How can engineers benefit society?

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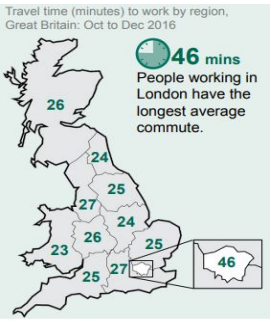
Commuting distances have been increasing since the late 1980s, due to higher demand for transport infrastructure, resulting in more easily identifiable commuter patterns. These patterns have been frequently changing as cities get larger and more people need suitable ways to get to work and travel around. As a society, we have to find modern solutions to reduce geographical immobility. This warrants a discussion regarding whether engineers can continue formulating innovative solutions and how this will benefit society.

My first point of discussion will be how the term 'beneficial' can be interpreted in different contexts surrounding engineering. In order to judge 'beneficial' fairly, we need to understand in which ways engineering structures would be deemed as benefiting society and the environment around them. The official definition of beneficial is when something 'produces good results or helpful effects' [1]. In the case of engineering structures, we can take this definition and adapt it to better suit the context. Some factors I will consider are: how it has impacted the local community; if the structure has been manufactured taking the environment into consideration; and whether the benefits of the project have outweighed the costs.

Transport systems designed throughout the 20th and 21st centuries often evolved from the Roman Transport Network [2]. The Romans designed and built over 50,000 miles of hard-surfaced roads that spread from Britain to The Middle East following the Tigris-Euphrates river system. Their roads connected major cities to Rome and were primarily designed for military use. This was advantageous during Roman invasions, as they had clear-cut routes to all of the important cities. Roman engineers followed techniques that used volcanic ash, known as *pozzolana*, and lime to build their roads [3]. For the time, these were extremely advanced methods. They used solid foundations and straight roads; these can still be seen today in parts of the Great North Road in County Durham. This ancient road stretched from London to Edinburgh and demonstrated the Roman engineers' fine skills and precision in their work. The methods that the engineers used in the 5th century were very successful as the structures have lasted over 900 years. The road network benefitted the Roman society at that time, helping them to be one of the greatest historical empires. As time progressed, the Roman infrastructure became the foundation for new and more advanced transport networks and an example for future engineers to analyse. In the past, the majority of journeys were made for trading or invasions, with most people remaining in their settlements. This has now evolved; people travel to other cities for appointments, work, and social events, resulting in higher demand for modern transport solutions.

Commuting in the modern day has significantly improved as a result of engineers pioneering structures, such as The London Underground. It officially opened in 1900, and has since been improved to consist of 270 stations positioned on 11 lines around London city [4]. Upon construction, engineers had to formulate solutions to a number of challenges, one being the design of a tunnelling system under the capital city. The underground had to navigate around sewer drains, electrical wiring, water pipes and other hazards. As a result of the huge quantities of planning, the system was built in sections to allow for certain routes to open without the entire structure being finished. This provided engineers with useful insight into commuter patterns route by route so they could cater for larger capacities on future routes expected to be popular. The completion of the Tube system has benefitted London city by reducing road traffic and therefore contributing to the *sustainability development goals 2030* [5]. These targets are extremely important to engineers when designing a large transport system such as the Tube because all new projects should be taking into consideration the impact on the environment. Forming sustainable methods of travel improves the city and caters towards the future. The system also allows for commuter traffic to be directed and controlled more systematically. This is necessary

when forming an efficient city, as traffic congestion can become a problem for commuters and could also impact other travellers. Controlling the traffic underground as well as above can ensure that transport runs smoothly, improving the wellbeing of residents in many cities. Construction and improvements to the Tube continue to make it paramount in many people's lives on a day-to-day basis. The pictograph shown demonstrates the average commuting time per region [6]. In general, the further south the population is, the longer the commuting time. This is especially significant in London where the time is, on average, just under double compared to elsewhere. The statistics provide a suitable reason why a large proportion of transport systems in the United Kingdom are constructed in London. More commuter traffic travels to London, requiring more infrastructure than elsewhere. These improving networks allow more people to travel between the North and South, keeping the financial capital connected with the rest of the UK.



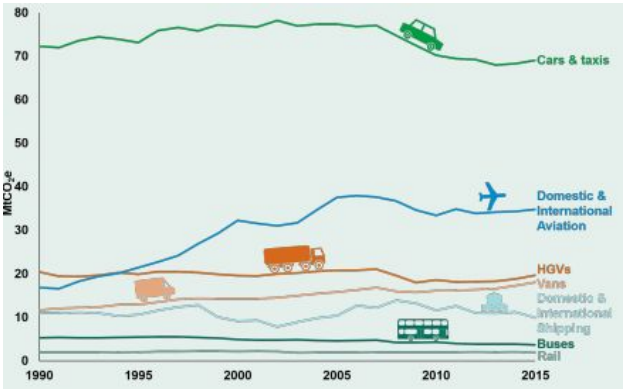
HS2 is a current project being designed by engineers to reduce commuting times, better connecting the North and South. This high-speed rail network consists of new railways connecting to existing routes providing quick transport targeted towards commuters. The new rail system will connect London with Birmingham, The East Midlands, and Manchester [7]. The engineers designing this project had to formulate unique solutions to preserve habitats across the country. Sixteen of the one hundred and fifty bridges will be specifically *green bridges* and sixty new green habitat spaces have been created in locations alongside the track to help aim towards net-zero emissions [8]. One of the highest priorities the engineers had to address was designing the railway in order to preserve ecosystems that otherwise would have been destroyed. In the past, similar projects divided land, placing a physical barrier between wildlife habitats. A green bridge in Banff, Canada (see photo) successfully connected two areas of wilderness obstructed by the Trans-Canada Highway and restored wildlife in the area [9]. A similar idea is being used with the green bridges over HS2 to protect the environment being destroyed by construction. The HS2 project has been broadcast as 'the biggest environmental project in Britain', and aims to encourage more commuters to travel via train rather than car or other modes of transport. Engineers have been able to design unique structures allowing this project to meet the *Net Zero Carbon Emissions Goal 2050* for the United Kingdom [10]. HS2 will massively benefit society by improving flow of goods and wealth up and down the country as well as meeting its sustainability goals: reducing river blockage, maintaining animal migration pathways and reducing noise pollution where possible.

Another transport sector that has been set the challenge of meeting the *Net Zero Carbon Emissions Goal* is the aviation industry. It has been one of the most rapidly improving transport sectors in the 21st century. There is a wide variety of engineers in this sector, spanning from aeronautical to electrical to structural. They all contribute towards creating safe and practical transport networks, accessible from all over the world. These networks benefit society by providing a global connection for people and freight. This ensures that travel for business and leisure trips can be accommodated, providing a more connected society worldwide. Around six million people fly each day around the world; the demand for aircraft is ever increasing. This increasing demand is encouraging engineers to build new, advanced aircraft and airports to accommodate large amounts of air traffic. The technology advancements over the past 20 years have enabled modern aircraft to be continually improved, and new designs for sustainable aircraft are continually in early stage testing.

Airbus recently worked on their latest E-FANX concept aircraft that was fully electrically powered[11]. The aim of this project was to provide a demonstrator aircraft: firstly to show the pioneering electrical technology worked; and secondly to encourage other aviation companies to follow in their footsteps. Since Airbus released the findings of this project, more companies have been focused on finding realistic, but innovative, solutions to

improve sustainability within the sector. The project came to a close in April 2020, but the E-FANX model demonstrated the capabilities of new technology. Engineers know that with these new advancements, they can manufacture more sustainable aircraft in the hope to meet global emission goals for the aviation industry. A problem with the manufacturing process of modern, sustainable aircraft is that they are designed over a much longer period of time than previous models. This is expensive for the companies, and unless the benefits outweigh the costs, manufacturing will not continue. However, the new technology will benefit society in many ways, primarily sustainability based. The aviation industry produces 2% of the world's human-induced carbon dioxide emissions every year [12], which is widely believed to impact global warming. By reducing these aircraft emissions, aviation can begin to tackle the extremely prevalent climate crisis. As travelling increases again after the COVID-19 pandemic, the industry can begin to introduce new technology from engineers, and pave the way for a more sustainable future.

Over recent years, sustainability has been another focus point where engineers benefit our society indirectly every day. Specifically, a focus over recent years has been sustainability. It is one of the most pressing discussions in current news with more data and statistics being released daily. Engineers have had to change the way they think about designing and constructing infrastructure to ensure it is suitable for new target emission goals, and that it will positively impact future generations. The graph below shows the different types of transport from 1990 to 2015 and the correlated emissions of greenhouse gases [6]. To summarise, 58% of emissions come from cars; this is around the same as it was in the 1990s showing that the increase in public transport has not encouraged people to take an alternative method of transport. This is often due to the cost and convenience of the public transport industry. Both of these problems have been tackled in many cities by improved transport infrastructure and decreased ticket pricing. Heavy goods vehicles have also remained at a similar emission level. As transport of heavy goods has increased, the emissions staying similar implies that other modes of transport such as freight trains have also increased, providing the extra capacity for transportation of goods. The largest increase in emissions between the 1990s and today is the aviation sector. The emissions have more than doubled since 1990 and as of 2015, aviation emissions increased by 10% (contributing to around 22% of the global transport emissions). As a result, engineers have designed new sustainable transport methods such as the HS2 train and electric vehicles to help transition towards a more environmentally friendly future.



On the topic of infrastructure, integrated transport systems have become an increasingly popular way to improve traffic flow and efficiency around cities. An integrated transport system involves the combining of different modes of transport to maximise ease and efficiency for the user in terms of time, cost, comfort, safety, accessibility and convenience [13]. This contributes towards a smooth system for transporting goods and people. Many cities have decided to incorporate integrated transport; for example, interconnecting train stations with bus routes to provide direct routes to many areas within cities. By engineering structures that connect different modes of transport, customers should find it easier travelling to different places. Firstly, this benefits the environment because more people are choosing to use public transport when commuting. It has become more convenient as a result of improved integration methods so more commuters decide to leave their cars at home, and as a result exhaust emissions are reduced. As transport continues to improve, more people will choose to commute using more sustainable, less expensive options and contribute to reducing carbon dioxide and sulphur dioxide emissions. In addition, economic benefits arise from the creation of integrated transport systems, as it gives the operating company monopoly powers over the region. They can benefit from economies of scale, which are important specifically for the transport industry, as it has high fixed costs due to

infrastructure. This means that the average cost of transportation is decreased, and these lower costs can be passed onto the customers providing a more economically viable alternative. Increased profits could be used for research and development leading to further advancements for the improvement of a city's transportation network. Furthermore, congestion has negative externalities such as increased potential for air degradation. An integrated transport system can mitigate this pollution (providing that it decreases demand for cars) by reducing emissions per capita. Finally, congestion issues may lead to decreased productivity, as being delayed in traffic for extended periods of time has significant mental health implications, which can reduce employee productivity at work. Therefore, by providing a more efficient and commuter-friendly option, there will be benefits for people and companies alike.

In a time when the prevalence of mental health issues is increasing, it is paramount that as a society, we make a collaborative effort to reduce the effects by contributing to resolutions. Engineer's contributions to diminished commuting times will likely have a positive impact on future generations. The framework and principles for efficient and sustainable transport that engineers are currently producing will have a similar level of influence as the Roman engineer's creation of international road networks. The foundations being set today will be of the utmost importance when dealing with the imminent threat of climate change. As we are not on track to meet the conditions set out by the *2015 Paris Climate Change Agreemen*t [14] and decades of political debate and discussion have not produced the feasible solutions required, engineers will be integral in formulating effective mitigation strategies. Engineers have done, do and will continue to be at the forefront of producing innovative solutions that improve the quality of life for everyone therefore benefiting society as a whole.

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