on-ground transportation system displacing national short-haul connections. This would free up to 10% of the existing South East airport capacity for more profitable, long-haul flights.

Decreasing UK Aviation Emissions

The long term ambition to displace demand for all commercial flights to reduce greenhouse gas emissions is an ideal one. However, our UK Spine route would be poised to make a significant dent to this end, providing an attractive modal shift from domestic flights to Hyperloop technology.

Based on a total of 7.3 million passengers per year travelling between Edinburgh, Glasgow, Manchester, Birmingham and London by air, it can be estimated using the ICAO's carbon offset methodology that around 600,000 tonnes of CO_2 is emitted per year as a result of these domestic routes. Whilst this accounts for the effects of plane type and passenger weighting among other factors, it does not take into consideration the effects of radiative forcing, nor NOx and soot emissions. Hence, we foresee a significant opening for the UK Spine to make a strong impact on the negative environmental effects of these domestic flights and influence key governmental figures in meeting key climate policies, soon to be outlined in the forthcoming 2017 *Emissions Reduction Plan* by the British Government.

Furthermore, a release of passenger capacity from the conventional rail network would enable a modal shift for freight transportation from trucks to rail. This modal shift forms a large part of the High Speed 2 proposal, and a Hyperloop route would contribute to continue the modal shift towards cleaner transport.

43%

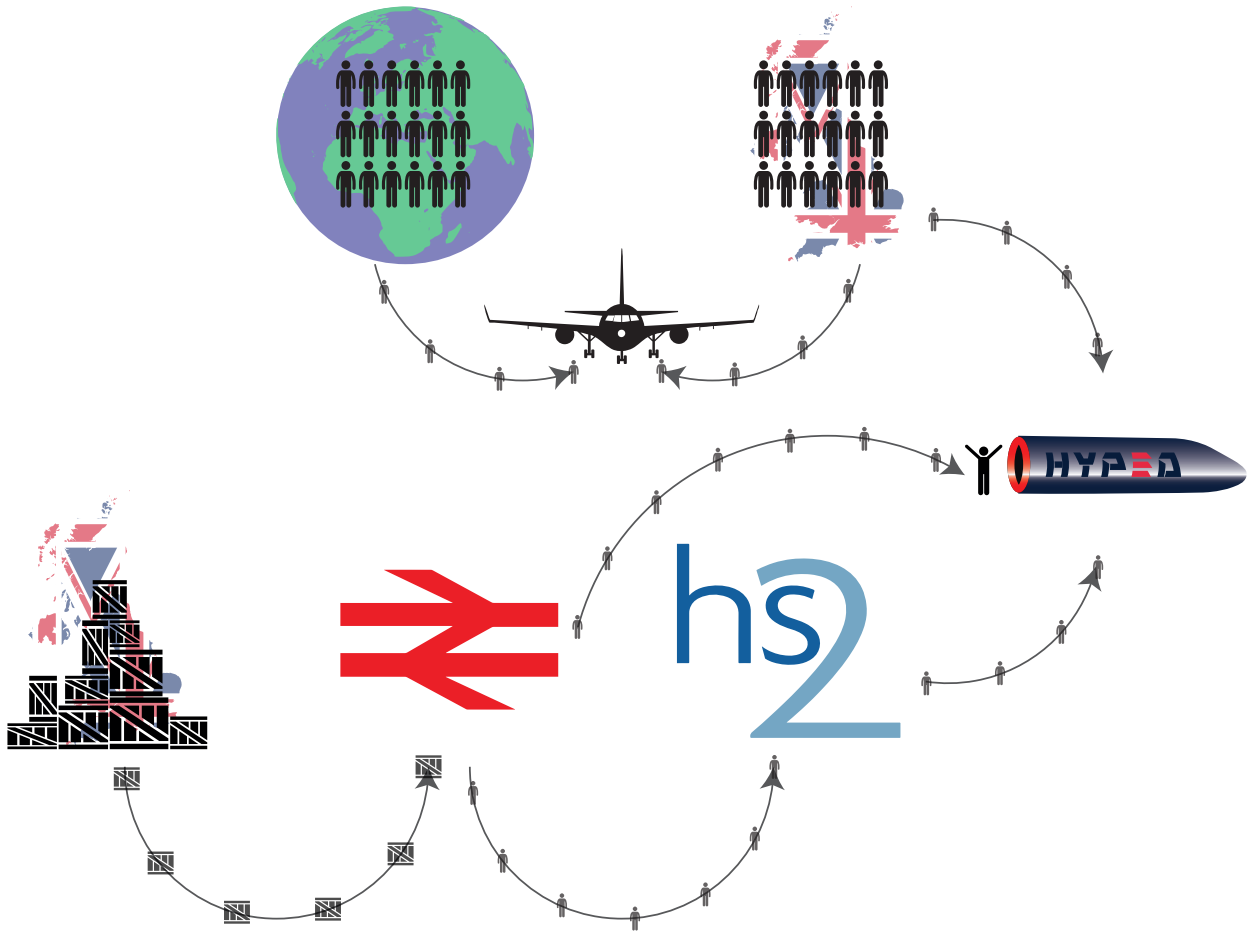
the amount between 2015 and 2030, that the UK plans to reduce transport emissions by

Committee for Climate Change

The United Kingdom's future position with regards to the Emission Trading Scheme (ETS) remains unknown. With Hyperloop pods running on a fully-electrified network, the source of electricity is expected to be subject to any emissions regulations as is currently with the rail sector. The current phase of the ETS (Phase 3) has set carbon restrictions at 1.74% each year, however this is already a higher allowance in comparison to the landmark Paris Agreement (COP21), meaning that there is a strong incentive to migrate towards greener and more sustainable forms of transport, such as a Hyperloop line to meet these targets.

Even after Brexit, the UK has pledged to maintain its CO_2 targets.

The tighter the carbon regulations in place, the greater the competitive edge of a Hyperloop route proposal in the UK. In the case of a "hard Brexit", the United Kingdom is likely to leave the EU ETS,



criticized for oversupply and a low carbon price. As a result, a domestic cap-and-trade system or a straight carbon tax may prove more attractive to a Government. However, the Industrial Strategy and the forthcoming Emissions Reductions Plan give confidence in the UK's commitment to shift towards cleaner modes of transport, and is favourable to Hyperloop.

600,000

tonnes of CO_2 emitted by flights between Edinburgh, Glasgow, Birmingham, Manchester and London per year

**based on ICAO's carbon offset methodology*

Implementation in a post-Brexit environment

Right of Way

The United Kingdom has a high population density and a geological structure that is not susceptible to seismic activity. The Edinburgh to London route is characterized by multiple ground profile changes and natural barriers such as national parks as well as the Pennines. Overcoming these geographical barriers prove challenging; with these factors combined, the preferred Right of Way for the UK Spine is underground.

The United Kingdom has a long legacy of tunneling, starting with Marc Brunel inventing the tunneling shield in 1818. London's £15 billion Crossrail is a good example of a recent, large-scale tunneling project pushing boundaries of efficiency, complying with its allocated budget and the predicted time deadline.

> To minimize the impact on local communities and reduce the risks of project delays, the preferred Right of Way for the UK Spine is ***underground***.

At first glance, the costs of tunneling could appear to be excessive if compared to overground solutions. However, as soon as one accounts for costs in terms of de-risking, tunneling has the explicit benefit of leading to minimal disruption to local communities. During construction, tunneling reduces the costs of litigation, compensation and any other costs associated with project delays. Although the process of tunneling is challenging, it could provide multiple benefits such as mitigation of risks associated with differential soil settlement and elimination of thermal-expansion problems thanks to a relatively constant sub-surface temperature. Both, in turn would increase safety, reduce complexity and lifetime costs of the scheme. Costain is a major UK construction company and has expressed preliminary interest in carrying discussions.

Impacts of Brexit on construction and engineering sectors

One of the major risks associated with Brexit is labour shortages, especially in construction, engineering and IT sectors. With 200,000 EU nationals working in the UK construction industry, any substantial reduction in that number could exacerbate the skills gap that already exists within the UK economy. However, as part of its Industrial Strategy, the Government has committed to address skills shortages. The Government conducted the first employer panels to design and develop new qualification requirements for roll-out in Spring 2017, with the first skills routes to be delivered in September 2019.

The implementation of Hyperloop would inevitably fall within the realm of major projects that have an expected total lifespan of **10 years** or more. Whilst this timeline compares unfavourably to the UAE, it leaves enough time to deliver technical education and answer the extensive labour needs of the project, significantly decreasing reliance on migrant labour. If the Government fails to address this skills gap, this could result in a loss of up to £27 billion per year to the UK economy. The UK Government can take this time as an opportunity to increase the promotion of STEM subjects at schools, specifically targeting girls and women, as they represent half of the national labour pool.

Comparatively long regulatory approval timelines leave enough time to bridge the skills gap in construction and engineering industries and make it more gender equal.

Brexit also poses new challenges and opportunities with regards to infrastructure funding and investment in innovative projects. Uncertainty and volatility in sterling, combined with escalating prices of raw material imports and higher costs of governmental borrowing could adversely affect returns on investment in the short term for British infrastructure projects - a deterrent to foreign investment. To overcome uncertainty connected to Brexit, the Government has placed investment in technology, skills and infrastructure at the core of its Industrial Strategy. The Government's commitment to injecting capital via R&D funding and the Industrial Strategy Challenge Fund (£4.7 billion worth of investment by 2020-21) aims to stimulate the development of innovation, and its consequent export.

Hyperloop could stand to play a key role in mitigating these risks by attracting greater inward investment for UK infrastructure projects and supporting innovative projects in the STEM sector. Given the aim to support 'smart and clean energy technologies' alongside 'robotics and artificial intelligence (including connected and autonomous vehicles and drones)' amongst others, the Hyperloop system meets the strategic targets of the Industrial Strategy.

Hyperloop stands to benefit from the Industrial Strategy's focus on improved infrastructure and clean transport solutions.

From a legal standpoint the ground beneath the surface is owned by the owner of the surface unless there is a special complication such as mineral deposits, oil or gas that are the property of the Crown. The law of land ownership in Scotland and England can be construed through the principle of ownership from the heavens to the centre of the earth. As such, deploying the proposed Hyperloop underground would still require compensation based on noise and vibration, a result of the Environmental Impact Assessment.

The three main stages in the development of tunneling are planning, approval and delivery.
The Environmental Impact Assessment can take up to 5 to 7 years and can be challenged in court by EU member states. Plans are subject to a public consultations, which may lead to a reconfiguration is design or Right of Way.

Overall, public consultations often cause delays, but tunnelling minimizes the interference in private properties, thus it is the preferred Right of Way.

*Going **underground** significantly **increases the deliverability** of the project.*

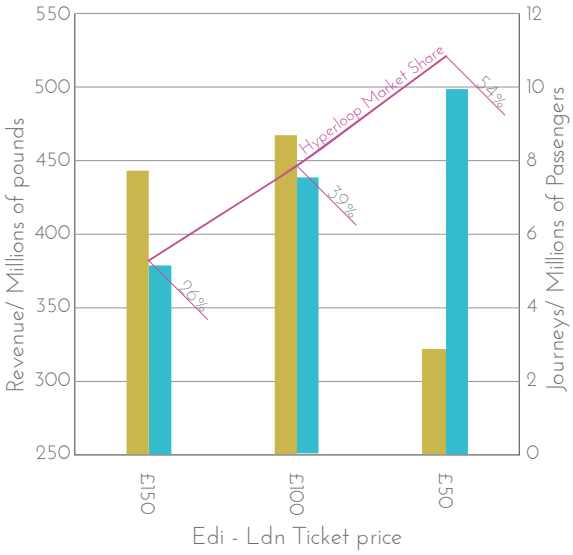
Demand Modelling

A Quality of Service Index analysis was conducted to compare the Hyperloop as a mode of transport to existing transport infrastructures. Based on the market shares of bus, rail and air travel in 2016, the model yields a projection of the market share that the Hyperloop LDN – BIR – MAN – EDI route is expected to capture in the first year of operations. A simulation of market shares and the resulting revenue figures has been conducted under 5 different pricing schemes, proportional to the distance of Hyperloop journey.

This model uses extensive data mining of current transport statistics (prices, timetables, demand) to select locations for Hyperloop stations and define their catchment areas. Economic data for these post-code regions were analysed to calculate utility factors and transport market shares for all O-D combinations. Data was sourced from ArcGIS, the Civil Aviation Authority, HS2 Ltd, and UK Department for Transport Traffic Counts.

The United Kingdom represents a complex mixture of urban-rural population and as a result, personal car travel is the preferred mode of transport. Despite accounting for nearly 70% of domestic journeys under 350 miles the model assumes no conversion of car passengers. This is caused by a temporary lack of reliable data and a lower value of generalized cost of travel for the car driver. Also, the demand model does not account for any induced demand (generated traffic) from Hyperloop, which leads to a significant underestimation of results.

Based on the ticket price of £150 for a non-stop one-way Edinburgh to London journey, the overall number of journeys made in the first year of operations of the UK Spine is expected to be just under 5.2 million, 0.6 million more passengers than on all domestic Heathrow routes combined. This price tag yields a revenue of over £460 million. As expected, a reduction in ticket price leads to a higher market share for Hyperloop: at a price of £50 for an Edinburgh to London journey, the share of Hyperloop travel exceeds 50% of all travel along the UK Spine.



A 30 minute journey time improvement on the rail link between London and Edinburgh (from 5h to 4h30, an 11% improvement) has caused a demand surge of 14.5% between 2013 and 2014. Again, an improvement in frequency by 32%, from 126 to 188 weekly trips, resulted in a 7% increase in cross-border journeys. Therefore, we expect significantly higher values for Hyperloop passenger numbers once induced demand is accounted for: given the cardinal improvement in travel times and frequency of departures, a significant increase in vehicle miles travelled is expected to follow.

Given the expected magnitude of induced demand and a general favourable trend in on-the-ground transport demand growth over the past 20 years, the UK Spine design should account for the boring of multiple parallel tunnels, since adding tunnels in a phased manner is expected to prove expensive.

A Multi-package Offer

How the UK Spine could impact the economic, social and environmental outlook of the United Kingdom

1. Economic

By adding value to the three key factors of production (infrastructure, human capital and innovation), productivity can be increased.

Result	Process	Factors of production
Resilience of UK labour market against shortages of migrant labour flows	Intensive education and training in technical skills	Human capital
An innovative economy that can export the results worldwide	Academic research of technology and best practices for implementation	Innovation
Improved accessibility and social mobility	Upgraded and integrated transport infrastructure	Infrastructure

Desired outcome: increased national productivity

2. Social

> *The UK Spine extended under Hyperloop One's Autonomous vision reaches half of Britain's population in 60 minutes driving time.*

- Delivers increased accessibility to employment and personal opportunities
- Bridges the skills gap in the construction and engineering sectors
- Creates thousands of jobs through construction of the route
- Promotes STEM subjects in apprenticeships and high schools with the potential to reduce the gender imbalance.

The revival of underperforming regions can spur productivity in areas with lower costs, cheaper land and other underused assets.

Desired outcome: a more equal society

3. Environmental

- Reduces greenhouse gas emissions from domestic aviation via displacement of short-haul UK-based flights to Hyperloop technology
- Frees capacity on the rail network for freight services through displacement of rail passengers to Hyperloop technology, again a cleaner transport method both in terms of greenhouse gas emissions and local air pollutants
- Promotes innovation in electrical transport methods overall with a significant spillover into other methods of transport: for example, autonomous electrical vehicles, aiding the development of an integrated clean transport system.

Desired outcome: a cleaner future

Airport Case

In the light of Brexit, it is vital that strategic infrastructure is capable to support economic development. However, the lack of runway capacity and a densely populated area surrounding Heathrow Airport put pressure on London's ability to maintain the role of a major European hub.

THE IDEA

Currently, airports can only expand using adjacent land in order to maintain operational integrity. By integrating a Hyperloop link into an airport's operations, expansion could be undertaken on any suitable site within a radius of 100km.

The application of autonomous, on-demand cars in such system would allow the entire transfer process to be within the same budget of time as for a passenger transferring between two terminals within a single airport. Controlled environment of airports at both ends of such route could also allow Hyperloop One to test fully integrated end-to-end transportation systems prior to implementation on public roads.

Opportunity

London airports serve more destinations than any other European city and in 2016 collectively, they handled over 163 million passengers. Heathrow is currently engaged in the planning phase of the third runway. However, the expansion of Heathrow has very localized negative impacts, such as the destruction of over 700 homes, increased congestion of the airspace and a significant rise in air pollution.

HypED has submitted a response to the Government's Consultation on the Draft Airports National Policy Statement, outlining the case for addressing shortage of runway capacity by implementation of a Hyperloop system.

London airports could be expanded whilst bridging any pre-existing constraints such as built-up areas or congested airspace. Effectively, this would lead to an increase in benefits generated through the aviation industry by improving airport connectivity, optimizing utilization of existing capacity and mitigating negative impacts on local communities.

1

Connection between Heathrow Airport and a greenfield site where a new satellite airport for Heathrow would be constructed

2

Connection between Heathrow Airport and an existing, disused runway, which could become a satellite airport for Heathrow

3

Connection between Heathrow Airport and another well-established airport e.g. Gatwick, Stansted etc.

Case study: Heathwick

London's Heathrow and Gatwick are, respectively, the busiest two- and one-runway airports in the world. Currently no fixed connection exists between them, therefore passengers arriving at each airport are constrained only to local onward flights.

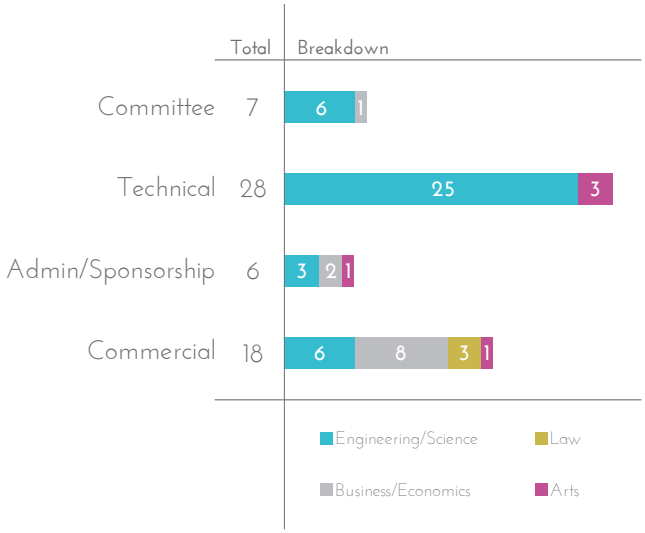
Should a 40km Hyperloop link be constructed, such a three-runway 'virtual hub' would have handled over 118 million passengers and connected a total of 286 destinations based on 2016 flight schedules, making it the busiest airport in the world. Construction of the new runway at Heathrow and, highly likely, of a new runway at Gatwick shortly after, would effectively create a five-runway 'virtual hub' and enable exponential improvement of hub connectivity.

Currently, both airports are owned by separate companies, however the case for integration is very strong. The group will pursue research within the field of airports and explore opportunities for implementation within the United Kingdom and worldwide.

Our Team

HypED is a multi-disciplinary student group from the University of Edinburgh and Heriot-Watt University working on the innovative ultra-high speed transport project Hyperloop. We have over 50 members, predominantly studying Engineering (Mechanical, Electrical and Civil) but also Mathematics, Physics, Computer Science, Law, Business, Politics and Economics.

At the first SpaceX competition in January 2016, the technical team won one of the 12 highly esteemed awards for Technical Excellence in Subsystem Design. Since, the group has grown from 20 technical members to 50 members across engineering, science, arts and humanities departments. HypED has now two teams: technical, which is building and testing the pod; and commercial, who is working on a pre-feasibility study for implementation of the Edinburgh to London route in the UK. The average age of team members is 21 and there is an even gender representation in the commercial team.



Technical team in June 2017

HypED successfully went through the Preliminary Design Briefing, Final Design Briefing and Final Design Presentation stages in the SpaceX competition and have officially qualified for the global finals of SpaceX Hyperloop Pod Competition vol. 2. The finals will take place in California at the end of August where we will join an elite group of 24 teams from around the world. Only three other teams from Europe qualified: Technical University of Munich, Technical University of Endem-Leer and Warsaw University of Technology.

Commercial team in June 2017

Our commercial team was shortlisted as one of semi-finalists of Hyperloop One Global Challenge where Hyperloop One, the U.S. venture funded firm (~£150M investment) is seeking global partners for conducting feasibility study and possible implementation of the technology. We joined a group of 35 semi-finalists among 2600 entries and will be presenting the economic case for an Edinburgh – Manchester – Birmingham – London route on June 7th at the Vision for Europe event in Amsterdam.

Alongside this, the team has been involved with issuing responses to Government consultations, namely the Draft Airports National Policy Statement and the Industrial Strategy Green Paper, proposing the

Hyperloop to Governmental bodies as a viable mode of transport to fulfil issues regarding infrastructure investment and air capacity in the South East.

Engagement of HypED

Hyperloop teams worldwide are the greatest source of inspiration for the next generation of STEM representatives. It is imperative that the Government, through universities, reaches out and inspires young people to take up STEM subjects. The UK will have to produce highly skilled STEM graduates with the entrepreneurial and technical skills that industry will demand in the forthcoming time. The Government can support this work through sustainable funding for STEM disciplines in addition aiming to create a more gender, race and class balanced research community for the future.

Academic support

The value of our multi-disciplinary work has been recognized by academics across multiple departments in the University of Edinburgh. The team has the official support of the University's Principal, of the Head of the College for Art, Humanities and Social Sciences as well as of the Schools of Engineering and Business. Furthermore, academic mentors of the team are Professor Gordon Masterton, Professor Paolo Quattrone, Professor Win Rampen and Dr Augusto Voltes-Dorta. We have also received support and coaching from MBA and PhD students from the Business School.

A strong need for research on Hyperloop

In their responses to the public consultation we published (" Hyperloop Strategy for the United Kingdom"), public stakeholders have made a strong case for more research on costs and benefits as well as the right of way of Hyperloop,before any formal commitments could be made. Moreover, during discussions with the Department for Transport, we have learned about the challenges analysts are faced with when trying to compare Hyperloop against existing modes of transport. Given that the system is expected to be on-demand and automated, there also exists a wide scope for research on operations and optimization of movement. On the technical side, many more challenges with regards to the creation of a vacuum, propulsion and safety are to be solved. The group is extremely diverse and has acquired a taste for work across subjects, with computer scientists working on demand modelling or engineers on regional legislation.

Stories of stakeholder engagement

The University of Edinburgh:
Our alma mater. We are supported by the School of Engineering and the Head of the College of Art, Social Sciences and Humanities, and actively supervised by Professor Win Rampen, Professor Gordon Masterton and Professor Augusto Voltes-Dorta. We have received over £25,000 from various funds and are featured in the permanent University exhibition "Inspiring students".

Innovate UK, UK's innovation agency:
Innovate UK is supportive of Hyperloop technology developments and has encouraged the team and the University of Edinburgh to pursue the pre-feasibility study and to apply for the Investment Accelerator Pilot.

Forthcoming Edinburgh Futures Institute (University of Edinburgh):
HypED is put as an example of multi-disciplinary work that the University of Edinburgh Engineering

and Business Schools seek to achieve in the nascent Institute.

Costain:
The relationship was formed at the "When Hours Become Minutes" event, the showcase of the Edinburgh to London route in October 2016. It resulted in HypED members speaking at a Costain's 'Engineering Tomorrow – Innovation Conference' in November 2016 and consulting Costain surveyors.

Social Media

As part of our outreach strategy, HypED has a very active Facebook presence, with just under 2,000 likes. Since January 2017, we post on average 3 times a week. Our communications are as follows:

I need Hyperloop: UK-specific facts that showcase the need for a Hyperloop system

What Is Hyperloop: Explanations of parts of Hyperloop technology, aimed at a non-technical audience

Humans of HypED: Interviews of team members, with intimate confessions on teamwork and what Hyperloop is to them

HypED for California/HypED for Amsterdam: Updates on the progress of teams on the submissions to SpaceX and Hyperloop One Global Challenge.

Typically, our posts have an organic reach of 3000 users, representing an engagement of over 45% of our page likes base.

Event Appearances

As part of our engagement strategy, HypED has attended numerous conferences and events with key stakeholders. This has included the UK Magnetics Society's Conference in February alongside University level engagement, such as participation in TEDx at UoE, running workshops as part of the Festival of Creative Learning and in numerous events promoting the society at School of Engineering open days and to alumni. On top of this, HypED has been involved in creating its own events, including a showcase on 27th October 2016 attracting 250 attendees and reaching approximately 3000 viewers on a live stream.

As a result of these engagements, we have been recognised by the University, receiving the Sustainability Award in March and reaching the shortlist for 'Best Academic Society'.


#ineedhyperloop
TGV began operating in France in the 80's, but the UK is still without high speed rail and we're pushing our old Victorian network to the limit.


#ineedhyperloop
ぼくらは、
まっすぐ、
つながっている。
Japan has been adding speeds
twice as fast as the UK with
their Shinkansen high-speed trains


#ineedhyperloop
Here we go
An on-demand Hyperloop system allows for more one-day impulse trips outside of London


#hyperwhat
The Hyperloop
travels in a near vacuum tube.
This is to minimise air resistance which generates drag on other modes of transport.

Commercial Team Members
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