NETWORK ANALYSIS APPLIED:
the railway network in South East England

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Christian Schwander
Space Syntax Ltd.

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Christian Schwander
Space Syntax,
4 Huguenot Place,
Heneage Street,
London E1 5LN, United Kingdom
c.schwander@spacesyntax.com

Abstract

The importance of public transport networks for contemporary city-regions is beyond question (Graham, Marvin, 2001) and recent Space Syntax research has shown the need to include them into a fully configurational urban simulation model (Chiardia, Moreau, Raford, 2005). This paper presents one possible approach, the network analysis, in a case study of the railway network in South East England.

Railways have strongly influenced the morphology of this city-region. Their emergence in the early 19th century was the basic prerequisite for suburbanisation (Hall, 1969). Today, rail travel accounts for over 40% of commuting into Central London (TfL, 2005) and is crucial for the City's global competitiveness. In the near future, new rail schemes are expected to come into operation: Channel Tunnel Rail Link (2007), Airtrack (2011), Thameslink (2012), Crossrail (2015) as well as improvements to orbital and tangent rail services.

There is a need to understand the impact of these interventions on the urban structure and to find evidence-based methods to quantify it. Network analysis is an alternative to the predominant demand-orientated transport models. While this method was originally developed in social sciences to study relationships between persons or social groups (Wellmann, 1983, Wasserman, 1997) it has also been widely used in regional studies (eg. Green, 2005, De Montis, Bathelemy, Chessa, Vespigniani, 2005, Taylor, 2003, Latora, Marchiori, 2002). This highly comprehensive method reduces a complex system to a mathematically defined graph consisting of interconnected nodes.

A network model has been developed for the railway system in South East England. The nodes consist of major urban centres (Hall, Pain, 2006) and main rail interchanges, while rail services form the links. They can either be binary (topological network) or weighted according to the frequency and travel time of the services (flow network). In order to assess the impact of the network configuration on traffic flows, quantitative indicators are calculated both on a nodal and a network level (Hagen, 2003, Borgatti, Everett, Freeman, 2002). These indicators are compared with empirical data about station usage (ORR, 2006) and travel behaviour (NRT, 2006, ORR, 2006, SEERA, 2006). As the best correlation (r2=0.73) is found between station usage and frequency-weighted nodal degree this measure is discussed in detail and used to assess the impact of future transport interventions. The method can be verified after new schemes have come into operation.

The case study shows that the network analogy is able to explain observed developments in the city-region, like the spatial polarisation between highly-accessible and less favoured places and supports the concept of Network Urbanism (Dupuy, 1991). In conjunction with a spatial accessibility model of the city-region this network model can be used to simulate, analyse and understand the regional development in South East England.

Introduction

After a long time of negligence, infrastructure networks have become a main focus for urban and regional studies again. Their impact on contemporary city-regions is beyond question. (Graham, Marvin, 2001) and recent Space Syntax research has shown the need to include them into a fully configurational urban simulation model (Chiaradia, Moreau, Raford, 2005).

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This paper presents one possible approach, the network analysis, and examines whether this method is appropriate to analyse contemporary city-regions. To this end, we undertake a case study of the railway network in South East England, organised in four steps:

- First, we define the scope of the study and provide background information about the city-region South East England and its railway network.
- Second, we develop a network model that is interpreted qualitatively and quantitatively with the methods of the network analysis.
- Then, we compare the findings with empirical data to verify the significance of the network model.
- Last, we set our findings into the wider theoretical context of network urbanism and network society and discuss the next steps to advance the model.

Background

City-region South East England

Recent research shows that the relationship between cities and its surrounding regions has changed fundamentally. (Sieverts,1997, Priebs, 2003, Kloosterman, Mustard, 2000). The concentric model, a core-city with its hinterland, which originates from the development of industrial cities in the 19th century, has been called into question. Specialised functions, like airports, trade fairs, commercial and shopping centres are located throughout the region and challenge the historic centre. The unilateral dependency of the region has been replaced by a multilateral interdependency between city and region: the city-region concept aims to describe this polycentric pattern of development, which is experienced in most metropolitan areas throughout the world, especially in regions surrounding global cities, so called global city-regions. (Scott, 2001)

The largest and arguably most buoyant city-region in Europe is the metropolitan area around London: South East England. London, the capital of the UK and one of the world's global cities is the undisputed centre. Its concentric growth in the past is still visible in the urban structure: the City of London in the very centre, surrounded by Inner London, roughly covering the built up area up to World War I and Greater London, which comprises the built-up area up to World War II. (Hall, 1989: 1) This concentric development came to an end in 1947, when Abercrombie's Greater London Plan was adopted: it bounded the built-up area by the metropolitan green belt and diverted the growth into the region. Either regional centres that already existed were expanded (expanded towns) or new towns were built in a ring around London, initially within a distance of 35 to 55 km (1950 and

60s), in a second phase (1970s and 80s) between 80 and 130 km from the centre.

This was the beginning of a more polycentric development. As a result of this policy, the metropolitan area exceeds the borders of Greater London and stretches far into the adjacent regions. It is impossible to define this metropolitan area by exact administrative borders or morphologic features. Instead, a functional definition is more appropriate to describe the contemporary city-region: A city-region is made up of a number of functional urban regions (FUR), each of them consisting of a core defined by employment size and density as well as a surrounding ring, defined commuting relationships to the core. (Hall, 2006)

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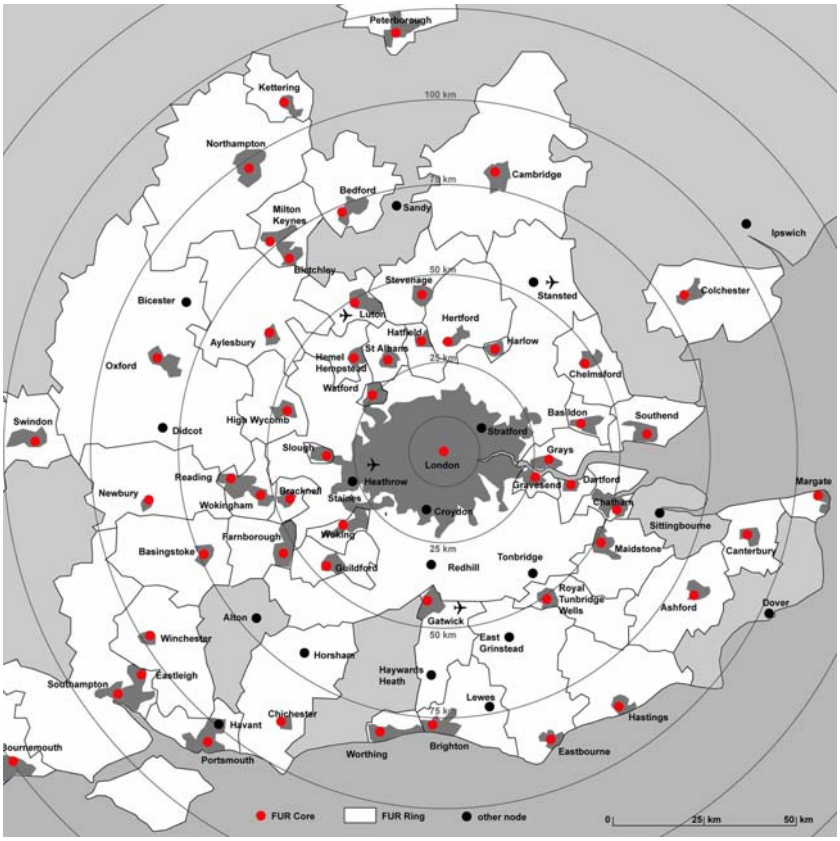

Figure 1:

Functional city-region

The resulting structure shows two characteristics:

- The city-region is not a homogeneous space, but shows gaps and nodes (nodality)
- The relationship between these nodes constitutes the city-region (connectivity).

The interdependencies between city and region are mutual. On the one hand, strong radial links exist into London, the prime location for commerce, work, etc. (in-commuting). On the other hand, the region itself is a primary location: besides historic towns and cities, new kinds of centres, as airports, universities shopping and commercial centres emerge throughout the region and attract out-commuting as well as cross-commuting. Hence, the city-region South East England is not defined by a certain territory, but by centres and their relationship: nodes and connections, which form a networked system. (Priebs, 2003: 17)

Infrastructure Networks

"Infrastructure networks are the backbone of contemporary city-regions." (Nakicenovic, 1995: 195) They integrate spatial distinct

locations into mutually interrelated entities and have dramatically changed the patterns of spatial, economic and social interaction within city-regions. They reduce the effective distance between geographically separated places by decreasing the “friction of space”. (Nakicenovic, 1995: 197) and facilitate the amalgamation of separate settlements to a single functional city-region.

The form of infrastructural networks is crucial in the configuration of urban space. (Graham, 2000a: 116) Are they centralised or decentralised? Do they have a high or low density? Their organisation shows the social and political conditions of a society: Do they follow the modern ideal of a standardised public-owned infrastructure or the liberal paradigm of a private-owned competition-orientated “unbundling” infrastructure? (Graham, 2000b: 188) Access to infrastructure is crucial for the economic and social performance of places and people. Contemporary infrastructural investments often have the tendency to link globally while excluding locally. (Graham, 2000a: 116).

The railway network is a very significant and illustrative example of an infrastructure network and we have chosen it for three reasons:

- Railways have strongly influenced the morphology of city-region South East England (Hall, 1969). Their emergence in the early 19th century enabled people to commute to work in central London. The resulting suburbanisation changed the spatial structure fundamentally and the city started to spread far into the region.

- Today, rail travel plays an important role in the daily life of many residents of the city-region: commuters to central London use national rail by 40% and spend an average of 71 minutes on their journey to work (TfL, 2005). They are highly dependent on an efficient network and extremely affected by service disruptions.

- Rail is crucial for the competitiveness of London and the city-region and investments in enhancements are expected in the near future: Channel Tunnel Rail Link (2007), Airtrack (2011), Thameslink (2012), Crossrail (2015) as well as improvements to orbital and tangent rail services.

There is a need to understand the impact of these interventions on the urban structure and to find evidence-based methods to quantify it. There exist different methods to asses the economic impact of transport improvements. The predominant approach are demand-driven transport models that consider a complex pattern of variables like fares, service quality, demographics and land use to calculate the travel demand (TRL, 2004). A more spatial oriented alternative, the network analysis, will be presented in the next section.

Network Analysis

In this chapter, we analyse the interplay between the railway network and the city-region in South East England using the technique network analysis. This method developed in social sciences to study relationships between persons or social groups (Wasserman 1997) has also been widely used in regional studies (eg Green, 2005, De Montis, Bathelemy, Chessa, Vespigniani, 2005, Taylor, 2003, Latora, Marchiori, 2002). After a short introduction into the methodology and its terminology, we develop a base line model for the railway network in South East England in three versions. We illustrate them and calculate indicators, can be compared statistically to empirical data.

Methodology

Network analysis is a highly comprehensive method that reduces a complex system to a mathematically defined graph that consists of

nodes, representing the actors, and links, representing their relation. There are two possibilities of translating this into a spatial model:

- Space Syntax usually considers two-dimensional lines (roads) as actors that are linked with one-dimensional points (junctions), in order to make predictions about roads. (Primal problem)

- As we are more interested in making predictions about one-dimensional points (railway stations) we consider them as actors, linked with two-dimensional lines (train services). (Dual problem)

However, both representations are closely related to each other and can be translated from one to the other. (Batty, 2004)

The graph theory has developed computer programmes (Hagen, 2003, Borgatti, Everett, Freeman, 2002) that calculate indicators describing the characteristics of a particular node (nodal indicator) or the network as a whole (network indicator). The most important indicators for our study will be explained briefly.

Centrality

The location of the most central nodes is one of the most interesting questions in each network. It can be defined in three different ways (Wasserman, 1997: 169):

- Degree centrality is defined by the number of links originating from a particular node (nodal degree). The most central nodes (hubs) are those with the highest nodal degree, a measure for connectivity on the local scale.

- Closeness centrality is defined by the number of steps from a particular node to all other nodes (nodal distance). The most central nodes are those with the smallest nodal distance, a measure for connectivity on a global scale.

- Betweenness centrality is defined by the number of shortest paths that go through a particular node. The most central node is included in the highest number of shortest paths.

Centralisation

The level of centralisation of a network can be exemplified by comparing two extreme structures (Wasserman, 1994: 171): In decentralised rings, all nodes have the same nodal degree and the same nodal distance, while in centralised stars, one hub node exceeds all others in terms of nodal degree and nodal closeness. If this hub is removed, the network becomes disconnected.

Connectivity and Density

The connectivity of a network indicates whether there exist direct links between pairs of nodes, while the density indicates the ratio of existing to potential links. (Wasserman, 1994:101)

- In a complete network links exist between each pair of nodes; its density is 100%.

- In a strongly connected network at least one path between each pair of nodes exists, so no node is disconnected.

- In a disconnected network nodes or pairs of nodes are disconnected. If every node is disconnected, the density equals zero.

Regularity

The regularity of a network depends on its clustering coefficient (Watts, Strogatz, 1998: 441), a local property which corresponds to the mean degree centrality.

- A regular network is highly clustered, i.e. all neighbours of a specific node are linked to each other. They are strong on the local level.

- In a random network, by contrast, the links between the nodes are distributed at random, regardless their neighbourhood. In return, these networks have shorter path lengths between each node; they are strong on the global level.

- At the border line between regularity and randomness exists a type of network that combines the advantages of both: a small-world network. (Buchanan, 2002) They are regular networks with some additional far-distance links that are randomly distributed. Therefore, they are highly clustered (strong on the local level) while having short path length (strong on the global level). It is not surprising that the small-world principle occurs in different fields: (Watts, Strogatz, 1998: 442) and can be found in nature (neuronal networks), as well as in social (relations between persons) and technical networks (electrical power grid).

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Hierarchy

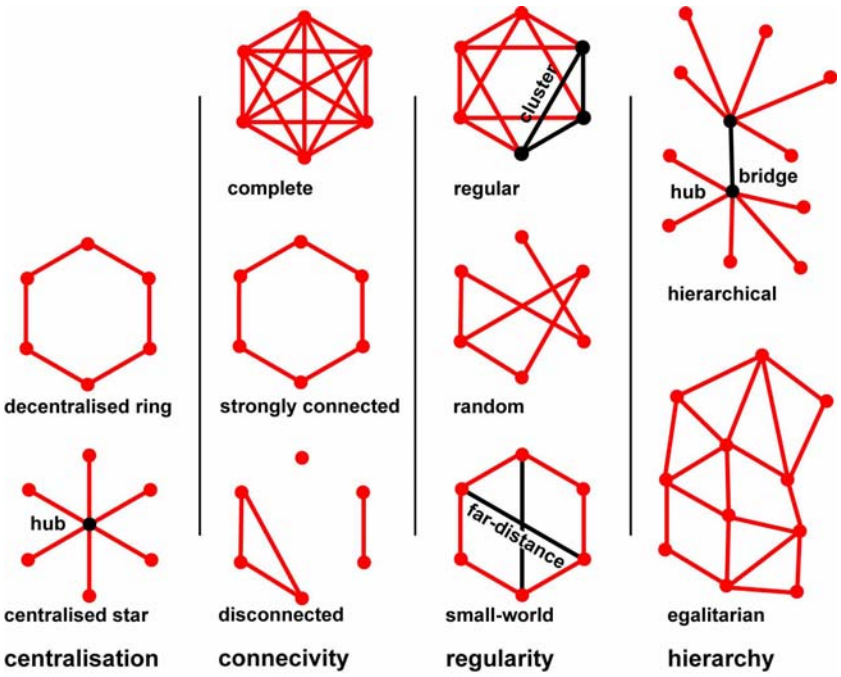
A network can also be classified according to its hierarchical structure, which can be measured by the distribution of nodal degrees.

- In an egalitarian network, the nodal degrees are equally distributed and no hierarchy exists between the nodes.

- A hierarchic network, by contrast, contains relatively few highly interconnected nodes, while the vast majority of nodes are weakly connected. The prominent nodes and links, called hubs and bridges, are essential for the connectivity of the network. If they fail, the whole network becomes disconnected. Therefore, these hierarchic networks, also called trees (Wasserman, 1994:14) are more vulnerable.

Figure 2:

Network indicators



Network Model

In this section we develop a model that is aimed at analysing the interdependency between the functional city-region South East England and its railway network. To this end, we have selected a set of 82 railway stations, which represent the principal nodes in the city-region:

- the cores of the functional urban regions (Hall, Pain, 2006)
- the hubs and spokes defined in the regional transport strategy (RTS, 2004)
- key railway interchanges.

These nodes are interconnected by railway services, provided by National Rail. Between the London termini we have also included London Underground links. As we are interested in the existence railway services (trains) rather than railway infrastructure (tracks), we include shortcuts like non-stop airport express services and analyse the so called "space of stops" (Kurant, Thiran, 2006). Three different versions of this model will be analysed:

- First, the topology of the network is assessed using a binary model.
- Second, the strengths of the links are weighted using service frequency as a measure for flows.
- Last, the time-based distance between the nodes is analysed using travel time as an indicator.

Topological Network

This binary model purely describes the topology of the network: which nodes are connected by railway services and which nodes are not. The information derives from the route map published by the Association of Train Operating Companies (ATOC, 2006). The network indicators for the topological graph shown in figure 3 are interpreted below.

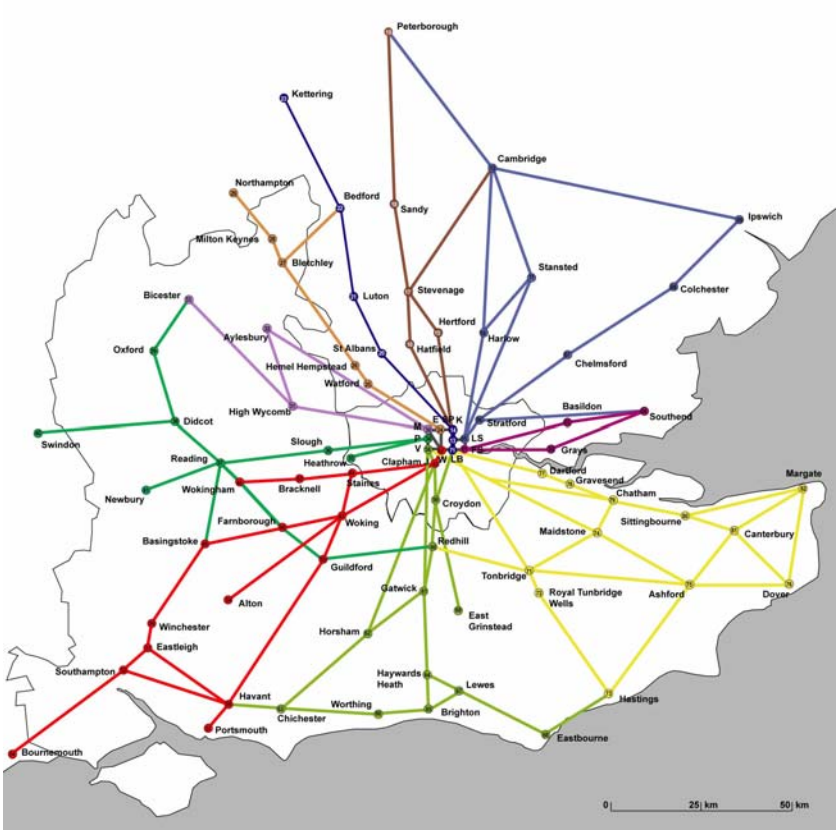


Figure 3:

Topological network

Nodal indicators

The network shows a polarised pattern in terms of nodal degree: highly centralised hubs face marginalised endpoints. The hubs, with a high number of adjacent lines (Clapham Junction, Victoria and London

Bridge) are the main interchanges, which benefit from high accessibility while suffering from heavy overcrowding. They also have the shortest nodal distance to other nodes. This does not only result from their central location, but also from their large number of direct links. As hubs are very important for the connectivity of the whole network, they are vulnerable to disruptions.

Endpoints (nodal degree=1) are not only located at the edge of the study area, but also within the region, e.g. Alton and East Grinstead. These towns were marginalised during the concentration phase of the British railways in the 1960s where many branch lines were abandoned. Therefore, they do not meet the criteria of the functional urban regions and form gaps in terms of accessibility within the city-region. Heathrow airport is an endpoint for completely different reasons. As a result of a monocentric development strategy in the past it only has railway access from central London. Consequently, it fails to play its role as a hub in the railway network and has a low modal share of public transport. While the most important cores of functional urban regions form a densely interconnected system of regional hubs, these emerging hubs are still to be integrated.

Network Indicators

On the network level, the degree of centralisation is very high. While the large number of radial links end at an inner circle formed by the London Underground Circle Line, there is only one cross-link from north to south. The orbital connections show huge gaps and tangent connections only exist in the West and South. In these areas, the hierarchical trees are complemented by cycles. They provide alternative paths between a pair of nodes, when a particular link fails and enhance the resilience of the whole network.

In terms of regularity, the network shows the characteristics of a small-world: every node is connected to its neighbour and there are a few additional far-distance connections. This small-world architecture enables the network to be highly efficient: despite its low density of only 0.04 most nodes can be reached within a comparatively short path length of under five steps (mean nodal distance = 4.95).

In order to identify the hierarchical structure of the present network, we consider the distribution of nodal degrees: While there are three hubs (nodal degree=6) and nine endpoints (nodal degree=1), most nodes range between a nodal degree of two and three. This distribution tends more to the characteristics of a hierarchical network (a few hubs with a high nodal degree and a large number of nodes with a low degree) than to an egalitarian network, where all nodes have nearly an equal degree.

Flow Network

The next section analyses a weighted network model, which provides quantitative information about the dynamics occurring in the network. The strength of a particular link can be characterised by the service frequency. It is measured by the number of trains running between two stations in one direction per hour. The information derives from timetables published by the Train Operating Companies and the online train information systems (www.nationalrail.co.uk, www.ftl.gov.uk). For this case study, travel information for a typical weekday off-peak period is used.

The graph in figure 4 clearly illustrates the characteristics of the flow network: The radial lines are the strongest ones, while orbital links are significantly weaker. As the distance to central London increases, the strength decreases. Airport express services provide additional strong radial links into central London, but not towards regional centres.

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Figure 4:

Flow network

The number of train services also affects the centrality of a specific node. The nodal degree corresponds to the number of trains calling there. There is no single super-hub but a set of hubs in central London with nodal degrees ranging from 22 to 48. The three highest ranking hubs (London Bridge, Waterloo and Clapham Junction) are all located South of the Thames. This results from the higher fragmentation of the network in North London, where traffic spreads out to more termini. However, there are also four hubs outside Inner London:

- East Croydon, a major business centre dating from the 1970s
- Gatwick airport, the airport in the South East which is the most accessible by public transport
- Reading, the heart of the economically thriving Thames Valley
- Stratford, the future focus of the Olympics in 2012.

These regional centres highlight the polycentric development pattern of the city-region. They are dedicated to specific functions and provide the opportunity to ease traffic in the central city and to achieve a more balanced spatial structure.

Time Network

Infrastructural networks influence the physical space because they contract spatially distant places by fast means of transport. Since the introduction of railway technology, travel time has decreased significantly and it is argued that they have shrunk the country's geographical space to between one-third and one-fifth. (Freeman, 1985: 26)

Figure 5:

Time network

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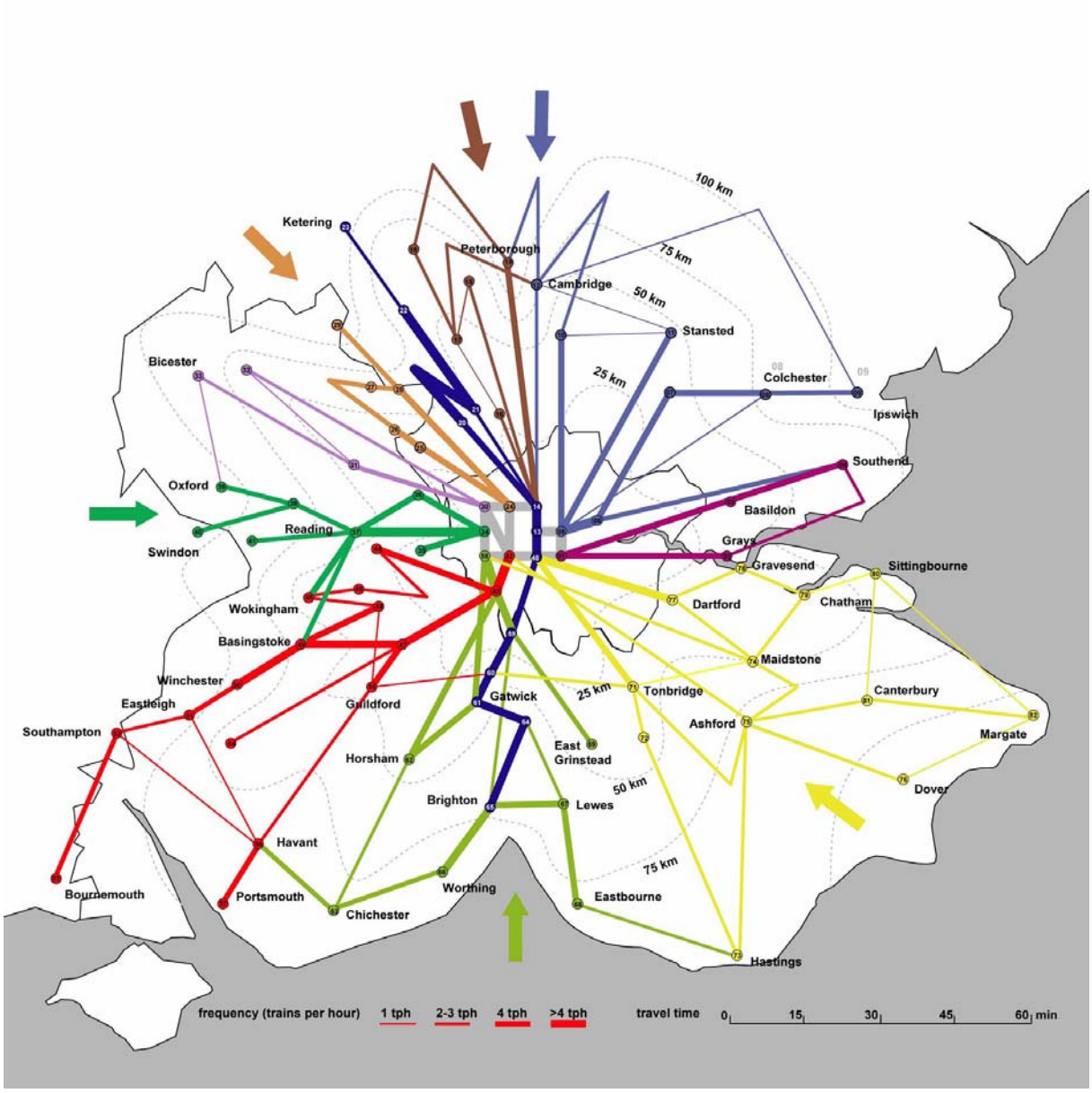

But this "sea-change in geography" (Batty, 2003) did not affect the whole territory equally. Only nodes, i.e. places with access to the necessary infrastructure could benefit from this development, while other places where not affected. Two examples illustrate this development:

- • Reading, a regional centre with a population of 144.000 (Census, 2001), about 60 km bee-line from London, is a node on the Great Western main line. It has a strong and fast connection to central London: frequent direct train services to London Paddington take less than 30 minutes. In consequence, Reading is contracted to London by the centripetal force of the infrastructure.

- • Maidstone, an equally large town of 139.000 inhabitants (Census, 2001), which is 10 km closer to London than Reading, is not located on a main line corridor. Therefore, travelling to London takes nearly twice as long (55 minutes) and Maidstone seems comparatively remote.

The time-based version of the network model in figure 5 shows the distorted image of the city region. The railway network contracts the territory on particular routes, the radial main lines, while orbital routes and rural areas are less affected. Dealing with the resulting territorial polarisation that transforms a concentric geographical space in a star-shaped time-based space becomes a main task for future regional planning in global city-regions.

Model and Reality

A major strength of the network analysis is that it provides quantitative indicators that can be verified by comparing them with empirical data. In this section we test the hypothesis that one or several nodal indicators of a particular station correspond to the number of people using it (station usage). If this hypothesis proves correct, the relevant indicator can be used to develop a forecasting model for future transport schemes.

Empirical Data

The most comprehensive publicly available dataset about station usage in the UK is published annually by the Office of Rail Regulation (ORR, 2006). It gives details about exits, entries and interchanges on 2,501 National Rail stations in Great Britain from April 2004 to March 2005. While the numbers of exits and entries are based on ticket sales from one station to another, the interchange figures were derived from the Central Allocation File (CAF), the industry standard for allocation of passenger revenue to Train Operating Companies. This data set has been adapted to the 82 nodes used in the network model.

This dataset has some restrictions:

- As London operates a zonal fare schemes, the exact numbers for the London termini are estimated. For this reason the model cannot make predictions about a particular London station, because the dataset is not precise enough.

- The dataset contains all rail journeys and not only those within the city-region. However, National Rail Trends data show that 94.1% off all journeys starting and finishing in one of the three observed Government regions were made within these regions (NRT, 2006). These figures give reasonable confidence, that the dataset is accurate enough for regional nodes, but edge stations might be underestimated.

Topological Indicators

First we use the topological model to test if there is a correlation between station usage and the centrality measures of this particular node. Table 1 gives an overview on the correlation R^2 between the station data and the three nodal centrality measures.

Table 1:

Correlation between the station data and the three nodal centrality measures

R^2	Nodal Degree	Degree Centrality	Closeness Centrality	Betweenness Centrality
Exits+Entries	0.341	0.273	0.292	0.577
Interchanges	0.323	0.256	0.253	0.471
Station Usage	0.370	0.297	0.314	**0.615**

The results can be summarised as follows:

- Betweenness centrality produces the best correlation (R^2=0.615)
- The correlations between station usage and the other centrality measures are weak.
- The inclusion of interchanges improves the correlation significantly.

Flow Indicators

Table 2:

Results of the correlation analysis

In the next step, we use the flow network that weights the links according to the train frequency. Table 2 shows the result of the correlation analysis.

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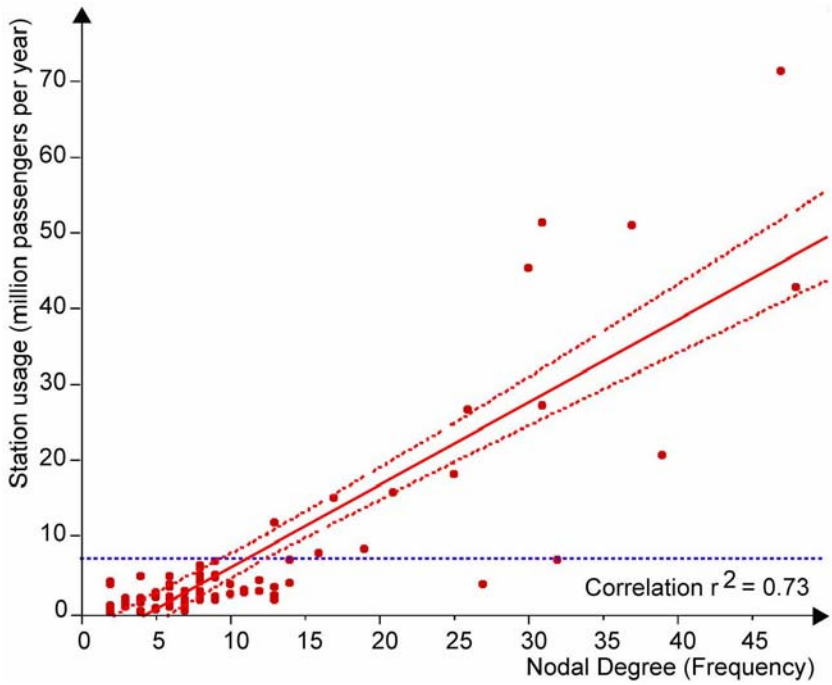
R^2	**Nodal Degree**	**Degree Centrality**	Closeness Centrality	Betweenness Centrality
Exits+Entries	0.692	0.690	0.313	0.565
Interchanges	0.513	0.511	0.313	0.551
Station Usage	**0.729**	**0.727**	0.338	0.616

- The correlations are significantly higher than in the topological model.
- Total station usage still produces the best results.
- The best indicator is the weighted nodal degree.

Figure 6 shows the correlation between the indicator frequency-weighted nodal degree and the station usage in a scattergram. This allows a closer look at particular nodes, especially those where the empirical data differ from the expected ones. These nodes are either over-performing, when the observed station usage is higher than predicted by the model or under-performing, when the usage is lower than expected.

Figure 6:

Scattergram



Although the distribution of indicator (weighted nodal degree) and observation data (station usage) are very similar in this model, they are not normal distributed. To achieve this, the dataset is normalised using the Box-Cox-transformation method (Box, Cox, 1964, SAS, 2003). The results of this transformation, producing a correlation of 0.70, are shown in figure 7.

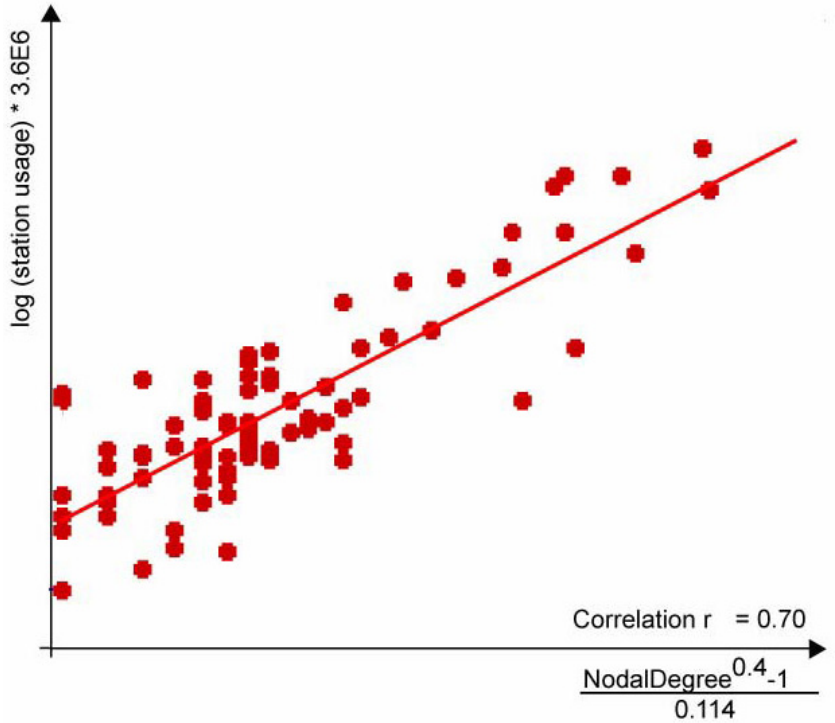


Figure 7:

Scattergram (Box-Cox transformation)

London Stations

The largest absolute deviations from the model predictions occur at the busy central London stations. Four of them have a usage higher than expected: Liverpool Street, Kings Cross, St Pancras, Waterloo and Victoria. These stations are well integrated into the London Underground system served by up to six underground lines. The three under-performing railway stations in contrast, City Thameslink, Marylebone and Clapham Junction, are poorly connected to the Underground system with only one or even none connection. These stations are highlighted in Figure 7. A more accurate prognosis for London would therefore require a more complex model integrating all London Underground lines. This would improve the accuracy within London, but hardly affect the rest of the city-region, our main interest for this study.

Regional Stations

The actual usage figures for the regional stations correspond quite well with the expected ones, with the following exceptions:

- On stations located at the edge of the study area, the influence of journeys outside the city-region the station usage is above average and these stations are accordingly over-performing. Therefore, predictions about these stations are generally to low.

- The four regional centres Reading, Brighton, East Croydon and Oxford show also a significant over-performance. This is not to limitations of the model but is a result of the character of these places. They have benefited from the regionalisation particularly in the service and IT sector that resulted in a more mutual interdependency between city and region. Attracting out-commuting from central London as well as cross-commuting from within the region they have become strong actors within the city-regions forming a counterbalance to London. This pattern is strong in the Western Crescent from Brighton – Reading – Oxford – Milton Keynes, but much weaker in the East of the region.

- In contrast, Ashford, a designated growth area South East of London, shows a significant under-performance with much lower

station usage than expected. This indicates that the development potential of this town is not realised yet. Such an underperformance over a long time may even lead to a reduction of train service provision. This has already been the case for international Eurostar trains, which have ceased to call in Ashford in favour of Ebbsfleet.

The analysis shows, that the performance of the regional stations depends both on the integration into the transport network and the realisation of this potential on the local scale.

Forecast Model

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In the next step we examine, how this model can be used to make forecasts about the impact of future transport schemes. Therefore, we include four new links into the flow model, which has proved to be the most significant one. We calculate how this affects the network properties, in particular the nodal degree, which has proved as the best indicator for station usage. We argue that an increase in terms of nodal degree will generate additional station usage potential for two reasons:

- Faster and more frequent railway connections will encourage modal shift from road to rail. It will also make these places more attractive both for commuters. Both will result in higher exit and entry rates at these stations.

- The higher nodal centrality improves the importance of these stations within the network and will increase interchange rates.

- In the near future, a number of new rail schemes are expected to come into operation, which will enhance the network in different ways. Five schemes are introduced in the frequency-based network model:

- Radial link (red) – The Airtrack scheme aims to introduce three new connections from Waterloo, Guildford and Reading to Heathrow via Staines, each one served by two trains per hour (2 tph).

- Crossing link (blue) – The two proposed Crossrail lines are assessed on the sections from Slough to Ebbsfleet and from Heathrow to Stratford, both served by four trains per hour resulting in a frequency of 8 tph on the core section.

- Orbital link (dark green) – For the East West Rail scheme, which is still in an early development stage, a 2 tph service is assumed on the whole route.

- Tangent link (ligtht green) – The South Coast express proposed in the South Coast Multi Modal Study (GOSE, 2002) is adopted with an additional 2 tph fast service between Southampton and Ashford.

- High Speed link (yellow) – The new Channel Tunnel Rail Link (CTRL), which is due to open in late 2007, will provide additional infrastructure capacity for regional trains. A 4 tph service between Ashford and St Pancras, as proposed in the Integrated Kent Franchise is assumed.

The effects of these new or strengthened connections are visibly on the network graph and measurable by comparing the improved network indicators to the previous ones.

Nodal indicators

The changes of the nodal degree, which range from 0 (no additional service) to 12 (12 additional pairs of train services per hour) indicate which stations would benefit most from the improvements. The three stations with the highest improvement are discussed below:

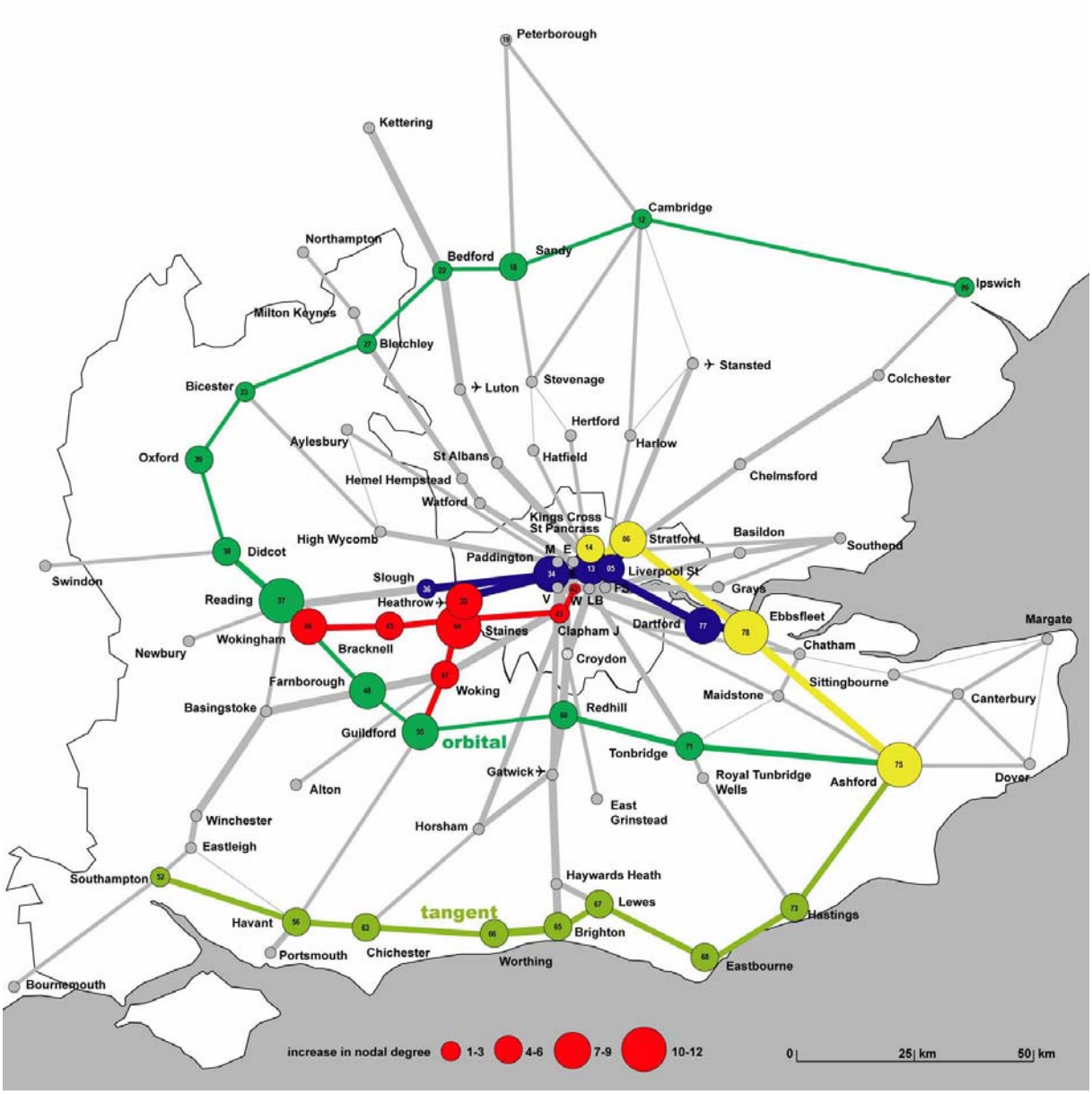
- Paddington, the terminus of the Great Western main line would develop into an underground through-station ranking fourth of all London stations after London Bridge, Waterloo and Clapham Junction, even exceeding Victoria. However, a quantitative forecast of additional passengers is not possible due the limitations of the model in central London.

- At Staines, a commuter town West of London near Heathrow airport, the three Airtrack lines would meet. At the moment, Staines is only served by one radial commuter line to central London, resulting in a weighted nodal degree of 6. The actual station usage of 2.2 million passengers per year is around 10% higher than the 2.0 million calculated by the model. The scheme would increase the accessibility of this town dramatically and create an important hub and interchange with the potential to double its station usage.

076-15

Figure 8:

Future network with changes in nodal degree



- At Ebbsfleet, some 30 km bee-line East of London, a new high speed train station is currently under construction. The station would be the major transport hub in Thames Gateway growth area. Three main transport corridors would meet there: the existing South Eastern line via Dartford to London Bridge in South London, the planned

Crossrail link via Liverpool Street station (East London) to Paddington (West London) and the Channel Tunnel Rail Link via Stratford to St. Pancras station in North London. This hub would be perfectly interwoven into the regional railway network. It is expected that this emerging hub would take over some traffic from nearby stations, which would generate a station usage of over 5.0 million passengers per year.

Again, this potential resulting from enhanced global accessibility by rail has to be realised through improvement locally.

Network Indicators

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On the network level, the mean nodal distance would change significantly, too. It would decrease by about 10% from nearly 5.0 to 4.5. That means that all journeys would get shorter as a result of the new travel alternatives: the orbital link in the North would enable direct services instead of changing in central London. At the same time, the density of the network would not change much, only from 0.14 to 0.17. This clearly shows the global effects that local interventions generate.

Conclusion

The case study shows that the network model is able to explain observed developments in the city-region, like the spatial polarisation between highly-accessible and less favoured places and supports the concept of Network Urbanism (Dupuy, 1991). The correlation analysis shows that the frequency-weighted nodal degree correlates with passenger usage at a specific station. It is a combination of a topologic factor (location of the station within the network) and the flow factor (train frequency). This indicates, that a spatial model is most accurate, if it takes into account both spatial and non-spatial aspects, the traditional geography of locations and the geography of relations corresponding to the “space of flows” (Castells, 1998).

As the model corresponds to empirical data on station usage it can be used to assess future interventions and forecast their impact on the network. These forecasts can be verified after the new schemes have come into operation. However, local the accessibility of each node is equally important. This can be modelled by a regional spatial model. Both, the network model and the spatial model are needed to fully simulate, analyse and understand the city-region South East England.

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