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Will the current public transport network in Birmingham support passengers disembarking HS2?

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Abstract

By modelling potential passenger demand will the current Birmingham Public Transport network best support passengers disembarking from High Speed 2 (HS2)? This research created two models by which answer this question. As data for Birmingham with regards to public transport journeys was not publicly accessible, the Oyster card journey data was used, obtained from the TfL website. This data contained 5% of all Oyster card journeys for a week, giving the mode of transport and some mode-specific journey data.

King's Cross St Pancras station was chosen to be modelled due to similar characteristics with Birmingham Curzon Street station, which is the final destination of the HS2 project. Rail and bus data were filtered to include journeys that originated from or coincided with King's Cross station. The model was then created and passenger numbers noted to then create the proportion of travellers from King's Cross that terminated their journeys in a zone.

Various assumptions were made due to some limitations with the data as covered in the report. Zones for Birmingham were identified as this showed the future plan for the city. Using some of the city zone allowed for future comparison between these reports findings and the Big City Plan. Some additional zones were added to ensure that as much of the city was covered by the model. Zones were then paired up according to the characteristics identified in the initial model. The pairing was complete based on an individual best fit case instead of a whole set best-fit case. Having paired up the zones the proportions of travel to each zones from London were then transferred across to Birmingham to view how the predicted flow of passengers would occur from HS2.

The demand for HS2 in Birmingham was reviewed and the increase in the number of passengers due to HS2 analysed. As a result, this research found that the increase solely due to HS2 is insignificant in relation to the expected population increase when HS2 is completed. Therefore, the findings were that by attempting to accommodate the large population increase, the additional influx from HS2 will be adequately supported. Giving the recommendations of implementing a greater number of Sprint buses to provide high-speed transit from areas outside of the city into Curzon Street. Supplement the current bus network to areas that are closer to the city centre like Aston in order to ensure that growth will still occur in these areas due to the increasing accessibility to the city centre. Increasing rail capacity to reduce the overcrowding at New Street station, by a higher number of services

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during peak time or increasing train length. Alternative transport modes can be offered, with the suggestion to extend the Midland Metro line to potentially reduce the demand on New Street.

Keywords: High Speed rail; HS2; Public transportation

1. Introduction

Among the conflict about the success of HS2, which is a Second-High speed rail project servicing between London and Birmingham, the key question is set as "Will the current Birmingham public transport network best support passenger disembarking from HS2?". As the final destination of the HS2 project, Birmingham city council have created a strategy for connectivity to the HS2 network and allows for the best flow of passengers from Birmingham Curzon Street to final destinations in the Birmingham area. This plan only provides a rudimentary guide as to the changes planned in Birmingham and the surrounding areas (Birmingham City Council, 2015a). Also, a comprehensive idea to change the planned for the transportation network by creating a model of passenger flows into Birmingham and around the city was launched for upgrades transportation services (Centro, 2013).

The strategy for linking the HSR system with other HSR lines or other public transportation have been widely found in many cities in Asia and Europe. It aimed at connecting city-to-city or among cities for generating impact within a region, for example, Macon and Le Creusot in France, Madrid, Ciudad Real and Puertollano in Spain (Yang et al., 2018; Moyano, 2016; Moyano and Coronado, 2017). However, the linking between HSR and public transportation (i.e., bus, tram and intercity rail) can contribute the success of HSR network as the spatial connection is enhanced (Loukaitou-Sideris and Sider, 2015; Green and Hall, 2009). Moreover, public transportation in European countries have been improved to minimise transfer time and provided more frequent service to the passenger (Clever, 1997; Maxwell, 1995)

These advantages give a new perspective to potential passenger flows based on an alternative model and using different data. Due to the lack of data publicly available for Birmingham, the data from London, which was collected from the oyster card, will be used. The Oyster cards are a travel card used in London for all public transport modes as functioning with a tap on tap off the system. This will give a very good understanding as to the proportions of people visiting certain areas of London from a single point station. For example, the Oyster Card data may show where passengers go once they have come into Kings Cross St Pancras. This will give an indication if King's Cross St Pancras is more of a hub station or a final destination.

Regarding public transportation in Birmingham, the swift smart card was launched, which works in similar ways to the Oyster card in London. Using the Oyster card data will give an indication to the potential flows in Birmingham in such a time when the Swift card develops like the Oyster card allowing the model to apply to the future conditions of transport around Birmingham.

The model will be created for a single station in London and then compared with Birmingham Curzon Street. Urban dynamics will be used to capture the passenger flows towards different urban areas. Similarities in the zones to Birmingham can be drawn out and using the limited publicly available data for Birmingham a projected model of Birmingham can be created. This can be used to estimate suggested changes to the transport network. The changes recommended by this project can be compared with those proposed by BCC and Centro. Areas that have differing views from the two models can be investigated to determine the most effective upgrades to carry out.

This will give a unique model of expected passenger flows in Birmingham using a model from a city with a well-established public transport network. Although this model may not show exact numbers, the proportion of people visiting areas from Curzon Street can be identified. This would show if passengers are heading towards the city centre, the NEC, the Airport or Villa Park. This can then be used in turn to also predict the usage patterns of HS2 and how they may change if there is a match at Villa Park or a concert at the NEC.

Nomenclature

CDRs	Call detail records
HSR	High Speed Rail
HS2	High Speed 2 project, which is a new line linking London to Birmingham
LNWR	London North Western Railway
NEC	The National Exhibition Centre
PRISM	Policy Responsive Integrated Strategy Model
TfL	Transportation for London
TFWM	Transportation for West Midlands
WMR	West Midland Railway

2. Literature Review

2.1. Demand

The demand on a HSR network is typically conducted through surveys and estimations on current networks in place. HS2 Ltd (2010) undertook an assessment into the potential future demand for the HS2 network. Three stages of modelling were used, each stage to increase the accuracy and reliability of the demand estimations. Overall patterns from across the UK were analysed to determine the demand between large cities. Following these different scenarios were trailed, changing the station locations, the route and the number of the station were all varied to optimise the final route layout and stations. However, other modelling techniques could have been utilised as investigated (Toole, 2015). The use of call detail records (CDRs) from mobile phones along with crowdsourced geospatial data, census records and surveys. The first two are of particular interest as there is no evidence that HS2 Ltd utilised these methods when determining demand. The advantage of using CDRs are the huge levels of data available due to high mobile phone usage. Regarding a period of six weeks in Boston, United States, for example, 1 billion calls were made by 1.6 million users (Toole, 2015; Ferreira et.al, 2010). This give a huge level of data that can pinpoint the exact movement of people from door to door. By knowing this information precise area hotspots can be easily identified. This technique would use data from a significantly higher number of people than survey data would. However it is to be noted that this study was conducted in the United States, data protection laws may be different making such an undertaking impossible in the United Kingdom.

2.2. Transportation in Birmingham

The city of Birmingham is currently undergoing a vast overhaul of transport connections into the city and between suburbs. This new development is the main driving force behind more efficient and effective travel around the city; reducing travel time and increasing capacity. These are the two largest issues that HS2 will face in order to be a success in Birmingham.

2.3. Existing Links between London and Birmingham

The current services between London Euston station to Birmingham New Street station on the West Midland Railway (WMR) and London North Western Railway (LNWR) takes approximately 2 hour and 15 minutes (West Midland Train, 2018) and the Virgin Train service takes approximately 1 hour and 20 minutes (Virgin Train, 2018); whereas, HS2 will take approximately 50 minutes. (HS2 Limited, 2013), leaving a possible 30-minute reduction in journey time as shown in Fig.1. This narrow window for saving time makes the need for effective and efficient connectivity with HS2 paramount. The development of transport links within the city between Curzon Street Station and other city centre stations will be of particular importance. New Street station is the busiest station outside of London with a substantial number of daily passengers. A train arrives or departs every 37 seconds (Ballantyne, 2015). The need for effective movement of passengers is key. The station has recently received extensive renovation

work to it, allowing for a higher capacity and easier movement. A tram service also terminates at the station and runs out of the city centre providing an easy link to neighbouring locations. New Street can be seen as a hub station for travellers moving around the country, coming from outside Birmingham or from the suburbs of the city. This aspect of New Street needs to be carefully considered as the needs of the passengers will be different from that of a regular station. Hence during the renovation work, the transit of passengers from trains and different modes of transport has been carefully thought.

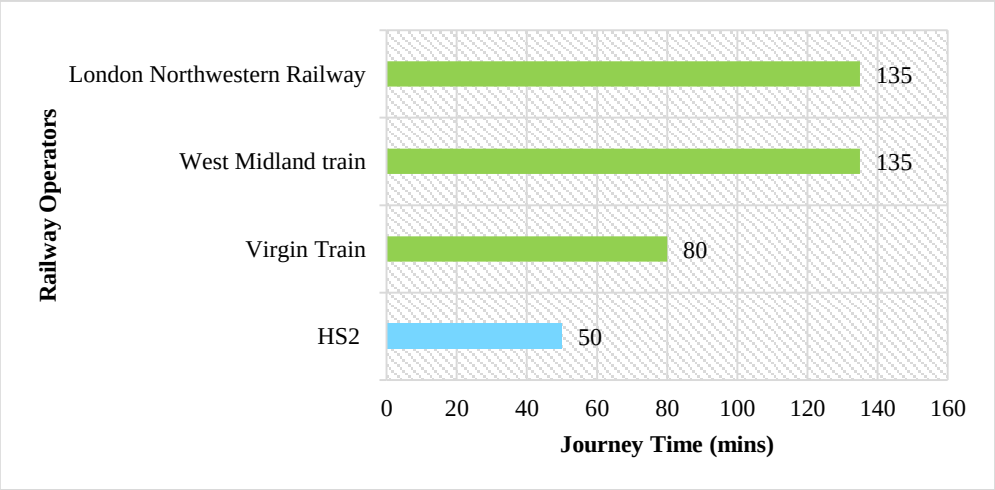

Fig. 1. The comparison of train service between London Euston station and Birmingham new street station.

2.4. New Links

Transport for West Midlands (TFWM) has a series of upgrades to existing service planned to accommodate HS2 and allow for better connectivity. These have been discussed with Birmingham City Council and are finalised. The upgrades range from making changes to rail services to the possibility of increasing capacity on the certain roads to ease traffic. The new links will be installed at both Curzon Street and Birmingham Interchange.

2.5. Existing plans for Birmingham

The current development plans can be viewed in two parts. The immediate area around Birmingham Curzon and then the wider area. By separating these two areas out different focuses can be applied. Birmingham City Council (2015a), have created a document entailing the plans for the immediate area around Birmingham Curzon.

2.6. The Masterplan area

Regarding the report created by Birmingham City Council, a strong grasp as to the intended plans of Birmingham Curzon can be obtained. The Birmingham Curzon HS2 Masterplan provides the framework and principles to guide development, regeneration and connectivity to ensure that the city can capitalise upon the arrival of HS2 and fully realise its transformational impact (Birmingham City Council, 2015b). The report focuses on the immediate areas surrounding the station. The Masterplan builds upon previous plans for the city of Birmingham. An image is wanted to be portrayed as a cleaner, affluent and a more sustainable Birmingham.

As discussed in the connectivity section of the report the transport strategy aims to reduce the road traffic in the area by creating pedestrian areas and reducing parking. The plan is an attempt to encourage the use of public transport in the area; with buses, trams, walking and cycling recommended.

As shown in Fig. 2a., the walking and cycling routes are extensive within the Masterplan area, and they extend out towards other hubs trains stations, in particular, New Street Station. An extensive reach of primary walking and cycling routes can be seen. This indicates that movement to and from the area has been considered which will greatly aid the movement of passengers from Birmingham Curzon to other stations close by.

Fig. 2b. shows the proposed bus and Metro routes within the Masterplan area. The routes have been designed with movement to and from the area in mind, with only five Metro stops planned. It can be noted that only Digbeth Coach Station and Snow Hill Station have direct Metro or bus links from Birmingham Curzon, and New Street does not. This can give an indication as to the intended method of transport for transitioning to New Street from Birmingham Curzon. This would suggest passengers walk. This would cause a lot of foot traffic as New Street is the busiest train station outside of London (BBC News, 2015).

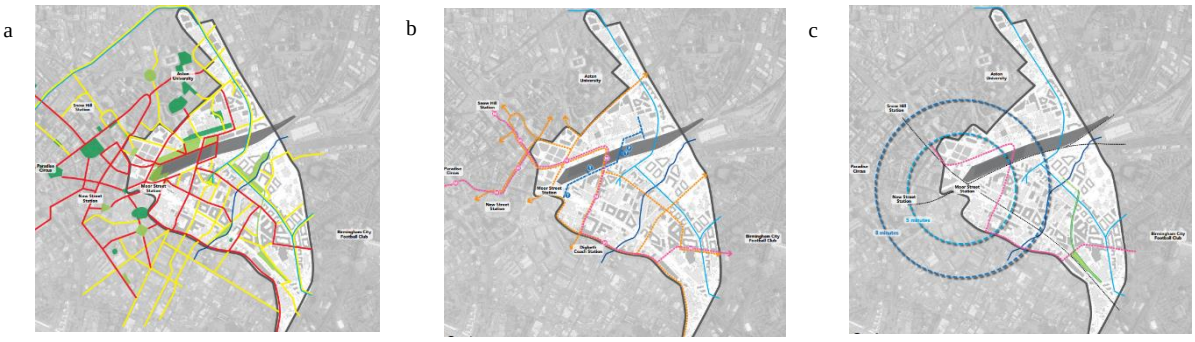

Fig. 2. (a) Walking and cycling routes; (b) Connectivity with public transport at Birmingham Curzon;
(c) Connectivity with Birmingham Curzon (Birmingham city council, 2015a)

However, Birmingham Curzon station is approximately a five minute walk away, which equates to roughly a 400 m (Evstudio AEP, 2016). This clashes with the general guideline discussed by Aurecon Australia Pty Ltd (2013) that people are unlikely to walk further than 400m to access public transport. This can be an issue as New Street Station is 400m away and is a Major hub station in Birmingham and for the West Midlands.

However, Walker (2011) stated that ‘However, people walk further to faster services. (Rail advocates are more likely to phrase this as “people walk further to rail”) This doesn’t have to be a sociological or humanistic debate, though urbanists often frame it that way. If you are a rational and informed actor seeking to minimize travel time, it often makes sense to walk more than 400m to a rapid transit station rather than wait for a bus to cover such a short distance.’ This intuitively corresponds to logical thinking. Even if passengers are unhappy about the distance of the transit covered by walking the alternative is less preferred. In the report by (Birmingham City Council, 2015a) the distance between Birmingham Curzon and the surrounding stations is not discussed. A rough walking time guide is provided as shown in Fig. 2c. The distance between Birmingham Curzon station and other connecting stations may prove to be an issue if the number of passengers using HS2 is high. It is likely that a large portion of passengers may use New Street to take connecting trains at New Street is the busiest station outside of London (BBC News, 2015). This leaves a high level of foot traffic moving through the city centre, which in turn can cause a large amount of congestion on roads and footpaths.

2.7. Modelling

Typically for this kind of work, a form of modelling software would be used. This is due to the high volume of data and detailed analysis needed. For example, when adding a new train station with connecting bus routes it would be useful to have all the passenger numbers for the routes and volume of traffic at each stop. This would allow for more accurate predictions to be made should a change occur to the current network. As discussed by Transport for London (2010), there are various types of models that can be used and differing software that specialises in certain aspects of a system. With some like OSCADY PRO for single intersections and TRANSYT which is widely used

for signalised networks. Each has their own advantages and disadvantages and often they are used in conjunction with each other.

2.8. PRISM

Policy Responsive Integrated Strategy Model (PRISM) is the model used by TFWM to evaluate changes to the transport network in Birmingham (MacDonald, 2017). It was created with Mott MacDonald and RAND Europe for the West Midlands. It uses a method of zones of differing size based on the volume of traffic in that area but can be changed for specific reasons. It models the following changes in travel responses to congestion, investment and policy: trip making, destination, mode, time of travel and route.

The data is collated through ticketing information, survey data and passenger counts. It is then inputted into a series of matrices to allow for the analysis to take place. New stops or stations can be added and this will an effect upon the whole network allowing for appropriate changes to be made depending on the effects. This model has been used to assess links for the HS2 connectivity package in Birmingham, such as the Midland Metro Extension (Powell, 2014). As the model was created especially for the West Midlands using it for the HS2 connectivity package may be the best option. However, although the model does have its benefits there are limitations to it. The model will be predicting flows around the area for years in the future, one of which is 2031 when HS2 is due to the fully completed. This leads to the issue of using data today to predict everyday occurrences in over ten years' time. Many factors could change causing great influence to the model. For example, bus routes or stops may change to accommodate for Birmingham Curzon. Since the routes have not been finalised and they run by private operators (West Midlands Combined Authority, 2017) it is impossible to truly model the effects as it is certain that bus route will change when Birmingham Curzon is finished. This is shown by Birmingham City Council (2015b) with the bus routes around Birmingham Curzon, although the operators are not finalised the route around the station are likely to be due to the traffic reduction schemes in place as discussed by HS2 Ltd (2014).

3. Methodology

The data from Transport for London was sorted to give journeys that either originated from King's Cross St Pancras or regular bus routes that include King's Cross as a stop. This reduced the size of the data set to all relevant entries only. Entries can be divided upon by transport mode, rail or bus.

In order to create the model, data for passenger journeys in Birmingham and the surrounding area is needed. This data was not publicly accessible, and it was unable to be obtained from TFWM. This lead to the search for usable data. The Oyster Card journey data from Transport for London (TfL) was used. This was due to a number of reasons, but primarily because it was publicly accessible allowing it to be easily obtained. The journey data from TfL showed the mode of transport used, i.e. rail or bus and the stops taken on the rail network. This will allow for a comprehensive model to be created for London.

This data is used as there are strong comparisons between London and Birmingham. In the Big City Plan by Birmingham City Council (2011a), comparisons with London are drawn with the discussion of walkways and creating business areas. This is a correlation with what Dakers (2015) said that the Big City Plan has elements in its plans that can be seen in London today. Thus, the use of data from TfL can be relevant to Birmingham as the predictions made from it are for the future in line with the Big City Plan.

The data shows 5% of the journeys in London by Oyster card for an unspecified week in November 2009, totalling 2.623 million journeys. A model was to then be created around a station in London that best matched Birmingham Curzon Street. Key factors of Birmingham Curzon Street where identified that made it unique to the region. The first factor was the strong link between Birmingham Curzon Street and New Street, a major hub station with a large number of commuters passing through to assess other areas of the city (HS2 Ltd, 2010).

The next factor was a termination point for a High-Speed Rail (HSR) line. This would be key as a termination station will need to have connecting transport modes in order for it to be effective.

Finally, the station needed to have good transport connections with other modes of transport or hub stations. By using these criteria, it was determined that King's Cross St Pancras would be the ideal station to use. Two HSR lines

terminate at this point, the East Coast Mainline and the Eurostar. This will act in a similar way to Birmingham Curzon Street, bringing new passengers into the city. King's Cross St Pancras also has extensive connections to other modes of transport like buses and the Underground.

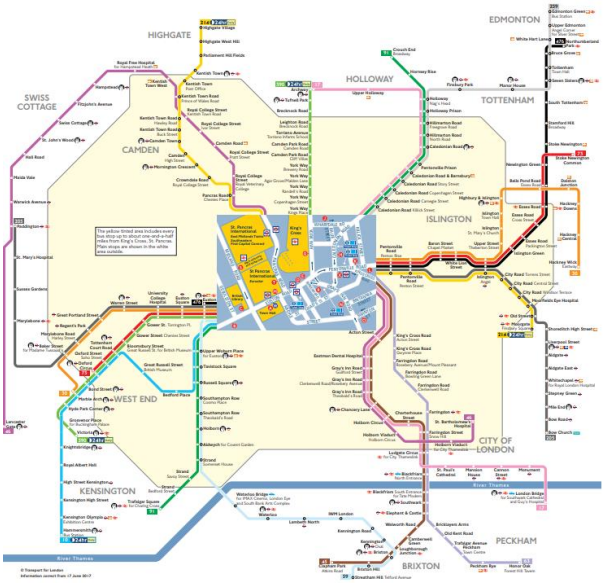

Fig. 2. Buses from King's cross St. Pancras (Transport for London, 2017)

As can be seen in Fig. 2, showing the bus route from the area. The choice of using King's Cross St Pancras ultimately came down to logical reasoning, engineering judgement and defining the key aspects of Birmingham Curzon. Having made this decision, the model can then be created and used.

a. b.

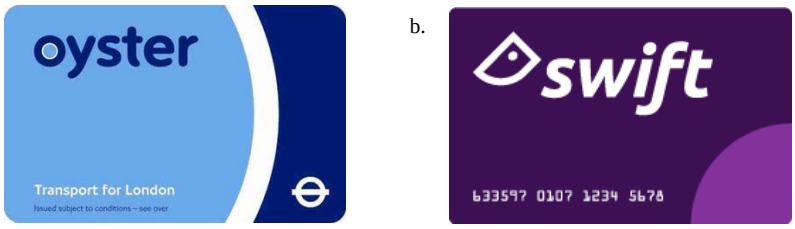

Fig. 3. (a) Oyster card for transportation in London; (b) Swift card for transportation for West Midland

3.1. The London model

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Finally, the station needed to have good transport connections with other modes of transport or hub stations. By using these criteria, it was determined that King's Cross St Pancras would be the ideal station to use. Two HSR lines terminate at this point, the East Coast Mainline and the Eurostar. This will act in a similar way to Birmingham Curzon Street, bringing new passengers into the city. King's Cross St Pancras also has extensive connections to other modes of transport like buses and the Underground.

3.2. The Birmingham model

Using the model will involve using the predicted flows of passengers generated from the model and applying it to the current infrastructure in Birmingham. The zones from the London model are matched up with zones harbouring similar characteristics, which is shown in the analysis. The primary urban use for the zones is given and paired up accordingly. The proportion of travellers to each zone in London is then applied to the Birmingham counterpart. The Birmingham zones are taken from (Birmingham City Council, 2017), which contains Birmingham's plan for 2031. Using these zones will allow for a stronger comparison with the HS2 demand values for 2033 as the future time frames are closer. New zones are added in areas that are not covered by the plan to determine if development is needed. This based on the assumption that the information used to assess the zones is accurate and the matching up process is the best match process. The best match process tries to match each zone up individually, one by one. Instead of trying to find the best fit for the zones as a collective group. This is due to the great diversity in zones and number of very closely match zones. Analysis of the model and network can begin upon completion of the model. Recommendations can be suggested from the proportional figure obtained from the model and demand given by HS2 Ltd (2010). These can then be checked against the recommendations by WMCAB (2017) to identify any areas that have been overlooked or that may need additional support. This gives a second view to the justification to the planned changes and can either support the plans or contradict them.

3.3. Demand

The demand for HS2 in Birmingham is reported by HS2 Ltd, which gives a breakdown of the predicted demand of HS2 in Birmingham for 2033 (HS2 Ltd, 2010). However, the data is still applicable as the demand was based on trends in transport usage. This predicts that Birmingham Curzon will have 31,000 daily journeys along with Moor Street receiving an additional 3,000. But, then leads on to say that New Street will experience a reduction of 36,000 as HS2 will reduce the demand for services from there. During the analysis stage, the additional demand placed on the system will be taken as 9,000, this is a total difference between 2033 with HS2 and without.

Table 1. The prediction demand of HS2 (HS2 Ltd, 2010)

Daily boarding and alighting (including interchanges)	Without HS2	HS2 with Parkway	HS2 without Parkway
Moor Street	19,000	22,000	24,000
New Street	213,000	177,000	179,000
International	28,000	14,000	16,000
Birmingham Curzon	0	31,000	50,000
HS2 Parkway	0	23,000	0
Total	**259,000**	**268,000**	**268,000**

4. Analysis

Due to the nature of the work and the lack of data publically available a series of assumptions had to be made. Firstly that the data obtained from the TfL website, (Transport for London, 2017), can be applied to Birmingham by drawing comparisons between areas of the city. The comparison for the regions will be carried out based on research into areas around King's Cross St Pancras Station. Also, the transport behaviours of passengers are the same so, the attitudes would be the same in Birmingham.

Additionally, King's Cross St Pancras is an appropriate station to use to model Birmingham Curzon, the justification is discussed late within the report. But this station was chosen as it was the best option for modelling Birmingham Curzon Street.

Finally, the proportion of travellers visiting the areas in London is directly applicable to the movement of travellers in Birmingham. It is key as there was no publically accessible data for passenger flows in Birmingham. So this assumption will be the primary basis for the analysis of the TfL data and creating a model for Birmingham.

The connection between King's Cross and St Pancras is of minimal distance as they are within the same building. It is not familiar with the case for Curzon Street and New Street stations. According to HS2 Ltd (2010), 25-30% of passengers using the service will access Curzon Street via Moor Street or New Street. Moor Street will be located at very close proximity to Curzon Street, making the transfer seamless. However, New Street will be approximately 400 m (Birmingham City Council, 2011), this can be from a five to ten-minute walk. However, due to the potentially high volume of passengers, the transfer will be assumed to be seamless and not affect the decision to use New Street for connecting services.

4.1 Zones pairing

The selection and creation of the zones are discussed, giving justification to their use and assessing the urban land usage. The purpose of zones is key to model as it allows for simplification.

4.1.1 Zones in London

To enable to an analysis of the data the routes for the bus network were carefully assessed. Each route passes through or terminates in different boroughs. So, in order to determine where the flow of people would be the zones were created to simplify the movements. Individual boroughs were chosen to be zones, this was due to the great diversity between the different boroughs and to simplify the model. This gives 11 different zones that the bus network connecting to King's Cross St Pancras passes through. Each zone was research to identify key features within it, such as residential, shopping or business. Doing this gave a good idea as to the possible reason for visiting the area. Thus the assumption can be that people visiting these areas are going to partake in whatever the zone is famed or popular for as there is no way to determine their intentions from the data. The zones are listed below with a brief description as to what the area is famed for, along with accompanying references..

- Kensington – Well known for being a very affluent area of London attracting the wealthiest people in the city.
- High-end shopping is also present with the likes of Harrods (London town, No Date; The Royal Borough of Kensington and Chelsea, No Date; The guide to Kensington & Chelsea, No Date).

- Camden – Containing the well-renowned Camden Market. Considered an area with a lot of places for shopping and events. (Camden.gov.uk, 2016; Visit London, No Date)
- Westminster -sightseeing and shopping. This area contains a large portion of the main tourist attractions making it a hotspot for tourism. Some shopping areas as well. (Parliament UK, No Date; Mayor London London assembly, 2018; All In London, 2018a)
- Hammersmith – A number of large international businesses have offices located here, making it a draw to young professionals. Also three major football teams are with the borough, Chelsea FC, Fulham FC and Queen Park Rangers FC. (Mayor of London - London assembly, 2018; All in London, 2018b; Yell, No Date)
- Brent – A very diverse area, with many different cultural influences. Majorly housing, but also contains Wembley Stadium and Brent Cross Shopping centre. (Mayor of London , 2018; Brent Council, 2015; London Town, No Date)
- Southwark – Contains some tourist attractions like The Shard. Large areas for living away from the Thames (Mayor of London - London assembly, 2018; Southwark Council, 2018; All In London, 2018d)
- City – business. Being very Central London this area is predominantly for business and commerce (Mayor of London - London assembly, 2018; City of London, 2017)
- Tower hamlets – ethnically diverse, residential, impoverished areas. Residential with some business. Most ethnically diverse in London. High poverty levels some of the highest in London. (Mayor of London - London assembly, 2018; London's poverty profile, 2018; All in London, 2018e)
- Islington – living, shopping and unique culture. Up and coming residential area, with unique culture and vibe shopping areas as well. (Mayor of London - London assembly, 2018; All In London, 2018c)
- Hackney – living and some light industry. Majority residential housing with some light industry, increasingly ethnically diverse. (Mayor of London - London assembly, 2018; LB hackney Policy Team, 2016; Discover Hackney, No Date)
- Lambeth – sightseeing, culture hub, living mostly. Some areas for tourism that aid creating a cultural hub in Lambeth. Largely residential areas. (Mayor of London - London assembly, 2018; Lambeth.gov, 2018; Lambeth Council, 2014).

4.1.2 Zones in Birmingham

As mentioned previously, zones from the Birmingham Development Plan by Birmingham City Council (2017) will be used. Additionally, zones will be used. These are given below with the existing zones with the typical zone type and justifications new areas added.

- City Centre – The hub of business in Birmingham. Mostly business and retail. Growing residential population (Birmingham City Council, 2017)
- Greater Icknield – Currently underdeveloped but with plans on the area to become residential (Birmingham City Council, 2017)
- Aston, Newton and Lozells – Varied land usage from residential to business. Diverse communities but a low income area of the city. (Birmingham City Council, 2017)
- Sutton Coldfield Town Centre – Largely retail but with residential nearby in Sutton Coldfield. (Birmingham City Council, 2017)
- Bordesley Park – Industrial and residential areas. Area scoped for regeneration. (Birmingham City Council, 2017)
- Eastern Triangle – Mixture of industrial, residential and retail. However retail seems to be closely packed.
  (Birmingham City Council, 2017)
- Selly Oak - Largely residential areas, but contains a University and has major with plans to develop economic diversification. (Birmingham City Council, 2017)
- Edgbaston – Largely residential but close proximity to a University. Typically an affluent area of Birmingham. (Birmingham City Council, 2017)
- Longbridge – Major redevelopment planned. Residential and business. New urban park for job creation.

(Birmingham City Council, 2017)

- Sparkbrook – Diverse area with residential and retail within the area. (Visit Birmingham, No Date)
- Solihull – Upmarket area, with high-end living and retail. Event arenas are also close by. (Visit Birmingham, No Date)

The zones that have been included from the report by Birmingham City Council (2017) are deemed to be the most appropriate areas. Some zones given were to be constructed and were very specific locations. Regarding the purpose of this analysis, larger zones were needed. The two additional zones of Sparkbrook and Solihull were chosen as they were not part of the development report. Sparkbrook was chosen due to its high diversity, closeness to the city centre and makeup of residential and retail. Solihull was selected as it is considered an upmarket area of the city with a thriving business in the area, with the potential for residents to live in Solihull but commuting to London, using HS2.

4.2 Data collection

Regarding the data collection from TfL, the data set is important to understand as this gives an indication of the reliability of the model. The dataset given was only 5% of all the journeys for a week. It is unknown if it is representative or random. This gives a medium level of confidence in the data set as the source is reliable but with a reduced number of data points. TfL (2012) stated that the Oyster card (See Fig. 3a) journeys account for more than 80% of public transport journeys in London. With this number being so high the confidence in the data increases slightly. It can be said that by this determination that the confidence in the data set obtained is of a medium-high level. Therefore, the reliability of the data is medium as a higher number of data sets would improve this.

4.2.1 Data collection for King's cross St. Pancras model

The model is to be created using data from the bus and the rail network. The bus journey data does not have a start point or end point, but only the route that is used. This leads to an assumption being made. The model is created based on the assumption that all of the journeys on that route originates from King's Cross St Pancras and terminates at the pre-determined main stopping point for each route. The pre-determined main stopping point for each route is listed below with justification for each given. The rail network does give the start points and end points. Due to a large number of stations in the network zones for the rail journeys we created to group the stations simplifying the analysis. The zones are given below with justification. The model is created on what each borough is famed for or its largest use. The bus network will take the most popular one. The rail network will collate the stations by each borough so it can be easily collated with data from the bus network.

4.2.1.1 Bus journey data

Using the framework of the zones a bus network model can be created. By viewing the routes, the number of zones the route passes through can be determined. Due to the nature of the data obtained a series of assumptions were made in order to create the model. Firstly, every journey is to start at the King's Cross St Pancras and terminate somewhere on the route in one of the predetermined zones. This assumption is made since the data provided does not show the start or end locations for bus journeys. By assuming every journey originates from a central point the distribution of passengers can be determined in terms of proportions instead of an actual number. This will allow the model to be applicable compared to Birmingham. Next following on from the nature of data there are numerous stops on the routes, and each route visits a number of zones. It is assumed that the number of passengers that visit each zone is split evenly by the number of zones of that route. For example, if there are 100 passengers and five zones, then each zone will have 20 passengers disembarking. This simplification is defined in order to reduce a bias towards a certain zone when the data does not show one.

4.2.1.1 Bus journey results

The results below, in Table 2 demonstrate the number of total passengers on each route and the number of zones on each route. This also for further calculations to take place determining the high demand zones in table 2.

Table 2. Bus route with number of passenger

Route Number	**Number of Passenger**	**Number of Zones**	**Number of passenger per zone**
Route 10	5,105	2	2,252.60
Route 17	3,927	3	1,309.00
Route 30	5,533	4	1,383.25
Route 45	6,878	3	2,292.70
Route 46	3,596	5	719.20
Route 59	5,521	4	1,380.25
Route 63	7,735	3	2,578.30
Route 73	7,938	5	1,587.60
Route 91	5,405	3	1,801.70
Route 205	8,363	3	2,787.70
Route 214	4,388	3	1,462.70
Route 259	7,039	3	2,346.30
Route 390	5,018	5	1,003.60
Route 476	5,139	4	1,284.75
Total Journey		81,585	

Table 3, below illustrates the zones and the total number of passengers disembarking and the proportion of total journeys made this accounts for. This last figure enables popularity between the zones to be visualised, thus creating a model from the popularity of each zones. This then allows for a heat map of the whole area to be created, that can then be compared and contrasted with Birmingham.

Table 3. Passenger flow data in London by zones

Zones	Number of routes through zone	Routes that pass through zone	Number of passengers	Proportion of total journeys (%)
Brent	2	46, 476	2,004	2.45
Camden	6	30, 46, 73, 214, 390, 476	7,441	9.12
City of London	4	17, 45, 46, 63	6,899	8.46
Hackney	5	73,205, 214, 259, 476	9,469	11.61
Hammersmith and Fulham	2	46, 390	1,723	2.11
Islington	12	17, 30,45,46, 63, 73, 91, 205, 214, 259, 390, 476	20,557	25.2
Kensington and Chelsea	5	10, 59, 73,91,390	8,326	10.21
Lambeth	1	59	1,380	1.7
Southwark	5	17, 30, 45, 59, 63	8,944	11
Tower Hamlets	1	205	2,788	3.42
Westminster	6	10, 30, 59, 73, 91, 390	9,709	1.19

4.2.2.1 Rail journey data

The Rail data, unlike the bus data, did have start and end points. This allowed for a much more accurate consolidation of the data. The same zones were used to group the rail data. This allows for easy comparison and for the data of different transport modes to be collated. Table 4, which is the number of journeys and the percentage of rail journeys to those zones, can be interpreted popular routes. It determines that 63.39% of total journeys from King's Cross station went to one of the predetermined zones.

Table 4. Number of passenger by zones

Zones	**Number of journeys**	**Percentage of journeys to zones**
Brent	289	3.24%
Camden	1034	11.59%
City of London	886	9.93%
Hackney	51	0.57%
Hammersmith and Fulham	643	7.21%
Islington	695	7.79%
Kensington and Chelsea	659	7.39%
Lambeth	1002	11.23%
Southwark	768	8.61%
Tower Hamlets	624	7%
Westminster	2268	25.43%

4.3 Results for all transport modes

By combining the two sets of results, a model of the zones can be created and identified the popular area. Table 5 shows the percentages of total journeys taken within the closed system to each zone. Thus, the model for King's Cross St Pancras station can be used to aid the creation of a model for Birmingham Curzon. Areas of high traffic have been identified and earlier research into each borough will allow for a comparison of areas in Birmingham and London.

Table 5. Total journey data by zones

Zones	Number of journeys by rail	Number of journeys by bus	Total number of journey	Percentage of total journeys
Brent	289	2,004	2,293	2.60%
Camden	1034	7,441	8,475	9.61%
City of London	886	6,899	7,785	8.83%
Hackney	51	9,469	9,520	10.80%
Hammersmith and Fulham	643	1,723	2,366	2.68%
Islington	695	20,557	21,252	24.11%
Kensington and Chelsea	659	8,326	8,985	10.19%
Lambeth	1002	1,380	2,382	2.70%
Southwark	768	8,944	9,712	11.02%
Tower Hamlets	624	2,788	3,412	3.87%
Westminster	2268	9,709	11,977	13.59%
Total	8919	79,239	88158.00	100%

4.4 Zone pairing

The zone pairing is based upon matching each zone in London to its counterpart in Birmingham. This is done by using the brief details given in the descriptions and wider reading into the areas. Table 6 lists the zones for each city with the counterpart.

Table 6. Zones pairing between London and Birmingham

Zone in London	Zone in Birmingham	Predicted percentage of passenger flow
Brent	Sparkbrook	2.60%
Camden	Eastern Triangle	9.61%
City of London	City Centre	8.83%
Hackney	Sutton Coldfield Town Centre	10.80%
Hammersmith and Fulham	Longbridge	2.68%
Islington	Solihull	24.11%
Kensington and Chelsea	Edgbaston	10.19%
Lambeth	Selly Oak	2.70%
Southwark	Greater Icknield	11.02%
Tower Hamlets	Aston, Newton and Lozells	3.87%
Westminster	Bordesley Park	13.59%

Using the results from Table 6, areas that need infrastructure development can be identified. The total number of journeys in Birmingham on a daily basis is estimated to be 8 million on a typical day including all modes of transport (Centro, 2013). TFWM (2016) provides values of modal share for transport in Birmingham. The demand for passenger assessing public transportation seemed to reduce as shown the whole journeys were 4.96 million across the west midland regions. However, the Birmingham Interchange will be expected to receive 23,000 daily passengers and, the number may be increased to 50,000 daily passengers subject to the service from HS2 across the Birmingham Curzon station. Nevertheless, this research mostly concerns with the Birmingham New Street station; therefore, the demand proceeding HS2 will be slightly higher than a continuation of the current trend without HS2, with an increase of 3.5%.

5. Discussion

The scope of the project is also reviewed looking at the wider implications and effects of the implementation of HS2. With respect to the London's model, the distribution of passengers to certain areas that create the popularity of areas is shown. The model can provide a good indication for the levels of total commuter traffic passing through the area. For example, Islington is the final destination for 24.11% of passengers but, Hackney is the final destination for 10.80% of commuters. In order to get to Hackney from King’s Cross station, one has to go through Islington. It can determine that the through-flow of commuters is 34.91%, much higher than the initial 24.11%. It poses a greater issue as when analysing the data the percentage of passengers reaching their final destinations was calculated but, the cumulative load on the network in each zone was not so, the proportion of zone flow should be concerned as shown in Table 7.

Table 7. Zones flow propotions

Zone in Birmingham	Predicted percentage of flow	Percentage of total flow on branch to zone
Sparkbrook	2.60%	9.73%
Eastern Triangle	9.61%	41.42%
City Centre	8.83%	8.83%
Sutton Coldfield Town Centre	10.80%	100.00%
Longbridge	2.68%	17.07%
Solihull	24.11%	90.26%

Edgbaston	10.19%	64.90%
Selly Oak	2.70%	17.20%
Greater Icknield	11.02%	100.00%
Aston, Newton and Lozells	3.87%	100.00%
Bordesley Park	13.59%	58.58%

With respect to table 7, certain areas have a high portion of through traffic in comparison to final destination journeys. When assessing the transport connectivity this through following must be considered as it increases the demand for higher capacity in the area. For example, the infrastructure through Sparkbrook will have to support the flow to Solihull even through over 90% of users will go to Solihull.

Reviewing the demand for HS2 in Birmingham from initial viewing the increase does not appear to be very large, only 3.5% around the city (HS2 Ltd, 2010). But, the distribution of passengers will not be uniform, and certain areas are likely to experience higher inflows. So, these areas will need more significant development to support the whole network. Without access to journey data and numbers from TFWM it is difficult to say with certainty "which areas will require higher levels of development?”. However, the prediction on can be made from zone flow proportion in Table 7. The increase in total journeys due to HS2 in 2033 will be 9,000 passengers per day. If this amount is applied to the highest percentage, an additional 2,170 people will journey to Solihull as a final destination.

Moreover, this increase in demand does take into the account the growth of Birmingham, which is expected to grow by 150,000 by 2031 (Birmingham City Council, 2017). This whole number will put a massive strain on the infrastructure in its current stated. Birmingham City Council (2017) estimate rail travel into the city centre to have increased by 60% from 2001 to 2011 caused by the infrastructure will be under even greater strain.

5.1 Population growth

The inflow of additional passengers from HS2 is not a significant number in relation to the current passenger numbers but, the biggest challenge to the rail network will be the population changes. The Department for Transport – Rail Executive discovered that there was currently an issue with overcrowding in the Birmingham New Street stations during peak hours, which 13.1% of passengers were standing on the train (Department of transport, 2013). The current levels of overcrowding are estimated to be at 0.7% of total capacity.

With Birmingham projected to rapidly grow over the next 14 years overcrowding levels are going to increase (Birmingham City Council, 2017). So, the best support passengers disembarking from the HS2 network will need to be developed to reduce overcrowding as a whole. By decreasing the overcrowding across the network, passengers from HS2 will be best supported and ensure effective flow of passenger. Although overcrowding at very low levels, like the 0.7% current in Birmingham, does not directly prevent the movement of passengers it creates an unpleasant journey and is a sign of needed change.

Upon reassessing the question, HS2 may not have a massive direct impact regarding sheer passenger numbers but, the growth of the population will. So, when making recommendations for developments to the network, the population growth is an aspect that must be deeply considered. To combat the issue of general overcrowding of the network will support passengers disembarking from HS2. So extensive works will need to be carried out to reduce overcrowding, in the form of increased capacity or providing alternative transport methods, like the Midland Metro.

5.2 Oyster Card Usage

The usage of Oyster card data did also pose some issues. In the fact that, all public transport passengers in London doesn’t use an Oyster card because they use single tickets or contactless bank card. Therefore, the data set is not truly representative of London transport usage. For example, tourists or people coming for a day may not purchase an Oyster card skewing the data to favour those who are regular users of public transport in London. Using this additional data would enhance the model as a greater understanding of public transport usage would become apparent.

Additionally, the Oyster card data only contained 5% of the journey data for one week in November 2009. The data set is limited and is not an accurate representation of usage. Many external factors may influence travel, like weather conditions and time of day. Without a greater number of varied data sets the reliability of the model decrease. Multiple full data sets of travel in London are needed, taken at different points throughout a year. It will allow for any external factors that may distort a single data set.

The average double-decker bus has a base a capacity for 67 passengers, looking at the increase in numbers to destinations. Sparkbrook will receive 234 out of the 9,000 passengers. Sparkbrook has the smallest increase but, an increase of this size would suggest the need for more buses to increase capacity. It leads to all of the areas investigated needing additional development since the rise in other areas is significantly higher.

5.3 Other forms of data collection

Other methods of data collection from other sources in addition to that from TFWM would be very beneficial in creating a model. As discussed in the literature review (Toole, 2015) investigates the use of CDRs with mobile phone masts and crowdsourcing geospatial data to aid the creation of a model. This method would have the benefit of a massive number of data points and enable right start and end location to be identified. Also, Hotspots within the transport network can be defined allowing recommended changes to serve the passenger.

Investigating the possibility of using sources such as CDRs for data collection add a new dynamic to work carried out and seek to enhance the model by incorporating data directly related to user behaviours. Another method to incorporate this would be survey data, but the quantity of data provided by CDRs is unparalleled making it an attractive avenue to explore.

5.4 Suggested changed to the network

The changes to be made to the network following the work from this research will focus on two aspects. Increasing the capacity of a mode of transport or creating an alternative mode of transport to reduce demand on another. The recommendations are made using the data analysed in this report and other sources regarding the current plans and state of public transportation in Birmingham. The modes of public transport that are available were taken from the TFWM website.

An extension of the Midland Metro network from New Street station to reach further out parts of the city will reduce the demand for rail travel from New Street. This will reduce overcrowding and allow for a more effective transition from HS2 to the final destination.

Increased number of buses on high traffic routes where trains are not available such as Aston, Newton and Lozells, this would allow for a higher number of passengers to use the services. Regular buses can be used for these areas as they are close to the city centre and covering a larger area.

Increase the number of Sprint buses and routes (Transport for West Midlands, 2017) these will give a faster service than regular buses and allow for passengers to rapidly move from Curzon Street out of the city centre. Similar to express services in other cities.

Increasing rail capacity on the Solihull line as a large portion of the 9,000 additional passengers are predicted to go here. The extension of capacity will allow for the rapid mass transit of passengers. However, this is assuming that passengers who travel to Solihull would not us the Birmingham Interchange, which is very unlucky due to the distance. In which case a Sprint bus link to Birmingham Interchange may be more appropriate.

Regarding the purposes of this study, the usage of Birmingham Interchange as an alternative was not considered to simply the model.

For rail, a citywide increase in capacity would be beneficial due to the issue of overcrowding in the city centre (Department for Transport - Rail Executive, 2013). More capacity would allow for effective transit and reduce congestion in the city centre during peak times. It allows the links between Curzon Street and New Street to be faster to walk reducing time wasted. This method is suggested due to the overcrowding issue and also due to the massive expected rise in population and the increased demand that will be placed on New Street (Birmingham City Council, 2017). Areas like Solihull may require an improved rail link instead of Sprint buses if a high demand is seen from Solihull to access HS2 from Curzon Street. The likely outcome is residents in Solihull will use the

Birmingham interchange instead of travelling to the city centre; this is due to the shorter travel time and the distance..

5.5 Comparison to current connectivity package

Regarding the connectivity package put forward by Birmingham City Council, the focus is around three main modes of transport: Sprint buses, rail and the metro. Similar to the findings of this report, extensions of the Midland Metro line are recommended from the New Street station out of the city centre. However, the use of a Metro line in Wolverhampton is also considered (Birmingham City Council, 2015b). There is extensive use of Sprint bus links from outside the city centre to enable rapid transit. The development of regular bus networks will allow for more efficient travel for a growing population if not directly aiding transit from HS2. And, the rail improvements are varied with some being very light and, others suggesting to be significant developments.

6. Conclusion

The findings of this research conclude that the current transport system cannot support passengers disembarking from HS2 at Curzon Street. The whole network will need to undergo development due to effectively support HS2 and the massive prediction of population growth in Birmingham.

The changes will vary following the area and the urban land usage. Implementing this changes will enable Birmingham to cope with the increase to the population and reduce the demand on some modes of transport.

However, lacking publicly accessible data for public transport usage in Birmingham is recommended that a model for Birmingham is created using data for the city. Given access to this data, the zones used could be more precise making the model more detailed. Additionally, the data would allow for flow to be calculated using numbers of passengers instead of proportions. The data allow for more suitable recommendations for transport modes to be made as the required number of passengers to move it known.

A data set for transport usage in Birmingham would also give indications as for the travel attitudes in the city in case of the metros are preferred to buses. Also, the data increases the reliability in the model significantly and increase the confidence level as fewer assumptions can be identified.

Conducting surveys of transport usage in Birmingham. This would give an indication towards passenger attitudes about public transport within the city currently and potential future usage. Using this in conjunction with statistical data from models would allow a more detailed model to be formed including passenger attitudes. Attitudes may have a significant influence on the potential demand of the network.

One factor that can have significant influence is the price of usage HS2. It was not considered during this project as it is the demand aspect of HS2. In case of the expensive ticket on HS2 service, it may reduce the number of passenger access the Birmingham New Street station; therefore, the new plan on the bus network should be adjusted to serve passenger in the Birmingham New Street station rather than Birmingham Curzon Street station.

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